Book of Abstracts

1st World Congress of Agroforestry

Working Together for Sustainable Land Use Systems

27 June – 2 July 2004

Orlando, Florida, USA

Congress website: conference.ifas.ufl.edu/wca/

FOREWORD

This Book contains the abstracts of papers that were selected for presentation at the 1st World Congress of Agroforestry (WCA), 2004. Except for the abstracts of 29 invited presentations for seven symposia included in the beginning of the book, all were voluntary submissions for oral or poster sessions.

In preparation for the Congress, we solicited potential participants to submit abstracts for presentation during oral and poster sessions. The response vastly exceeded our expectations: we received more than 800 voluntary submissions from all over the world. The abstracts were sent to the respective WCA session organizers for their scrutiny and decision on their acceptability for oral or poster presentations. Although the session organizers were requested to be as accommodative as possible in making their decisions, quite a few abstracts had to be rejected as they were deemed unrelated to agroforestry even by the broadest definition of the term. The authors were then given the opportunity to submit revised and updated abstracts. The final selected abstracts were then edited for uniformity in length (maximum 250 words), presentation format, and language. Because of the volume of work that had to be accomplished within a tight time schedule, the edited versions could not be sent back to the authors for their approval; we request the authors' understanding and forbearance for this. At the time of sending this to the press, some authors' attendance in the Congress and presentation of their work are still uncertain because of financial and administrative reasons. Nevertheless, all abstracts processed as above are included in this book with the authors' approval.

Undoubtedly, this Book of Abstracts represents the current state of information and knowledge in agroforestry worldwide. Several of these presentations will be developed as full-length journal articles for the special issues of thematic journals that will feature Congress presentations (at the time of this writing, arrangements have been confirmed for special issues of seven scientific journals). But, for the majority of the abstracts that may not be published as professional and academic publications, this Book of Abstracts will remain the only source of reference. Thus, we believe that this book will be a valuable resource for future use. The book will also be made available to Congress participants as a CD, and the abstracts will be posted on the Congress Web-site (http://conference.ifas.ufl.edu/wca), and retained for several months after the Congress.

Compiling this Book of Abstracts involved the efforts of a number of individuals. I wish to express my sincere appreciation to my colleague Dr. Samuel Allen of the Center for Subtropical Agroforestry (CSTAF), University of Florida (UF), who edited the final abstracts for technical language, length, content and style. Other CSTAF colleagues, notably Dr. Michael Bannister and Ms. Julie Clingerman, provided considerable support and assistance to Dr. Allen in accomplishing this task. Special thanks are due to the Congress Coordinator, Ms. Mandy Stage, who with the assistance of Ms. Tracy Nininger and others at the UF Office of Conferences and Institutes, has handled effectively and tirelessly the myriad of logistics and communication associated with the development of this Book, including the final proofing and printing. Finally, I sincerely thank all the authors and session organizers, without whose cooperation and timely inputs this publication would not have been possible.

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Chair, Global Organizing Committee for the 1st World Congress of Agroforestry, 2004

Gainesville, Florida, USA
April 2004

PREFACE

This Book of Abstracts represents the collective endeavor of hundreds of researchers, extensionists, landowners, students and others interested in agroforestry around the world. We trust that it will be useful as a source for the state-of-knowledge and practice of agroforestry.

The Congress program consists of eight symposia (with invited contributions) and 32 sessions (with voluntary presentations). Each session and symposium has four oral presentations (except for the symposium on "Public/Private Partnership in Agroforestry," which is a panel discussion with no formal presentation planned). Therefore, the arrangement of this Book is as follows:

Symposia abstracts (29) are arranged alphabetically by the first author's last name in the following topic categories:

I. Agroforestry and Food Security
II. Biodiversity
III. Carbon Sequestration
IV. Ecological Basis of North American Agroforestry
V. Technology Transfer
VI. Trees and Markets
VII. Water Issues

Additionally, the 717 voluntary abstracts of oral and poster presentations at the 32 sessions are arranged alphabetically by the first author's last name within each of the following six broad groups:

I. Adoption, Food Security and Poverty Alleviation
(Includes topics related to sessions on: Agroforestry Adoption (Tropical and Temperate), Agroforestry and Food Security, Agroforestry for Health and Nutrition (AIDS/HIV), and Poverty Alleviation and Sustainability)

II. Biodiversity, Ecoagriculture and Homegardens
(Includes topics related to sessions on: Biodiversity, Ecoagriculture, Medicinal and Aromatic Plants in Agroforestry, and Tropical Homegardens)

III. Biophysical Aspects
(Includes topics related to sessions on: Biophysical Interactions, Carbon Sequestration and Landscape Ecology in Western Europe, Carbon Sequestration and Environmental Benefits, Decision Support Tools, Environmental Amelioration, and Climate Change)

IV. Economic and Social Aspects
(Includes topics related to sessions on: Economic Analysis, Land Tenure and Gender Issues, Local Agroforestry Knowledge in Global Context, Policy and Institutions, Scaling up of Agroforestry Benefits, and Mechanization)

V. Semiarid Regions, Soil Fertility and Agroforestry Education
(Includes topics related to sessions on: Agroforestry in Semiarid Regions, Land Owners' Session, Small Farm Soil Fertility Management Strategies, and Agroforestry Education)

VI. Tree Domestication and Management
(Includes topics related to sessions on: Managing Genetic Diversity, Short-rotation Woody Crops, Phytoremediation, Tree and Component Management, Tree Domestication, and Trees in Fragmented Landscapes)

As mentioned in the Foreword, the authors' original abstracts were edited for uniformity in format, 250-word limit, spelling, scientific nomenclature, and overall readability. Making these modifications, and that too without having the opportunity of discussing them with the authors (for reasons of time constraints) has been a difficult and at times painful task. In doing so, I have tried to retain the technical content and ensure readability of each abstract as much as possible; for any inadvertent deletions or other deficiencies in this process, I beg the understanding and forbearance of the authors. In spite of the above difficulties, I have enjoyed the task and gained considerable insight into the current state of agroforestry in the world.

I thank Professor Nair, the Congress Chair, for entrusting me with this task; and Dr. Michael Bannister and Ms. Julie Clingerman of CSTAF and Ms. Mandy Stage, the Congress Coordinator, for their constant assistance and support in fulfilling this task.

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- Center for Subtropical Agroforestry, SFRC, IFAS, University of Florida
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- World Agroforestry Centre (ICRAF)

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Symposia Abstracts

I. Agroforestry and Food Security

Agroforestry for Improved Livelihoods and Food Security for Diverse Smallholders in Latin America and the Carribean

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One of the great challenges facing developers of science-based agroforestry systems is the heterogeneity and diversity of the livelihood systems of smallholders who can benefit from the technology. Diversity exists, of course, across regions and among communities, but even within seemingly homogeneous communities, there is heterogeneity among households. This latter source of diversity is especially challenging because agroforestry at this level must accommodate the whole farm system and livelihood strategies of the smallholders. These systems and strategies vary widely due to their insertion in historically-shaped landscapes, and in families that are constantly evolving in their composition and needs. This paper focuses on methods being used to improve agroforestry development to fit the diversity and heterogeneity of smallholder livelihood strategies in this hemisphere.

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Agroforestry for Asian Food Security

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With roughly 60 per cent of the world's population depending upon only one-third of the world's land area, Asia is hard put to provide the basic needs of its expanding population. Although past agricultural extensification and the Green Revolution-led quantum jumps in food grain productivity have averted recurring famines in parts of Asia, under the ‘business as usual scenario’ most Asian countries will not be able to feed their projected populations in the 21st Century. On the one hand, there is less land per person in the Asia of today than in other parts of the world, and on the other, productive land is displaced by urbanization. Problems of soil salinization and water logging, which render arable lands unproductive, also continue unabated. Moreover, without proactive efforts, a considerable amount of irrigated lands may go out of production and that global warming might engineer food insecurity in several Asian nations. Woody perennial-based production systems, however, have the potential to arrest land degradation and improve site productivity by their interactions among trees, soil, crops and livestock, and thus return part, if not all the degraded lands, into the production process. They also have ability to maintain sustainable production and sequester large quantities of atmospheric CO_2. Above all, the intrinsic ability to provide multiple outputs, generate cash returns, improve the standards of living of rural poor and accomplish social equity are noteworthy. Prominent examples include tropical homegardens, taungya, parkland agroforestry, poplar/other tree-based production systems, integrated agriculture-aquaculture systems and the sloping agricultural land technologies.

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Agroforestry & Food Security: Challenges in the Developing Countries

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In the last three decades, the food situation in the developing world has never been so worrying. Although in the early nineties, access to adequate and sufficient food was recognized by the international communities as the most basic human right and the founding block for human aspirations, about 840 million people are still starving from hunger because of conditions of land mismanagement and inadequate access to food, including abject poverty. The World Food Summit, convened by FAO in November 1996, expressed serious concerns about the deteriorating food and nutrition situation of developing nations and set the political, conceptual and technical blueprint for an ongoing effort to eradicate hunger in all countries with an immediate view to reducing to half the number of undernourished people by no later than the year 2015. Agroforestry practices have been paid more attention and hold a promising solution in the developing countries to help in securing food production, while protecting a safe environment and conserving biodiversity. The purpose of this paper is to show how and where agroforestry may be used, in a sustainable manner, to increase food security and alleviate poverty and hunger, including biodiversity conservation. We believe that agroforestry has an important and increasing role for many of the rural poor that live off the land. This integration of trees with agricultural production can enhance soil sustainability, assist in or directly provide a range of food products and can provide a range of wood products and other services.

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Agroforestry & Food Security in Africa

S. Sadio
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J. C. Dagar
FAO of the United Nations

Over the last 20 years, Africa has been identified as the only region of the world where food insecurity is becoming of serious concern and leading to increased poverty. Land and soil degradation is believed to be among major factors affecting agricultural production, particularly in Sub-Saharan Africa. Indeed, there is a continuous population pressure threat on land resources, exacerbated by climate change (drought), resulting in significant production shortfalls in the sub-region. The biggest challenge for sustainable development in arid and semiarid African zones, seems likely to be how to provide enough suitable land to poor farmers while preserving a safe environment and conserving biodiversity. Recent studies have identified a U-turn in integrated natural resource management and land use, through improvement of farming systems by adoption of new technologies and on-farm forestry. Indeed, introduction and protection of young regenerated nitrogen fixing trees has contributed to improve substantially the fertility of acid soils and revert soil erosion by runoff control, thus leading to resource enhancement, and rising household income. However, food production will still need further support by integrated production systems in which trees will have a central role to play. Agroforestry thus will have close links with social forestry to meet smalholders' needs such as food and water, fuelwood and improved living conditions. This paper intends to show how, through appropriate adoption of agroforestry systems, small farmers can achieve food security and alleviate poverty and hunger, including conserving biodiversity.

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II. Biodiversity

Agroforestry and Biodiversity Corridors

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Biodiversity is facing crises of major proportions, particularly in the tropics where most globally irreplaceable conservation goals are concentrated. These places, especially those known as biodiversity hotspots, also happen to harbor disproportionally more people, a large fraction subsisting under precarious conditions. In the long run, protected areas alone will not be sufficient as landscapes evolve towards human dominated land uses, particularly those that create sharp edges or biologically inhospitable areas, inevitably threatening the persistence of parks and reserves. Furthermore, protected areas may face occasional threats stemming from competing land use claims that emerge from short-term economic and social challenges. One of the responses to these scenarios is planning and implementation at the landscape level through large-scale biodiversity corridors, or ecological networks. Biodiversity corridors provide a way to subdivide large areas into biologically and ecologically relevant sub-regional spaces that allow for conservation planning and implementation. Planners can appropriate the subdivisions within landscape corridors so that biodiversity and economic goals are met (areas under strict protection, economic development, mixed goals). In this context, agroforestry may prove a viable land use alternative that provides for both ecological and economic benefits. Agroforestry systems can be integrated into such corridors for a variety of uses, such as timber and non-timber forest products, thereby minimizing the exploitation of protected areas. Similarly, managed forest plantations as well as forest mixed with agriculture can be planned and managed for increased conservation value as appropriate buffers or links between protected areas.

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The Contribution of Shifting Cultivation Landscapes to the Conservation of Tropical Biodiversity: A Forest Ecologist's Viewpoint

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The alternation of crops and woody fallow vegetation on the same site defines shifting cultivation as an agroforestry land use. Biodiversity in shifting cultivation landscapes is of interest because of its potential contribution to agricultural sustainability and human wellbeing, and because such landscapes may contribute to the conservation of native forest biodiversity. The second point is the focus of this paper. In relation to forest biodiversity, key ecological aspects of shifting cultivation are high-frequency, drastic disturbance, the small sizes of individual habitat patches and the predominance of fallows and crop fields as cover types in landscapes. Fallow is usually the single most extensive cover type. Species richness of plants and animals increases with fallow age though compositional similarity between fallow and mature forest may be much greater for animals. Fallows will usually lack most mature forest tree species and be dominated by increasing populations of pioneer species, including aliens, with resprouting capacity key to fallow composition. Plant beta-diversity is likely to be lower in fallows than in mature vegetation and the sometimes diverse 'weed' flora of crop fields is unimportant to conservation. The primary function of fallows is agronomic and two important tendencies in their use, unfavourable to conservation, are towards shorter length and more intensive management. Management to increase the contribution of shifting cultivation landscapes to the conservation of native biodiversity should concentrate on the landscape level and involve common-sense measures applicable to any anthropogenic landscape.

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Fitting the Pieces Together: The Role of Agroforestry Systems in Conserving Biodiversity in Modified Forest Landscapes

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Dominant-use and multiple-use approaches to land management are often regarded as competing paradigms with respect to site-level interventions. This paper argues that such a polarized view is generally unhelpful and has contributed to unwillingness between different stakeholders to negotiate and balance trade-offs, on one hand, and lost opportunities to optimize ecosystem functionality, including biodiversity values, on the other. Under dominant-use scenarios, biodiversity values are maximized at specific locations only (protected areas) and ignored elsewhere, while site-level multiple-use interventions tend not to discriminate sufficiently between the ordinary and the extra-ordinary. It is proposed that dominant- and multiple-use approaches be considered in terms of scale dependency, with dominant-use an operational reality at site level and multiple-use an imperative at landscape level. Such realism is particularly urgent in dramatically-modified landscapes and where forest-related goods and services are now supplied at socially and environmentally sub-optimal levels. Using examples from dryland Africa this paper will explore how agroforestry has contributed to biodiversity conservation, particularly within modified and degraded tree-dominated landscapes. The practical challenge is how to establish conditions so that different forest-related land-use activities can conserve more biodiversity at landscape scale than the sum of their "site-level" parts. This paper concludes that traditional approaches such as expert-driven land-use planning will seldom succeed and argues against the temptation to plan landscapes. The authors propose that more attention should be given to understanding the institutional and political context that shapes landscape functionality and, in turn, identifying and removing obstacles that constrain individual and community action.

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Tree Biodiversity, Land Dynamics and Farmers' Strategies in Southwestern Burkina Faso

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Paul Nikiéma
INERA, Bobo Dioulasso, Burkina Faso

In the sub-humid part of Burkina Faso, population growth, migrations and new marketing opportunities induce rapid agricultural changes. Resulting land-use changes and social reorganization lead to renewed approaches to natural resource management. Out of about 100 tree species existing in the area, only 3 indigenous species and 2 exotic hold a significant importance for farmers, all for their fruits, and for all farmers. No indigenous tree species is planted, but a few are protected when clearing the land, leading to the development of a parkland landscape. Planted cashewnut tree orchards are seen as a land tenure guarantee, and are an important source of income. Given these series of facts, the perspectives for tree biodiversity management in farmers' land may appear bleak. Yet, the importance given by farmers to specific tree products, and the understanding of trees' ecological and social roles demonstrate that trees do play a part in land development and farmers' strategies. Existing practices by all farmers show a strong potential for land-use development and spatial structuration of the land, as revealed by emerging parklands and orchards. Our data do not confirm common statements that migrant farmers do not manage the land as sustainably as native ones. Rather than trying to conserve tree biodiversity as it is, researchers and developers should identify with farmers the complementarities between trees and farms and promote tree biodiversity through existing practices.

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III. Carbon Sequestration

Carbon Sequestration in Tropical Agroforestry Systems: Opportunities and Trade-offs

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[3] University of Columbia, New York, USA
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The paper will review the main tropical agroforestry systems and their impact on carbon storage, in biomass, litter and soil compartments. A special attention will be given to soil carbon storage, green-house-gases emission control and carbon losses by erosion to assess soil carbon sequestration potentials of tropical agroforestry systems. Quantity and quality of the carbon inputs, location of carbon in the soil (especially in soil structures that are physically protected against mineralization) are important variables for potential soil carbon sequestration. As carbon sequestration is one of the environmental outputs of tropical AF systems, other benefits as biodiversity, erosion control, have also to be quantified. A few examples will be presented. If agroforestry has a potential to sequester carbon from the atmosphere, limitations of their implementation by farmers have to be assessed; adoptability and profitability of those alternative practices need to be characterized, especially if agroforestry is looking as a tool for environmental-friendly projects like CDM (Clean Development Mechanisms) as defined in the Kyoto Protocol. As global carbon market will develop in the coming decades, valuation of carbon from agroforestry systems has to be implemented. Different methodologies will be presented.

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Agroforestry Systems and Carbon Sequestration: Potential and Perspectives

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Available estimates suggest that land use may mitigate additionally from 1 to 2 GtC per year between 1995 and 2050. Achieving this full carbon mitigation potential will require that we use all land-use related options for carbon sequestration. Here, agroforestry and silvopastoral systems may play an important role. Although the average carbon density per unit area of these systems is lower than that of plantation forests, other aspects, such as those related to economic and social sustainability and permanence of the carbon stocks, may offer an interesting option for the use of agroforestry in the Clean Development Mechanism (CDM) and Joint Implementation (JI) projects. Accurate methods are needed to assess the dynamics of carbon fluxes and storage under alternative management regimes. Models will be particularly critical for the examination of alternative carbon crediting schemes of Joint Implementation (JI)- and Clean Development Mechanism (CDM)-related projects. This paper examines the potential of agroforestry and silvopastoral systems in carbon sequestration using the CO2FIX V.2 simulation model and illustrates its application to different case studies describing common management options and scenarios for agroforestry systems. The model is able to handle uneven-aged, mixed-species regimes or multi-cohort systems - typical in most agroforestry cases. On the other hand, the use of agroforestry systems under the CDM and JI may encounter problems related to basic definitions, such as “afforestation” and “reforestation”. These issues and their potential implications are also discussed in this paper.

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Terrestrial Carbon Sequestration in Tropical Forest Ecosystems

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Tropical forest ecosystems (TFEs) occupy about 1.8 Billion hectares (Bha) out of the total area under global forest biomes of 4.2 Bha. The soil carbon pool in TFEs represents about 14% of the global soil organic C (SOC) pool of 1550 Pg. In a natural TFE, the SOC density depends on many factors including soil moisture regime, species composition, soil texture and predominant clay mineral, and landscape position and internal drainage. Deforestation and conversion of natural to agricultural ecosystems depletes terrestrial C density by drastically reducing the vegetation carbon density and also reducing SOC density. The SOC density in TFE soils may decrease rapidly upon conversion to agricultural ecosystems, especially in arable land use on sloping terrain with plow tillage cultivation. In addition to erosion, other processes with adverse effect on SOC density include decline in soil structure, soil compaction and densification, reduction in activity and species diversity of soil fauna (e.g., earthworms, termites), nutrient depletion, etc. The SOC pool can be enhanced by restoration of degraded soils and ecosystems, adoption of improved farming/cropping systems and use of conservation-effective measures including integrated nutrient and pest management, etc. Use of agroforestry is another viable option of enhancing terrestrial C density in general but SOC density in particular. SOC sequestration in soils of TFEs may be 100 to 500 Kg C/ha/yr. Improving SOC pool is a win-win situation because it improves soil quality and biomass/agronomic productivity, and mitigates global warming by reducing the rate of enrichment of atmospheric concentration of greenhouse gases.

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Carbon Sequestration: An Underexploited Environmental Benefit of Agroforestry Systems

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Agroforestry has importance as a carbon sequestration strategy because of carbon storage potential in its multiple plant species and soil as well as its applicability in agricultural lands and in reforestation. The potential seems to be substantial; but it has not been even adequately recognized, let alone exploited. Proper design and management of agroforestry practices can make them effective carbon sinks. As in other land-use systems, the extent of C sequestered will depend on amounts of C in standing biomass, recalcitrant C remaining in soil, and C sequestered in wood products. Average carbon storage by agroforestry practices has been estimated as 9, 21, 50, and 63 Mg C ha^{-1} in semiarid, subhumid, humid, and temperate regions. For smallholder agroforestry systems in the tropics, potential C sequestration rates range from 1.5 to 3.5 Mg C ha^{-1} yr^{-1}. Agroforestry can also have an indirect effect on C sequestration when it helps decrease pressure on natural forests, which are the largest sink of terrestrial C. Another indirect avenue of C sequestration is through the use of agroforestry technologies for soil conservation, which could enhance C storage in trees and soils. Agroforestry systems with perennial crops may be important carbon sinks, while intensively managed agroforestry systems with annual crops are more similar to conventional agriculture. In order to exploit this vastly unrealized potential of C sequestration through agroforestry in both subsistence and commercial enterprises in the tropics and the temperate region, innovative policies, based on rigorous research results, have to be put in place.

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IV. Ecological Basis of North American Agroforestry

Some Ecological Aspects of Intercropping and Silvopastoral Systems in North America

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Agroforestry systems embrace both production (food and wood) and the provision of 'services' that may ultimately be manifested in changes in soil properties, micro- and macro-climatic parameters, nutrient distribution or a combination of these and other environmental or ecological characteristics. The best-designed agroforestry systems, therefore, minimize negative interactions between tree and crop components and maximize positive interactions. This may be easier to do in systems where trees are in widely-spaced linear strips (e.g., shelterbelts) compared to where they exist as low-density cover in conjunction with a crop or animal (e.g., intercropping, silvopastoral systems). In these latter systems, only a systems ecology perspective will provide the mechanism necessary to understand competitive interactions between species. Intercropping studies have revealed several complementary interactions in this regard. Crop yields and tree growth in many intercropped scenarios, although variable, show little deviation from yields and growth in monocropped situations. Intercropping may also hold potential to reduce nitrate loading to adjacent waterways via deep interception by tree roots. The net carbon-sequestration potential in fast-growing tree-based intercropping systems is also noted, as is their potential to reduce nitrous oxide emissions from agricultural fields through reduced fertilizer use and more efficient N-cycling. The ecology of silvopastoral systems is similarly complex. More sheep can be grazed in these systems compared to pasture, although forage quality and quantity, and ultimately sheep productivity, may diminish. Understanding the ecology of both intercropping and silvopastoral systems is important to realizing the economic, ecological and rehabilitative contributions these systems can make to agro-ecosystems.

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An Ecological Approach to the Study, Development and Implementation of North American Agroforestry Systems

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Historically, much of the terrestrial world has been forested. However, because climates that support forest cover are also generally more suitable for food production, much of agriculture has developed at the expense of forests. Agroforestry systems offer one of the best opportunities to ameliorate the undesirable alterations of forest ecosystems. Well-designed systems require an understanding of how ecosystems function and respond to change. The best foundation for agroforestry system design is experience and adaptive management (AM) – learning by doing. AM is an effective approach to the management of relatively simple, spatially uniform systems such as agriculture and fisheries. It is less effective in forestry endeavors, wherein the consequences of choices today may not be measurable for decades. Agroforestry falls somewhere in between agriculture and forestry, so both AM and alternative approaches are needed. To overcome problems of spatial and temporal variability and slow feedback, we can combine experience with knowledge of ecosystem and biological processes to produce forecasting systems that can provide best estimates of possible agro-ecosystem futures. Thus, agroforestry research should be designed to provide the understanding needed to produce scientifically credible and practically useable models and the data needed to validate them. And as the world becomes more urbanized, there is a growing need for zonation in the application of more extensive systems of agricultural production such as agroforestry. This calls for use of large-scale regional models that can examine the tradeoff in values between different landscape patterns of agriculture, agroforestry and forestry, and which incorporate human values.

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Ecological Design, Development and Function of Shelterbelt Systems in North America

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When shelterbelts are established, they are usually composed of one to a few tree species and are relatively uniform in appearance with wide spacing between trees and adequate weed control. Over time, other tree and shrub species can become established in the shelterbelt, resulting in a more diverse and longer-lived shelterbelt. Nutrient cycling within the shelterbelt develops slowly but may be enhanced by the input of organic matter, fertilizer, and soil from adjacent crop fields. From the perspective of wildlife and insects, a shelterbelt provides variation in the vegetative structure associated with crop fields, thus providing numerous niches and opportunities for many species. From the perspective of crops, the primary shelterbelt effect is to create variation in windspeed across the landscape. Plants near 3 to 6H (H is average height of the shelterbelt) from the leeward side of the shelterbelt, often yield more than plants in other parts of the field because of reduced windspeed, increased daytime temperatures, reduced nighttime temperatures, improved water use efficiency, and other effects. From the perspective of humans, shelterbelts contribute to development of an aesthetically pleasing landscape that positively impacts crop yield, soil retention, wildlife habitat, and carbon sequestration. As shelterbelts age, interconnectedness between disparate woodlands may be enhanced, and especially in landscapes with low forest cover, shelterbelts can play an important role in erosion control, nutrient retention and biodiversity maintenance. To create stable shelterbelts that contribute at both local and larger scales, a mix of species is desirable and site-specific species selection is critical.

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Ecological Processes in Integrated Riparian Management Systems in North America

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In North America, integrated riparian management is one form of agroforestry recognized by the Association for Temperate Agroforestry, although the interaction between tree and crop production occurs at the landscape scale, compared to the plant-plant scale that occurs in other common agroforestry systems. Riparian areas are among the biosphere's most complex ecosystems and play important roles in maintaining fluvial and landscape vitality. Over the past several decades, extensive research efforts have been undertaken to understand the dynamics of these systems. Natural riparian systems display a high variability in structural and functional characteristics, which is reflected in physical heterogeneity of drainage networks, the processes shaping the stream channel, and characteristics of the biotic community. Primary losses of riparian forests, on a global scale, are occurring as a result of forest harvesting operations, agroecosystem development, urbanization and industrialization, and expansion of transportation networks. These activities have led to losses of riparian zones ranging from 85 to 98% in agricultural watersheds, and up to 100% in previously forested watersheds. Rehabilitation efforts have been variable, ranging from planting of cold and warm season grasses, to planting trees, to planting mixtures of grasses and trees. To date, research efforts in North America, on rehabilitation processes, are ongoing, with a major focus on understanding the efficiency and ability of riparian systems to attenuate NO_3-N. This paper focuses on the processes linking terrestrial and aquatic ecosystems within riparian buffers, taking examples of biophysical changes as a result of rehabilitation efforts from both forest and agricultural landscapes.

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V. Technology Transfer

The Role of National and State Policy in the Adoption of U.S. Agroforestry

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Major factors currently constraining U.S. agroforestry development are a lack of understanding of agroforestry, a lack of incentives to stimulate adoption and narrow landowner participation. Agroforestry is still widely misunderstood at the field level and outside the forestry/natural resources community. Government policy in support of agroforestry, including the careful application of incentives, is one critical catalyst to national acceptance and adoption of agroforestry. Incentives are important because they provide cost sharing and reduce up-front expenses for installing agroforestry practices. Federal cost-share is used by over half of the current installations in the South, for example. The opportunity to mitigate current or potential environmental problems, or at least the fear of regulations and desire to avoid them, is another incentive to landowners.

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Linking Agroforestry Research with Technology Transfer, Science with Practice

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In addition to policy issues, for temperate zone agroforestry to spread from its current limited base of interest and application, it must have both sound scientific underpinnings as well as practices of use to the landowner. The University of Missouri Center for Agroforestry (UMCA) technology transfer strategy links UMCA training activities with a strong basic and applied research program and couples this with an active demonstration effort at University of Missouri (MU) research properties. In addition, landowner demonstrations are being developed in locations adjacent to the outlying research properties to add practical credibility to training events. MU's outlying research properties will become focal points for future UMCA technology transfer activities. Effective technology transfer also requires the creation of active partnerships and networks, training "trainers", direct interaction with the landowner and the development of portfolio of tools, including training manuals and technical guide sheets, for effective outreach and communication.

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Engaging Landowners and Producers to Transfer Agroforestry Technologies in the Midwestern United States

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Agroforestry can be a hard sell to Midwestern US producers. Like producers everywhere, many are reluctant to take land out of crop production for conservation purposes, particularly with increasingly thin profit margins. With the strong trend toward increasing farm size, producers are not interested in increasing the complexity of their farm enterprises with tree and shrub plantings. Other barriers to large-scale adoption of agroforestry include: lack of producer knowledge of agroforestry opportunities; viewing trees as long-term impediments to agriculture; incompatibility with large farm equipment or irrigation systems; insufficient subsidy payments; and a reluctance to plant woody plants on high productivity land. Thus, faced with relatively stiff producer resistance, agroforestry change agents in the Midwest need to use creative and innovative strategies to increase agroforestry adoption. This paper will: 1) assess landowner/producer-perceived barriers to agroforestry adoption, 2) discuss a range of strategies that can enhance adoption, and 3) present several case studies of innovative and effective agroforestry technology transfer strategies used in the Midwestern US.

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Subsidies: The Sacred Cow of Agroforestry Extension?

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Farmers want them, government ministers rush to announce them and extension agents love to give them out. Subsidies for the establishment and management of trees on farms have become the foundation of so much farm forestry and agroforestry extension around the world. Australia is no exception. State government agencies continue to launch programs offering landowners direct financial support if they undertake to establish forests on cleared land. But are these programs effective in stimulating agroforestry or do they actually stifle investment and discourage innovation? This paper reviews the use of subsidies as an extension tool for promoting agroforestry in Australia.

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Agroforestry in BC: Technology Transfer for Development of an Emerging Industry

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Within British Columbia, Agroforestry is an emerging industry composed of subsets of BC's agri-food and forest industries. It is arising from an escalating interest in alternate crops, adaptations of current practices and use of agroforestry systems to meet environmental objectives. For example, interest in managed silvopasture systems has evolved from livestock grazing on public forest lands and forest vegetation management with sheep and cattle. Florals, mushrooms and botanicals have historically been wildcrafted, but with an increasing intensity of harvest due to market expansion. Thus, management of these alternate crops in a biologically- and economically-sustainable manner has become a rising issue. Over the past 10 years, technology transfer has focused on awareness of alternate crops and products, and more recently, their potential for enhanced production and integration into managed agroforestry systems. In 2002 a survey of practitioners and potential practitioners was conducted to identify industry stakeholders, the current condition and outlook for Agroforestry in British Columbia, the industry goals and the means of achieving those goals. Technology transfer was identified by producers as a priority development area and forms an integral component of the Industry Strategic Plan. Activities identified by producers were access to on-farm demonstration sites, technical expertise, on- and off-farm workshops, and printed materials. Topic areas ranged from technical training to market research and development and information on value of crops produced in agroforestry systems. Current initiatives will be discussed and placed in context with identified information gaps. Success stories will be outlined along with some road blocks experienced.

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VI. Trees and Markets

Scaling Up the Impact of Agroforestry: Lessons from Three Sites in Africa and Asia

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This paper assesses recent lessons in scaling up agroforestry benefits, drawing on three case studies: fodder shrubs in Kenya, improved tree fallows in Zambia, and natural vegetative strips coupled with the Landcare Movement in the Philippines. Each innovation is being used by over 15,000 farmers and the main factors facilitating their spread are examined. Ten key elements of scaling up are presented and the use of each element in the case studies is examined. The key elements contributing to impact were a farmer-centered research and extension approach, a range of technical options developed by farmers and researchers, the building of local institutional capacity, the sharing of knowledge and information, learning from successes and failures, and strategic partnerships and facilitation. Three other elements are critical for scaling up: marketing, germplasm production and distribution systems, and policy options. But the performance of the cases on these was, at best, mixed. As different as the strategies for scaling up are in the three case studies, they face similar challenges. Facilitators need to (1) develop exit strategies, (2) find ways to maintain bottom-up approaches in scaling up as innovations spread, (3) assess whether and how successful strategies can be adapted to different sites and countries, (4) examine under which circumstances they should scale up innovations and under which circumstances, they should scale up processes, and (5) determine how the costs of scaling up may be reduced.

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Progress and Prospects for Strengthening the Tropical Tree Seed Sector

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Agroforestry has been elevated in many national and international development plans to assist in rural development, income generation and provision of food security. In response, smallholder tree planting is increasing although availability of tree seed is often cited as a bottleneck. Even if only 10 new trees were planted per hectare throughout agricultural land in the tropics in the coming decade this would require more than 15 billion trees. Sourcing the seed for this enterprise remains one of the least planned activities in agroforestry. Well-planned projects do exist but these are often localised initiatives in the form of support to National Tree Seed Centres, and these have not had the anticipated impact. Furthermore, success stories are reported by site-specific species interventions and not by country or region since even national centres do not serve a nation but more typically geographically close farmers. Analyses of the tree seed sector for case study countries and for tree types (e.g., fodder, fertiliser, timber) are presented to draw out generic observations. The tree seed sector is increasingly being recognized as extending beyond seed to involve nursery operators and farmer interest groups. Suggestions for action to counter under-investment, poor coordination, declining extension services are provided. Steps to formulate ways to integrate the demand and supply of tree germplasm (seeds and seedlings) are also presented.

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Mobilizing Markets for Agroforestry Products in Developing Countries

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In many developing countries, especially in Africa, farmers have been introduced to agroforestry with little consideration for the markets for trees and tree products aside from potential productivity gains to food crops. It is now being recognized that expanding market opportunities for smallholders particularly in niche markets and high value products is critical to the success of agroforestry innovations. Some recent research on marketing agroforestry products, linking farmers to markets and assisting farmer organizations, shows how constraints are tied to both long-standing market structures as well as shifting market imperatives. Forest policy, physical and social barriers to smallholder participation in markets, the overall lack of information at all levels on markets for agroforestry products, and the challenges to outgrowing schemes and contract farming inhibit the growth of the smallholder tree product sector outside of traditional products. Notwithstanding these constraints, there are promising developments including contract fuelwood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations, and collaboration between the private sector, research and extension.

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Tree Domestication and the Market

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Domestication of agroforestry trees is largely a farmer-driven and market-led process. Specifically it is about matching the intraspecific diversity of many locally important tree species to the needs of subsistence farmers, the wide range of product markets and the diversity of agricultural environments. The products of domesticated agroforestry trees require greater recognition in national development as well as international markets and policy and perhaps they should be called Agroforestry Tree Products (AFTPs). This would distinguish them from extractive tree resources which are collectively referred to as non-timber forest products (NTFPs). The main challenges in designing and implementing tree domestication programmes are the inadequacy of knowledge and urgency of progress needed. For most agroforestry tree species, investment in any single tree species will not match that for the few commercial species which have undergone conventional tree improvement. Market and home use requirements also differ for tree products (and services) not only between species but also within species.

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VII. Water Issues

Agroforestry in the Riparian Zone for Water Quality

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Agroforestry technologies in riparian areas have great potential to mitigate serious water quality problems in many countries. Agriculture is a major source of pollutants that contribute to poor water quality. Runoff following rain storms and irrigation transport eroded sediments along with excess fertilizers, animal wastes, and pesticides to surface waters. Agroforestry designs located in the riparian zone between a stream and cropped fields can protect the stream by filtering pollutants from runoff. They also help stabilize and protect stream banks from erosion and provide additional benefits to stream health. Current evidence clearly indicates that riparian agroforestry is capable of producing substantial water quality improvement. More research, however, is needed to define how agroforestry designs must be tailored to fit local conditions in order to achieve this benefit. To be effective, a design must be located to intercept and disperse agricultural runoff, have adequate size, contain proper vegetation, and be actively managed. While riparian agroforestry is a promising technology for improving water quality, detailed information is still needed to facilitate planning and proper design so that its effectiveness can be ensured.

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Soil Erosion Control, Ecosystem Reconstruction, and Sediment Reduction in the Yellow River Basin of China

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The Yellow River in China carries the greatest sediment load in the world. Most of the sediment comes from the loess plateau, which is located in northwest China and covers an area of 640,000 km^2. Annually, about 1.6 billion tons of sediment discharge into the Yellow River, with about 0.4 billion tons deposited in the lower reaches of Yellow River bed. Consequently, the river bed in the lower reaches is rising by 8-10 cm each year. The soil erosion not only results in environmental degradation, rural poverty, and a delay in the economic schedule, but flooding in the lower reaches can severely threaten people's lives and property. To control soil erosion and reduce flood damage, China initiated large-scale soil and water conservation projects in the loess plateau in the early 1950's. By the end of 2000, the treatment area had reached 180,000km^2, where there were over 110,000 key and warping dams and more than 4,000,000 small-scale water storages such as ponds, pools, and cellars. About 6,500,000hm^2 of basic farmland has been treated and 11,500,000hm^2 now has vegetation that promotes soil and water conservation. After 50 years of effort to improve soil and water conservation practices, sediment discharge into Yellow River has been reduced by 0.3 billion tons per year (18.8%). We have made great progress and have learned that no single measure can control soil erosion. Examples of China's success in controlling soil erosion, increasing agricultural production, enhancing the eco-environment, reducing flooding, and improving living conditions, are given.

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Riparian Forest Restoration: Improving In-stream Habitat, Ecosystem Function, and the Processing of Water Pollutants on Agricultural Landscapes

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Riparian forest buffers are recommended as a land use practice to protect small streams and rivers from non-point source pollution on agricultural landscapes. Here I support that contention and propose that the restoration of riparian forests is also critical to restoring the stream's ability to deliver important ecosystem services to humanity. Such in-stream services include the processing of nutrients, degradation of pesticides, and the filtering and sequestering of pathogens. Improved delivery of stream ecosystem services accrues from the positive effect of streamside forests on the structure and function of the stream ecosystem. These effects are mediated largely through improvements of in-stream habitat due to the restoration of a forest canopy over and/or along the stream (e.g., more natural size and shape of stream channels, water velocity, bed roughness and substrate size, light and temperature regime, and food quality/quantity). I propose that this in-stream aspect of riparian forest buffers adds another dimension to their utility, making them best management practice for mitigating both point and non-point source pollutants in streams draining most agricultural landscapes.

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Agroforestry: A Sustainable Option for Waste Water Reuse in Developing Countries

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Increasingly large volumes of domestic and industrial wastewater are produced in rapidly growing cities around the world. Each day over 2 million tons of waste is dumped into rivers and lakes. There is now about 12,000 cubic km of polluted water on the planet, more than the contents of the world's ten biggest river basins, and equivalent to six years' worth of worldwide irrigation needs. Wastewater treatment is costly, and worldwide only a very small percentage is treated; the rest is left to flow into natural water bodies. In developing countries, untreated wastewater represents an important resource for farmers, and is used extensively for urban and peri-urban vegetable and fodder production. Wastewater provides a year-round water supply, and nutrients for plant growth. However, besides organic effluents, wastewater often includes heavy metals, pesticides, antibiotics, and other toxics. Prolonged use for agriculture can be a public health and long-term environmental risk, as heavy metals build-up in soils, and accumulate in agricultural crops. Tree-based systems to produce valuable economic products, including timber, fuelwood, and pulp, provide a sustainable alternative to wastewater use trends in developing countries, offering a profitable livelihood option for urban, peri-urban and rural farmers, while mitigating environmental and public health risks. Options for treatment and use of wastewater, and bio-remediation of associated polluted sites, using tree-based approaches are discussed. Identification of specific systems-based approaches, which meet local bio-physical, economic, and socio-cultural criteria for adoption and success, is required to develop sustainable wastewater technologies applicable to the needs of developing countries.

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Session Abstracts

I. Adoption, Food Security and Poverty Alleviation

Includes topics related to sessions on:

Agroforestry Adoption (Tropical and Temperate),
Agroforestry and Food Security,
Agroforestry for Health and Nutrition (AIDS/HIV),
and Poverty Alleviation and Sustainability

Planning of Silvopastoral Systems in Cuba Using Geographic Information System (GIS) Technology

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A Geographic Information System (GIS) was used to describe the principal natural and potential resources of the cattle region of Jimaguayú, in the Camagüey province of Cuba. Specifically, the study was carried out to evaluate the soil differences in the region and to identify the variants and alternatives most convenient for developing forests and cattle by means of silvopastoral systems. Mathematical and Structural Query Language (SQL) operations were made using different graphic tables, and a digital map was created to define the areas to be reforested, taking into consideration the behavior of a group of exclusive variants. Both the variants and alternatives analyzed should be useful to decision makers in proposing new locations for silvopastoral systems as well as other combinations of trees, shrubs and grasses for the region.

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Diverse-crop Agroforestry Systems and the Prospects for Forest Preservation and Farm Sustainability among Rural Farmers of Petén, Northern Guatemala

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Through the designation of the Maya Biosphere Reserve (MBR) in 1990, subtropical Petén was internationally recognized as a biodiversity "hotspot". However, since the early 1960s, successive governments have promoted Petén as a frontier ripe for agricultural development. The situation in Petén is complicated by a) extraordinary human population growth; b) ethnic and cultural heterogeneity of colonists, leading to community tensions; c) increasingly numerous and larger cattle ranches which convert forest to pasture; d) indifferent government interest in conservation, and e) increasing influence of the illegal drug trade in the region. In an effort to mitigate these unsustainable development trends, this study examines locally evolved agroforestry systems and their contribution to *campesino* (peasant) household livelihood strategies. The study also examines whether wider promotion of agroforestry systems can help mitigate further forest destruction. Survey results show that most farmers prepare a conventional milpa on their land, primarily consisting of maize (*Zea mays*), frijol beans and pepitoria (*Cucurbita* sp.). However, some individuals have developed complex rotational systems that include "alleys" of cultivated cedar (*Cedrela odorata* L.) and mahogany (*Swietenia macrophylla*). Other locally valued species are also cultivated such as fruit crops, root and tuber crops, and horticultural crops, exceeding 60 species. Often these highly productive *parcelas* have been farmed for two or three generations, as in the study communities of Ixhuacut, Sacpuy, and San Andrés. The study underscores the need for agricultural extension efforts that merge modern science with traditional knowledge to promote environmentally sound farming methods that also improve *campesino* household incomes.

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Agroforestry Adoption among Peasant Farmers in Western Nigeria

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Agroforestry has been widely acclaimed as a means to mitigate land degradation because it is comprised of a suite of useful practices that can be adapted to various situations. It is therefore viewed as a valuable land-use technology for peasant farmers in western Nigeria where the rainforest has been gradually transformed to savannah. The study focused on the awareness and adoption of agroforestry practices by peasant farmers in the region. Adoption was determined by indication of the farmland components and the integration of these components with one another. One hundred and sixty-seven (167) farmers were interviewed from the two vegetation zones in the study area. The average farm size was 3.7 ha with farm components including food crops (99.6%), livestock (58.1%), poultry (57.7%), fruit trees (49.1%), timber trees (18.4%) and fish (1.1%). Most crop production and silvicultural practices were well known as against livestock practices, with the following response rates: shifting cultivation (89.9%), planting of legumes (87.6%), silvopasture (2.6%) and apiculture (3.7%), while adoption of the practices recorded fewer responses: 28.5%, 19.9%, 0.4% and 0.0%, respectively. Respondents planted more fruit trees (mean 16.7) than timber trees (mean 7.5). Livestock raised were poultry (85.8%), goats (77.5%) sheep (58.4%), pigs (5.6%) and cattle (4.8%). Constraints experienced in agroforestry were mostly lack of capital (83.5%) and tree crop inputs. Overall, the state of agroforestry adoption in the region is incidental rather than active since the majority of respondents have not substantially integrated the components of their farms to enhance land utility and management.

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"Lapat"—An Indigenous Natural Resource Management System among the Tinguian Tribes of Abra, Philippines

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Among the Tinguian tribes of Abra, in north-central Philippines, there is now a growing awareness and appreciation by local government units for the effectiveness of "Lapat" as a natural resource management system. The Legislative Council of the Province of Abra in its resolution no. 09-2002 dated February 4, 2002, formally asked the Secretary of the Department of Natural Resources to formally accredit the "Lapat" System of Abra. "Lapat" means "ban" or "prohibit". It is a centuries-old system of regulating the use of natural resources among the Tinguian tribes of Abra. It enjoins all community members and neighboring communities to abide by its rules pertaining to forest conservation and environmental protection, like refraining from the cutting of trees, gathering of rattan, hunting of wild animals, and even fishing in the river. The "Lapat", while common to almost all the mountain tribes of Abra, is varied in scope and application. In some areas, it covers all types of timber and non-timber species, including wildlife. In other areas, only species of flora and fauna are covered. Still, in other places, even fishing in the river at a given period is prohibited. This paper describes the underlying principles and rituals of "Lapat" and how people can benefit from these resources. It is a system that enables local communities to actively and effectively participate in natural resource management, conservation and protection.

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The Impact of HIV/AIDS on Agroforestry Management in South Africa

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South Africa has one of the highest cases of HIV infections in the world. Of the 23 million adults and children living with HIV/AIDS, about 18 percent live in South Africa. With the epidemic continuing to evolve at an alarming rate, the South Africa government regards this a developmental and socio-economic policy issue. This has meant the reallocation of resources towards HIV/AIDS prevention. A growing number of research evidence suggests that the HIV epidemic could have severe impact on labour supply and productivity. The HIV epidemic has caused labour shortages, knowledge loss and loss of formal and informal institutional support in agroforestry management. Owing to the gender division of labour and knowledge, the epidemic is likely to have a devastating impact on agroforestry management. A growing number of studies highlight the far-reaching impact of the epidemic on South African economy. While these studies illustrate the economic impact of HIV/AIDS, they do not form a coherent body of information that allows one to evaluate the impact on agroforestry management. In this paper, we assess the impact of HIV/AIDS on agroforestry management and discuss the range of interventions, which are being implemented in the agricultural sector, to combat the epidemic. The review concludes with consideration of opportunities and challenges facing agroforestry management in South Africa.

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Agroforestry for Improvement of Rural Livelihood in Bangladesh

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High population density in Bangladesh and scarcity of natural resources has led to over use of land for food and habitation. Increased pressure on land has resulted in decreased soil fertility, vegetation and suitable agro-climate. An intervention was made to introduce multipurpose trees of *Leucaena leucocephala, Albizia procera* and *Morus indica* around vegetable garden, pond and crop field for use of foliage as forage, supply of fuelwood, soil fertility and fence. The trees were 2 meters high by 2 years and approximately 1 meter of tree branches were lopped 4 times a year. Estimated yield of foliages and fuelwood was 9.6 MT and 8.3 MT per ha, respectively. Plantation has increased soil pH by 10%, OM by 5%, N by 15%, P and S by 17%. Supplementation of tree leaves at the rate of 25% of DM requirement to lactating cows fed basal straw and grass diets increased milk yield by 37%, live weight of cows and calves by 12%. Monetary benefit of US $137 per household in terms of gross income was generated from milk, live weight, forage and fuelwood. This accounted as 32% improvement of monthly income for an average family. Additionally, trees provided live fence around the plantation areas and extra 6 hrs of work/household was generated mostly for women after introduction of multipurpose trees. It is concluded that agroforestry system of multipurpose tree plantation increased livestock productivity and soil fertility, supplied fuelwood, generated work and improved socio-economic condition of the farmers.

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Contribution of Agroforestry to *Outgrower Schemes* in Brazil

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In the past few decades, the world's rapid population growth and increasing need for suitable agricultural lands and forest products has occurred at the expense of forests, woodlands, grasslands and biodiversity, leading to food insecurity and extreme poverty in the most vulnerable areas. Tree planting and management can help solve the demand for forest products and also reduce poverty through increased production and income generation. Among many initiatives, *outgrower schemes* have been implemented in different countries to provide needed wood to forest companies as a way of providing income alternatives for small and medium farmers. Given the importance of subsistence crops and forest products to smallholders and the economic viability of agroforestry systems in Brazil (Capobianco, 1997), opportunities for outgrower schemes exist in that nation. In a previous study, only one scheme in the South of Bahia (in northeastern Brazil) was involved in tree planting in association with agricultural crops in the outgrower schemes. Two other outgrower schemes have been selected for a private forest company in the south of Brazil. Other communities had yet to show interest in outgrower schemes and therefore may need encouragement from government agencies and other stakeholders. Based on research on three outgrower schemes in Brazil, this paper examines the involvement of companies (state and private), NGOs and other stakeholder-related institutions, in the promotion of outgrower schemes through integrated tree-crop systems. Such integrated systems are viewed as offering opportunities for improvement of food security and short- and long-term income to rural farmers in Brazil.

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Nature and Prospects of Agroforestry in Ghana

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Ghana has been richly endowed with natural resources, which are vital for the country's development and future prosperity. Timber from the tropical high forests has traditionally ranked third as a foreign exchange, while fuelwood, bushmeat, medicinal plants and other natural products have continued to contribute significantly to the welfare of most Ghanaians. Unfortunately, exploitation of these resources to satisfy socio-economic needs has resulted in deforestation and destruction of wildlife habitats, as well as resource depletion and degradation. This has been due to the ever-increasing pressure from rapid population growth, leading to clearing of forests for farming, illicit logging and surface mining, uncontrolled bush fires, collection of fuelwood and excessive hunting and poaching of wild animals. In an attempt to solve the problems of destruction and deforestation, tree planting (agroforestry) was introduced in Ghana in 1985. Included among these efforts have been the activities of the Forest Commission, which embarked on tree planting exercises to restore the deteriorated forestlands. The Ministry of Food and Agriculture is also embarking on agricultural extension and education of farmers on land and water management through agroforestry projects. NGOs are assisting farmers to cultivate plantation crops. Voluntary organizations, communities, schools and churches occasionally participate in agroforestry projects. Through its existing agroforestry practices, Ghana can recover about 65% of its renewable natural resources by the year 2020.

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Gaining Access to Agroforestry Innovations and Practices: In Search of Inspiring Stories

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For decades now, Philippine upland resources have suffered from increasing migration, illegal logging, shifting cultivation, forest fires and other forms of degradation—reducing forests to 5.5 million hectares, causing rapid biodiversity loss and creating harmful effects to the lowlands. This worsening situation has urged calls for technologies that could rehabilitate, conserve and protect these upland resources. Agroforestry was recognized as one of these technologies. Although practiced in the Philippines and the subject of much attention over the last three decades, agroforestry practices and innovations have not been extensively documented. Recently, the Program to Enhance NGO/PO Agroforestry Capabilities for Food Security and the Environment (PEACE) sought out the farmers and communities who have learned and experienced agroforestry. PEACE's multi-disciplinary technical committee developed the criteria and indicators as a guide in identifying the successful agroforestry farms in various areas of the Philippines. Long and short listing of agroforestry farms ensued to further identify the farms to be documented and written as case stories. The stories not only described the procedures and technicalities of practicing agroforestry, but focused on the inspiring stories of resourcefulness, courage and perseverance of these agroforesters. PEACE described how and why agroforestry is being practiced in the Philippines, especially the new innovations and technologies developed by the farmers themselves, and how existing resources were utilized amidst problems and challenges. More importantly, farmers were able to share agroforestry's impacts on production, sustainability, adoption, and specifically their lives. Lessons and insights were also shared on sustaining the agroforestry initiatives documented.

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Socio-economic, Cultural and Food Importance of the Baobab Tree (*Adansonia digitata*) for the Otammari People in the Sudan Zone of Benin

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The study was undertaken with the Otammari people in the North of Benin between 9°45 and 12°N latitude. Surveys on food consumption and assessment of farm tree densities were conducted, together with an ethnobotanical and market survey. Also, analysis was carried out in order to measure the chemical composition of leaves, seeds and fruit pulp of baobab (Adansonia digitata). For a period of three months, marketing of pulp provided around US$ 30,000 to the local populations involved. Otammari people regard some baobab trees as divine figures and occasionally perform traditional rituals around them. On farm, protected trees have a mean density of three individuals per ha. Furthermore, the lab analysis results showed that pulp and leaves have low lipid content (from 0.41% to 1.69%) and relatively low protein content as well (3.28% and 14.12%, respectively). The seeds unlike the previous organs are very rich in protein (33.88%) and lipid (28.28%). Ash content is highest in pulp and leaves: 88.66% and 75.06%, respectively, compared to 29.59% for the seeds. The energy value of these organs is high (372 Kcal/100g in the pulp and the leaves and 508 Kcal/100g in seeds). Different organs from the baobab tree also contain high amounts of calcium (Ca), magnesium (Mg), iron (Fe), potassium (K), phosphorus (P), zinc (Zn) (ranging between 0.176mg/100g and 0.332 mg/100g) and antibiotic substances.

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Adoption of Agroforestry and Effect of Tree Species on the Hill Crops in Nepal

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Agroforestry is one of the important farming systems in Nepal, where traditional homesteads are predominant. Nepalese farms are characterized by smallholding, multiple cropping, and livestock integration. Farmers keep the livestock for milk, meat, manure and draught power. Agrosilvopastoral, silvopastoral and hortopastoral systems are common. Farmers have traditionally adopted more than 100 multipurpose tree species and forage crops. Literature suggests that agroforestry research has covered various aspects under varied agro-ecological conditions. Research in agroforestry has focused on species selection/evaluation, alley/inter-cropping, tree-crop interaction, and growth monitoring. The paper highlights findings of different experiments conducted in the hills during the last decade. In the tree-crop interface studies, fodder trees had different effects on the growth and yield of maize (*Zea mays* L.) and finger millet (*Eleusine coracana* L.). The data revealed that the closer the crops are grown to trees, the more severe the effect on different parameters, where maize was more affected than millet. The mature trees had significant and negative effects on growth and yield up to 2-3 m from the tree trunk. *Ficus auriculata* had severe effects followed by *Ficus semicordata* var. montana Amatya. However, *Albizia julibrissin* and *Litsia polyantha* trees favored the crops. The overall mean yield of maize under tree canopy was less (2601 kg ha^{-1}) than outside (3757 kg ha^{-1}). Effect on millet followed a similar trend. The yield was less (737 kg) in lower terraces than upper (1575 kg ha^{-1}). North and west aspects were more favorable. Several recommendations were made based on the results.

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SKYPONDS: Tapping the Potential of Upland Fishponds in the Healing of Degraded Ecosystems

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The climatic irregularities presented by the El Niño phenomenon present an opportunity for tapping the potential of fishponds as one measure to mitigate the impact of weather abnormalities. If created in large number and in strategic places in the mountain areas, these “skyponds” can result in a virtual oasis that among other things can help plantation projects serve drought and forest fire occurrences. Apart from helping to divert or reconfigure the often exploitative and unfriendly ecosystem attitudes of many upland-based community activities, skyponds have bright prospects for enhancing agroforestry farming, nutrition productivity, biodiversity, and people participation in mountain ecosystem rehabilitation and conservation. This paper includes practical suggestions on how upland fishponds could be made to maximize their potential in the production of food while conserving the upland community resources. It also deals with opportunities for community involvement and options for upland development strategies in protecting our mountain environments.

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Fruit-Based Agroforestry for Food Security in the Guatemalan Altiplano

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In Guatemala's highlands, similar to many tropical mountain regions, agricultural productivity is low because of steep slopes and poor soils; cool and unpredictable weather adds to the problems. Small land holdings, usually less than 0.5 ha, further limit productivity and food security. Previous attempts to increase productivity with cool season vegetable cropping failed to enhance food security or nutritional status. Agroforestry-based alternatives may increase economic and biological yields through more efficient resource-partitioning between crops and trees. Fruit-tree based agroforestry systems (*Malus*, *Pyrus* and *Prunus* spp.) with annual crops are prevalent; however the benefits of integrated fruit production have not been well characterized or quantified in marginal highland areas. Ethnographic information on farms and families in two communities, selected based on the presence of fruit tree-based systems, was gathered using national and municipal data, published technical reports, field observations, and semi-structured interviews. Additional information on farming practices was collected from field plots and local markets. A linear-programming model was used to analyze livelihood options. Labor and inputs for sole cropping, intercropping, and mixed cropping, land holdings, and family composition, were considered. The roles of livestock, fodder and non-food crop components were also considered, as was off-farm employment. The effects of farm size, family labor, and commodity prices were assessed. Fruit-tree based agroforestry appears to contribute to food security and income to farms. While household consumption of fruit is an incentive for adoption of such practices, poor market infrastructure is a disincentive. Low fruit-quality and unpredictable yields make intensive management less attractive.

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Agroforestry for Sustainable Development in Nepal

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Agroforestry is a land use system in which tree species are deliberately grown alongside agricultural crops, and often in conjunction with the rearing of livestock. The advantages of agroforestry are that positive biological interactions between the various components of the system result in increased yields and thus increased income. Nepal stands to benefit greatly from the introduction of agroforestry, as its natural forest reserves are at present diminishing rapidly. Nepal is a country with widespread poverty that could be reduced to a great extent by agroforestry farming methods. This is specially the case in mountainous areas, whose characteristics are such that they suffer from an additional variety of problems, but also makes these areas most able to benefit from agroforestry technology. Various agroforestry systems are being introduced in Nepal, varying across the country with climate and physiographic zones. Examples include home gardens, alley cropping, planting trees among agricultural crops, intercropping with horticultural trees, taungya systems, silvofishery, silvopastoral systems, etc. This paper identifies the different agroforestry practices/models prevailing in different physiographic regions of Nepal, explores research and development initiatives of Tribhuvan University / International Development Research Center-Farm Forestry Project (1983-1997), and examines its impacts on rural development in selected areas of Terai, Inner Terai and Midhills of Nepal. Based on these experiences, recommendations are made for sustainable agroforestry development in Nepal.

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Himalayan Biodiversity Conservation: Opportunities and Challenges for Sustainable Development of the Himalayan Regions (A Case Study of Nepal Himalayas)

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The Himalayan region is one of the world's richest ecosystems in terms of biological diversity. The Himalayas are home to hundreds of endemic plant species and some of the world's rare and threatened wildlife species. Approximately 54 percent of Nepal's area is covered with some sort of vegetative cover (forested area 37%, shrub land 5% and grass land 12%). A total of 118 ecosystems with 75 vegetation types, and 35 forest types, have been identified in these realms. These rich biological resources have traditionally served as the foundation for the economic and cultural life of the Himalayan people. However, these resources are heavily threatened from increasing population growth, slash-and-burn agriculture, and the general over-exploitation of forest and vegetation resources for fuel, fodder, manure, grazing, fishing and hunting. Conservation of Himalayan biodiversity is thus one of the important global responsibilities of mankind to ensure its safe future. This paper critically examines the current status of Himalayan biodiversity conservation at different levels, conservation and management approaches of biodiversity conservation, and institutions involved in conservation and management of Himalayan biodiversity conservation. Unless species conservation provides a direct benefit to the rural people, it would be very difficult to attain goals of sustainable development. The goal cannot be attained in isolation. The challenge is how to empower and motivate the larger sector of the society in this direction. Based on these facts and findings, recommendations are made for Himalayan biodiversity conservation to achieve sustainable development of the Himalayan region with emphasis on Nepal Himalayas.

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Agroforestry in Andhra Pradesh, India

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In the state of Andhra Pradesh many research institutes, non-governmental organizations, the forest department, and even the state government are attempting to introduce different agroforestry systems not only to improve living standards of the rural poor and forest dependent communities, but also to tackle the problems of environmental degradation. Agroforestry in Andhra Pradesh is practiced by both marginal farmers to a small extent and by rich farmers to a larger extent, benefiting them substantially. This stands true especially in certain districts of the state that are drought prone and have poor soil fertility status. These farming systems can be broadly grouped into two categories 1) growing trees in and around fields with food crops (agrisilviculture) and 2) growing forestry species on farms for commercial purposes, usually in agricultural fields, on farm boundaries or as separate wood lots (Farm Forestry). However, in spite of the several problems, such as cumbersome government policies, inappropriate knowledge of silviculture and lack of technical support, non-availability of quality planting material, and marketing problems (in the case of rich farmers) and constraints such as small land holdings, lack of water, and grazing problems (in the case of marginal farmers), adopting agroforestry/ farm forestry has proven beneficial to both to a certain extent. The present paper assesses the status of agroforestry vis-à-vis the economic strata of the beneficiaries by documenting a few case studies, and reviews various agroforestry schemes/ projects implemented by various organizations and government bodies across the state of Andhra Pradesh.

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Agroforestry and Sustainable Development in Cameroon

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Agroforestry could be presented as one of the means to reconcile the need for agricultural or forestry production and the protection of soils and the environment. The assessment of agroforestry experiences in Cameroon shows that some factors still hinder the full expression of its potentialities. Those factors include, among others: choice of the species planted; mastery of agricultural and forestry techniques, and, more globally, the integration of agroforestry in the global agenda on sustainable development. This paper builds on the positive points of agroforestry as proven by field experiences, to advocate that it can play a better role in the constant search for more sustainable development strategies.

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Improving Rural Livelihoods through Sustainable Land-use Systems (Perspectives on Agroforestry from Uganda)

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The Rio Conference (1992) created public awareness about the critical environmental issues facing the world. The Cairo Conference (1994), in turn, highlighted critical issues pertaining to high population growth. Less publicized, however, but very critical to the future of humankind, is the need to greatly improve agricultural productivity in a sustainable manner, commonly referred to as integrated approaches or initiatives. Environmental degradation, high population growth in developing countries, and the need to enhance sustainable agricultural productivity are now interlocked issues that constitute a triple global challenge. *How then is the world going to feed the high population and improve their livelihoods without compromising the environment that is already under great stress? Could agroforestry be part of the answer?* This paper will focus on agroforestry as a sustainable land-use system aimed at improving rural livelihoods and solving the three interlocked global environmental issues. It will discuss how rural-based farmers can through their experiences work together with other focal points in promoting agroforestry as a sustainable land-use system.

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Enhancing Food Security with Livestock in Agroforestry Systems in the Philippines

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In developing countries, most smallholder sloping land farmers integrate livestock with trees and annual crops. The SAFODS Project, or Smallholder Agroforestry Options for Degraded Soils, is an EU-funded collaborative research in Indonesia and Philippines from 2002 to 2005. It aims to understand tree-soil-crop interactions, select locally-suitable components and conduct limited field trials. The livestock component examines livestock production benefits to households, in relation to food and tree cropping, landholding size, slope, etc. Farm trial interventions into farmers' practices aim to optimize household benefits from farm integration with multipurpose trees and crops for animal feeds, manure for fertilizer, harnessing idle family labor, food, cash income and savings. In Claveria, Misamis Oriental, the Philippine site, a 1998 survey revealed 17% malnourished children from 1 to below 5 years old, in 20% of communities. This is partly due to poor roads and access to market and supply of fish, the country's principal source of dietary protein. The 2002 Project household survey showed that chickens provided the most home-consumed benefit, followed by pigs then goats. Pigs were raised in 56% of households, cattle in 45%, chickens in 39%, water buffaloes in 21%, goats in 6% and native pony in 2%. With selected households, the Project will demonstrate increased animal feed and livestock production through fodder tree hedgerows for ruminants and/or intercropping with taro, cassava, cowpea or pigeon pea for non- ruminants. Collaboration with local health workers will monitor the effect of improved availability of animal products and reduced malnutrition from the livestock interventions.

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Spontaneous Agroforestry Adoption: Transforming Shifting Cultivation Areas and Degraded Grasslands into Productive Agroforestry Farms (Two Case Studies from the Philippines)

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This paper focuses on two cases from the Philippines which proved that agroforestry adoption can be done with minimum government interventions. One case involves a woman who converted 100 hectares of degraded grasslands into a very productive agroforestry farm. The other one is of a man who transformed 18 hectares of shifting cultivation area into a sustainable and profitable agroforestry enterprise. The common design of the two model farms includes soil and water conservation, year-round income, efficient utilization of space, nutrient recycling and multiple cropping. The driving forces associated with spontaneous agroforestry are: market, labor availability, land tenure, social capital, local policy support, managerial ability, entrepreneurial spirit, and aspirations in life. The production system initiated becomes the basis of a rapidly expanding sustainable land use system in the locality that is first copied by the immediate members of the family followed by relatives, friends and acquaintances.

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Exploring the Effectiveness of the Promoter Model as a Means of Integrating Agroforestry Adoption in Veraguas, Panama

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The *promoter system* of agroforestry extension for adoption of sustainable agricultural techniques has been widely studied and accepted as a tool for agricultural development. This approach has been particularly effective where local resources are scarce. Much development work has been done in Panama using the promoter model. In order to ascertain the local success of this model, promoters trained by World Vision were visited and the adoption of agroforestry practices were measured in five communities where seven promoters were trained and placed in the province of Veraguas, Panama. Despite the long-term presence of World Vision and trained promoters, only two farmers have adopted at least one agroforestry technique as a result of these extension efforts. Reasons for this low rate will be discussed. Also, the study will discuss the need for and benefits gained by more localized research.

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The Impacts of Illness on Livelihoods and Household Coping Strategies in Western Kenya

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This study explored how the livelihoods of subsistence farming, fishing, and small business are impacted by illness and the range of coping strategies used to ameliorate these impacts. A total of 120 household interviews were conducted in two study sites in western Kenya. Each interview included a general questionnaire and a case history for one illness episode. In addition, group interviews were conducted to explore the communities' impressions of the consequences of illness. Respondents were stratified post-facto to analyze the differences between female and male-headed households and between households in the two sites. The most commonly reported impacts included; missing work due to personal illness or caretaking, changes in agricultural production due to lack of labor or resources, decreases in livestock, which were sold to pay medical expenses or slaughtered for funerals, temporary or permanent interruption of small businesses, and the inability to visit friends or relatives. There was surprisingly little evidence of differences between female and male-headed households for many of these impacts. Funeral customs result in widespread impacts to livelihoods in these communities, which were explored qualitatively through group interviews. Common coping strategies included borrowing labor and resources. These strategies were also analyzed for differences between female and male-headed households. Differences in access to social networks and their use in times of illness were also explored.

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Proposal for the Creation of a National Center of Research in Agroforestry Systems in Venezuela

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Venezuela is a country with enormous potential for agroforestry activity. At the moment there is no research center in agroforestry systems which could serve to meet the demands of original goods and services of the nation's forest ecosystems, empower the country or encourage the economic growth of resource-limited rural populations. In poster will appear the proposal for the "Creation of the National Center of Investigation in Agroforestry Systems (SAF's)" within the Institute of Agricultural Research in Venezuela. This work includes the following aspects: strengths, weaknesses and opportunities to conduct research in agroforestry systems; geographic areas with high potential for SAF research projects; human resources and expected performance of research staff; research and development aims; and national and international cooperative strategies. The high-priority areas to develop in investigation include: database development, publication and popularization of existing agroforestry information; design and ecological characterization of forested areas with potential for SAF using GIS data; production of seeds and identification of high-priority species; genetic improvement and biotechnology; forestry and plantation technologies; identification and use of non timber products; environmental services and carbon sequestration; development of rural communities; problem solving of community issues; recovery of degraded areas and conservation of soils; use of residual waters to supply forest plantations; economic aspects and fiscal incentives for reforestation inside and outside of the sector; forest fires and forest protection; use of lesser-known forest species and energy plantations; and other aspects related to this investigation, including participatory investigation, support activities, technology transfer, nets, and popularization strategies, among others.

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Agroforestry Policy and Food Security in Brazil

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This study analyzed the particularities of the inclusion of Cerrados into the productive process in Brazil, with emphasis on forest management. Although the Cerrados, the Brazilian savannah, were the object of scientific studies in the 19th Century by European Naturalists, most agricultural and ecological systematic studies started in the 1940's. In the 1970's the Cerrados became a privileged space for public policies. Notably, reflecting the general pattern of rural development, growth in the Cerrados were predatory to sustainable and socioeconomic development, a fact observed in rural and peri-urban areas, with increasing marginalization of workers. The aggression to the Cerrado ecosystem is an extremely worrisome fact given its prominence among tropical ecosystems. Moreover, the growth strategy collided with the objective of providing food security in the country, a fact of great relevance considering that the Brazilian society started the 21st Century with expressive portion of its population in absolute poverty. Nowadays, the State gave priority to hunger eradication in the country with *Projeto Fome Zero*. In this project, structural actions consistent with this objective, notably with respect to agrarian reform, are identified. In this aspect, this study analyzes the public policies related to agroforestry systems adoption in the Cerrados. The findings are based on surveys and literature review on public policies and their impacts on the agricultural frontier of the Cerrado. Alternative agroforestry technologies are proposed to mitigate those impacts and to improve food security for the small and medium farmers in the region.

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Agroforestry for Sustainable Livelihood of Tribal Peoples in North Andhra Pradesh, India

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Andhra Pradesh is the traditional home of nearly 33 tribal groups and most of these communities are found inhabiting in upland region. The area is semicircular, scattered broken chain of mountains, hills and hillocks ranging from 50 to 1,110 masl. The climate is tropical sub-humid and the average rainfall varies between 1200 mm to 1400 mm. Nearly 75% of the rains are received between June and September, the rest between October and December. The region is a reservoir of floristic diversity. The prevalent agroforestry can be categorized into traditional and introduced practices. The tribals have practiced agroforestry since time immemorial. Gradually they moved to shifting cultivation with occasionally trees in cultivated lands. The blending of the available biodiversity and their cultural needs helped for domestication and naturalization of important tree species from their surrounding forests. Shrubs and trees are planted as hedgerows and live fencing in the farms. Fruit trees, vegetable crops, and spices are cultivated as a part of the traditional agroforestry system. The degraded hills are covered with introduced agroforestry, which is a mostly single species crop. In the introduced practice, large-scale cashew plantation in low altitude areas and coffee plantation in high altitude is promoted. Pineapple is promoted as an intercrop in cashew gardens. Stabilizing the large-scale single species crops, blending people's choice, adapting scientific methods, utilizing ecological and genetic diversity, promoting value addition methods for their produce can help in sustainable land management and better livelihood for the tribal peoples.

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Agroforestry Development in Sri Lanka

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The fauna and flora of thousands of species in the world's forests have been supplying materials and services to mankind for generations. Until recently the financial value of a forest was determined according to the timber it supplied. However, research by various organizations has proved that the non-timber resources available have surpassed the place of timber, in usefulness. It is observed that the non-timber products provide a continuous support to the rural community. In Sri Lanka, 78% of the population live in rural areas, of which nearly 50% of the labor force is employed in agriculture and related activities. Subsequent to rapid population growth, destructive practices adopted by the settlers, harmful to the environment, and the rising demand for fuel wood, have contributed to the depletion of the forest cover in Sri Lanka. The tropical rainforests are of paramount importance and are indispensable in Sri Lanka. They are particularly important for their unique biodiversity, water conservation, water resource management, and soil conservation qualities. The non-timber wood production concept has been acclaimed as an effective strategy for forestry economy and sustainable environmental conservation. In terms of overall achievements, the study observed that growing of cane, bamboo, kitul, and perennial crops (e.g., mahogany, teak, jak, eucalyptus) under agroforestry development will facilitate socio-economic enhancement of the community, through improved production and marketing methodologies, whilst combating land degradation, resulting in the conservation of the unique biodiversity of the region.

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Contribution of Agroforestry to Rural Livelihoods: Experience from Nepal

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Agriculture and forestry are closely linked with the livelihoods of the rural population in Nepal. Since time immemorial, traditional agroforestry practices have been major practices supporting subsistence agriculture in the rural areas of Nepal. Therefore, this study was carried out to analyse the contribution of these agroforestry practices to generate various resources (capitals) for the people that use them to build their livelihoods. The study was conducted in Syangja District of central mid hills of Nepal. The secondary information obtained from various reports and other relevant documents were supplemented by the data gathered from sample household survey and group discussions with the study households. The findings of the study indicate that agro-silviculture was the common agroforestry system adopted in the mid hills of Nepal. It has contributed mainly to the improvement of people's livelihoods in two ways, namely, providing food security in the communities and financial capital formation in rural communities. Milk from livestock, timber, fruits and off-season vegetables were the main sources of cash income of households. The main seasonal sources of livestock feeds such as fodder were from private land as well as community forests and crop residues from agricultural land. Therefore, agroforestry has been a major practice to create and enhance the livelihood resources in the rural areas of Nepal.

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Growth and Productivity of Poplar Based Agri-Silviculture System for Diversification and Food Security in Northwest India

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India is a developing country with more than a billion people to feed, house and clothe. Up to the late 1960s India was importing food from developed countries when she started agricultural reforms and the states like Punjab and Haryana progressed through an enviable “Green Revolution”. These States are now facing the problem of overproduction of grains from wheat and rice rotation. Earlier the States were encouraged to produce more of grains for the “Central Pool” whereas now the farmers are being advised to ‘diversify’ from rice-wheat rotation. Poplar, *Populus deltoides*, offers an excellent choice for diversification from rice cultivation and also ensures food-security. The farmers adopted Poplar cultivation on a large scale and the region has now become surplus in farm-grown Poplar timber. Eighteen block and seven boundary plantations were studied. Regression equations for tree height with age were Log ht = 1.4464 – 0.6933*1/A in block, and Log ht = 1.3286 – 0.42533*1/A in boundary plantations. Similarly, DBH regression equations came out as DBH = 6.2602 + 2.9575*A in block, and DBH = 5.6709 + 4.1855*A in boundary plantations. Tree height growth was better in block plantations. Study revealed that farmers were producing 59.1 m^3/ha/annum under well-managed conditions in riverbed areas, and 48.1 m^3 in tableland situations; 30.7 m^3/ha/annum and 26.1 m^3/ha/annum in well-managed and in somewhat less managed six-year old plantations, respectively; and 49.4 m^3/ha/annum and 9.33 m^3/ha/annum in well-managed and neglected nine-year old plantations, respectively. Performance of associated crops in agroforestry systems is discussed.

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Agroforestry for Upland Livelihood: The Case of MFR Farmers in the Philippines

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With an area of 4,244 ha and located 65 km south of Manila, Philippines, the Makiling Forest Reserve (MFR) is an important natural resource due to its multiple uses. Under the jurisdiction of the University of the Philippines Los Baños (UPLB), the Reserve serves as UPLB's outdoor educational laboratory for the biological, physical and social sciences. It is also an important watershed for a number of towns and communities surrounding it. The Reserve's biological diversity is one of the highest in the Southeast Asian region and is an important recreational and ecotourism area. Like many upland areas in the Philippines, farmers who either reside and farm inside the Reserve or live outside the Reserve but farm inside occupy MFR. These farmers have maintained their agroforestry farms as source of income coming mainly from fruit trees and food crops which comprise the multistory cropping system. Analysis of household income points to the importance of agroforestry crops in the household economy of these upland families. However, some social, policy, and institutional issues have to be addressed in order to sustain the productive as well as the protective functions of the MFR.

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Agroforestry Challenges among Equatorial African Hunter-gatherers: The Case of the Baka Pygmies in East Cameroon

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The continuous degradation of tropical forests and inappropriate forestry legislation constitutes, amongst other factors, serious hindrances to the hunter-gathering lifestyle the Baka Pygmies have been living for the past thousands of years. The adoption of agroforestry is seen as an option that could stabilize this semi-nomadic population, and enrich their natural diet, which is becoming more and more unbalanced. Out of the ecological constraints linked to adopting an agrarian system that integrates food cropping, domestication of wild fruit trees, the introduction of useful exotic trees and small animal husbandry, this study will focus on the socio-cultural and institutional aspects that regress the advent of agroforestry amongst Baka Pygmies, who only started a sendentarized lifestyle in the 1950s. Four main articulations will illustrate the magnitude of this challenge: (i) the difficulty for the Baka people to evolve from a labour reward/return system with "immediate return", towards that with "delayed return"; (ii) the backwardness of the political situation of the women coupled with their numerous household and subsistence tasks; (iii) the conflict between the traditional social organization and the new organizational structures to support agroforestry; and (iv) the land tenure problem opposing the sedentic Bantu agriculturists and the semi-nomadic Baka Pygmies. The actual experience of some Baka groups will constitute the basis of this article.

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The Role of Fruit Trees in Food Production Systems in Rural Areas of the Eastern Cape, South Africa

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This initiative aims to assist in the transformation of poverty into wealth in some of the worst afflicted areas of South Africa and to develop economically viable, self-sustaining homesteads by building upon and supplementing those resources (material, traditional and spiritual) that already exist in these stricken communities. A homestead-based approach is followed and preferred to communal sites. The homestead is the single unit that embodies a viable, healthy, dignified group of human beings who live by the product of their own efforts and contribute to the common good. The average family size in the study area in the Eastern Cape, South Africa consists of 12 members with an average household garden of 1.1 ha and a monthly income of R530. In addition to household gardens, some families have permission to utilize an additional portion of land which could be several kilometres from the homestead. Subsistence farming is usually practiced on both land portions. The objectives are therefore to improve land usage, household income, food security, food variety and nutritional status and introduce sustainable farming methods. To achieve these objectives, homestead high-value fruit tree gardens were introduced. As a result of limited household land available for utilization, high-density tree plantings are utilized and intercropping is practiced. Vegetables and herbs are used for intercropping. High-density tree plantings result in an earlier economic break-even point and a shorter wait-time for optimum production per hectare. A total of 74 homestead-based mini-orchards have been established utilizing conventional and traditional tree crops, vegetables and herbs.

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Agroforestry as a Means to Conserve *Gnetum africanum*, *Voacanga africana*, *Prunus africana* and *Ancistrocladus korupensis* in the Mt. Cameroon Forest Region and their Status to the Community

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This work is aimed at making a critical assessment of the status of *Prunus africana, Voacanga africana, Gnetum africanum* and the *Ancistrocladus korupensis* in the Mt. Cameroon forest region and their conservation strategies. The primary phase included field studies aimed at having firsthand information on the species abundance and diversity. The secondary phase included the use of questionnaires, interview with conservationists, farmers and researchers, so as to determine the various strategies used by agroforesters in species conservation. The result showed that these species are the most threatened and classified under appendix II of CITES. Mount Cameroon holds the most important single repository of this biological diversity. The socio-economic value of these plant extracts (bark, stem and leaves), is the motive behind this current exploitation. For instance, the bark extract of *Prunus* (CV-136) is used to produce the drug Tedanin and Pygenir for the treatment of prostrate cancer, *G. africanum* is used as food, *V. africana* is used to cure madness, malaria and stimulate breast milk production, *Ancistrocladus* is currently under research for the production of a vaccine for HIV/AIDS. Therefore, effective agroforestry and agroplantation strategies have to be implemented (*ex situ* conservation) besides the already existing *in situ* conservation. To conclude, responsible management of these species remains inevitably a real opportunity for the government and local community to demonstrate their commitment to pursue commercial objectives without compromising the future with the risk of extinction.

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Methods of Determining the Sustainability of Agroforestry Land Use Systems

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In the development agenda, the problem *of sustainability* has become a great concern. Because sustainability cannot be measured directly, interest has been directed to the *indicators* on how to measure it even indirectly. The methods of its measurement are examined in this paper. Consequently, a simple framework for its determination is proposed.

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Forage and Cattle Production in Slash Pine-Bahiagrass Silvopasture in South Central Florida

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There is a dearth of information on cattle productivity in silvopasture in Southeast USA. Utilizing 12-yr-old slash pines (*Pinus elliottii*) planted in 1.2 x 2.4 m double-rows spaced 12.2 m apart, forage and cattle production of two silvopastures with 309 and 494 trees ha^{-1}, respectively, were compared with an open pasture. All pastures were 'Pensacola' bahiagrass (*Paspalum notatum*) with legumes, 'Florida' carpon desmodium (*Desmodium heterocarpon*) and 'Shaw' vigna (*Vigna parkeri*) and stocked at 2.5 cow-calf pairs ha^{-1}. Braford cows (>4 yr, 52 cows @ 511 kg) and calves (112-d-old, 164 kg) grazed the two silvopastures and open pasture for 112 d from 1 June to 15 September 2003 (weaning). Seasonal forage accumulation was greater (P=0.001) in open pasture (10,180 kg ha^{-1}) than in two silvopastures which were not different (avg. 7485 kg ha^{-1}). Forage mass averaged 2,188 kg ha^{-1} in all pastures on 1 June and declined linearly over the grazing period in silvopastures. Forage mass changed quadratically in the open pasture by increasing from 1 June to 21 July, then declining to 15 September. Cows lost more weight (P<0.001) on the silvopastures (avg. 88 kg) than in open pasture (22 kg). Calf weight at weaning (236 d) was higher on open pasture (212 kg) than on silvopastures (179 kg). Pines reduced forage accumulation by 26.5% and calf weight by 15.6%. Profitability of silvopasture will depend on whether loss of income from livestock later in the timber rotation will be offset by the value of timber.

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Forestry Extension: Behavioural Research Foundations for the Promotion of Livelihood and Ecology through Agroforestry (A Study from Karnataka State, India)

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The impacts of afforestation programmes have not yielded desired results, as they were not tuned up with the perceptions, attitudes, motivational patterns and cognitive domains of the farmers on the consequences of degradation of forests. This paper is based on the experimental study conducted in three villages, and looks at development of tests/scales for the measurement of perception, attitude and motivational pattern of farmers towards agroforestry, and the impact of three extension methods on behavioural dimensions, and assesses their implications for adoption of agroforestry for the improvement of farmers' livelihood and ecology in rainfed areas of Karnataka state, southern India. The pre-tested schedule was used to elucidate the data by employing the personal interview method from 46 farmers of each village before and after the treatment given (1994) and then during the year 1995 and 2003 to analyze the adoption level and impact respectively. The findings revealed that all the farmers had poor perception, unfavourable attitude and less motivation and hence they had poor knowledge and adoption level of agroforestry practices before exposure to the extension methods. Emphatically, 'training' and 'focus group discussion meeting' were found to be effective in molding the behavioural dimensions in a desirable way than the 'study tour' with respect to different dimensions of agroforestry. The data collected after eighth year also displayed that the 61 percent of farmers were knowledgeable and adopted majority of the agroforestry practices which in turn brought improvement in the socio-economic status of resource-poor farmers and ecological conditions of the area.

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Marketing Behaviour and Information Source Consultancy Pattern of Farmers Practicing Farm Forestry: Case Study of Teak Producers in Karnataka State, India

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Teak (*Tectona grandis* L.) is a high-value tree crop having alarming demand. Therefore, farmers in the Malnad region of Karnataka state, southern India, started growing it as one of the tree crops in their farms. With the increase in the teak production in the area, the marketing behaviour and information source consultancy pattern of teak growers has become an interesting phenomenon. Thirty villages were selected for the study and in each village, three farmers practicing farm forestry were selected randomly. Thus a total sample size consisted of 90 farmers. The data were collected from the respondents through personnel interview technique and analysed. The study revealed that 37 percent of the growers cut the tree in the age group of 20-30 years followed by 25 percent between 30-40 years and only 17 percent of farmers harvested above 40 years old trees. Fifty-four percent of the growers got permission to cut the trees after 6 months to 1 year period. Sixty-two percent of the farmers sold their produce through forest contractors, 27 percent through saw-mill owners and 11 percent directly to consumers. The study also revealed that the 58 percent of the farmers were not aware of the market price of teak. The friends and neighbors served as important source of information (79 percent), followed by relatives (66 percent), agricultural assistants (30 percent), assistant conservator of forests (28 percent), and saw-mill owners (22 percent) for seeking the information on cultivation, harvesting and marketing of teak.

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Adoption of Agroforestry Technologies in Dingle, Iloilo, Philippines

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This study on the adoption of agroforestry technologies was conducted in four barangays (communities) of Dingle, Iloilo, Philippines, in order to determine the profile of the agroforestry farmers who were receptive to new strategies and effective delivery systems. The study determined the relationship between the rate of adoption of the agroforestry technologies and delivery systems and socio-economic profile of the respondents. The three delivery systems used were: focus group discussion, cross-farm visit, and seminar/training. The data gathered were described and analyzed using the percentage, mean, Friedman Analysis of Variance and Coefficient of Contingency set at 5% level of significance. The results revealed that farmers with ages 30 and below, attained secondary education, had low family monthly income and leased their farms, and had the highest rate of adoption. A significant difference existed in the adoptability of the respondents through seminar/training when classified as to family income. Finally, a significant relationship existed between cross-farm visit and rate of adoption and also between focus group discussion and rate of adoption. The researcher recommends that in introducing agroforestry technologies, the extensionists/trainers should use focus group discussion or cross-farm visit when the educational attainment of the participants is at least secondary level.

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Agroforestry in Kandi/Semiarid Region of Jammu & Kashmir State of India

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In the agroforestry systems different crop rotations have been recognized by farmers in the Himalayan region of India. The most distinguished one is agroforestry system with trees and annual crops. However, the most widely adopted form of agroforestry is the planting of trees and shrubs around agricultural fields and pastures. Fuel and fodder are the prerequisites for the sustenance and progressive livelihood for any rural setup. Fuel for human life and fodder for cattle are essential criterion, which are mutually interlinked for their co-existence. The dry, semiarid terrain of Jammu region is crucially affected by unpredictable weather aggravated by prolonged dry spells in the last couple of years. As such, dependence upon green covers surrounding their habitat is of paramount importance. Naturally growing tree species *Acacia nilotica*, *Acacia modesta*, *Butea monosperma*, *Ziziphus* sp., *Grewia optiva, Dalbergia sissoo*, *Acacia catechu*, etc., form the bulk of fodder and fuel. The sloping and undulated terrain of the region has necessitated the prime need for the plantation of agroforestry tree species. The tree species to be planted should be easily propagated, fast growing and should have enormous vegetative cover. Being deep rooted they too serve as a check to soil erosion. The availability of fuel and fodder, and increase in production of milk animals, is economically important to poor peasants. The spiny branches/twigs of *Acacia modesta, Acacia nilotica* and *Ziziphus* species are excellent and reliable rural fencing materials utilized extensively by the peasants in this semiarid region.

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Forest and People's Livelihood System - Jammu & Kashmir State of India

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Jammu and Kashmir (J&K) State, situated in the extreme north of India, has a forested area of 6.58 lakh hectares accounting for 27.23% of total state area. In this hilly state, both coniferous and non-coniferous forests yield Rs 4500.00 lakhs revenue annually. Non-commercial reserves are situated on 1,963 km^2 and commercial reserves are on 20,180 km^2, making a total area of 22,144 km^2. Non-coniferous forests cover 945 km^2 and coniferous cover 19,235 km^2, including 1,122 km^2 under Deodar, 1,773 km^2 under Chir, 1,877 km^2 under Fir and the rest under others. Economy of state depends upon forests largely, but over-exploitation has decreased forest area rapidly. Seventy per cent of the people live in vicinity of forests and since agricultural production is insufficient, stress on non-timber forest products has increased for food and income needs. Increase in human and livestock population from 3,560,976 (1961) to 10,069,917 (2001) and 40.86 lakhs (1961) to 91.75 lakhs (2001) respectively, has put heavy pressure on forests. Thus the need of the hour is afforestation. Fruther state imported 0.78 and 0.33 lakh tons of rice and wheat in 2001-2002. Since area under agriculture cannot be increased due to limited resources, so to make the state self-sufficient, area under single land use should be brought under agroforestry. Agriculture and forests should be integrated to meet demand for food, fruit, fodder and timber. Present study makes an attempt to study changes in forest area, its composition, revenue and expenditure on forests in J&K state of northern India.

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Agroforestry Efforts in Rwanda

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Many Rwandans depend on agricultural production and animal husbandry for their survival. However, not only is the family agricultural exploitation decreasing because of demographic pressure on land (310h/km in 2002), but also there is soil degradation because of insufficient application of techniques of protection of basins and vegetation. We are also encountering progressive degradation of other natural resources thus leading to ecological and socio-economic problems. Then, an agroforestry program shall ensure ecological and economical security of reforestation through the planting of indigenous and exotic tree species that go well with the different land regions of Rwanda which will then lead to a significant increase of biodiversity species and many trees. This will also fight against erosion. Within the general principles of the National draft Forestry policy, due to the lack of enough land to plant new forests, there is a need of focusing on mixing trees within crops and plants on agricultural farms (Agroforestry). This strategy will encourage farmers to reforest on their farms, thus agroforestry has a special privilege in the reforestation of Rwanda in future. The Government of Rwanda recognizes the development of the forestry sector as a national priority, with a 30% increase of forests on the national territory by 2020. The Agroforestry system is to progress and attain 85% of cultivated land. Thus the Rwanda Wildlife Clubs and ICRAF are committed to put into place a sustainable agroforestry system in the country, and with the partnership of the Ministry of Forestry this shall be possible.

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Sustainable Land Use Practices for the Uplands of Vietnam: Science and Local Knowledge for Food Security

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Land degradation and, eventually, declining crop yield have been recognised as the major problems in the uplands of the humid tropics when forests are converted to farmland and cultivation becomes more intensified. A better understanding of the underlying reasons for land use changes is required, as well as new sustainable land use options for food security **and** environmental protection. The food security of smallholders includes income security with market integration and local food production. Our general hypothesis is that watershed management based on landscape relationships and a participatory approach with involvement of local and external stakeholders are suitable for the development of sustainable land use practices with high acceptance by the local land users. A Knowledge-Based System approach, whereby local and scientific knowledge is combined to develop new land use options, is being tested at Dong Cao catchment (20° 58' N, 105° 29' E), in Hoa Binh province, Vietnam. The scientific knowledge contains erosion measurements at catchment level and simulation using Water, Nutrient and Light Capture in Agroforestry Systems modelling – WaNuLCAS. Local knowledge contains Local Ecological Knowledge of soil-tree-crop interactions within a landscape, which was gathered and analysed using PRA/RRA tools and the Agro-Ecological Knowledge toolkit for Windows – WinAKT 4.06. As a result, several Farmer Field Schools were organised by local farmers to test the domesticated bamboo species Bat Do and the species *Brachiaria ruziziensis*, *Stylosanthes guianensis*, *Tephrosia candida,* as well as to compare them with the local bamboo and grass species in terms of income generation and soil improvement.

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Contribution of the Grasses and Forages Experimental Station "Indio Hatuey" to the Development of Agroforestry Systems in Cuba: Aspects of Animal Production

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The silvopastoral systems, that at the moment constitute scientific achievements of the EEPF "Indio Hatuey", are based on the results of investigations which, from the decade of 1980, were carried out to improve the productivity of natural pastures with the introduction of herbaceous, voluble and tree legumes and also to determine the essential elements of pasture management such as optimal stocking rates and suitable methods of grazing to obtain a good stability of the systems. Among the diverse types that conform the silvopastoral systems, the *Protein Banks* and the *Multiple Associations of legumes and grasses* have been those that have contributed more with important results in Cuba, as much to produce milk as meat and they are outlined at the present time like systems that can be generalized, integrated to the set of productive intentions of actual Cuban cattle production. *Leucaena leucocephala* has been the more used tree on silvopastoral systems and also the one that has contributed more in the country with experimental data to evaluate the real advantages of agroforestry, but it is not the only one. Other species such as *Albizia lebbeck*, *Erythrina berteroana*, *Erythrina poeppigiana*, *Gliricidia sepium*, *Bauhinia purpurea*, *Morus alba*, etc., have been tested with a lot of successes and appear as important elements of diversification of plant communities in the silvopastoral systems for milk and meat production. The main results obtained with the use of Agroforestry for Animal Production in Cuba are also presented in the discussion.

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Opinion of the Farmers on Effectiveness of Agroforestry towards Sustainable Agricultural Development in Bangladesh

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Agroforestry has been practiced to achieve more sustainable and productive use of limited land resources. The main objective of the study were i) to determine the extent of adoption of agroforestry activities, ii) to determine and describe the selected characteristics of the farmers, and iii) to explore the relationship between the farmers' selected characteristics and their opinion on effectiveness of agroforestry towards sustainable agricultural development (SAD). Data were obtained from 120 randomly selected respondents of eight villages of two upazilas in Sirajgonj district, Bangladesh. The average lands were 0.52 ha, and Eucalyptus, Mahogany, Akashmoni, and Raintree were frequently planted in the crop field. About 60% and 65% respondents received primary and ongoing information about agroforestry practice from National Development Programme (NDP), 72% respondents have established agroforestry by their own funds and others had taken loan from NDP. Also, 43.33% respondents were purchased seedlings from NDP and 30% from private nursery. Majority (88%) of the farmers opined that agroforestry had moderately to highly positive effect of agroforestry towards SAD while the rest opined on less positive effect. Correlation indicated that the characteristics of the farmers such as education, farm size, annual income, communication exposure, cosmopoliteness, innovativeness, perception of sustainable agricultural development, knowledge of agroforestry, and awareness on effectiveness of agroforestry on environment had significantly positive- and age, training attended, organizational participation, farming experience, and fatalism- had insignificantly positive relationship with the opinion of the farmers on effectiveness of agroforestry towards sustainable agricultural development.

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Study on Growth and Management of Bamboo Based Agroforestry System to Rehabilitate Degraded Jhum Land in Northeastern India

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The study aimed to recommend the most suitable bamboo species under agroforestry system to be introduced by farmers to reclaim their degraded jhum land in Sakawrtuichhun and Luangmual villages of Aizawl, India. Effect of fertilizer (NPK) and humus on the number of new culms, culms height and basal diameter of culms of bamboo was significant. Further, the effect of NPK has maximum positive effect on growth performance of bamboo species, followed by that of humus and least in control. In the third year, mean comparisons indicated significantly better growth in basal diameter of bamboo species under 4x4 m spacing compared to 3x3 m spacing. Significant effect of bamboo spacing on height of tillers (ginger) in second and third year, and yield of ginger only in third year increased. Soil nutrient status decreased marginally after intercrop harvest. The result of edible bamboo species grown with soybean in agroforestry system on Eastern aspects indicates that effect of spacing on culm height and diameter of bamboo was significant in third year. Effect of spacing on the number of culms was significant in the third year; the effect of fertilizer (NPK) on height and diameter of bamboo was significant throughout the three years of the study. Best height growth occurred in *Dendrocalamus longispathus* followed by *Dendrocalamus hamiltonii* and least in *Bambusa tulda*. Also, the effect of species and spacing on the yield of soybeans was found significant in the third year. Suitable management practices (e.g., harvesting intensities for three edible bamboo species) are reported.

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Impact of Regulatory Mechanism on Agroforestry Systems: The Changing Face of Rural India

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In India, the presence of 18% of the world's cattle population coupled with low per capita forest availability has resulted in immense stress on forest resources to meet the tremendous national demand for timber, fodder and fuelwood products. Forests of India can provide fodder for 270 million of the 445 million livestock at present. In order to meet this demand and develop linkages of socio-economic conditions of rural India with developmental program, the Social Forestry Program was launched in mid 1970`s with agroforestry as a major thrust. The policy planners introduced a regulatory mechanism, which influenced the farmers' decisions in the selection of species for planting, thereby influencing the traditional practices in different agroclimatic regions of the country. Agroforestry is also the major component of the integrated watershed management program in vogue for sustained land-use practices. The program has emphasis on community participation with use of Multipurpose Trees (MPT) with traditional agroforestry systems (AFS) prevalent in India. The AFS are based on traditional and indigenous preferences based on knowledge and cultural diversity spectrum of the community. The external funding for watershed management programs and the agroforestry projects have led to introduction of exotic species resulting in new combinations of the MPTs for different agroclimatic regions of the country. This paper analyzes the factors influencing farmers' decisions and preferences for selection of different MPTs based on regulatory mechanisms affecting traditional agroforestry practices for sustainable agriculture tree-based land-use practices in India with a case study of foothills of Himalayas.

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Contribution of Agroforestry to Food, Feed and Wood Self-sufficiency and Sustainability in Rural Livelihoods in Ethiopia

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Food self-sufficiency and sustainability is ensured in general in any country and in Ethiopia in particular where trees exist abundantly as a land cover biological resource. A scattered tree of multipurpose role in crop and pasture ensures food and feed self-sufficiency better than any sole production of crop or pasture. System inputs for growing trees are totally organic under traditional practices. Other direct and indirect benefits that trees as a mix contribute (compared to monocultural farming systems) are discussed in several agro-ecological settings. Recurrent drought and scale of the problem will be correlated with population increase positively in the system. These topics will be discussed by using research statistics as an example. The study will review information on traditional farming systems and uses generated from farmers' traditional practices and will quantify the contribution from a sustainability, production increase, storability and product quality perspective. Trees that have a complementary production role are identified. Agroforestry's role in soil and water conservation, honey bee forage, temperature stabilization, and other indirect roles are presented with practical examples, and research results. Recommendation is made in each specific example towards formulation of appropriate agroforestry packages. In the introduction and discussion part, conventional confusion between constraints and opportunities will be presented and discussed. This section will play an important role in new conceptual and attitudinal changes of the major actors in rural agricultural development professions. In sum, the contributions of perennial agroforestry interventions for short- and medium-term perennial solutions in food, feed and wood self-sufficiency are presented.

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SWOT Analysis of Some Agroforestry Systems Implemented in Sarawak, Malaysia and Their Future Directions

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Agroforestry experiences in Sarawak, Malaysia started more than 100 years ago along the traditionally managed system as a way of making claims or right on the area first cleared after shifting cultivation and for subsistence food production. Agroforestry was first mooted by the Forest Department of Sarawak, Malaysia in the late seventies as a possible strategy to contain the problem of shifting cultivation and loss of forests within the permanent forest estate. The first organised and intensively managed project by the Department was implemented since 1987 until recently. The various agroforestry systems implemented in the state of Sarawak, Malaysia are reviewed and future directions are discussed in relation to the strong emphasis to this land use systems in the Third National Agriculture Policy covering the period 1998 – 2010. Integration of resources and technology is vital in future agroforestry development programmes in Sarawak.

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Assessing Agroforestry Adoption Potential in Cape Verde – A Multivariate Approach

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Farmers on the Cape Verdean island of Santiago were surveyed to determine their interests in applying agroforestry practices on their farms, and the opportunities and constraints they face in doing so. Farmers identified the primary crops and benefits that they would produce from the added trees as fruit, fuel, and shade for livestock. Farmers then identified whether or not they would indeed plant trees for these purposes. Of the farmers surveyed, 53 percent expressed a willingness to plant trees for fuel, 73 percent expressed a willingness to plant trees for fruit, and 16 percent expressed a willingness to plant trees for shade. Discriminant analysis models were developed for these three groups to relate tree planting willingness to farmer characteristics such as age, gender, family and farm size, etc. Using a jackknife validation procedure, the models had correct classification percentages ranging from 63 for farmers willing to plant trees for fuel to 88 for farmers unwilling to plant trees for fuel.

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The Project for the Development of Community Forestry Methods Appropriate for Turkey: "Community Forestry Project" Experience in Sinop/Durağan and Erzurum/Uzundere (1991-2000)

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In 1991, the Development Foundation of Turkey (TKV), a voluntary organization, had started its project Development of Community Forestry Methods Appropriate for Turkey (Community Forestry Project) in 14 villages of Durağan (Sinop) and Uzundere (Erzurum) regions of Turkey in cooperation with the UN Food and Agriculture Organization (FAO) and Ministry of Forestry. The project was completed in 2000. The main objective of the project was set as follows: "to promote country relevant natural resources management systems so as to improve the socio-economic status of communities in and around forests and to mitigate existing pressures on natural resources." The project was planned and implemented in three stages: 1) Project Development (1991-1992); 2) Project Implementation (1993-1997); and 3) Withdrawal (1998-2000). Participation and sustainability were two basic principles observed in this context. As the basic prerequisite for participation and sustainability, on the other hand, emphasis was given for the last two years of the project to capacity building and empowerment instead of service delivery. The project envisaged the cooperation of local communities, government and the voluntary organization around common problems; local people's active participation to decisions and implementation; and mutual support and solidarity in technical, administrative and financial issues.

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Baobab (*Adansonia digitata*) Food Banks in Mali: When a Huge Tree Becomes a Garden Vegetable

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For centuries, the leaves of the baobab tree have been a mainstay in the diets of people throughout the Sahel of West Africa. Now, in Mali, agroforestry researchers and farmers working together have come up with a revolutionary new way to cultivate them. Until now, the baobab tree has grown virtually wild in parkland agroforestry systems. In the dry season people harvest its fruit to eat fresh or to dry for preparing delicious beverages, rich in vitamin C. The trunk is used to make fiber, and upper limbs are used as an apiary for honey production. And vitamin A-rich baobab leaves are the staple vegetable in oft-consumed sauces. However, due to the enormous size of adult baobab trees, leaf picking is a risky venture. And timing is also a problem, as leaves must be harvested during the short three-month rainy season, a time when family members must tend to annual crops. But growing young trees in garden plots and harvesting the leaves regularly can solve all of these problems at once. Researchers at the World Agroforestry Centre and IER in Mali point out that these miniature baobab gardens can help solve various problems related to land degradation, desertification and population pressure. When people start to cultivate and harvest leaves from their own baobab trees, this will reduce leaf harvest pressures on wild baobab, restoring its ability to bear fruit. That will mean more fruit, healthier trees and, with easy access to fresh baobab leaves in their own gardens, healthier people.

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HIV/Aids and Natural Resources Interface: The Current and Potential Responses of Miombo Woodlands as a Safety Net, and the Likely Impact on the Sustainability of the Resource

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Miombo woodlands form an integral part of the livelihood and farming systems of Southern Africa. Woodlands are held in a variety of tenurial regimes including State Forests**,** either managed entirely by the Forestry Department or co-managed with local communities**,** and customary land forests. Households rely on woodlands to supplement their food supply, through collection of wild foodplants, bush meat, nuts, leaves and roots. Even in times of abundance such gathered wild foods are an essential source of micro-nutrients. Woodlands are also a source of traditional medicines; income from sale of non-wood forest products such as mushrooms, and wood products such as fuelwood and poles. In commercially managed miombo forests timber is still a valuable product. The paper discusses the results of an FAO survey conducted in Malawi and Mozambique in 2003/4 to ascertain the impact on the resource of the pandemic and the possible responses that miombo woodlands may be able to provide in terms of: *Food:* collection of wildfood plants; bushmeat, nuts, leaves and roots; availability of fuelwood; *Treatment of opportunistic infections*: traditional medicines; *Income*: from non wood forest products. Suggestions as to ways to directly feed these results into ongoing community forestry management programmes, as well as possible actions with regard to policy, and research direction with regard to HIV/Aids, forestry and agroforestry focus in the region, are discussed.

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Food Value Opportunities for Mitigating Rural Poverty and Conserving Forest Biodiversity in West and Central Africa: Case of Non-Timber Forest Products

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In west and central Africa, non-timber forest products have potential to contribute to food and nutritional security, rural incomes and to meet part of urban food needs. Understanding the food value of these forest products is an important part of developing alternatives to overcome rural poverty and save the forests. Indigenous trees producing forest foods are important components of multi-strata agroforests. These trees, planted or unplanted, enrich the biodiversity in agroecosystems throughout the subregion. In this paper, the potential food value for some promising non-timber forest products was reviewed. Although most of the data reported are scattered throughout the sub-region, they however, show that forest foods have great popularity and contribute substantially to meeting people's daily energy and micronutrient needs, cash provision, income diversification and can be a mobile for sustainable forest management if sufficient adding value is taken into account or used to develop the exploitation of these forest foods. It is likely that subsistence farmers wish to escape the poverty trap by getting out of farming, supplementing their farming activities or becoming commercial farmers for their own benefits.

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Agroforestry Adoption: Current Practices and Avenues for Development in Bangladesh

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Agroforestry has been adopted in Bangladesh in the form of homestead forestry, farmland forestry, etc., for supplementing foodstuff, providing wood, energy and medicine. The species planted may be identified in four groups: A) *Foodstuff*: Jack fruit, Mango, Jam, Boroi, Palmyra Palm, Coconut, Dates, etc; B) *Housing material*: Bamboo, Koroi, Jam, Palmyra Palm, Mahogany, Teak, etc.; C) *Wood energy*: Koroi, Babla, Ipilipil, etc.; and D) *Medicinal plant*: Arjun, Amloki, Horitoki, Bohera, Jarul, etc. This traditional forestry management cannot cater for the present needs. On the other hand, deforestation trend has been continuing to expand arable land. To reduce pressure on the forestland, better technique of Agroforestry is adopted to increase land productivity. Responsibility has been entrusted to the Forest Department (FD) under the Ministry of Environment and Forest. There may be four primary areas identified in order to increase efficiency for practicing agroforestry properly: 1) *Institutional efficiency*: the FD has been following almost the same organisational structure, which had been formulated for forest management since its inception during the British colonial rule. Even though considerable changes have been made over the periods, the FD has yet to be restructured in order to drive new conception of Agroforestry of the present needs. 2) *Adopting proper policy*: Land use policy and Forest policy should be reformulated in order to match Agroforestry and Social Forestry practices. The last two areas are: 3) *Increasing coordination between the departments and stakeholders concerned*, and 4) *Selecting proper tree species and land with participants' involvement*.

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Grow *Buchanania lanzan* in Agroforestry System to Bring Prosperity to Farmers

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Chirongi (*Buchanania lanzan* Spreng.) is a multipurpose tree species and important in rural and tribal economy. District Chhindwara of Madhya Pradesh has one of the most producing Chirongi district. Amarwada and Harrai Block of District produced 2500 t seed and business of more than 15 crore per year. It is exported from India to other countries. Now it is a very important tree to generate the foreign currency. At present the rate of kernel is Rs 300/kg, but it may be increased to Rs 1000/kg in future because number of trees are decreasing daily and seedlings for new plantation are not available. Farmers of this region are continuously trying to grow its seedling but without success. Because of low germination rates and slow seedling growth, the species is slow to grow even under favourable conditions and its coppicing capacity and reproduction of root suckers is not high. In view of paucity of information on its germination behaviour, experiments were carried out under field condition. The data revealed that germination percent increased progressively with increasing seed weight. Maximum 62% germination was noted with 100 seed weight class 35-40 g while lower class ranged 10-15 g gave only 8% germination. Among various pretreatments tested, seed soaking in 80% sulphuric acid for 10 minutes proved as best treatment to enhance seed germination 64% and increase 54% seedling survival in polythene bags after one year. In control treatment the value of seed germination and seedlings survival were 7 and 4% respectively.

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Investigations on Growth and Yield Pattern of Different Alley Crops under Agroforestry in Gangetic Plains of India

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Experimental findings from 1992 to 2002 in the Gangetic plains of New Alluvial Zone, India, revealed that under agroforestry several conventional and non-conventional crops recorded significant yield. In the alleys of 28 forest trees and 16 fruit, spice and medicinal trees, 42 alley crops out of which 18 pasture grasses and legumes were tried during this period. *Brassica campestris* recorded 0.90 t ha^{-1} seed yield under the alley of *D. sissoo*. The corn yield of *Amorphophallus paeoniifolius* recorded 36.7 t ha^{-1} under the alleys of *E.* hybrid was significantly higher than 32.10 t ha^{-1} under *G. sepium* of pollarded condition. The highest yield of ginger corm (11.82 t ha^{-1}) was recorded under the alleys of *S. mahogoni*, whereas the lowest (5.42 t ha^{-1}) was under *Gmelina arborea*. Likewise, the yield performance of kaempferia, turmeric, upland taro, three plantation crops (tea, coffee and cocoa) and some other crops were studied. No significant difference in yield was observed in case of *Dioscorea alata* under different shade tree species. Similar results were obtained in case of biomass production of different grasses and legumes, although considerable yield reduction was noticed in the alley of *Tectona grandis*. The panicle length, number of berries/panicle and yield of black pepper were significantly higher (dry weight: 834.77 gm/plant) when it was grown in association with *D. sissoo* and lowest (dry weight: 582.72 gm/plant) with Eucalyptus. Thus, the study aimed at the development of agroforestry for better utilization of both land and space restoring the biodiversity of the ecoregion.

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Agroforestry and Rural Livelihoods: The Case of Western Kenya

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With only 2% forest cover, Kenya is struggling hard to achieve its vision of poverty alleviation, food and energy security, protect biodiversity and conserve the environment (GoK, 1999). Among the various actors, the role of agroforestry systems in tree-based rural development is recognizable in this endeavour. Western Kenya is one of the poorest provinces in the country with 31.5% of the households being among the hardcore poor (Swallow et al., 2001). Among the agroforestry technologies introduced in Western Kenya are the soil fertility agroforestry-based technologies. These are aimed at improving the socio-economic welfare of the poorest farmers in the province. The poster seeks to present the agroforestry-based soil fertility technologies in reference to rural livelihoods, their impacts and the way forward. Farmers have been able to adopt both the use of improved fallows and biomass transfer technologies over different seasons and duration, despite the steadily decreasing land availability in agricultural production. These farmers have recorded impacts, notably increased food security, improved household consumption, increased income through sale of surplus, and assisting neighbours and relatives with food, hence building up social capital (Place et al., 2002). The agroforestry-based soil fertility replenishment technologies have also contributed greatly towards improving rural livelihoods, with various species having dominance in different parts of the province.

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Effect of Shelterbelts of Exotic Trees on the Growth and Yield of Wheat in Agro-ecosystems

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Agroforestry is widely adopted in different nations as a means to enhance financial gains besides several other benefits, since it combines the best attributes of agriculture and forestry. However, in developing nations, this practice is not paying as much as it should have because of the lack of knowledge regarding selection of tree-crop combination, management of competitive and phytotoxic interactions and geographical and climatic suitability. A study was conducted to determine the effect of shelterbelts of exotic trees like *Eucalyptus tereticornis*, *Populus deltoides*, and *Leucaena leucocephala* on the adjoining crops. A comparison was also made with unsheltered area or those fields having shelterbelt of native tree *Dalbergia sissoo*. It was found that density and initial growth of wheat was adversely affected compared to unsheltered fields or those sheltered by *D. sissoo*. Greater reduction in growth of wheat was observed near the treeline. This also affected the overall yield of wheat. The study deals with the role of allelopathy in the observed growth retardatory effect on the wheat crop and suggestions to implement the practice shelterbelts in a sustainable manner.

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Sustainability of Poplar Agroforestry Systems in North-west India

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Over the last three decades, farmers have been growing poplars (*Populus deltoides* clones G_3, G_{48}) on the fertile north-western alluvial plains in the form of block plantations (5 x 5 m). Agricultural crops such as wheat, sugarcane, turmeric and forage crops are successfully grown between the poplar trees. It is a high-input and high-output agroforestry system that has already influenced the region's economy. The annual average circumference of trees ranged from 11.1 cm in 6-year old plantation to 17.7 cm in 2-year old plantation; the values decreased sharply in 5-and 6-year old plantations. Production of litter in poplar plantation ranged from 3.18 t ha^{-1} in 2-year old plantation to 5.53 t ha^{-1} in 6-year old plantation. The rates of litter decomposition were much faster during initial three months i.e. January to March decomposing 38 to 42 per cent of litter, while 85 per cent of litter decomposed from January to June. The age of plantation did not have any significant impact on the rate of decomposition. Biomass of wheat in 3-year, 4-year and 6-year old plantations was estimated as 11.61, 9.43 and 7.53 t ha^{-1}, respectively; out of this biomass, 1.35, 1.09 and 0.89 t ha^{-1}, respectively, was left in the field in below-ground parts (roots and shoot stubble). Decomposition of below-ground parts of wheat during 5 months (April to September), was estimated to be 90 per cent. The results are discussed in context of sustainability.

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Reviewing Agroforestry Technologies through an HIV/AIDS Lens: Opportunities and Benefits of Agroforestry to Mitigate the Impacts of HIV/AIDS in Southern Africa

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The HIV/AIDS pandemic has claimed the lives of over 20 million people in Africa, where majority of the people are rural and dependent on agriculture. Rural areas in Africa are severely undercapitalized as reflected in their poor access to health and education services, and limited use of agricultural inputs. Moreover, agricultural labor has declined partly due to the HIV/AIDS pandemic. Most governments in the region have responded to the pandemic by easing access of anti-retroviral (ARV). However, the success of these initiatives partly rests on the food security and nutritional status of their beneficiaries; food availability and nutrition are relevant to treatment. Agroforestry can contribute towards alleviating the impact of HIV/AIDS particularly in southern Africa where droughts are prevalent in several ways. Firstly, by increasing access to macro- and micro-nutrients thereby helping maintain and improve the nutritional status of infected people and hence delay the progression from HIV to AIDS-related diseases. Secondly, income generation from agroforestry buffers vulnerable families from unavoidable sale of assets to cover medical and funeral expenses. Thirdly, some agroforestry species have food values and medicinal properties that help to fight opportunistic infections traceable to HIV/AIDS. Fourthly, agroforestry technologies that buffer farmers from effects of drought improve their resilience to cope with effects of the pandemic. Lastly, agroforestry technologies provide labor-saving benefits, thus mitigating effects of labor shortages brought about by HIV/AIDS. The paper highlights pathways on how agroforestry contributes towards mitigating the impact of HIV/AIDS in southern Africa.

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The Contribution of Non-Timber Tree Products to the Household Economy in Thies, Senegal

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The contribution of non-timber tree products to the household economy was studied in three villages of the Thies region, in Senegal. Data was gathered from 101 households and 10 focus groups in these three villages, as well as from 37 consumers and 54 merchants in the four biggest cities of Senegal. Results showed that non-timber tree products are far from being marginal products in the consumption habits of the family. Products from several tree species including *Adansonia digitata*, *Borassus aethiopum*, *Sesbania sesban*, *Combretum micranthum* and *Mangifera indica* are used in human and animal nutrition, medicine, crafts, construction, etc. Commercialization of non-timber tree products also earns important revenues for the family. Half of the farmers said that they get more than 25% of their revenue from non-timber tree products. However, transportation appears as a very important constraint to the commercialization of these products.

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Land Tenure-Related Factors and the Adoption of Improved Live Fences by Farmers in Segou, Mali

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Improved live fences are diffused to farmers in Mali as an efficient and sustainable way of protecting their off-season crops from roaming livestock. In order to identify socio-economic factors influencing the adoption of this technique, a study was undertaken in Segou, Mali. Data was gathered in 11 villages through a participatory methodology including group interviews, village territory mapping, transect and semi-structured interviews. Results showed that several factors affect adoption. Land tenure-related factors are among the most important ones. Under the customary land tenure system, one farmer who wishes to plant a live fence must hold primary rights to the land first, which is the case for a limited number of families only. Furthermore, a head of family holding such rights is not usually very fond of allowing other family members to plant live fences, since it could modify eventual inheritance rights to the land, that would be shared among the descendants of the planter only, and not among all family descendants. In other respects, planting live fences is not always appreciated by farmers and the village authority since it is perceived as a sign of conflict between neighbors, especially in low population density villages. Nevertheless, in high population density villages, planting trees around fields for delimitation seems to be already accepted. Thus, live fences participate in a current of land appropriation resulting in fragmentation of the land.

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Will French Farmers Adopt Agroforestry Technology in the Near Future?

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Farmers did not consider silvoarable agroforestry technology until 2001 in France due to regulations that excluded would-be agroforesters from the compensatory payment scheme for annual crops. This policy had a strong negative impact on traditional silvoarable systems in France during the 90s: farmers uprooted trees in fields to enlarge cropped areas that benefit from compensatory payments, and traditional systems such as poplar-maize or walnut-cereals were discarded. In 2001, after intense lobbying by farmer unions and conservation organisations, policy restrictions were dropped: intercrops are now no longer excluded from the crop payment schemes and grants are now available for planting trees in agroforestry designs. This has changed the scene for Agroforestry in France. A review of the current agroforestry policy issues in France will be presented. A survey of farmers was conducted in 2003 in three Provinces of France to test the reaction of French farmers to the agroforestry technology. The results are surprising. In 2004, major modifications of the European agricultural policy are expected: they may incite farmers to adopt more sustainable agricultural technologies, and will focus on diversification strategies. The challenge of the coming years is to achieve fair regulations that will allow agroforestry technology to play a significant role in Europe in the near future.

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Agroforestry Adoption, Innovations and Smallholder Farmers' Motivations in Tropical Uplands of Southern Philippines

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Agroforestry systems were first introduced in Claveria, Mindanao, Philippines, in the mid 1980s. Since then, different agroforestry systems are dispersed across the undulating Claveria landscape. A combination of Participatory Rural Appraisal (PRA), household survey and in-depth case studies were conducted to understand what motivates Claveria farmers to plant trees and adopt agroforestry. Results revealed that their major motivations in planting trees are (1) higher/additional income, (2) future savings since trees are considered as "green gold", and (3) soil and water conservation. Of the 300 households surveyed, 72% adopted agroforestry systems. Parkland system is the most widely practiced (30%), followed by hedgerow NVS (18%) and block planting (16%). Only 8% of the respondents adopted border planting. Parkland system allows farmers to plant more annual crops and there is lesser tree-crop competition since the trees are widely spaced. Low labor requirement is the main reason for farmers' adoption of hedgerows NVS system. The agroforestry system adopted by farmers varies with their motivations. If the primary motive is to have additional income, farmers practice either block planting, border planting, or parkland system. For soil conservation, farmers prefer hedgerows system or natural vegetative strips (NVS). Farmers wanting to protect their crops from strong winds plant trees along farm boundaries as windbreaks. Banana (*Musa* sp.) is the most preferred perennial crop and is widely planted at all elevations (400-1000 masl). In upper Claveria (elevation>600 masl), coffee and *Gmelina arborea* are widely planted while *G. arborea*, coconut and mango are preferred in lower Claveria.

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Food Security of Agroforestry System Farmers in the Degraded Soils of Claveria, Northern Mindanao, Philippines

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A combination of participatory approaches including Participatory Rural Appraisal (PRA), household survey and contextual case studies were conducted in Claveria, Northern Mindanao, Philippines. The study aims to understand the role of agroforestry systems to household food security in terms of availability, stability of supply and accessibility to food. Seventy percent of the 300 households surveyed in Claveria have adopted agroforestry systems (AFS). The average proportion of land devoted to annual crops ranged from 42% in block planting, 68% in parkland, 71% in hedgerow, and 79% in border planting systems. Annual cropping fields have 88% of the land planted to annual crops while trees are found in the rest of the parcels. Widely planted staple annual crops are corn and rice. About 66% of total rice production and 38% of white corn production is allocated for home consumption. Great bulk of tomato (85%), yellow corn (80%) and white corn (48%) production are sold to market. Greater proportion of land is planted to fruit trees than timber trees. Banana is the number one ranking perennial fruit crop planted in the farms. Farmers harvest bananas twice a month and about 80% of banana production is sold to market, providing a steady source of income. Timber trees serve as "green bank" providing savings for future major expenses such as schooling and house construction. The paper discusses the coping mechanisms of agroforestry farmers, the emerging issues on food security in relation to agroforestry systems and the implications to land use, resource management and policy planning.

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Constraints in Adoption of Poplar (*Populus deltoides*) based Agroforestry in Haryana State, India

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Agroforestry aims to optimize the benefits from biological interactions created when trees and shrubs are deliberately combined with crops. It promotes many forms of diversity in the agroecosystem, creates habitats for wildlife and beneficial organisms, offers a greater diversity of products, and can lower the need for external inputs. In this regard, forests play an important role in the economy of developing countries, including India. A large segment of India's population depends on forests for energy, housing, timber, and fodder. Poplar attains a high rate of growth and can meet the material shortage of wood-based industries. The present study was undertaken among 100 poplar growers in Haryana State (India) to ascertain the constraints in adoption of poplar based agroforestry to meet farmers' livelihoods. The study revealed that 81% of farmers had no knowledge about application of fungicides on branch cuts after pruning. Overall knowledge index was 65.50%. Full adoption was found in practices like variety, irrigation, age of sapling, weed control, time of transplanting, and pit size, spacing and pruning time. It was further observed that 94% of farmers were not applying any fungicide on cuts after pruning. Overall adoption index was 59.44%. The study further indicated other constraints, including non-availability of credit facilities, quality saplings and trained labor, risk in price fluctuation, low market price, absence of regulated market, non-availability of government agency for guidance, lack of formal long-term land tenure system, non-possibility of paddy cultivation under poplars, and lowering of yield due to shade, etc.

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AGROffice - an Integrated Farm to Fork Solution

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Documentation is a *must* according to EU legislation and is the base knowledge that one has to have when he wants to trace back to farms according to the EU "farm to fork" legislation. Documentation and traceabilty is only one element of an integrated solution on the fields. With PROGIS AGROffice technology, many activities on the farm will be measured or done as there are: *Documentation and Traceability* (regulation EC 178/2002 General Food Law), *EU subsidy claim calculation* (orthoimage and GIS-based technologies are a must from 1.1.2005 according to regulation EC 1593/2000), *Fertilizer balancing* (from 1.1.2005 expected- in several EU countries already local legislation), and *Field profit margin calculation*—all these activities and more can be done by PROGIS AGROffice with a simple mouse-click at once. In Germany e.g. this technology has been installed as service model together with the German Machine Cooperatives. Thus 250,000 farmers all over Germany have access to this new technology independent if they are able to use a PC, have an internet link or only use paper. Further to the a.m. our service partners can offer additional software/services like: Logistics for cultivation, caretaking, harvesting, precision or smart farming with all their positive business and ecological aspects, virtual farming to overcome the European farm structure, environmental planing and rural area planing in cooperation with other organisations, forestry, (water/wastewater...) -pipelines, smart communities, sensor integration (meteorology, water, soil) and geographical information based on orthoimages/vector data for any thematic map with GPS/dGPS (future GALILEO) integration, etc.

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Fodder Bank: A Technology for Sustainable Land Use System and Improvement in Small Scale Rural Dairy Production in Nigeria

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The qualities of forage seeds brought from very few companies in Nigeria are not usually of very good quality. Establishment of higher seed quality companies will result to higher fodder yield. Livestock that depend on natural pastoral environment may lose much of the body weight during dry season due to low quantity and quality forages that are available. However, under traditional condition, cows take a long time to reach a sizeable body weight and exhibit low calving percentage and high calf mortality. It was found that indoor cattle keeping in urban areas has become an increasingly important economic activity enhancing livelihoods of farmers. However, major constraints in dairy production are that of low quality and quantity of fodder especially during dry season. Farmers confirmed that cotton seed cake, which is an expensive supplement, continues to increase the cost of production and reduces return from dairy and dairy products. The primary objective of fodder banks is to provide supplementary feed for cattle in order to increase productivity and survival rate. The effect of some institutions introducing this innovation to the pastoralists increased their milk production, fertility and calf and cow survival. The ultimate success or failure of fodder banks will depend on the extent to which they can meet the pastoralist's requirements. Extension agents should contribute by enhancing the acceptance of informing on fodder banks by the dairy farmers on the realities and potentials of fodder banks to increase their production, security of tenure, rural poverty alleviation and sustainable land-use system.

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Adoption, Impacts and Policy Issues in Agroforestry for Improvement of Rural Livelihoods in Nigeria

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The dynamics of human factors in Nigeria have led to serious consequences for environmental stability and sustainability of rural livelihoods. Land productivity has declined to an alarming level so much that sustainable production and carrying capacity of the environment have been greatly threatened thereby resulting to loss of biodiversity, deforestation and desertification. A holistic land-use system that checks the problems of rural poverty, ecological catastrophes and economic stagnation is therefore imperative. The adoption of agroforestry in Nigeria has led to improvements in socio-economic livelihood of rural population and environmental stability. However, agroforestry has not been a panacea to problems of land mis-management, rural poverty and environmental degradation in Nigeria. A number of factors affect the prescription of any particular model. This paper examines the various land-use systems currently practiced with a view to determining agroforestry models most suitable to each agro-ecological zone. The study explores the factors affecting the adoption as well as limitations of agroforestry in Nigeria. The paper maintains that the livelihoods of rural residents in Nigeria can be considerably improved if appropriate policy initiatives are initiated and implemented. Recommendations on how agroforestry-based poverty alleviation strategies can be made compatible with biodiversity conservation are suggested as well as how landowners can be encouraged to accommodate various social and ecological roles of agroforestry.

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Analyzing Agroforestry Adoption with Attribute-based Choice Experiments (ABCEs)

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The rapidly expanding agroforestry adoption literature has two distinct lines. *Ex-post* studies typically use binary choice regression of household survey data to characterize past adoption behavior, but tell us little about farmers' demands for new systems. Systematic *ex-ante* assessments of experimental systems are less common, partly because some scientists believe they are too "soft" or "subjective" to qualify as rigorous analyses. We present an alternative method for examining farmers' *ex-ante* demands and values for new agroforestry systems. Attribute-based choice experiments (ABCE) encompass a variety of multi-attribute, regression-based methods (generically referred to by many as "conjoint analysis") recently adapted by economists for natural resource valuation problems. Using survey-based techniques, ACBEs derive the value of particular attributes (and combinations of attributes) of goods and services based on individuals' choices. ACBEs have been widely used by market researchers in the design of new multi-attribute products, a problem with many similarities to designing multi-attribute land use systems like agroforestry. ACBEs allow one to determine the combination of attributes of products (land-use systems) that consumers (farmers) are most likely to purchase (adopt). Using a case study from the Calakmul Biosphere Reserve in Quintana Roo, Mexico, we demonstrate how ACBEs can be used to assess the economic and non-economic criteria that farmers use to evaluate potential systems, how farmers value different attributes of agroforestry systems, and how these values may affect adoption and subsequent management behavior.

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Impact of Participatory Agroforestry Practices in North-Eastern Areas of Bangladesh

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Bangladesh is a developing country where per capita forest area is 0.022 hectare and deforestation rate is 3.3 percent annually. Bangladesh also inherited a traditional forest management system wherein people's participation was ignored. The main causes of deforestation are population pressure, land use pattern and biomass fuel consumption. As a result, forest resources were seriously damaged and forestlands were encroached. To combat the situation, the government has introduced participatory agroforestry in 1981 by involving local landless and poor people including women. The participatory plantations were raised with fast-growing exotic species for short rotation period. The participants were allowed to cultivate crops in plantations as intermediate crops. Benefits received by participants included all intermediate crops and 45% of final harvest. Data used for the present study on participatory agroforestry practices in Mymensingh, Sherpur, Netrokona, Kishoreganj and Jamalpur districts of northeastern region of Bangladesh were for the period January 2001 to June 2003. The study found that 2411.96 hectares agroforests and woodlots and 164 km strip plantations were sold out and Taka 49.79 million (60 Taka=1 US$) were distributed as benefit shares among 3,974 participants. The impacts of benefit share distribution were substantial. It spread tremendously among the rural poor people and most of them got interests to be involved in participatory forestry. The study revealed a significant impact on production of crops, revenue earning and benefit share distribution among participants and suggested for its further replication in other areas of the country along with guidelines for resolving conflicts among different stakeholders.

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Planning Agroforestry Demonstrative Units at the Southern Margin of the Amazon in Northwestern Mato Grosso, Brazil

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The southern margin of the Amazon is experiencing significant settlement pressure. Appropriate agroforestry systems have the potential to enhance land productivity of already-deforested land while conserving the ecosystem functions of natural and agro-ecosystems. The present paper discusses the process leading to the design of agroforestry demonstrative units (DUs) in process of being established in northwest Mato Grosso, Brazil, within the framework of a GEF-sponsored biodiversity conservation and sustainable development project. Design of the DUs was based on on-farm diagnostic surveys in the municipalities of Juína, Castanheira, Cotriguaçu, Juína and Juruena. The emerging data were discussed with local stakeholders (small farmers and municipal authorities) and the system specifications and guidelines elaborated during a workshop. Local stakeholders recommended that the DUs should represent more sustainable land-use alternatives than slash-and-burn systems, be representative of biophysical and socio-economic conditions affecting local farmers, and be located on farms with diverse and innovative agroforestry systems. Six farmers were selected on the basis of these criteria, and the objectives and expected results of the DUs were discussed with them. The production systems already existing in the selected small farms were characterized. Agroforestry practices and management were discussed for each DU and training activities and farmer-to-farmer and inter-community knowledge exchange methods were suggested. Criteria for efficient management of DUs as well as improved farm-products processing, storage and commercialization were also considered during the workshop. These DUs have now been established and are being monitored for use in field days with surrounding communities as the project develops.

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Gender Issues in Agroforestry and Sustainable Land Use in India

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Agroforestry holds potential for bettering the economic status of women in rural India because women are often the main repositories of knowledge concerning the use and management of fuelwood, fodder, and other forest plant species. Women's agroforestry preferences include commercial fruit and cash-crop trees as well as fuel and fodder species. Studies from different parts of the country illustrate the degree of dependence on minor forest products (MFPs) for livelihoods. In Manipur, for instance, 87% of the population depends on MFPs as the major source of livelihoods, with two thirds of the women surveyed in Manipur collecting MFPs as their only source of income. Due to insufficient data on the economic roles of women in farming and forestry, women's issues have usually been regarded as welfare and equity concerns. As a result, concrete programs have been centered on easing women's fuel and fodder collecting workload in the interest of their health and welfare. Agroforestry seems to be a promising approach for poor households and women since it replicates the multiple products of the natural forest. Here production of fuelwood can be combined with food production or other income-generating resources like fodder or categories of MFP. In this regard, agroforestry is viewed as the best approach for women involved in agriculture, where animal husbandry is the second most important source of income.

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Peasants, Agroforesters, and Anthropologists: A 20-year Haitian Chronicle of Trees and Hedgerows

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This paper discusses key aspects of a donor-funded agroforestry extension project implemented over a twenty-year period in Haiti. A large percentage of all Haitian rural farm households participated, and a change in farmer tree culture behavior was observed by the end of the project. This was due to a project design based on the economic self-interest of farmers, the decision to operate the project through local NGOs instead of the government, the use of small-container tree technology, and project management policy that facilitated farmer-induced adaptations. The authors support the use of subsidized small-container tree seedling distribution in the circumstances found in Haiti. They further note that such a project is not an environmental panacea that will cover entire watersheds. The environmental contribution of such a project will be a side-effect of an essentially economic decision by farmers.

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The Impact of Improved Fallow Technologies on Household Income and Food Security in Kakamega District, Kenya

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Kakamega District in Kenya has low agricultural productivity due to land depletion and declining soil fertility. In 1997 improved fallow technologies were introduced to ameliorate the problem. This study investigated the changes in producer and consumer welfare due to improved fallow, the contribution of improved fallow to household income and the relationship between the improved fallow and household food security in 2003. A two-stage stratified random sampling technique was used to collect data from 200 farmers. The data was analyzed using both descriptive statistics and the economic surplus model. The analysis showed that use of improved fallow technology increased small-scale farmers' marketable surplus by 40%. At 35% of the marketable surplus producers' welfare gain is 70% of the total welfare benefits while at 40% both producers and consumers gain equal welfare benefits. Above 40% of the marketable surplus consumers' welfare gain is more than producers' welfare gain. Seventy percent of the farmers with improved fallow technology realised 50-100% yield improvement. Use of improved fallow reduced input-use costs up to 60% in the two seasons annually. It is necessary to encourage use of improved fallow technologies to improve household incomes, reduce food insecurity and poverty. The main policy measures to enhance the use of agroforestry include making available the requisite seed/seedlings, provision of credit facilities and information on improved fallow technologies. These measures should be undertaken together with the production of other staple food crops to facilitate sustainable use of agroforestry.

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Food Security in *Panchayati Raj Institutions* through Agroforestry Based Programme: A Case Study of Rural Maharashtra, India

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The *Panchayati Raj Institutions*, a form of local government in India, are known as *Gram Panchayats* at the village level. These institutions being nearer to village people, play a very important role in the programme related to food security. The Gram Panchayat is primarily organized to provide economic and social benefits. The Gram Panchayat members are elected by the people and for the people. A vast resource in the form of wasteland is available in each village of our country. Though appropriate soil conservation measures and agroforestry programmes, the soils can become most important resource to increase the income of the farmers by providing fruits, milk, meat and other edible products, which form the part of food and livelihood for the rural people. The present paper is an attempt to study the food security in Panchayati Raj Institution through agroforestry-based programme. The data has been collected from four Gram Panchayats in Bhandara district using qualitative techniques. Anthropological approach was used for collection of information. The analysis reveals that Panchayat at the village level can support the rural poor farmers to accelerate their economic growth. A local representative institution and micro-planning are thus a must to raise local production, which in turn offers the best food security to the poor. Panchayati Raj Institution (Gram Panchayat) plays an important role in food security through agroforestry-based programmes. What FAO and others can do is to aid the Panchayats in this endeavor.

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Traditional Agroforestry System in Northern Rural Bangladesh: Management, Production and Farmers' Ecological Knowledge

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Supari (*Areca catechu*) based agroforestry system has been practiced traditionally by the farmers of northern rural Bangladesh for decades. The study clarified the existing land-use systems in the study areas, components of agroforestry system and their interactions, indigenous cultivation and management of agroforests, production and marketing of products and income of farmers from their agroforests. Field data were collected by interviewing 100 farmers who practiced *supari* based agroforestry system in five villages of Panchagarh district. Farmers were categorized into five groups based on extent of their total land holdings: landless (up to 0.20 ha), marginal (0.21-0.50 ha), small (0.51-1.0 ha), medium (1.01-2.0 ha) and large (>2.0 ha). Twenty households (four from each category) were selected randomly from each village. Farmers' ecological knowledge about production system, marketing and income derived from sale of products were also taken into consideration. Field visits to the agroforests were made. Results of the study showed that farmers allocated a portion of their agricultural land along with homesteads for *supari* based agroforestry practices as they felt the system was sustainable and profitable. The production system played an important role in farmer's household economy. Combination of species in agroforestry system was highly influenced by farmers' ecological knowledge, and farmers had more indigenous ecological understanding about above-ground interactions than below-ground interactions. Indigenous techniques in cultivation and management of different agroforestry components were described and discussed. Finally, perceptions of farmers were also described and discussed in the context of opportunities and constraints of this type of agroforestry.

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The Effect of Cutting Height of *Senna singueana* in Alley and Mixed Intercropping Systems on Biomass Production and Maize Yield at a Study Site in Morogoro, Tanzania

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A study was conducted during 1998-2001 at Kitete, Morogoro, Tanzania to determine the potential use of a commonly occurring shrub—*Senna singueana* (Del.) Lock—in tropical Africa for soil fertility replenishment. *Senna* was examined in alley cropping and mixed inter-cropping trials at four cutting heights (25, 50, 75 and 100 cm), measuring its biomass production and maize yield. In both trials, *Senna* was established using 3 months-old seedlings at 4.0 m inter-row and 0.5 m intra-row in alley cropping and at 2.0 m x 0.9 m in mixed inter-cropping. Staha maize variety was used as the test-crop. Foliar biomass, maize yield and N-partitioning between maize parts (grain, cobs and straws) were determined. In both alley and mixed inter-cropping systems, *Senna* had highest growth rate during 4-10 months after establishment. Biomass yield increased with cutting stubble height to 75 cm after which it declined. Cutting *Senna* plants at 75 cm height maximized both its potential for foliar biomass production (1.63 t ha^{-1}), N contribution to the maize crop (59.5 kg N ha^{-1}) and maize grain yield (2.7 t ha^{-1}). It is concluded that *Senna* grows rapidly and recovers fast to coppice profusely following foliage harvesting. Pruning *Senna* plants at 75 cm height optimizes soil N availability and plant uptake and promotes healthy plant growth, maximizes biomass production and yield of associated maize crops. It is, however, suggested that future genetic improvement research should focus on evaluating various *Senna singueana* provenances with a view of identifying the strains that maximize its productivity.

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Cocoa Production in Cameroon: Issues facing the Cocoa Agroforestry Sector

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Cocoa (*Theobroma cacao*) remains the main cash crop for more than 75% of the population of Cameroon, West Africa. Its production is mainly by peasant farmers who, though they are the main producers of the high demand crop, do not still meet their needs to maintain a moderate standard of living and as such are left to suffer, endangering the Cocoa sector and their entire livelihood. Some factors however account for this negative trend, and these include: 1) neglect of the sector by the government since this sector was privatized without necessarily letting the peasant farmers know what privatization was all about, as initially under the National Produce Marketing Board (NPMB), 2) poor knowledge on the exact period to apply fungicides and pesticides on the cocoa fields, 3) resistance to insects pests on particular chemicals, 4) poverty, 5) lack of inputs, 6) lack of warehouses to store dry cocoa, 7) lack of sound market to avoid prices being dictated upon farmers by buyers, 8) poor farm-to-market roads, 9) lack of transportation equipment, 10) lack of cocoa drying facilities, and 11) poor and falling prizes. Therefore, due to these factors, the Cocoa Agroforestry sector is being threatened with very negative consequences like the exodus of rural workers for better opportunities in the urban areas. This results in increases of poverty, poor health conditions, prevalence of diseases and hunger within villages. These problems need to be stemmed and taken care of by the same factors above if put into proper consideration.

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Natural Fallows of Southern Cameroon: Trends and Implications for Agroforestry Research

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The humid forest zone (HFZ) of Cameroon supports more than 4.7 million people, of whom some 48% live in rural communities. Major factors of deforestation and forest fragmentation in the HFZ include rural poverty, increasing pressure on land for agricultural use and slash-and-burn agricultural techniques, leading to an increasing abundance of fallow lands of various ages and types. Small and scattered in the landscape and even though their aggregate area constitutes less than 1% of the country's forested land, fallows are extremely productive and particularly valued by local communities of the HFZ for many purposes. There is an increasing awareness of the potential of fallows as important land uses that need special attention from land use managers and researchers in the area. Studies on their ecological performance revealed a loss in species diversity, outbreak of pests and diseases and soil erosion, hindering biomass production and non-timber forest products' supply, depriving smallholder farmers of food and nutrition, and skewing income generation and employment opportunity. Major constraints to sustainable fallow management are scarcity of land in densely-populated areas of the HFZ, poverty and inadequate transfer of technological know-how from research agencies to local communities. Lack of sound statistical data on potentiality and various socio-economic aspects of fallows is an impediment for impressing the policy-makers to undertake programmes for their sustainability. Effective models can be developed for intensified and diversified cultivation of indigenous key productive trees on fallow lands, and management of fruit species improved.

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Studies on Relationship between Forestry Situation and Poverty in China's Wuling Mountain Region

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Wuling Mountain region of China has a mountainous subtropical humid monsoon climate. The soil is mainly red limestone soil. The vegetation is subtropical evergreen broad-leaf forest. To date, 65.62% of the total area in this region is being used for forestry. Local people are relatively reliant upon forestry for their production and livelihood. We find here the dilemma of environmental protection and economic development. Our studies show that the poverty of this region has many connections with the development of forestry. The main poverty features of this region are as follows: The infrastructure is lagged far behind other areas. There is still quite a number of the population living in absolute poverty conditions (10% of the population). There are many natural disasters in the poverty-stricken area. Steep hillsides cover 80% of total land area, most of which is karst landscape. There exists a striking conflict between dense population and less farmland. There are many causes associated with the poverty in this region. Those relating to forestry (whether directly or indirectly) are as follows: (1) tough and adverse environment, (2) limited infrastructure, (3) forest cannot provide benefit to local economy and the environment quickly. Through the discussions with staff from related forestry departments, interview with members of poor families, condensed survey from selected local cadres and villagers, we get a better understanding of the poverty conditions and their relief requirements. They generally need help in those areas such as environment protection, funds, technology, information, market and infrastructure construction, etc.

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Factors Affecting Adoption of Agroforestry Practices by Farmers in Cameroon, West Africa

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This paper attempts to systematically discuss some of the empirical evidence regarding the impact of socio-economical factors in adoption of different agroforestry techniques. Analysis is conducted using primary farm-level data collected from June to December 1996 in Cameroon, West Africa. Three major provinces of the country were covered: Centre, Southwest and Northwest. Several types of agroforestry technologies have been promoted among farmers in the zone, including alley farming, improved fallow, live fencing, cut-and-carry fodder and apiculture. The results in this paper describe the status of adoption of each agroforestry technique and identify factors that significantly affect their adoption. These include sex of farmer, households' family size, level of education, farmers' experience, membership within farmers' association, contact with research and extension, security of land tenure, agroecological zone, distance of the village from nearest town, village accessibility, livestock income. Finally, it is shown that the factors affecting farmers' adoption of different agroforestry techniques are not similar across techniques, thus generalization should be avoided.

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Diagnosis of the Development of Agroforestry in Cuba: Impact on the Food Security of the Nation

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This report will evaluate the problems that have been present in the development of agroforestry in Cuba, with a focus on the strengths and weaknesses, opportunities and threats in the sector. It will also examine the impact that these problems have had on the agricultural situation and food security of the country. Multi-criteria methods will be used for analysis of the problems and the detection of their motive variables and clerks. A summary of these problems and priority needs will aid in the formulation of three-year strategy proposals.

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Agroforestry Technologies: Adoption, Feedback Provision and Impact on Livelihood in Southeastern Nigeria

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This paper examines the adoption, provision of feedback and impact on the livelihood of agroforestry technologies among farmers in southeastern Nigeria. This is based on the fact that given the ecological and the socio-cultural conditions of the area, the introduction of agroforestry practices has improved the land use in a way that woody perennials interact biologically and economically with crops and animals in some form of spatial arrangement and temporal sequence. One hundred and sixty-three respondents were randomly selected from three states in Nigeria (Edo, Abia and Rivers) and data were collected with the aid of an interview schedule based on a structured questionnaire with a reliability coefficient of 0.85 from a split half technique. The result shows that the adoption of agroforestry practices is generally high among farmers: windbreaks (66%), live fencing (92%), fuelwood production (96%), borderline planting (82%) and Taungya (92%). The result further shows that feedback are provided by farmers to extension agents and researchers on technology such as alley faming (86%), woody perennials (84%), mono-silviculture (97%) and Taungya (99%). The prominent form and channel of feedback provision are question (84%) and correspondence (91%) respectively. The result on the impact of agroforestry technology on livelihood shows that benefits derived include higher income (70%), diversification of production enterprises (80%), maintenance of soil fertility (67%), and higher yield (83%). The foregoing description stresses the important role agroforestry is playing in Nigeria. This should however be made sustainable over years through effective linkage between research, extension and farmers.

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Developing Agroforestry Systems in Cool Temperate Climatic Zones

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Northern Ireland (NI), the Falkland Islands (FI) and Tierra del Fuego (TdF) are located in the cool temperate climatic region of the northern and southern hemisphere. For much of the history of man's settlement of these areas, sheep farming has been the most important socio-economic and environmental rural activity. The climate is cooler and windier in both the FI and TdF with annual precipitation of 440-800 mm and annual temperature average of 6.5°C compared to NI (750 mm and 9°C respectively). In NI the majority of the land area is pasture dominated by perennial ryegrass, and broad-leaved native trees such as *Quercus robur* and *Fraxinus excelsior* make up less than 1% of the land area. The vegetation in the FI is dwarf shrub heath, tussock grassland and the islands are naturally treeless. TdF is dominated by scrub and 30% of the land surface is *Nothofagus* spp. forest. In NI there is a need to introduce trees into intensively-managed pasture to encourage diversification, absorb nutrients and enhance both biodiversity and landscape. In the FI and TdF, stock diversity is low and farms are extensive. The integration of trees at a range of levels and spatial arrangements (as in silvopasture, coppice, woodland or shelter systems) offers different opportunities to improve options for rural income generation. This paper outlines how livestock and forestry can be integrated in agroforestry systems to bring economic, social and environmental enhancements to the farmed landscape.

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Agrosilvopastoral Systems with Small Animals in the Southern United States

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Multiple-use management of forestland in the Southeastern United States (SUS) has been a recommended practice for forestland owners for almost twenty to thirty years. Such management practice allows for the diversification of land resource activities for income generation and environmental sustainability. The silvopastoral activities represented a specific agroforestry system that integrates livestock grazing and forage production with timber management and production. Although large animals, such as beef cattle production, have been practiced in SUS, only very recently has the use of small animals such as goats, sheep and swine become an accepted practice with great potential. Although information is still very limited, there is evidence that many limited-resource farmers in the region with timberlands have started using small animals, especially goats, for their silvopastoral systems. In Southern Alabama and Northern Florida, limited-resource farmers are converting forestlands or planted pines from the Conservation Reservation Programs (CRP) into silvopastoral systems with goats. Many of these farmers have experience as goat producers or managers of forestland for timber production. According to one of these farmers, even though they were still in the early stages of managing their silvopastoral systems, they were already earning income from the practices. With income from their Boer goats and guard dogs, such income generation ensures diversification of the farming systems as they wait to sell their timber under improved market conditions. This paper further discusses the extent to which the practice of agrosilvopastoral systems with small animals occurs in the SUS.

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Mangrove-Aquaculture Agroforestry Land-use System: How Sustainable?

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The need to address the increasing international market for cultured shrimps has spurred the invasion of mangrove-aquaculture agroforestry systems into coastal forests, especially in the third world tropical countries like the Philippines. This fragile coastal forests land-use system was perceived to be a promising option for improving the local and the national economy. This coastal forest agroforestry system virtually signaled the massive conversion of most of the old-growth mangrove forests to fishpond development in order to accommodate this seemingly untested land-use scheme in wetland environment. The sustainability over spatial and temporal dimension of this agroforestry system is highlighted together with the identification of new protocols and innovations to reverse and therefore arrest the progressive depletion of the coastal woodlands.

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Mainstreaming Agroforestry Adoption: Actors, Motivations and Options

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Agroforestry as an alternative to “slash and burn” agriculture for degraded uplands can best meet small farm household’s food needs as well as improve environmental services. However, shifting from purely annual mono-crop to tree-based system requires adjustment in farmer’s labor and cash inputs which may not necessarily bring immediate pay-off to the household. Mainstreaming the adoption of agroforestry needs in-depth understanding of farmers’ motivations and contextual setting. Farmer typology can help project designers address adoption constraints to avoid wasteful efforts and resources in promoting agroforestry by small farmers in degraded tropical soils. A farmer typology study was conducted in Claveria, Philippines using PRA, Social Survey and In-Depth Case Analysis. Farmers were grouped into: (i) swidden farmers practicing “slash and burn”, (ii) annual monoculture farmers growing tomato, string beans, cabbage and sweet pepper, (iii) farmers in transition to tree-based system who were motivated to plant trees for soil-water conservation measures, and (iv) agroforestry farmers who are income-driven and earlier had responded to tree growing campaign in the 1980s. Farmers’ motivations and options were confronted and they vary with respect to their socioeconomic, biophysical and institutional circumstances. To encourage annual mono-cropping farmers to integrate trees in their farming system, an information campaign is needed, with provision of free seedlings or at discounted price along with livelihood support. Farmers in transition to tree-based system, sure market and good price are basic conditions. Additional land area with secured tenure and a support system such as credit and technical assistance would increase farmers’ motivation.

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Regression Analysis of Binary Adoption Data: Is the Devil in the Method?

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Researchers interested in the determinants of agroforestry adoption routinely collect survey data and estimate regression models to analyze adoption. To what extent are findings from these models and from the literature in general conditioned by the specific regression method applied? We investigate these issues by cataloging and applying a wide range of econometric methods to binary adoption data to assess robustness of the results to the methods employed. The econometric methods applied fall into three basic categories: (a) parametric models including the popular probits and logits, (b) non-parametric models, and (c) semi-parametric models including maximum score (median regression) and single-index methods. These methods cover an entire spectrum of “assumed structure” concerning the estimated model. Non-parametric methods do not assume any structure, while parametric methods assume both the distribution of adoption probability and the functional form of the dependence between adoption choice and its determinants. Semi-parametric methods represent a middle-ground. Typically, researchers do not test assumptions regarding regression error and functional form. These assumptions of parametric models allow researchers to utilize small samples to test hypotheses, evaluate multiple regressors, perform out-of-sample predictions, and generate results with greater statistical precision. In contrast, it is not only impossible to test hypothesis and extrapolate model results with non-parametric and semi-parametric methods, but also difficult to display, report, and interpret these results. We discuss software requirements for the three methods. We then apply the methods to an agroforestry adoption dataset to evaluate impact of econometric method selected on the findings regarding determinants of agroforestry adoption.

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Taking Stock of Agroforestry Adoption Studies

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Despite some impressive scientific and technological advances over the last three decades, agroforestry rural development projects have experienced uneven success rates in many parts of the world due to inadequate adoption rates and/or abandonment soon after adoption. This has highlighted the need for more socio-economic research on agroforestry. From the mid-1990s, journals began publishing empirical adoption studies at a rapid rate, reflecting researchers' efforts to better understand behavioral components of agroforestry adoption. We compare and combine the specific cases described and modeled in the published literature to find general patterns in agroforestry adoption. We draw on previous reviews of empirical technology adoption literature to identify clusters of factors that explain technology adoption and, thus, extend previous work. In reviewing 120 articles on adoption of agricultural and forestry technology by smallholders, we find five categories of factors that explain technology adoption within an economic framework: preferences, resource endowments, market incentives, biophysical factors, and risk and uncertainty. We apply vote-counting based meta-analysis to 32 studies primarily from tropical areas that focus on agroforestry and related investments, and evaluate the inclusion and significance of the five adoption factors. Our analysis shows that preferences and resource endowments are the factors most often included in studies. However, adoption behavior is most likely to be significantly influenced by risk, bio-physical, and resource factors. Finally, we discuss specific recommendations for the next generation of adoption studies and meta-analyses that include considering a more complete menu of variables, reporting key statistics and marginal probabilities, and conducting weighted meta-regressions.

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Implementing Agroforestry at the Family-Level: Modest Projects that Make a Big Difference

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There is a perceived shortage of natural resource conservation assistance available to developing countries, and indeed, many international agencies and non-governmental organizations spend considerable resources attempting to implement environmental improvement projects. In some countries, the problem of visible results may lie in the method of implementation. In cultures where social norms do not fit development projects objectives, there is considerable risk of wasting time and resources. Perhaps the answer lies in the scale and model of the project? This presentation will share techniques and testimonies from coastal Ecuador. Here, volunteer organizations implemented a successful agroforestry campaign which was suitable and appreciated by forest families, and achievable and cost-effective by local volunteer group efforts. As individual families, modest projects can make a big difference, and as an aggregate group, the ecological impact and large-scale development goals can be realized.

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Fertilizer Trees and Food Security in Western Kenya

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This paper draws from a recently completed ex post analysis of the impact of improved fallow and biomass transfer systems on food security in western Kenya. Qualitative and quantitative approaches are used in the analysis which looked at adoption of technologies, yield effects, income effects, and food and nutritional effects from using the agroforestry systems. Large samples (2,000 households) were used for adoption analysis, while baseline and post-treatment measurements of impact indicators were taken for just over 100 households. Among the food security measures included caloric intake, protein intake, and intake of various vitamins at the household level. These were assessed by intensive 24-hour recall surveys administered at various times of the year in the baseline and follow-up years. Qualitative case study approaches were used to better understand the processes by which households benefited or not from the agroforestry technologies. The results found that many poor households were using the agroforestry systems whereas they previously were not active practitioners of effective soil fertility management practices. Yields of maize increased noticeably, on average more than doubling. Nonetheless, areas under the improved systems remained small for most adopters and thus they had no significant impacts on food security at the household level. The paper goes on to examine the requirements or circumstances under which these technologies could lead to substantial improvements in food security.

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Partnership for Sustainable Land Use in Nigeria: The National Tree Nursery Development Programme Model

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The total area under forest reserve in Nigeria by 1970 was 96,518 km^2 and by the 1990s this had declined to 46,542 km^2. This disturbing trend was in spite of multilateral investments in Forest Management Projects in four rainforest and Guinea Savanna states and Afforestation Programme in 19 states of the Sudano-sahelian zone. A major drawback of these interventions was the top-down approach in decision-making process. To stem this, the Federal Government instituted the National Tree Nursery Development Programme (NTNDP) in the year 2000 as a component of the National Food Security Programme to backstop stakeholders in massive high-quality seedling production based on local species preferences and effective distribution to reclaim the degraded biophysical environment and enhance food security and poverty reduction. To date 2,065,619 seedlings of various plant types have been raised by out-growers, of which 549,450 (26.6%) have been distributed. The balance is those with longer nursery gestation and a few other short nursery gestation seedlings still with outgrowers. The programme has generated over 10,000 short-medium-long term employments with youth and female topping the list. Action plans and strategies for the next three seasons (2003/4 – 2005/6) include intervention in selected strategic grazing reserves aimed at revegetation with fodder and economic species, effective publicity of the programme, alternative to firewood, exploring market outlets, processing of substances like oils, resins, juices, meals/cakes for food, animal feed, medicinal and other uses from plant parts. The model has the potential of enhancing sustainable rural livelihoods.

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Agroforestry with People's Participation: A Sustainable Land-use System for Improvement of Rural Livelihood in Bangladesh – A Case Study

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Bangladesh is the most densely populated country in the world with limited resource base. The economy is primarily agrarian and is the major source of income and employment sector for the rural people. The country has only 1.43 million ha (about 10% of total land area) of state-owned forestland and per capita forestland is one of the lowest. Agroforestry is not new in Bangladesh. There exists age-old traditional agroforestry practices in different agro-ecological zones. Traditional ways of raising plantations proved to be unsuccessful due to non-cooperation of local people. So, it was realized that management practice should be based on benefit-sharing principles with people's participation. Starting from 1980 some distinctive programs were implemented and, by 2003, a total of 7,738ha of agroforestry plantations have been raised with participation of 10,317 landless people with a condition that they would get 100% of the agricultural and intermediate tree crops as well as 45% of sale proceeds of final harvest. On attaining maturity (10 years) in the last 4 years, 1,596ha plantations have been harvested and Tk. 56,602,964/- ($975,913) has been distributed among 2,119 participants, averaging Tk. 26,712/- ($460) per participant. Moreover, 10% of the money has been kept for Tree Farming Fund for self-sustaining the program. Women with ownership rights enjoy equity with men in terms of control over sale proceeds and resources. Agroforestry has proven profitable and contributes significantly for improvement of rural livelihoods, and it would be a sustainable broad-based production system for the people and the country in future.

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Influence of Agroforestry on Poverty Reduction: Bangladesh Perspective

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Various plans and programs have been undertaken at different times to reduce poverty in Bangladesh. Agroforestry is one of the significant parts of these plans and programs. Agroforestry plays an important role for poverty reduction in Bangladesh because it significantly contributes to the life of poor people in meeting their expenses and different types of needs. It also creates opportunity for employment of rural poor women by engaging them in different types of economic activities. They obtain various types of raw materials like bamboo, cane etc., for small and cottage industries by participating in agroforestry and thus the women are able to increase their economic support and social status. Agroforestry significantly contributes to rural health by producing medicinal plants. Indigenous *'Kabiraj'* (medical practitioner who follows the 'Ayusvedic' system of treatment) and *'Hakim'* (doctor) extract different types of medicine for local primary health care from trees and plants. At present agroforestry is also important and effective for conserving and managing bio-diversity. So agroforestry reduces poverty by increasing the per-capita income and health of the poor people, and also improves the natural environment.

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Adoption of Eucalyptus-based Agroforestry Systems in Rainfed Semiarid Areas of Andhra Pradesh, India

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As there is a wide gap between the domestic requirement and supply of pulpwood in India, there is an urgent need to take up tree plantations using high quality, fast growing pulpwood species. There has been strong interest in recent years on eucalyptus (*Eucalyptus* spp.)-based agroforestry in the state of Andhra Pradesh. The objective of the present study was to review farmers' practices of this technology, examine the factors influencing adoption and its impact on farmers' livelihoods. The study was conducted in three villages in Khammam district, where there is maximum acreage under the technology. Information was collected from 66 farmers consisting of 51 adopters and 15 non-adopters through formal interview. Short rotation cycle, high biomass production, and assured market with buyback arrangement for the wood led to large-scale adoption of agroforestry. Farmers' practices differed in terms of intercrops and fertilizer application to trees, but they harvested trees at the end of four years and took two coppice cycles. Wood yields ranged from 20 to 30 Mg of (fresh) wood/ha/year and net revenue varied from Rs. 20,000 to 30,000 (1 USD= Rs. 46.0 in 2003), which is 2 to 5 times higher compared to annual cropping systems. Variables that influenced adoption include farm size, farmer's education, income status, distance from the company, non-agricultural income, contact with company extension people and previous experience of tree farming. The paper discusses the impact of this technology on the resource base of the farm, returns to land and labor, and household livelihood status.

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Documentation of Farmer-Based Extension and Technology Promotion Strategies: A Case of 1:4 Pooc Agroforestry in Silang, Cavite, Philippines

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In the Philippines, 35 years ago, evolved the 1:4 Pooc Agroforestry System, a typical multistory cropping where farmers of Pooc grow four or more crops simultaneously in one hectare of land and can afford to integrate animal units in the production system. The best species combinations for the site, climate and culture ended up to be: coffee + papaya + pepper + pineapple + guyabano + lansones + mahogany + and its variations where short-term high value crops are integrated in the system. Farmers derived an annual net income of Php 250,000–300,000 ha/year on these cropping combinations. One of the unique characteristic of the farmers in Pooc is they belong to elite farmers, most of them are professionals who chose to come back to farming as a major source of income. The 1:4 Pooc Agroforestry provides protection to the community watershed, thus continuous potable supply of water is available throughout the year. The value added to this is the barangay local government unit generated livelihood project as supplier of water for domestic use. The ideal species and site combination developed through the ingenuity, innovativeness and experience of the farmers in Pooc is worth sharing and learning, and is viewed by the farmers as a blessing from God to be shared. The 1:4 Pooc Agroforestry now serves as an extension and technology learning laboratory managed by its key farmers who teach and train others from neighboring provinces and regions about the social, economic and environmental benefits of this system.

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The Panama Canal Watershed Conservation Project: Participatory Agroforestry Development

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The Panama Canal Watershed Conservation Project (PROCCAPA), coordinated and executed by the Panamanian National Environmental Authority (ANAM) and Japan International Cooperation Agency (JICA), aims to "engage the farmer groups in participatory activities that contribute to the sustainable conservation of the Panama Canal Watershed". The project consists of three components: agroforestry, silviculture and participatory development; and its purpose is to provide alternatives for the small scale farmers in the western bank of the Upper Canal Watershed. The project has been in execution since September 2000 with the participation of eighteen small communities from the El Cacao area in the Canal Watershed and is consistent with the Panamanian government's sustainable land use plan. Prior to any project support, the farmers' needs are identified by PRA in order to provide appropriate skills and training courses, ranging from agroforestry and silviculture to gender awareness. All participants share their experiences with their group members and subsequently practice their acquired skills back in their group farms. Another benefit of this project is that some farmers are so well-trained that they become instructors for some training courses. Project advisors attend the weekly group activities to provide support and to collect recent information. Monthly meetings are held at each group for a self-evaluation of their activities and for planning future events. One clear achievement of this project is the farmers' decision to form their own association to continue these new practices after the termination of this project in September 2005.

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Multi-storey Cropping: An Intensive Agroforestry System for Small Upland Farmers in the Philippines

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The system involves the cultivation of several perennial cash and food crops with different heights and growth characteristics on the same area. It is intended to maximize the use of resources (soil moisture and space) for increased productivity and income. The system is practiced by small landholders on a volcanic landscape about 60 km south of the capital city of Manila. A typical multi-storey farm consists of coconut (tallest) followed by banana, coffee, papaya and pineapple. Root crops like sweet potato (*Ipomea batatas)* and taro (*Colocasia esculenta)* are also occasionally grown. The cropping system provides excellent surface protection for the land surface minimizing erosion even on sloping land. Nutrients are recycled as the litterfall will decompose. However, because of the intensive cropping, supplemental application of commercial fertilizers is necessary to maintain soil fertility. The crops in the system require different farming schedules for planting and harvesting. Thus, the farmers can cope up with the labor required because it is distributed over time. The system provides year-round source of food and income as the various components have different maturity periods. Multi-storey cropping has been proven to be a sustainable technology for farmers who have limited land resources. Growing different crops is also a way of distributing risk due to severe climatic aberration such as El Nino and La Nina.

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Agroforestry: A Potential Income-Generating Land Use System in Bora'a Mountain of Yemen

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Yemen is a Least Developed Country. Only 6% of the total land is arable for agriculture. Bora'a Mountain region is situated on the west of Yemen. It is renowned for coffee production. The farmers of the study area have been practicing agroforestry for a long time as the main land-use option. The second land-use option is agriculture. Because of hilly topography, agricultural production is not sufficient to meet the demand for food. The alternative land-use system is agroforestry. It has potential to meet the demand of the locality by producing more than one output and by ensuring the maximum utilization of the land. Various agroforestry systems are found in the Bora'a Mountain. The agroforestry practices are also distinct in highlands and lowlands of the region. The study attempted to determine the potentialities of the agroforestry production system by comparing it to other non-agroforestry practices in the Bora'a Mountain. The sample size of the study was 100 to examine the potentialities of agroforestry as a land-use option. It compared the annual income of agroforestry to the income of other non-agroforestry farming activities. Multiple linear regression analysis was used to determine the significant variables that contribute to the annual income. It was found that agroforestry land-use option was more productive than the other land-use options. Based on the findings it is to be recommended that the farmers of the study area should be patronized by providing inputs or cash support to ensure maximum utilization of the land through agroforestry technology.

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Betel Leaf Based Forest Farming by Khasia Tribes: A Sustainable System of Forest Management in Moulvibazar District, Bangladesh

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The Khasia tribespeople, who live within the fringe of reserved forests of Moulvibazar district, have been traditionally growing betel leaf on naturally growing trees. Each family has been allocated 1.21 hectares of land for farming and 0.06 hectares for dwelling houses including establishing homegardens. While deforestation is a serious concern in Bangladesh, the Khasia tribe living within forests are protecting trees for their livelihood such as selling of betel leaf, collecting firewood and consumption and selling of fruits from support trees. Thus the tribe has been contributing in production, protection and conservation of biodiversity in the surrounding reserved forests. Productivity of betel leaf depends on mixture, age and tree density. Association of betel leaf (*Piper betle*) with *Artocarpus chaplasha* has been found to be most productive in terms of cash return. However, the area is predominantly occupied by mixtures of tree species of low commercial value (1279.8), while occurrence of *A. chaplasha* is only 98.15. Net annual income per farm was US$ 2651 during last 12 years rotation of betel leaf. The benefit-cost ratio for betel leaf production was 5.17. Firewood consumption was 1.72 metric tons and fruit consumption was valued US$ 18.50 per farm per annum. Moreover, they had extra annual income from selling of fruit valued US$ 28 per farm. The system is sustainable, and can be improved through integration of high-value crops with betel leaf which will benefit the Khasia tribes as well as create an avenue for collecting revenues for the government on a perpetual basis.

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Effects of Polyolefin-coated Nitrogen Fertilizer on the Growth and Yield of Upland Rice in between Leucaena Hedgerows in the Philippines

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The influence of polyolefin-coated urea (a slow-release nitrogen fertilizer) on the growth and yield of upland rice varieties planted in between *Leucaena leucocephala* hedgerows was studied for three years under rainfed conditions. Three upland rice varieties—PSB Rc 1, PSB Rc 3, PSB Rc 5—were planted in the alley (4 m) of 7-year old double hedgerow Leucaena trees. The rice plants were supplied with the following recommended rates of fertilizer: urea (45%, quick release N fertilizer); EM-Cote Type S100 (41% N, slow-release N fertilizer); EM-Cote Type L100 (41% N, slow-release N fertilizer); except for the control treatment: F0 = no fertilizer. Results indicate that, using analysis of variance-repeated measurements, the fertilizer treatments had affected the height, aboveground biomass and leaf color of the three upland rice varieties. Regardless of varieties tested, unfertilized plants were smaller (height), lighter (biomass), yellowish (leaf color), less number of tillers, panicles, and spikelets compared to fertilized ones. Plants applied with quick-release (urea) and slow-release N-fertilizer were comparable. The height of rice plants at vegetative stage had a very strong correlation with leaf color but such relationship declined at reproductive stage. A modest correlation were noted in all varieties tested on the number of panicles and number of filled and unfilled grains, and aboveground biomass at harvesting and number of filled grains. In conclusion, the use of polyolefin-coated nitrogen fertilizer enhanced nutrient-use-efficiency and reduced nutrient spillage, which is known to have an adverse impact to the environment through time.

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Adoption of Agroforestry Technology: The Case of Live Hedges in the Groundnut Basin of Senegal and in the Cotton Zone of Mali

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A socio-economic study was undertaken in the groundnut basin of Senegal and in the cotton zone in Mali to determine the factors that determine the adoption of live hedges. Data were collected on the socio-economic characteristics of households in both regions. A chi-square test was used to determine variables that affected the establishment and adoption of live hedges. The results suggest that the principal constraints to the establishment of live hedges are the availability of planting material and the means to transport farm inputs and equipment. In the southern part of the groundnut basin in Senegal, respondents indicated that the reasons for their adoption of live hedges were mainly ecological – to combat wind and water erosion. The reasons for the adoption of live hedges in the northern groundnut basin in Senegal and in the cotton zone in Mali were similar and included a combination of social (secure land and avoid conflict) and ecological factors. The ethnic group of the farmer and ownership of farm equipment were important determinants in the northern part of the groundnut basin in Senegal. In the southern part of the groundnut basin the main factors that enhance the adoption of live hedges were the age of the household head, belonging to a village group, the number of active household members and ownership of transportation means. In the cotton zone in Mali, the adopters are independent family members and those households experiencing land scarcity.

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Adoption of Agroforestry Model – A Suggestive Tool for Fulfillment of 21st Century India's Food Requirement

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India, the second largest populated country, is a tropical country occupying 2.5% of geographical area of world. Its population is growing at faster rate. It is estimated that it would reach about 3 billion by 2051 AD, for which India would require about four-fold food grains production over present level i.e. 186 million tons. India's cultivable land and water are limiting factors shrinking daily due to conversion to non-agricultural use. Most of cultivable lands are un-irrigated and rainfed. Thus, increase in food grain production is not possible by excessive use of agro-inputs which have reached saturation. The forest/land ratio of country is 22.5% against its optimum level i.e. 33% of the total geographical area. Blind deforestation, uncontrollable forest fires, jhum farming, etc., are crucial factors responsible for this causing lesser and uneven distribution of rainwater in different parts of the country and reducing food grain production. Arranging sufficient irrigation water through rivers, dams and ground water by appropriate and careful adoption of Agroforestry Management, is ultimate solution for increasing land/forest ratio and food production. For this, farm people, government and NGO'S should come together for vigorous afforestation of fast-growing economically beneficial trees, post-care of previously planted trees, check of unwanted deforestation, and expansion of more agroforestry areas in phased manner. In so doing, optimum level of land/forest ratio can be achieved which will certainly increase ensured sufficient rain water and food grain production of India, for enabling millions of additional mouths to meet their food requirements.

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Evaluation of the Adoption Potential of Baobab Production on Horticultural Plots in the Segou Region of Mali

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To deal with the strong pressure on baobab (*Adansonia digitata*) trees due to intensive harvest of their leaves, researchers from the International Centre for Research in Agroforestry (ICRAF) and the Institute of Economic Research (IER) in Mali conceived of a technique that permits baobab to be cultivated on horticultural plots. The technique consists in sowing baobab seeds in small plots and letting the plants grow to a height of approximately 30 cm. A portion of the leaves is then harvested at regular intervals, so as to maintain the plants at a relatively constant level. In order to adjust the new technique to real conditions faced by local farmers, a preliminary evaluation of its adoption potential was undertaken. Semi-structured interviews and field inspections were conducted in villages of the Segou region where the technique has been promoted. Farmers are interested in the idea of baobab production on horticultural plots and speak positively on the subject, but preliminary observations reveal diverse constraints on eventual adoption of the technique. Among them are the lack of labour, delayed and low seed germination, the need to protect the parcel against animals, lack of access to land or a water source, and the fact that the economic profitability remains to be proven. Removing such constraints would seem necessary to stimulate the adoption of baobab production on horticultural parcels in the Segou region. It is recommended to begin extension activities in villages with access to a community-owned horticultural perimeter.

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Food Security through Agroforestry: Successful Case Study from North India

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The success of agroforestry in Haryana and neighboring districts of Punjab, U.P and Uttranchal States of Northern region of India has led to evolution of an annual market of wood products worth more than US $210 million in Yamunanagar district of Haryana, benefiting not only farmers but has also generating employment of various kinds at different levels, which in turn has successfully ensured food security in the region along with spin-off benefits of ecological and environmental security. Increasing pressure of population on the land mass dictates the need for optimum utilization of all available land resources. Agroforestry has huge potential in meeting up challenges of food security, due to increasing population and degraded environment. *Eucalyptus* spp. and *Populus deltoides* have been most common species under agroforestry systems in Northern region of Haryana, India which brought substantial change in economic conditions of the farmers. The paper/poster analyzes various aspects of success, which is rooted in choice of species, market linkages and assured market.

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Agroforestry and Food Security: Experiences of Farmers in Uganda

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Agroforestry is a traditional way of faming in many parts of Uganda. Farmers reserve part of their farms for wood lots, which generate products and income on sloping lands where agriculture would not be profitable. On terraced lands in Kabale, farmers are testing small woodlots for the degraded upper parts of the terraces. In these cases, when the right tree species is chosen more than 20 tons of wood can be produced within 2 years, worth about 1 million Uganda shillings. Furthermore the trees help to rehabilitate soil fertility. This is a common practice around Lake Victoria where shade trees are left in fields or are planted, and enhance production of coffee and bananas. In northern Uganda, indigenous trees, like the sheabatter tree that produces high-value products, are protected. Fruit orchards are one of the most favored agroforestry interventions, as they enhance the farming family's nutritional and income status considerably. Improved varieties of fruit trees have been identified and are now available. These produce better quality fruits in a shorter time and take up little space on the farm. Also trees grown along boundaries and contours can produce timber, firewood, stakes and quality timber. Managing these trees is important to reduce competition with crops and to achieve good timber quality. Uganda has the plan for modernization of Agriculture (PMA) as a key policy of the Ugandan government towards eradicating poverty in the country. The plan is being implemented and farmers have welcomed it, with integration of Agroforestry in their farms.

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Impact of Regulatory and Policy Constraints on Agroforestry Production in UP State of India

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Agroforestry holds important environmental and economic benefits for the people of Uttar Pradesh, India; however, there are disincentives and constraints to its commercialization. Uttar Pradesh, consisting largely within the fertile gangetic plains of north India, has a total forest area of 7%. Tree cover in forest area is 4.46% while the state has 8.8% tree cover. The rest 4.32% tree cover is contributed mainly by agroforestry. The estimated demand for commercial timber and fuelwood is 56.27 Mm^3 while the supply from government-owned forests is 3.85 Mm^3. Part of this gap is covered by agroforestry and part is not covered (Source: SFAP, Government of UP, 1996). There are disincentives and constraints to agroforestry production with respect to UP Protection of Trees in Rural and Hill Areas Act,1980 and UP Transit of Timber and other Forest Produce Rules. Some amendments are required in the existing legal provisions restricting felling, transport and sale of agroforestry produce. It is also necessary to identify risk factors and to develop mitigating measures. There is lack of awareness regarding provisions of existing laws. Restricting the act to only a few plant species of religious, social and cultural value (e.g., *Ficus* spp., *Azadirachta indica*, etc.) would be advantageous. Harassment from police and forest officials is another disincentive. Amendments in regulatory and policy frameworks will help in the enhancement of agroforestry production. Ideally, gaps in demand and supply of wood will be fully covered by enhancement of agroforestry production.

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Adoption of Riparian Forest Buffers on Private Lands: Factors Affecting their Use in Two Nebraska, USA Watersheds

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Pesticide and nutrient runoff from agricultural fields is an environmental problem that impairs surface water quality and affects the health of human, plant and animal communities. Riparian forest buffers (RFBs) are an agroforestry practice that mitigates the negative effects of runoff. Despite social and economic benefits associated with the use of RFBs, few landowners adopt the practice. To understand the factors affecting the use of RFBs, data were collected from 564 landowners in two Nebraska watersheds. A mail survey was used to assess variables affecting the use of RFBs. Recognizing that not all landowners are producers, the population can be studied from multiple perspectives including: producers and nonproducers, adopters and nonadopters, and in-residence landowners and absentee landowners. Descriptive and multivariate statistics were used to identify differences between these groups. Using factor analysis, three underlying factors were identified that influence the use of RFBs: perceptions of RFB compatibility with current farming practices; perceptions of RFB governmental programs; and, perceptions of RFB functional impacts. The study found that adopters and nonadopters are significantly different with regard to all three factors influencing the use of RFBs, particularly regarding their perceptions of RFB governmental programs. Producers and nonproducers also were significantly different regarding their perceptions about the functional impacts of RFBs. Understanding differences between and among landowners is important in order to induce greater adoption of RFBs by crafting more effective policies and programs, and more precisely structuring educational and technical programs by Extension and other natural resource agencies.

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Agroforestry in Meeting Challenges of Productivity, Environment and Community in India

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Although cultivated land in India is becoming limited, a 50% increase in production is targeted for the next two decades. In this regard, agroforestry can provide food security to human and animal populations, sustain economic growth and protect the environment. It can meet these challenges by enhanced availability of water, biological products and improved ecosystem functions. There is a need to assess the achievements, reassess the potential of agroforestry and harmonize these with farming systems and policies. The role of agroforestry in erosion control, nutrient cycling and moisture regime needs to be well-integrated with farming systems and watershed management. Components of reduced tillage in time and space, deep and extensive root systems, vegetative cover, management of degree and length of slope, and contribution from leaf litter provide additive build-up effects. Management of agroforestry systems is highly site specific and no generalization should be attempted. The synergy has to assimilate the farm power availability vis-a-vis reduction in tillage, erosion problem and its control, nutrient needs, availability and gap management, market needs and diversification, respectively. Poverty alleviation issues, imparting diversification and commercialization, year-round production, employment and income need to be the specific objectives of agroforestry systems for middle and low income countries of the world. The path is to have participatory designing and have synergy in implementation. Potential exploitation, soil erosion control, moisture conservation, nutrient cycling, income generation, progressive and graded induction of agroforestry systems in arable, non-arable lands and home gardens should be major thrust areas.

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An Agroforestry for Every Reason: Adoption Potential in Changing Rural Pennsylvania

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Agroforestry practices have gained notice among many groups in Pennsylvania who are interested in land management tools that enable rural community revitalization, natural resource conservation, and sustainable agriculture. In order to create effective outreach programs for a rapidly changing rural population, Pennsylvania State University Forestry Cooperative Extension conducted an agroforestry adoption potential assessment. Applying a social marketing research framework, focus group interviews were conducted in Fall 2002 and a mail survey was sent to 500 landowners in February 2003 to gain insight into current practices, land management objectives, needs, and perceptions regarding agroforestry. Factor analysis was employed to group variables and a two-step cluster analysis was used to produce landowner clusters based on their agroforestry preferences. Cluster analysis produced four landowner clusters: Woodland Managers, who were interested in crop tree management, Part-Time Progressive Land Managers, who preferred forest farming and conservation practices, Progressive Livestock Managers, who sought supplemental income and silvopasture technologies, and Aging Woodland Owners, about 12% of the study population, who were in large part not interested in learning about new agroforestry practices. The analyses show that agroforestry practices can indeed play a role in land management for a diverse population and a wide range of objectives, if the landowner groups are targeted according to their unique interests and values. With the results of this study, PSU cooperative extension can design programs that enable county agents to assess their client types and use appropriate materials and teaching styles for those groups.

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Community-Driven, Local Government-Led Agroforestry: The Adoption of a Strategy towards Natural Resource Management and Food Security in Public Lands in Central Philippines

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Public lands in the central Philippines are faced with grave ecological threats as they continue to be subjected to illegal logging / slash-and-burn practices of marginal forest occupants. One way or the other, it would seem poverty is the constant denominator of such desperate actions. Yet, poverty is also a cause and effect of environmental destruction. While punitive measures used to be the restraining action against these poor communities, it is quite a relief there was a redefinition of the problem and the solutions for the past few years. Such transformation has been strengthened by emergence of people–centered and more participatory development efforts resulting in a paradigm with a holistic and sustainable approach. Parallel to this, enactment of Local Government Code (1991) represents a shift in governance mandating devolution to local government units (LGUs) of many functions (including that of environmental/natural resources management) - previously carried out by national agencies. LGUs now have greater autonomy to support and advocate community undertakings by providing needed resources and promoting tenure security, with assistance from government financial intermediaries. The community of farmers in the public lands of Central Visayas have taken bold initiatives – with assistance of technical agencies and in a few cases with linkages from ICRAF – to identify and implement agroforestry as their primary activity towards conserving soil and water resources, advancing food security and providing for alternative livelihood. Such undertaking is most visible community-driven response to the governments' call for sustainable development through adoption of appropriate natural resource management technologies.

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Wild Dietary Plants and their Domestication Potential in Traditional Agroforestry Systems in the Sikkim Himalaya, India

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The edible wild plants are notably well-liked all through the Himalayan region and provide a crucial source of food for aboriginal societies of the region. In the Sikkim Himalaya as many as 190 wild growing plant species are consumed either raw or as an important component of local cuisines, and nearly ¼ of the total plants are demanded on large scale. Of the total edible plants, 65% were consumed for their fruits, 22% for leaves/shoots, 7% for flowers and 3% for roots/rhizomes. A few plants are exploited at large scale for their edible parts and also form a source of earning for a few families who sell them in local markets. These species, though found in low densities, are an important constituent of the forest diversity. Species producing edible fruits with market demands are highly threatened (i.e., *Baccaurea sapida* (Roxb) Muell.-Arg., *Diploknema butyracea* (Roxb.) Lam., *Elaeagnus latifolia* Linn., *Eriolobus indica* Schn., *Machilus edulis* King, and *Spondias axillaris* Roxb.). The poor regeneration and high anthropogenic pressure on them, however, deserves priority action for their conservation. Fortunately farmers desire to raise such plants in their farms, and a value addition to the fruits increased the return by at least 3-5 times after making pickles, squash and jam. It is strongly recommended that the high diversity of edible plants needs to be conserved for future use. Some species may be grown in traditional agroforestry systems and on marginal lands that will help to protect these wild plant resources in their natural habitats.

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Potential of Contour Hedgerow-Intercropping for Management of Degraded Shifting Cultivation Areas in North East India

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The North-east region of India is home for over 31 million people that comprise more than 100 tribal communities within 0.26 million km^2 land area (c. 7.76% area of India). Shifting agriculture is main agricultural land-use that has been practiced for centuries. This system ensures long-term environmental management, soil fertility replenishment and food security. With increases in population pressure, fallow period between cropping phases has reduced drastically, leading to instability in practice. An answer to this problem has to be found within traditional framework, and, given complicacies of land ownership and tenureship, any technology to the problem has to be acceptable to practicing communities. Contour-Hedgerow-intercropping is being proposed as an alternate along with other allied technologies that aim at land and water management of the farmers' fields within traditional framework, without changing cropping practices. Significant data have been collected on best hedgerow species for region, impact of hedgerow species on crop yield, runoff and soil erosion. Results indicated that the technology can help in fertility recovery of degraded soil, i.e., restoration to productive soil, thus ecologically sound, and increases farm returns that make it economically feasible. The advantages of the technology are that it is a simple, applicable, low-cost, and timely method of farming uplands. This paper deals with findings and experiences with Contour-Hedgerow-intercropping in North eastern region, particularly for potential hedgerow species and their performance, impact of hedgerows on runoff and erosion, crop productivity, soil moisture and fertility. Cost:benefit analysis is also done for the technology.

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Long-lived Agroforestry Adoption in Java

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Agroforestry as a forest management practice has been adopted in Java since centuries ago in Teak and other forest plantations. The system has evolved over time with a broadening role of rural communities and some modifications in planting patterns. Taungya, daily wage, and social forestry systems—each has particular planting patterns, species composition, spacing, terms of tenure, social conditions, etc. Taungya and daily wage are standard systems. Social forestry emphasizes improvement of poor forest villager's incomes. It is implemented in higher-pressure forest areas, at wider spacings for agricultural crops for a longer term up to rotation age, and with various fruit species. Three categories of species composition play important roles and functions and shape forest biodiversity: (1) main forest tree species; (2) mixing species: border, hedge, intercrop, interplanting and filling tree species; (3) agricultural crops. The species composition is selected based on agro-ecosystem suitability and designed in linear arrangement for best growth of polyculture forest plantations, minimum competition, mutualistic interaction, and future forest management. It is undeniable that the system is strategic to successful forest rehabilitation and reforestation in Java. From the total of 423,499 ha forest plantation during 1993–2000, 80% had been done successfully through taungya system with higher growth percentage than daily wages system. Successful reforestation through social forestry programs from 1993–1998 covered an area of 32,580 ha. Agroforestry is in many ways a tradition of rural communities for meeting their basic needs. Today it is starting to develop for financial return for rural households.

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Agroforestry Models Developed for Tropical Alfisols of Tamil Nadu State, India

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The Tamil Nadu State, located in the southernmost tip of India, has diverse soil types and climate. The dominant food crops grown in the dry alfisols of the region are sorghum, cumbu, maize, sesame, sunflower and beans. The type of land use is mono-cropping during rainy season (October-December) and fallow in other months. Hence studies were designed to identify agroforestry models to have cropping throughout the year. The studies identified the following models, which are followed by their respective findings: (i) 'Fruit-Forest trees-Animal' combination: combination of Guava + Gliricidia + six goats + milk cow; (ii) silvopasture: *Acacia leucophloea* + *Cenchrus*; (iii) 'Forest tree-Vegetables' Land use system: combinations of Sword bean and Eucalyptus and Sword bean and Casuarina are best; (iv) Tree mixtures: mixtures of Sapota and Leucaena; Sapota + Casuarina; Mango + Leucaena and Cashew + Casuarina are promising; (v) Mixed forest trees System: vertical growth of Ailanthus was increased when grown in espacements of 7 x 7 m inter-planting of six rows of N-fixing tree species; and (vi) 'Fruit–Fodder System: combinations of Mango + Fodder Maize and Guava + Fodder Maize are best for dry alfisols. Lastly, for (vii) Dry Grazing Pastures: direct seeding is the best for *Cenchrus setigerus and Pennisetum polystachion*. Also, dual inoculation of *Azospirillum* and Phosphobacteria registered 2.6 times higher yield in *P. polystachion* and 3.7 times in *Andropogon gayanus* compared to no inoculation; and, seed treatment with K_2HPO_4 at 2% concentration is best for pre-monsoon sowing in *P. polystachion* and *A. gayanus.*

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Agroforestry: Sustainable Land Use Systems Vis-À-Vis Sustainable Subsistence

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This paper discusses the sustainability of various agroforestry systems (AFS), and is based on four decades of experience in Asia, the Pacific region and Africa. Systems discussed include shifting cultivation, taungya, homegardens, plantation crops grown under shade of trees, intercropping of commercial and horticulture trees, silvopastoral systems, and agro-silviculture systems. In this regard, the issue of sustainable land use (SLU) has arisen mainly in the developing countries where dense human and domestic animal populations have led to overexploitation of AFS. When there is threat of unsustainability, or more demand for goods and services, the current land use system (LUS) is either improved and/or completely changed. These changes have also been prompted by the acquisition of new skills. Except for the AFS in which commercial trees, fruits and plantation trees/crops are a component, all other AFS are practiced by subsistence farmers of the developing countries. Since farmers subsist on them, they make the system sustainable. All things being equal, the system will break down if overexploited. Sustainability therefore is an issue of economics and income. While research efforts have been promoted vigorously and some infrastructure has been created, yet the research itself is in its infancy. Research and Development activities thus remain in the "description" mode. It will take some time before "prescription" mode will prevail. While "action" mode by way of creating awareness has been there, yet "action for application" is yet to be started. Till then, the subsistence farmers will be left to their traditional low subsistence agroforestry practices.

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Participatory Agroforestry in Desertified Areas of Guanajuato State, Mexico

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With the aim of diminishing desertification process in marginal zones, in 2001 a state participatory agroforestry campaign in Guanajuato State, Mexico, was implemented under the direction of researchers from INIFAP and in cooperation with SDA technicians. The first phase of the campaign consisted of planting agroforestry plots with native multiple purpose trees in four pilot watersheds. In the second phase the activities were extended to 72 communities of poor climate and social marginality in 29 municipalities of the state. Between the two phases a questionnaire was given to farmers with the aim of identifying native multiple purpose trees; in addition, seeds of interesting trees were collected and plant production in school and communal tree nurseries was begun. During summer 2002 109 agroforestry plots of 1 ha were planted with the participation of people from each rural community. Total planted trees were 53,855 of 33 different species with survival data of 75%. The activities of the campaign over one year were the realization of 30 participatory workshops (diagnosis and training), 10 farmers experiences interchange journeys, 24 agroforestry demonstrations and 91 communal reunions; and results were diffused through newspaper, radio, television, fairs and congresses.

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Poplar (*Populus deltoides* Bartr.) Based Agroforestry Systems in North India: A Success Story

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Poplar (*Populus deltoides* Bartr.) is one of the most successful tree species in agroforestry systems in the northern states of India, and has been so for the last three decades. It is a fast-growing multipurpose deciduous tree having a four- to five-month leafless period during winter that allows farmers to grow one winter crop without much difficulty. A sporadic survey revealed that about 37% of farmers intermixed poplar plantations with various crops, while 63% of farmers have opted for plantations on bunds. Poplar plantation has also been suitably adapted on boundaries of fruit orchards as a horti-silvicultural system. A few prevalent practices include the follow species combinations: poplar-mango-turmeric, poplar-litchi-gladioli and/or turmeric, poplar-pear-turmeric, etc. Typical spacings adapted for agroforestry systems are 5x4 m, 5x5 m, 7x3.5 m, 8x3.5 m and others, which allow tractor harrowing and other operations without much difficulty and damage to the plants. A large number of clones have been released and recommended by the universities, forest department and private companies. An evaluation and analysis showed that clones *viz.* S7C1, S7C4, S7C15, L13, L34, L 12, S7C8, ST-92, Pant Poplar-5, and D 163, were not only at par with the check clones, but were also sufficiently genetically divergent to avoid any kind of genetic mono-culturing. However, recent price declines have discouraged farmers from poplar production. Government and private organizations, particularly users, are being brought to the common platform to devise an amicable solution.

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Agroforestry Practices and Adoption by "Small" Farmers in the Pacific Islands

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The paper starts by defining agroforestry, and "small" farmers in the Pacific island context and explains why the paper focuses on "small" farmers. The authors who are themselves Pacific islanders who have been involved in agroforestry research, education and training and development, have two major objectives for the paper, in relation to the adoption of agroforestry practices in the Pacific islands:

(1) to share knowledge, experiences and ideas; and (2) to suggest future strategies in agroforestry research, education and training, and development. Even after development agents such as the local Agriculture Department confirm that they have found an appropriate agroforestry system for the local situation, farmers may not rush out and start using the system – as they have may have "other issues" to consider apart from the availability of a technology considered appropriate by the development agents. These "other issues" may include economic, sociocultural and spiritual considerations which the development agents may have not even considered. The paper suggests strategies for filling this gap between the expectation of the farmer and his/her development agent. The paper further explains that the farmer and development agent start off this process with different worldviews and it is essential that the development agent has a good understanding of his/her own worldview and that of the farmers he/she serves if he/she wants greater success in the adoption of technologies he/she wants to introduce.

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Participatory On-Farm Development of Agroforestry Proposals for Central Amazonia

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Several forms of participatory on-farm research were used to develop agroforestry proposals for small-scale farmers (Manacapuru, Amazonas, Brazil). Farmers choose species and number of plants; researchers donated planting material; farmers furnished land and labor and managed the plots in their way. Results refer to work on 24 farms installed from 1993 to 1999. Resulting agroforestry plots differed substantially in size, species composition and management. Most plots consisted of a mixture of minor fruit species. Most developed well, but farmers showed limited interest in them. Much better results were obtained with systems designed around economically important perennial crops, such as *Theobroma grandiflorum*. Fifty tree or shrub species were tested. *Bertholletia excelsa*, *Couma utilis*, *Oenocarpus mapora* and *Inga edulis* performed well on nutrient-poor soils exhausted by annual cropping. Many other species grew under these circumstances but produced little or no fruit. *Gliricida sepium* only developed in places that had been fertilized in the past. For successful introduction of nitrogen-fixing species more assistance proved necessary. Nitrogen-fixing species were installed and maintained by researchers for two years, after which farmers took over. One farmer substantially expanded his area of nitrogen-fixing species and uses them to mulch his irrigated crop of *Malpighia punicifolia*. We learned that agroforestry projects should not concentrate on adding a tree plot to a farm, but try to interfere with major farm activities, and pay substantial attention to nitrogen-fixing species and organic-matter management. This requires intensive interaction over a long period but can have an important influence on the farming system.

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Keeping Agroforestry Relevant in Situations of High HIV/AIDS Prevalence

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Today, 95% of people living with - and an even higher proportion of those dying of - HIV/AIDS are in developing countries. The overwhelming majority are the rural poor, and among them women figure disproportionately. However, most of the response to the epidemic has come from the health sector, not the agricultural sector. The agricultural sector cannot continue with “business as usual” in communities where vast numbers of adults are dead, leaving only the elderly and children. It has to revise the content and delivery of its services. The paper discusses the impact of HIV/AIDS on rural livelihoods; agroforestry possibility for the mitigation of HIV/AIDS and agroforestry strategies for HIV/AIDS contexts. The paper concludes that agroforestry interventions may play a unique role in the mitigation of the impacts of HIV/AIDS. They can improve the communities’ long term resilience against this and other external shocks, in a way that agricultural interventions on their own cannot achieve. Agroforestry technology can be finely tuned to respond to the AIDS affected communities’ shortcomings regarding labour availability, both in the short term and long term. By providing labour management, income generation, and soil enhancement possibilities, agroforestry technologies may mean the difference between hunger and food security. The paper recommends that current and future agroforestry programmes and forest policies should be reviewed to assess their effects on key determinants of HIV vulnerability. A review process would assist project programmers and policymakers in identifying where and for whom prevention and mitigation efforts should be targeted and focused.

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Agroforestry in Northeastern China

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Northeastern China includes Liaoning province, Jilin province and Heilongjiang province. Its total area accounts for about 10% of the total land area of China. This region has suitable temperate climate and environmental conditions for agricultural productions. The total cropland area in the region is about 20 million ha. Northeastern China is considered as one of the most important cereal grain production bases. In order to protect these croplands from soil erosion and desertification, and to improve agricultural production, various agroforestry systems have been established and developed. Such systems include: (i) the large-scale farmland shelterbelt networks established since the 1950s for protecting farmlands from wind erosion and desertification in the western area of the region, (ii) the combinations of farmlands, shelterbelts and woodlots for protecting farmlands from water and soil erosion in the northern high plain rolling slope area of the region, (iii) the special northern ecological homegarden model combining fruit tree planting and small greenhouse production of vegetables, (iv) pigs and biogas in homegardens developed and extended in the middle and southern areas of the region, and (v) the combination systems of medicinal herb production and tree plantations in the eastern area of the region. The constructions and functions of these agroforestry systems are described. Some existent problems and future developments of these agroforestry systems in the region are discussed.

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Rural Diversification in the Canadian Prairies of Saskatchewan

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The province of Saskatchewan is comprised of 29.7 million ha of agriculture lands and 35.5 million ha of forested lands. The primary economy of the province is from agriculture practices while forest products come in a close second. Over the past several years annual profits from farming have decreased. Farmers are either not producing quality crops due to environmental conditions, or the markets for these crops have taken a downfall. The province of Saskatchewan has implemented a policy in 2003, allowing new forest product companies to obtain 80% of their wood from the crown forest, thus potentially driving the remaining 20% towards the private landowner. All of the above reasons are enabling farmers to use trees as part of their regular cropping practices, to provide not only cropping diversification, but another source of income, which may be a more lucrative source of income for the landowner in the long run. The Saskatchewan Forest Centre is aiding farmers in making decisions on how to best use trees in agroforestry practices on their land base and cropping rotations. The area of interest in the province for practicing agroforestry is located in the “forest fringe”, the transition between the Boreal and Grasslands Eco-region. Over 1.2 million ha of lands have been identified in this area for potential development in farming diversification using agroforestry practices.

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Agroforestry Extension Program Design in the Southeastern USA

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Before prioritizing regional agroforestry training and extension content, it was necessary to discover which practices are common, what benefits are perceived, which barriers prevent use, and how agents feel about practices. Agroforestry taps both agriculture and forestry agencies to increase the possible set of educators for landowners. Interdisciplinary activities also present barriers to agents unfamiliar with topics or not served by partner agencies. To understand motives, barriers, and needs involved in extension, CSTAF designed a survey to gauge knowledge, practice, and information needs of professionals in Alabama, Florida and Georgia. Open-ended interviews formed the basis for a closed-ended mail survey to all agriculture and natural resource agents and county foresters in the subtropical area. We obtained a return rate of 43% (278/653) from Agriculture (31%); Natural Resources (26%); Horticulture (21%); Forestry (15%); Other (15%); and Livestock (14%) agents. Ranked potential for use of agroforestry was 11% very high, 25-30% high to moderate, and only 3% no potential (10% no-response). Respondents indicated streamside buffer practices as the most important practice followed by patio gardens, forest farming, windbreaks, and silvopasture. In all three states, wildlife habitat, water quality and soil conservation were the most important benefits. When asked to rank concerns, most important were lack of familiarity, lack of demonstrations, no financial incentive, and lack of information. This data tells us how to prioritize research and materials development and leads us to believe our agroforestry training can be of expected value to at least half of the regional forestry and extension professionals.

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Contribution of Agroforestry in Post Genocide Recovery of Rural Smallholder Farmers in Rwanda: Experiences and Lessons Learned

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After the 1994 genocide, most rural smallholder farmers of Rwanda had to face several challenges including rebuilding family structure, re-establishing effective agricultural production systems, and restoring severely deteriorated forest and soil resources. From the highlands to the eastern savannas, agroforestry has emerged as an effective approach to on-farm production of food, wood, fodder, fruit and other high-value products. It has been a major contributor to soil conservation and fertility in particular and to sustainable management of natural resources in general. On typical smallholder farms (0.6 ha), agroforestry options yielded benefits within six to eight months. Smallholder farmers were able to harvest firewood, stakes for climbing beans, and fodder for livestock. Average annual income per household increased from USD $150 to more than USD $1,500 with dairy cows, climbing beans and fruit. This allowed more children, particularly girls to attend school. Overall household livelihood was improved within 5 years. Such benefits were the main catalyst for large-scale adoption, which was the basis for community transformation and development as well as empowerment of vulnerable community members. Further, the national program has significantly contributed to rebuilding human capacity from farmers to scientists. In several cases, agroforestry has served as a catalyst for reconciliation and empowerment of women and orphans. This paper presents the overall impact as well as case studies of agroforestry impact in the process of recovery following the 1994 genocide in Rwanda. It highlights the potential role of agroforestry under extremely difficult situations and provides insight to lessons to be drawn.

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Practical Recommendations for Managing Loblolly Pine Agroforests in Southern USA

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Forestry and agriculture are the two most common kinds of land management in the South. Usually they are practiced separately. Yet, growing rows of trees between alleys (up to 10 m wide) allotted for agricultural crops or animals is attractive for a variety of ecological, economic, and personal reasons. To help landowners, we developed a guide that provides information for the key components of sound agroforestry: (1) tree growth, (2) crop yield, (3) schedule of recommended management activities, and (4) costs and returns of every operation. The guide was constructed on the basis of analysis of long-term measurements of agroforests and regular plantations of loblolly pine (*Pinus taeda* L.). We recommend to plant single rows of trees because of their greater resistance to ice damage. The trees are planted in square clusters of 4-5 seedlings. Optimal number of clusters increases with site index while rotation age decreases. The clusters help to compensate for the establishment mortality, allow selection of better trees, lessen root rot and other risks. Trees are pruned two times to clear one sawlog. Due to mutually beneficial land use for forestry and agriculture, reduced cost for stand establishment, pruning, optimal stand density and rotation age, on good sites agroforests provide equal annual income of about $220 per hectare, which is substantially higher than that obtained by growing trees and agricultural crops separately.

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II. Biodiversity, Ecoagriculture and Homegardens

Includes topics related to sessions on:

Biodiversity,
Ecoagriculture,
Medicinal and Aromatic Plants in Agroforestry,
and Tropical Homegardens

A Participatory Approach to Medicinal Plant Conservation and Agroforestry Management in the Idukki District of Kerala, India

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Rural and tribal people in India have been typically familiar with the medicinal properties of plants growing close to their homes and surrounding fields. However, the waning interest of younger generations and the loss of plant biodiversity in natural habitats has led to the deterioration of this indigenous knowledge. To address this problem, a comprehensive survey of medicinal plants in the Idukki district was carried out to identify local medicinal plant resources as well as opportunities for community involvement. The survey indicated that at least 46 rare, endangered and threatened (RET) plant species were present in the district. An herbarium of 434 species was prepared from collected samples, and seeds of 169 species and 50 raw drugs were displayed in a medicinal plant museum. An ethno-medicinal forest (EMF) was established on a 10 acre (1 ac = 0.4 ha) site containing 256 species of medicinal plants to conserve RET plants and to meet community needs. A community awareness program involving training, demonstration and exhibits, was also undertaken to spotlight the need for conservation and sustainable use of medicinal plants and for preservation of local health traditions (LHTs). The target groups were womens' self-help groups, school teachers, school children, medicinal plant cultivators and raw drug collectors. Training was given to approximately 14,000 people on the importance of medicinal plants in primary health care. In addition, home herbal gardens consisting of medicinal plants and agroforestry species were established among 2,056 households, and cultivation of medicinal plants was adopted by 160 marginal farmers.

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Linking Trees on Farms with Biodiversity Conservation in Subsistence Farming Systems in Nepal

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The Kingdom of Nepal extends 800 km east to west along the southern slopes of the Himalayas in South Asia. The biogeographical position of Nepal is very heartening for the fact that it harbors biological riches of both the Indo-Malayan and Palaeoarctic realms. Besides forest ecosystems, a large number of tree and shrub species are maintained on farms in the subsistence farming systems. The role of these plant species for the sustainability of agricultural productivity has been well studied. In addition, the role of agricultural crops for biodiversity conservation has also been studied and well documented. However, the status and role of farm trees and shrub species in biodiversity conservation is scantily studied and poorly documented. The paper is based on case studies from two villages in rural areas of Nepal. It presents facts on basic traditional farm management systems and argues that subsistence agricultural economy is heavily dependent on the maintenance of diverse tree and shrub species. The diversity and dynamics of shrub and tree species on farms is presented. The paper argues that trees on farms could be regarded as an attainable means to biodiversity conservation in rural areas of Nepal by reducing pressure to the natural forests and creating favorable environment for many animal species including birds. The paper presents the causes for the loss of trees and shrubs in farmland, and opportunities and constraints associated are discussed. The improvement possibilities of farm trees and shrubs for biodiversity conservation are suggested.

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The Cropland Agroforestry Experience of the Village and Farm Forestry Project in Northwest Bangladesh

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A participatory action research programme was launched in 1987 by the Village and Farm Forestry Project of Swiss Agency for Development and Cooperation (SDC) in north-west Bangladesh for developing a viable model of cropland agroforestry on privately-owned land. Forty tree species were tested on highland and medium highland situations and involving predominant (rice-based) cropping systems. Trees were planted at 8 x 8 m spacing and root- and branch-pruning treatments were applied before planting of agricultural crops. Tree growth and crop yields under and beyond tree crowns was recorded twice yearly. This paper highlights experiences of the action research from 1987 to 1999. Among the 40 species tested, only 18 survived and grew well – but farmers widely adopted only five species, namely *Dalbergia sissoo*, *Swietenia mahagoni*, *Eucalyptus camaldulensis*, *Melia azedarach* and *Albizia saman.* The other 13 species (*Acacia auriculiformis*, *Leucaena leucocephala*, *Azadirachta indica*, *Albizia procera*, *Albizia lebbeck*, *Anthocephalus chinensis*, *Gmelina arborea*, *Acacia mangium*, *Terminalia arjuna, Albizia richardiana*, *Acacia albida*, *Trewia nudiflora* and *Cassia siamea*) received only limited adoption. Of the five widely adopted species, *E. camaldulensis* had the highest mean annual increment (0.034 m^3/ha/yr) followed by *M. azedarach*, *A. saman* and *D. sissoo*. Crop yield was least impacted (1-7% reduction) by *A. mangium*, *A. nilotica*, *D. sissoo, A. albida, L. leucocephala* and *A. chinensis*. In general, trees increased organic matter content in topsoil to a distance of 3m from trees. Financial analysis revealed that *E. camaldulensis* was the most profitable species (IRR = 0.38) followed by *D. sissoo* and *M. azedarach*.

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Phenological Adaptation of Atlas Pistachio (*Pistacia atlantica* Desf. ssp. *atlantica*) in Three Microclimatic Zones of Algeria as Measured by Stomatal Dimensions

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Atlas pistachio (*Pistacia atlantica* Desf. ssp. *atlantica*) is a semi-evergreen tree endemic to the Mediterranean area, and a potential agroforestry species. Our study monitored variations in stomatal dimensions of three populations of Atlas pistachio to derive information on its adaptive abilities in various microclimates. The studies were conducted in the Ain Oussera, Messaad (Djelfa), and Taissa (Tamanrasset) areas of Algeria. In xerophytes, the reduction of stomatal dimensions and the increase of their frequencies by square millimeter of epidermis are positively correlated with the environnment and degree of aridity. The study found that, at the Ain Oussera research station, which has an average of eight months of drought, the population of the Atlas pistachio exhibited stomatae with an average length of 42.37 µm, an average width of 34.85 µm, and an average stomatal density of 282.90 st/mm². At the Messaad station, where the drought period can be year round, these values were 40.40 µm, 32.73 µm and 303.35 st/mm², respectively. Finally, at the Taïssa station, characterized by the most extreme aridity, the adaptation of the Atlas pistachio showed stomatae with an average length of 24.27 µm and average width of 14.89 µm, but with an elevated stomatal density averaging 427.36 st/mm². These findings point to the adaptive ability of Atlas pistachio in various microclimatic zones.

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Tropical Homegardens: Revisiting a Sustainable Traditional Agroforestry Practice

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In the tropics, the natural resource endowments and production activities interact to determine the overall livelihood security of rural households. Historically, homegarden households operate within their "production possibility frontier" under this stable and complex system. This paper reviews the global state-of-the-art on tropical homegardens, their nature, structure, biodiversity and production potential, perceived threats, tree/crop management, and external inputs. Specific case studies are drawn from surveys of biodiversity-rich homegardens in northeastern Brazil. Classification of these complex systems is based on the forms and functional factors relating to economic objective, nature and patterns of trees and crops, and structure and composition of the whole gardens. The households have a diverse livelihood portfolio, displaying high capability to make ends meet. The dynamic nature of the homegardens is reflected by the structures, age-class, species composition and abundance, and influx of exotics. The Brazilian example provides prospects for conserving and managing the biodiversity of economically important but threatened species for food, medicine and aesthetics. Farmers have customized homegardens to meet their changing needs, as reflected by different management patterns and combinations of components. There is a trend towards fruit tree crop-based systems, with frequent integration of domesticated and semi-wild animals. Although the home-consumption element was strong, the commercial prospect was poorly optimized. The paper highlights the shifting paradigms in tropical homegardens, including potential for carbon sequestration, policies and incentives, challenges and limitations, research and management issues. Developing the homegardens into viable agroforestry production enterprises that can be extrapolated to other areas, remains a major challenge.

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Improving the Productivity and Sustainability of Rural Peoples in the Lake Victoria Basin of East Africa through Appropriate Land Use: Role of the East African Regional Universities Programme (EARUP)

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The East African Regional Universities Programme (EARUP) provides a means of integrating the activities of the East African regional universities in collaboration with some UK institutions in addressing the sustainable productivity of Lake Victoria Basin (LVB) through selected appropriate land use technologies, including agroforestry. The paper describes the purpose and goals of EARUP in addressing the problems. The success of the programme is articulated through fundamentals of EARUP's networking and examples of its success. Specific elements of the evolution of the programme are presented. These include derivation of EARUP themes, selection of its partners, exposure of the selected partners to some principles of successful organizational methods, EARUP's local institutional teams helping stakeholders in undertaking local institutions in supporting EARUP's approaches, and monitoring and evaluation. The principles that govern successful performance of EARUP's activities are described. These include elements of collaborative leadership among heterogeneous institutions, derivation of community collaboration plans, and design elements for technologies. Also included in these principles are influences of heterogeneity in technology designs, major factors for successful collaboration, aggregating participating institutions at community level, implementation units, conditions for effective participation of collaborators in EARUP activities, and major challenges to success. The design principles are articulated in relation to integrated management of elements of EARUP. These include technological design adoption and proposed design principles for successful management of EARUP's activities. The EARUP programme is viewed as providing an appropriate mechanism for upscaling of productive land use activities which directly involve the participation of universities in the region.

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Communication in Protected Area Management: Implications for Agroforestry Development and Promotion in the Philippines

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Protected areas, as defined by IUCN, are "areas of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means." In the Philippines, protected areas are being managed by Protected Area Management Boards (PAMBs). They are examples of multi-sectoral collaborations where stakeholders are required by the National Integrated Protected Areas System (NIPAS) law to organize and collaborate in managing, protecting and conserving biodiversity in protected areas. This study examined the key roles played by communication in the organization and operation of a PAMB at Mt. Kanla-on Natural Park (MKNP), Negros, Philippines, gathered from key informants, focus group discussions, secondary information, and a survey. Communication was found vital in education and training, dialogues and interaction of members, committees and collective effort, and provision of extension services. Communication was found to serve as the "steering wheel" for the PAMB to become organized and collectively work for the biodiversity conservation of MKNP. Lessons learned from these studies have generated insights about agroforestry promotion and development as well. As in protected area management, agroforestry also requires the multi-sectoral and multi-disciplinary collaboration of concerned individuals, institutions and other stakeholders. Communication was seen as the vital link for collectively strengthening agroforestry education, undertaking agroforestry research, providing extension and other needed services, and enhancing networking efforts. More importantly, communication was recognized as the means for taking agroforestry into the kind of future its participants would want to have.

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Safed Musli (*Chlorophytum borivilianum*)—A Medicinal Plant for Providing Intermittent Income under Teak (*Tectona grandis*) in Central India

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Safed musli (*Chlorophytum borivilianum* Sant & Fernandez) is a flowering herb belonging to the *Liliaceae* family. It grows wild in teak (*Tectona grandis*) forests mainly in Central India. It has become popular in ayurvedic medicine for its aphrodisiac and other medicinal properties. Teak-musli systems have been developed in the region to utilize idle space during teak production and to serve as a means of short-term income. An experiment was carried out at TFRI, Jabalpur, to assess the performance of musli under teak plantation. A teak plantation of seven-year-old trees, planted at 2 m x 2 m spacing, was selected. In the first year, musli was grown in small plots of 2 m x 2 m size at 25 cm x 25 cm spacing, under four levels of tree crown pruning (i.e., 0%, 25%, 50% and 75%), as well as in open area. It was found that the yield of musli tuber was higher under 50% crown pruning of teak. The experiment was repeated in the second year by sowing the musli tubers under teak at 0% and 50% pruning, and in open area. In addition, addition of plant residues was tested for nematode control in musli. Neem (*Azadirachta indica)* cake was found to best control nematodes compared with fresh or dried leaves of bach (*Acorus calamus*)—an aromatic and medicinal plant. Thus, musli can be grown well under teak plantation as an additional crop by farmers, to enhance seasonal income and provide a greater return per unit of land area.

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Towards an Understanding of the Ecological Processes behind the Success of the Quesungual Slash and Mulch Agroforestry System (QSMAS) in Western Honduras

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The Quesungual Slash and Mulch Agroforestry System (QSMAS) has been the basis of a successful development strategy promoted by FAO for improved rural livelihoods in the Lempira Department. This alternative to slash and burn agriculture strongly builds on local knowledge and has been a critical option to achieve food security by resource poor farmers in the region. The widespread adoption of the QSMAS by more than 6,000 farmer households has been driven by more than 100% increase in crop yields and cattle stocking rates and reduced costs associated with agrochemicals and labor. Contrary to other agroforestry systems tested in sub-humid tropics with long dry seasons, where crops and trees coexist under intense competition for water, farmers recognize that a remarkable feature of the QSMAS is the increased soil water holding capacity and availability. Increased duration of soil water availability has been associated with a drastic reduction in crop losses. Besides making a substantial contribution to food security, QSMAS has shown a remarkable degree of resilience to extreme water deficits and also to excess water during natural catastrophes. Farmers practicing this system reported less soil, water and crop losses as a consequence of the El Niño drought event in 1997 and of Hurricane Mitch in 1998. Plant biomass, soil water and nutrient dynamics as well as key socio-economic determinants affecting adoption and farmer decision-making in QSMAS, are being studied using an integrated soil fertility management approach.

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Development of Sustainable Land-use Systems on Degraded Tropical Pastures in Belize, Central America, as a Model for Mesoamerica and the Caribbean

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The project aims to develop new sustainable land-use systems suitable to revitalize degraded pastures for sustainable use. The planned activities are based on first scientific results of an ongoing joint research project of the JANUS Foundation Belize together with the Albert-Ludwigs- University in Freiburg, Germany. The JANUS Foundation provides the infrastructure and the education center at the JANUS project site for the implementation of the project, establishes agroforestry demonstration plots, cultivates and provides plant material in the local nursery, conducts planting as required and will continuously care for the planted plots. Furthermore, a network of local farmers, rural villagers, non-governmental organizations and universities will be set up including a regularly information system about the ongoing activities. Instruction materials will be developed for education and future implementation activities. The project itself will also develop new course materials and will provide higher education possibilities for students at the University of Belize through independent research courses in the area of photosynthesis, water status and nitrogen nutrition of species. Additionally, economic evaluation of the planted agroforestry systems will be provided by the combined analysis of agricultural yield and the determination of growth parameters of the trees. The documentation of research results will be executed in the area of performance of photosynthesis, water status and nitrogen nutrition of species planted in the agroforestry plots as a base for long-term success of agroforestry areas. The web site address for the JANUS Foundation Belize is www.janusfoundation.org

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Cultivation of Medicinal Plants in an Alley Cropping System with *Moringa oleifera* in the United States Virgin Islands

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Medicinal and aromatic plants (MAPs) are horticultural crops with socio-economic significance in the United States Virgin Islands (USVI). MAP cultivation complements conventional fruit and vegetable production, enhancing small-farm productivity in the USVI. Field experiments were initiated to evaluate the agronomic and economic potential of alley cropping involving popular species of MAPs commonly used in the USVI. Medicinal plants included 'inflammation bush' (*Verbesina alata* L.) and 'worrywine' (*Stachytarpheta jamaicensis*) and the aromatic and culinary herbs evaluated were basil (*Ocimum basilicum*), lemongrass (*Cymbopogon citratus*), cilantro (*Coriandrum sativum*) and chives (*Allium schoenoprasum* L.). MAPs were planted in a randomized block design in 5 m wide alleys formed between *Moringa oleifera* Lam. hedgerows, in 6 rows spaced 71.4 cm, with in-row spacing varying between 20.3 and 60.9 cm, depending on species. For each crop, treatments consisted of hedgerow (alley cropping) and no hedgerow (monoculture). First-season results from the on-station experiment indicated that yields of basil, chives, cilantro, lemongrass and worrywine were significantly ($P<0.05$) reduced in alley cropping plots, whereas differences in yield between alley cropped and monoculture plots for inflammation bush were not significant ($P>0.05$). Concurrent on-farm trials were run for comparison. Net present value and the benefit/cost ratios for on-station yields were determined with a sensitivity analysis examining the effect of fluctuation in market prices for fresh herbs. Economic returns from *Moringa* yields at current USVI market prices do not offset yield reductions from intercropping. The potential economic viability of this system is subject to future markets for dried herbs and *Moringa* products.

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Diversity of Multi-strata Coffee Plantations in Costa Rica: Economic and Ecological Implications

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Steady declines in international coffee prices over the past 20 years have increased rural poverty in Latin America due in part to the abandonment of coffee plantations. Diversification of their production systems has become a key ingredient to the sustainability of those families that have chosen to continue growing coffee (*Coffea* spp.). Agroforestry systems based on multi-strata coffee plantations and intensified homegardens have been proposed as a means for continuing coffee production while increasing yields of crops for both household consumption and sale. Producers belonging to two organic coffee producing associations in Costa Rica were analyzed to estimate the impact of agricultural diversification on farmer income and agrobiodiversity. Agrobiodiversity parameters, including species richness and abundance of shade trees in coffee plantations and homegardens, were measured in the communities of Turrialba and El Dos. Household consumption, family labor investments, and sale of diversified products were also taken into account to determine farm sustainability. The results show that the shade component plays an important role in household consumption and cash sales while providing tree cover beneficial to wildlife. Although producers in these communities have diversified their production systems, more studies are needed to determine optimal cropping systems based on biophysical (interactions between species), cultural, and socioeconomic factors.

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Tropical Homegardens in Riverine Communities of Amazonian Estuary, Marajó Island, Brazil

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Amazonian tropical homegardens play an important social role beyond the economic and ecological aspects by promoting the family integration while sharing farming, managing and harvesting activities. The homegardens function as a place where the farmers exercise their knowledge and beliefs on dealing with the environment, with notable participation of women in the managing of the activities. As all the majority of tropical production systems in riverine areas, homegardens also possess many technical difficulties and for this are seldom considered as economically viable systems. However, it is important to know the species that compose these systems, as well as the socio-economic and ecological characteristics that result of these interactions. In this paper the description of tropical homegardens in riverine communities in the Amazonian Estuary is presented. Research was conducted in Santana do Afuá Community at Santana do Afuá River (0°09'32"S and 50°23'31"W; mean temperature of 26ºC and annual precipitation of 2,500 mm). Main economic activity is the wood and palm-heart extraction. Data on the species component uses and zones (measured in m^2) were collected through semi-structured interviews, surveys and direct observation. Descriptive statistical analysis was used. The following management zones were identified as: 1) Palm-heart trees; 2) Fruit trees; 3) Wood trees; 4) Ornamental and medicinal plants; and 5) Other (wood sawing or palm-heart storage spaces). Among the 58 identified species, the most important was *Euterpe oleracea*, an important multipurpose species with a very high meal value for farmers, beyond its economic importance due to palm-heart commercialization at local industries.

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Medicinal Plant-based Agroforestry Models: Strategy for Income Generation and Biodiversity Conservation

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The global interest in tropical medicinal plants has increased recently, especially in the Western countries. At present the international market for medicinal plants is worth 60 billion US$ $year^{-1}$, which is growing at a rate of 7% per annum. Consequently, the existence of these species, which augment the health care systems of more than 70% of the world's population, is threatened. This has already led to extinction of a number of key species, with many more under continuous threat. Furthermore, information on availability in natural forests, current threat status, cultivation aspects, marketing and value addition prospects, etc., of these medicinal plants, is very sketchy. Thus, many international organizations (e.g., FAO, World Bank, World Wildlife Fund) and national bodies (e.g., National Medicinal Plant Board of India, Ministry of Environment and Forests) have suggested that cultivation of commercially important medicinal plants offers great potential for income generation and *ex situ* conservation of globally important tropical biodiversity. However, in India, like many other developing countries, it is difficult to divert fertile agricultural land exclusively for medicinal plant cultivation due to land hunger for food production. Introduction of medicinal plant species as understory crops for commercial production in agroforestry plantations, therefore, appears to be a viable option to overcome this problem. The paper deals with the biological compatibility, physical possibilities and economic viability of such models, which have been developed at the Forest Research Institute by planting of medicinal plants under plantations of poplars, eucalyptus and fruit orchards in the Indo-Gangetic plains of India.

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Eco-agriculture and Application of Agroforestry for Urban Waste Management in India

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The Maharashtra state in western India has 325 towns and 33 cities. There are 232 municipal councils including A, B, and C classes, and 12 municipal corporations. These towns are now facing an acute solid waste (from agricultural markets) problem causing environmental pollution. The farmers from the periurban areas are bringing their agricultural products including vegetables into city markets. This in turn creates a large amount of solid waste from vegetables as well as animal excreta, especially organic waste, which contains a higher moisture content. In this light, the source reduction, source separation and producer responsibility are three critical factors in developing and designing ecological agroforestry models for economic and optimum utilization of land using composting systems in towns of Maharashtra. The authorities are dedicating a large budget for waste management. This paper deals with the present scenario in compost using organic waste from agroforestry and agricultural markets, etc. and its application in agriculture and agroforestry, as well as past efforts to ensure the economic development of compost process from agriculture/agroforestry waste, kitchen waste, market waste and organic waste. It also discusses some recent successful examples of public - private and peoples partnerships in agroforestry for biotreatment and marketing of these waste products. The paper emphasizes the need for extensive capacity-building for ecological agriculture for sustainable agroforestry.

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Guava (*Psidium guajava* L.) - A Suitable Fruit Tree for Agroforestry

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Guava (*Psidium guajava* L.) is a multipurpose fruit tree belonging to Myrtaceae family. Between the two basic categories of agroforestry, guava can be grown in various systems in the simultaneous category. Furthermore, it could be grown very well in a parklands system where the land is covered with combinations of trees and crops. In order to adapt this very important nutraceutical woody fruit crop from the tropical to the temperate climate, we need to develop cold tolerant transgenic plants of this species. As a prerequisite for the genetic transformation, *in vitro* plant regeneration protocols for guava were developed through somatic embryogenesis and organogenesis using young zygotic embryos and nodal explants, respectively. Single nodal explants of guava induced multiple shoots when cultured on MS (Murashige and Skoog) medium fortified with KIN, BAP and APS (aminopurine hemisulfate). Adding calcium nitrate to the medium was useful against shoot tip browning. Up to 65 shoots were obtained from a single guava nodal explant in a rocker liquid culture which seems to be a promising technique for woody plant multiplication. Resulting shoots were rooted on woody plant medium supplemented with NAA and activated charcoal. After acclimatizing, some of the plantlets were transferred to the soil in the specialty plant house, where they were established and have been growing well with 100% survival. Somatic embryogenesis has been achieved in guava from immature zygotic embryos using BJY (modified MS) medium containing IAA. Following these observations, further experiments towards genetic transformation of guava are underway.

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Forage Production and Nutritive Value within a Temperate Silvopasture System

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Incorporating trees into cool-season pastures may benefit forage production by optimizing available light, water, and heat resources. In 1995, black walnut (*Juglans nigra* L.) (BW) and honey locust (*Gleditsia triacanthos*) (HL) trees were planted within plots (r=3) of predominantly tall fescue (*Festuca arundinacea*) pasture. In each plot, four rows of each tree species were planted down a 12% slope with spacings of 1.8, 3.7, and 14.6 m within rows and 3.7, 7.3, and 14.6 m between rows. Spacings created low, medium, and high shade at shoulder, mid, and toe slope positions. In 2002 and 2003, forage sampling sites (n=54) under tree species, shading, and slope combinations were harvested May-November at 35-d intervals. Photosynthetically active radiation (PAR), soil moisture, soil surface and canopy temperatures were measured periodically to determine microclimate modification. Soil surface and forage canopy temperatures were moderated by medium shade while reduced PAR did not limit cool season forage production. Over the two growing seasons, forage yields were an average of 17% greater ($P<0.01$) under medium shade compared to low and high shade. Yields under BW were 22% greater ($P=0.073$) than under HL in 2002, but species had no effect on yield in 2003. NDF and ADF were lower ($P=0.04$) at the toe compared to shoulder and mid slope positions. As shading intensity increased, NDF decreased ($P<0.001$). Species had no effect on NDF, but ADF was lower ($P=0.065$) under BW compared to HL. Moderate shading in silvopasture optimizes microclimate resources for cool season forage production in temperate Appalachia.

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Effects of Silvoarable Management Practices in the UK on Ground-active Invertebrates

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In 1992 a silvoarable experiment with poplar (*Populus* sp.) was established at three sites in the UK. From January 2000 to December 2002, the effect of four silvoarable habitats (vegetated and bare understoreys; and cropped alleys next to either vegetated or bare understoreys) and a sole arable crop control on the number and diversity of ground-active invertebrates was assessed by monthly pitfall trapping. The principal taxa caught were carabid beetles, spiders and slugs, with maximum numbers in July and August. The numbers of slugs were generally least in bare understoreys and greatest in vegetated understoreys, but there appeared to be no positive correlation of numbers in the understoreys with their associated alley habitats. Greater numbers of spiders were captured in the vegetated understorey than in other treatments, and hence use of a vegetated understorey could encourage beneficial predatory spiders. The vegetated understorey was expected to provide a good habitat for overwintering carabid beetles prior to colonisation of adjacent arable crop in the spring. This is supported by the observation at one site that the number of carabid beetles in vegetated understorey peaked a month before that in the arable treatments. However, the overall effect was that greater numbers of carabid beetles were generally captured in control area than in the alleys and the two types of understorey. One explanation for this is that the agroforestry system provides a more stable habitat with a greater diversity of plants and animals, which limits certain carabid species from occuring in very high densities.

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Economic Valuation of Biodiversity Conservation in the Makiling Forest Reserve (MFR), Philippines

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Biodiversity comprises the following elements: genetic diversity, species diversity, and ecosystem diversity. Although there is no clear consensus on how to measure biodiversity value, a substantial body of literature focuses on the application of valuation techniques to a range of biological resources. This paper used the contingent valuation method (CVM). CVM determines and assesses the values that the people place on, are willing to pay (WTP) for, the conservation of biodiversity in MFR. A sample of respondents were asked to state their WTP for biodiversity conservation in MFR using continuous and discrete choice question formats. The WTP responses proved reflective of income levels as well as their preferences regarding the degree and extent of the use of the area. Visitor respondents had the highest income levels among those surveyed and expressed the highest WTP (P529). Although resident farmers had lower income levels, they specified the next highest WTP (P255), which could be explained by the fact that resident farmers derive their livelihood from MFR. The total capitalized value derived from MFR biodiversity using CVM is P28.9 billion. This result indicates a high level of awareness of the importance of forests. The outcome also underlines the importance of biodiversity conservation and related policies in developing countries like the Philippines.

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Biodiversity Assessment of Selected Agroforestry Farms in the Mt. Makiling Forest Reserve, Philippines

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An assessment of the floral diversity of selected agroforestry farms in one of the leased areas of the Mt. Makiling Forest Reserve, some 65 km south of Manila, the Philippines' capital, was conducted to quantify the levels of floral diversity that exist in the agroforestry zone of the Reserve using quadrat sampling technique. The taxa recorded during the assessment, the quantitative structural analysis, the comparative levels of diversity indices in all the sampling plots established as well as the list of recorded taxa that are in the IUCN's 2000 List of Threatened Species, will be presented and discussed.

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Live Fences and Connectivity in Fragmented Neotropical Landscapes

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Deforestation and fragmentation of forests has resulted in the loss of biodiversity worldwide. Currently there is great interest in understanding what biodiversity remains within agricultural and pastoral landscapes at both local and landscape scales. Many of these agricultural landscapes contain large networks of live fences, which may help enhance landscape connectivity and thereby help maintain biodiversity. In order to understand the role of live fences in enhancing landscape connectivity, we characterized 377 live fences in 500 ha (5 blocks of 1 X 1 km), in the pastoral landscape in the Atlantic region of Costa Rica, in the Tropical Wet Forest life zone. Of the 377 live fences measured, 45.5% were live fences; the rest were fences consisting of only wooden fence posts. The main tree species were *Erythrina costaricensis* and *Gliricidia sepium*. The mean length of the live fences was 87±5.25/100 m. The mean diameter at breast height was 8.93 cm ± 0.32 cm, whereas the mean canopy radius was 1.78±0.09m wide. The main habitats adjacent to live fences were pastures (71% of the cases); however 18% of the live fences were directly connected to riparian forests. Using GIS and statistical analyses, we compared the indices of structural connectivity in scenarios with or without live fences present. Our results suggest that the structure and spatial arrangement of live fences in the landscape can significantly affect the degree of physical connectivity in these landscapes and could have important consequences for animal movement in fragmented landscapes.

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Improving Growth and Nutritional Status of High Value Broadleaf Species with Intercropping in South-West of France

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Fertilizing forest trees established on previously arable lands is not usual because nutrient availability is then considered as meeting the requirements of forest trees. Nevertheless, agroforestry practices including fertilization of intercrops can be beneficial to trees. Moreover, tree-crop association is a practice of environmental interest due to the more efficient use of nitrogen. Results from a field experiment carried out near Toulouse (France) corroborate the positive effects of intercrops on wild cherry trees and hybrid walnut trees. At the end of the fifth year after tree establishment, growth increases by 20 to 50% in height and by 43 to 122% in diameter were recorded. Nitrogen and sulfur foliar concentrations of trees were improved with intercropping. Estimates of N, P and K accumulation in the tree leaf fraction calculated from leaf biomass and nutrient concentration measurements showed significant increases in the case of intercropping. Increased nutrient uptake might account for tree growth improvement in agroforestry. Interactions between trees and associated intercrops are discussed.

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Effectiveness of Using Two Natural Herbs, *Lippia javanica* and *Tagetes minuta* in Controlling Aphids on *Brassica capitata*

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Effectiveness of *Lippia javanica* and *Tagetes minuta* as natural pesticides was assessed in terms of how much they reduce aphid populations on *Brassica capitata*. Their effectiveness was compared against two synthetic pesticides, Aphid kill and Bexadust "L". The powdered forms of both herbs, the 1:1 and 1:2 dilutions of *T. minuta* and the 1:2 dilution of *L. javanica* did not reduce aphid populations. The 1:1 dilution of *L. javanica* reduced aphid populations by 24.65%, the standard solution of *T. minuta* by 8.75% and the standard solution of *L. javanica* by 53.16%. Aphid kill and Bexadust "L" reduced the aphid numbers by 78.32% and 96.68% respectively. It was concluded that *L. javanica* standard solution was fairly effective in controlling aphids on cabbages.

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Transpiration of Tree Species in Different Vertical Layers of a Multi-Layered Home Garden in Central Sri Lanka

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Multi-layered home gardens (MHG) are a common agroforestry system in Sri Lanka. Our objectives were to quantify the water use of three representative tree species in a MHG and to find relationships between transpiration rates and environmental parameters. This study was conducted in a MHG in the high-rainfall (2,000 mm yr^{-1}) zone in Central Sri Lanka during March - July 2001. Three tree species were selected for continuous measurement of transpiration. These were *Artocarpus heterophyllus*, *Cedrela toona* and sapling *Swietenia macrophylla* which represented upper, middle and lower canopy layers respectively. Transpiration was measured as trunk sap flow rate using thermal dissipation probes in *Artocarpus* (DBH = 40.5 cm) and *Cedrella* (DBH = 9 cm) and dynaguages in *Swietenia* (DBH = 3 cm). Incident solar radiation and relative humidity were measured by tube solarimeters and solid-state humidity sensors. All measurements were done continuously at 30-sec time intervals, averaged every 5 minutes and stored in a datalogger. Measurements taken during a 72-hour period, during which soil moisture was at field capacity, were analyzed. Sap flow of *Artocarpus* was significantly greater than those of *Cedrella* and *Swietenia*, which ranged from 19% to 27% of that of *Artocarpus*. There was a linear relationship between daily transpiration and incident solar radiation for all tree species. This relationship can be used to predict the daily water use of a species when there is no significant soil water deficit. Transpiration rates of all tree species had negative linear relationships with the respective RH values experienced by them.

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Biodiversity of *Trichoderma stromaticum* and Biological Control of the Witches' Broom Pathogen in Cacao Agroforestry Systems in Bahia, Brazil

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Witches' broom, caused by *Crinipellis perniciosa*, is one of the most destructive plant diseases in Central and South America. In the State of Bahia, the main Brazilian cocoa (*Theobroma cacao*) growing area, production has decreased by 70% after the establishment of the pathogen. A commercial formulation of the mycoparasite *T. stromaticum* is being used in the field to reduce spore production by the pathogen. However, the inconsistent performance of the biocontrol agent hampers its use on a larger scale. In our studies, we used AFLP analysis to better understand the genetic diversity of *T. stromaticum* and exploit its diversity in order to select more effective biocontrol strains. Our results show that two distinct genetic groups of *T. stromaticum* occur in Bahia State. Molecular analysis of six different genes indicated that the two groups are not exchanging genetic material. Laboratory experiments, including growth on different media and temperatures, sporulation on rice, and siderophore production, showed clear differences among the genetic groups. Preliminary data from field experiments indicate that both genetic groups perform similarly on biocontrol of the witches' broom pathogen. However, other characteristics such as production of spores, natural spread, and sexual reproduction, which are not simultaneously present in both genetic groups, will greatly influence the choice of the biocontrol strain to be used in the field.

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Small Farm Agroforestry Systems as Potential Repositories for Endangered Biodiversity Resources in Nepal

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Review of available literature on agroforestry systems and surveys conducted in many small farms in Nepal show that the small farmers practice in an integrated farming system from which they obtain a large number of products essential to the well-being of their family and community. Small farmers have identified preserved, protected and multiplied many endangered plant species for their benefit. The surveys conducted amongst numerous small farms in Nepal show that they have successfully integrated, and are growing and using in a sustained manner, more than fifty species of rare plants in their farming systems and are using them successfully to improve crop production, for their domestic needs and to improve income in the farms. This paper presents the socio-economic conditions of these small farms, describes their farming systems and the techniques used for the cultivation of rare plant species, their processing, and utilization methods for the benefit of the farm household. The research survey for this study was conducted in the mid-hill regions of mid-west and eastern regions of Nepal, which were once famous for their biodiversity resources in the past. Many of the resources are found in small farms managed by farmers at present. A list of these species and their management packages adopted by the small farmers, will be presented.

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Land Imprinting Specifications for Conservation Seeding and Planting in Agroforestry

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The no-till method for seeding called *land imprinting* has been under development in Tucson, Arizona since 1976. Ranchers have applied imprinting to restoring perennial grasses on their degraded rangeland for erosion control and forage production. Since 1980 some 20,000 hectares have been interseeded with grasses in southern Arizona. Early imprinters were massive machines with large diameter rollers that were designed to operate on rocky, brushy terrain of the southwestern deserts. Imprinters are now being designed for ecological restoration and the establishment of cover crops. They have smaller diameter rollers and are easier to transport. Some can work on 2:1 slopes and even steeper. Simple seeders, directly driven from the imprinting roller, can deliver complex mixes of native seeds to the roller top where they are carried forward, dropped on the soil surface and then imbedded in the imprint surfaces. V-shaped imprints funnel resources downward where they can work in concert to germinate seeds and establish seedlings. Based on more than two decades of field experience, land imprinting specifications have been developed for ecological restoration and sustainable agroforestry. These include general imprinter and seeder design specifications that will help to ensure success of revegetation projects. Also, experienced fabricators can use these specifications as a guide for constructing state-of-the-art seeding imprinters.

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Improving the Growth of Soybean in Semiarid Regions by Microbial Inoculation

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The ecosystems of developing countries like Uzbekistan suffer from many problems such as soil salinization, erosion, and extreme climate conditions. The inappropriate application of mineral fertilizers in cotton production, for example, has resulted in pollution and salinization of agricultural lands and water resources. In such regions, leguminous plants—with their nitrogen fixing symbiotic bacteria—play an important role in soil productivity and health. *Bradyrhizobium* species thus have a great deal of practical and theoretical importance in agriculture. The objectives of this study were to quantify the effects of microbial *Bradyrhizobium japonicum* bacterial inoculation on plant growth of soybean (*Glycine max* (L.) Merrill)) in nutrient-deficient soil. Field experiments were carried out in southeast Uzbekistan with calcareous Calcisol soil in a randomized complete block design with four replications. Before sowing, peat-based inoculum was applied to seeds as a surface coating at a rate of 30 g/kg^{-1} of seed. Plants were harvested after three months for estimation of plant biomass and grain yield. Seed protein content was also estimated. A significant positive effect on growth and yield of soybean was obtained after inoculation with bacterial strain. Bacterial inoculation increased the length of plants, dry matter and nodulation of soybean. The yield of soybean increased 48% as compared with uninoculated plants. They are salt tolerant and temperature resistant, making them able to survive in dry, hot environmental conditions. In conclusion, our study observed that *B. japonicum* can play an important role in helping the plant establish and grow in saline, nitrogen-deficient calcareous soils.

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The Socio-economic Impact of *Acacia* Plantings on Local Communities Living near the National Parks in the Democratic Republic of Congo

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The utilization of natural resources around the National Parks in the Democratic Republic of Congo is having an important ecological impact on wildlife and on the income of local communities. The Bombo-Lumene area is a site experiencing significant population increase, poverty, low fertility of cultivated soils, and little or no management, all of which contribute to the degradation of the area. The local communities living around the area use the forests to make their agricultural fields as well as to produce charcoal. The preservation of biodiversity in the National Parks of the Democratic Republic of Congo, requires the integrated participation of local communities to avoid the destruction of these sites. The planting of *Acacias* around these areas thus affords several benefits: (i) protection of Park vegetation (forests); (ii) an increase in the income of local communities through the manufacture and sell of charcoal; (iii) protection of more animal species in *Acacia* forests; and (iv) a decrease in human pressure on the destruction of wildlife. The *Acacia* forests have thus become an important factor of development and a source of income for these local communities. Further utilization and exportation of these forests will help to reduce poverty and promote the development of local communities in the Democratic Republic of Congo.

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Agro-environmental Planning in the Almada River Watershed (Bahia, Brazil) Using a GIS-based Natural Resources Inventory

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The cocoa plantation region in Bahia, Brazil, faced with low prices for cocoa beans and the disease "witch's broom," is also at environmental risk due to the disappearance of the Atlantic Forest ecosystem in which cocoa is grown. Within this region, the Almada River watershed has great socio-economic and environmental importance, and includes an area of 1,670 km^2 with a large cocoa plantation, specially cultivated under the *cabruca* system—cacao (*Theobroma cacao* L.) trees growing under remaining species of Atlantic Forest. The purpose of this research is to establish action guidelines for the development of the watershed on the basis of analysis of natural resources, in order to contribute to the reorganization of the activities on the natural spaces, without promoting environmental degradation. Arc-view and Idrisi were the GIS instruments employed. By evaluation of the use capacity, six units of land use were delineated: II (18.83%), III (33.99%), IV (31.29%), V (6.15%), VII (8.48%) and VIII (1.26%). This information was subsidized with agro-environmental zoning: agriculture (22.92%), agroforestry systems (41.97%), livestock (15.52%), and preservation (19.59%). The major indicators were the soils, followed by relief, climate and vegetation, and environmental legislation. Agroforestry systems were deemed to hold great potential for coexisting with natural flora, supplying useful products to farmers, and accomplishing numerous agro-ecological activities.

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Effect of Forage Species and Tree Type on Tree Establishment and Nutritive Value of Hay Crops in an Alley-Cropped System in the Midwestern USA

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The integration of hay crops in an alley-cropped system was examined as a method of encouraging tree planting and enhancing biodiversity on Midwestern U.S. farms. Crop and tree performance were evaluated in an alley-cropped system using four hay intercrops – oat (*Avena sativa* L.) and red clover (*Trifolium pratense* L.); oat, red clover, and red fescue (*Festuca rubra* L.); oat, red clover, and orchardgrass (*Dactylis glomerata* L.); and oat and hairy vetch (*Vicia villosa* Roth) – compared to a herbicide, mowing and control (no management) treatment. Five tree species, divided into fast-growing hardwoods of two poplar (*Populus* spp.) clones [Crandon (*P. alba* L. x *P. grandidentata* Michx.) and Eugenei (*P. deltoides* Bartr. x *P. nigra* L.)], and silver maple (*Acer saccharinum* L.) were compared with two high-value, slow-growing hardwoods planted from seed and as seedlings: red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.). Tree survival and height across all tree species and sites was not affected by ground management treatments after two growing seasons, but tree diameter was greater in the herbicide treatment. Black walnut from seeds out-performed trees planted as seedlings, while poor performance of both hairy vetch as a forage intercrop and red oak trees from seeds highlighted the superior value of other forage/tree combinations. The nutritive value of the hay crop was excellent in the second year of tree establishment, with crude protein content and digestibility at 17% and 71%, respectively, in the red clover/red fescue treatments.

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Integrated Farming in Homegardens - Kerala State, India

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Agroforestry homegardens are the unique feature of Kerala, the southernmost state of India. They are primary models of integrated farming system. Homesteads of Kuttanad, a major agricultural sector of the state, hold tremendous potential for practicing integrated farming systems. Here water area equals land area. Integrated farming with crop and fish components is the best way to increase income at household level utilizing available resources. Integration of different components helps the social and economic uplift of small and marginal farmers having low input resources but surplus family labour. Studies on homestead models suggest that a homestead having 0.4 ha will be ideal and can be managed with available family labour of 3,200 hours from a four-member family. Coconut forms the pivotal crop in the interspaces of which other crops are grown. Agrisilviculture is practiced here. About 500 m^2 is utilized for aquaculture with different freshwater species with a stocking density of 1/m^2. From a household of 0.4 ha, farmer generated 2.1 tons of fruit vegetables, 100 kg of leafy vegetables, 310 kg banana, 200 kg cassava and 340 kg fish. The cost benefit ratio was 1:1.5 for aquaculture and 1:5 for crop components. Integrated farming with crop and livestock increased family income by more than 70% and reduced the cost of production by 50% compared to monoculture. The structural and functional diversity of the components in the model ensure a high level of resource use efficiency meeting the multiple demands of the house.

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Modeling Agroforestry Homegardens in Kerala, India

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Homestead farming has been resorted to by Kerala farmers as one of the survival strategies from time immemorial. Agroforestry homegardens of the state present a form of intensive cultivation, on the limited area of land, without any scientific basis. Ninety percent of the homesteads are below 0.5 ha and the size varies from 0.04 to 3.6 ha. In central Kerala, 180 homesteads were surveyed and models formulated by adopting suitable intervention strategies as adaptive scientific research. Rubber is the major crop in 57% of homesteads occupying 33-50% of the total area, and the remaining area is occupied by annual and perennial crops covering a vertical cross section of 3-5 stories. The major agroforestry class in homesteads is agrisilviculture. Mixed farming is practiced in 64.5% homesteads with major tree crops such as Jack, Teak, Wild Jack, Mahogany and Mango. Banana and major spice crops like Pepper, Ginger, Turmeric and Nutmeg and annual crops like vegetables and tubers are of usual occurrence. Interventions were carried out in selected homesteads for better crop husbandry, integrated pest management, nutrient recycling, cropping systems and better varieties. All these increased cropping intensity by 300%, employment potential by 1700 man-hours, cost benefit ratio to 1:10 from 1:2.5 and women's involvement by 100%. The farmer had a net income increase of 200-225% and 100% cost reduction in cultivation. The expenditure on fertilizer and plant protection chemicals was reduced by 50% by vermicomposting and integrated pest management strategies. The model presents a self-sufficient one integrating different systems.

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Insect-Resistant Transgenic Poplar as a Better Candidate Tree for Eco-agriculture

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Extensive use of wheat-paddy rotation has adversely affected our natural resources. Water table has gone down and soils become degraded. Under these circumstances, poplar-based agroforestry has played an important role in diversification, natural resources rejuvenation and economic upliftment of farmers. Large-scale plantation of limited genotypes of poplar leaves them vulnerable to insect damage. Application of insecticides to forest trees is beset with many difficulties. Thus, genetic transformation of poplar with insect resistance gene could play an important role in keeping insect damage under control. This would drastically reduce the chemical load and also fulfill the fundamentals of eco-friendly agriculture such as sustainable natural resource management to enhance productivity and biodiversity. Amines and their derivatives are known to influence insect behavior. In order to examine the feasibility of improving the resistance of poplar to insect pests by the introduction of a plant-derived amine-generating transgene, explants from hybrid poplar (*Populus tremula x P. alba)* were transformed with a *Camptotheca acuminata* tryptophan decarboxylase (TDC) cDNA. The enzyme TDC catalyzes the decarboxylation of tryptophan to tryptamine, a bioactive amine. Putative transgenic lines were confirmed by PCR and by the expression analysis of the transgene mRNA and encoded protein. No visible phenotypic changes were associated with ectopic *TDC1* expression. Chemical and radiotracer analyses of transgenic plants revealed that the ectopically expressed *TDC* was not further metabolized. Insect bioassays with *TDC* transgenic plants showed adverse effects on feeding behavior and physiology of *Malacosoma disstria* Hub., and resulted in 43% decrease in RGR of larvae over control.

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Adaptive Management of Medicinal Plants through Improved Monitoring of Harvest Levels

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In many forest-based communities, the boundary between 'forest' and 'agroforest' is a flexible one, depending on resource access, level of management, and cultivation. With increasing commercialisation of medicinal and aromatic plants (MAPs) harvested from managed forests, questions are being raised about the sustainability of such practices. The impact of harvesting must be assessed accurately in order to make decisions about cultivation, enrichment or protection of MAPs. Whilst biometrically reliable data are essential for management, field-based researchers emphasize the need for methods which are simple, rapid, focused on species with high potential for livelihood improvement, scientifically valid but usable by non-scientific forest managers. This paper addresses these demands on participatory MAP assessment, through a participatory research project in Nepal and India. Based on both local and scientific knowledge, community members and facilitators propose hypotheses about the effect on yield of biological, social and management factors, including harvest level and method. With the support of foresters and researchers, community members compare indicators, test correlations between indicators and make recommendations about changes in management to ensure sustainable yield. Importantly the results must be assessed in a participatory way, to support the incorporation of decisions into an adaptive management framework. The methodology is discussed based on experiences from the Western Ghats of India, and middle hills of Nepal. Analysis of results enables testing of hypotheses about management and yield, usability of indicators of sustainable yield, comparison of scientific monitoring with local monitoring, and the effect of such monitoring on local perceptions and action.

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Importance and Sustainability Problems of Tzotzil Sheep Production System of Chiapas, Mexico

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In the temperate mountains of the Highlands of Chiapas region, southern Mexico, the Tzotzil indigenous people practice a slope agriculture and animal production. Agricultural practices are characterized by integrated use of natural resources, by means of different production systems management, with complex spatial arrangements, connected by energy fluxes and material circulation. The sheep production system (SPS) practiced by the Tzotziles, is based on extensive grazing under an agrosilvopastoral management, where the producers use all the available fodder resources. As the grazing areas are frequently located far from the place where the animals rest during the night, it is common for the animals to browse in forest areas. On the other hand, to assure the feeding of the animals, the producers use shrub and tree foliages to supplement the sheep's diet, principally during drought. The objective of this study is to analyze the importance of SPS in the Tzotzil productive strategy, and identify the critical points of the system's sustainability. Information about both issues was obtained directly from sheep producers, by means of participative research (observations and/or workshops) and field journeys. Tzotzil sheep rearing fulfills three important functions: 1) ecological, 2) economic and 3) socio-cultural. Although there are elements of sustainability in the productive organization of the producers, the productive efficiency of sheep rearing has decreased due to social and environmental processes, which are not under control of the peasant communities. Sustainability critic points of the system point towards a low productivity and to a deterioration of the system's natural resources.

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The Farmers and Their Homestead in Kerala (India), Considering the Diversity for Sustainable Land Use

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In the small State of Kerala, south of the Western Ghats, extreme population density (819 hab/km²) limits resource availability. Any farm in Kerala is made up of at least a homestead garden, to which can be added one or more dry or wet land plots. All families, even owning only a small plot of land, practice agroforestry in their homestead. The diversity of the farmers, according to their activity (full-time or part-time farmers), their other sources of income if any, their household's composition, their access to the transport network..., is expressed by various strategies. Those strategies are refllected in the space organization and specific biodiversity of the farm. The important biodiversity of the homesteads gives them a high environmental value. Moreover the agroforestry systems in Kerala play a major economic role for the rural households, mainly for the poorest. But in spite of all their advantages, agroforestry practices in the homestead gardens are not considered as true farming systems by the Indian government. Even nowadays, Kerala State agricultural priorities are oriented towards monoculture and commercial crops. In order to implement more appropriate policies, it would be essential to consider the diversity of the farmers and the rationale behind their agricultural practices. The aim of this communication is to highlight, from a geographer's point of view, the diversity of the farmer's strategies regarding agroforestry in order to understand better how the farmers utilize and modify the environment, in terms of sustainable land use and development prospects.

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Agroforestry and Scope of Organic Farming for Sustainable Livelihoods in India

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Green revolution in India has helped to attain self-sufficiency in food production following intensive cultivation practices with the use of fertilizers, pesticides and other inputs. The intensive use of inputs has polluted the soil, water and resulted in environmental degradation and caused an alarm over sustainability of agroecosystems. In addition, food produced contains toxic levels of chemicals harmful to humans and livestock. It has been realized that the green revolution with high input use has reached a climax and is now sustained with diminishing returns and falling dividends. The paper analyzes trends in consumption patterns of different groups of pesticides and chemical fertilizers, and problems posed by their use. The effects of nitrate pollution, eutrophication, soil acidification and alkalization, pesticide poisoning in water and milk are highlighted. Organic farming by adopting agroforestry practices is a viable alternative because it enlivens the soil, strengthens the natural resource base and sustains biological production at levels commensurate with the carrying capacity of managed agroecosystems. Scope of organic farming, trade and regulatory mechanisms for production of organic products in India, are discussed. The management of agroforestry practices for organic farming as an alternative for chemical fertilizers and pesticides has been explored as a case study for the state of Himachal Pradesh, as well as the role it can play in economic gains for its people, as there is a growing demand for organic foods in the international market. *Thus, organic farming sustained by appropriate agroforestry practices may lead from green revolution to evergreen revolution.*

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Stability of Valepotriates under Different Storage Conditions in Rootstock of Indian Valerian (*Valeriana jatamansi* Jones)

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Indian Valerian (*Valeriana jatamansi* Jones) is an important medicinal plant species of India found in Western Himalayas from 1,200-4,000 m above mean sea level. The active constituent i.e. valepotriates is present in its rootstock which is used as sedative and tranquilizer in modern system of medicines. Due to presence of ester groups valepotriates are highly unstable. Any commercial activity requires minimum loss of active constituents during storage. So to enhance the productivity of any species it is necessary to minimize its losses during its storage. Keeping this in mind present investigation was carried out to minimize valepotriates losses during storage. This was done through study of the different storage conditions used for rootstock - storage in dark, polythene bags, etc. The details of the experiment will be discussed during presentation.

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Commercial Cultivation of Medicinal and Aromatic Plants through Agroforestry

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The State of Himachal Pradesh, which spreads over an area of 55,673 km^2 and ranges in altitude from 250 to 7,000 m above sea level, is considered a suitable emporium of medicinal and aromatic plants in the western Himalayan region. These medicinal and aromatic plants contribute a major part in national economy and also provide employment to rural poor in interior and tribal areas. As a result of over-exploitation by rural people and to meet the ever increasing demand of herbal industry, many of these medicinal plant species are on the brink of extinction. To save this natural wealth and also to ensure their purity, authenticity, and sustainable supply of raw materials, it thus becomes most urgent to domesticate them for commercial utilization. But in this region cultivation of medicinal plants for sustainable utilization has yet to catch on. As people here depend mainly on agriculture for their livelihood, we view agroforestry more beneficial both for them and conservation of natural resources, being an interaction of agriculture, forestry and environment. Moreover, medicinal plants have great potential for commercial cultivation in this region that will thus have supplementary and complimentary effects on existing cropping systems. Better production technology, post harvest care, proper packing and different marketing strategies of these medicinal plants will increase economy of the farming community in the region. In the paper more emphasis is laid on selection of species for cultivation, utilization potential and post-harvest management and commercial cultivation of medicinal and aromatic plants through agroforestry.

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Temporal and Spatial Patterns in Ant Populations in Rubber-Morinda Ecosystem and Their Value as Ecological Indicators

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Ant populations in agroforestry project of rubber (*Hevea braziliensis*) – morinda (*Morinda citrifolia*) in Malaysia were monitored with pitfall traps. The data were analyzed to determine the ants' temporal and spatial patterns in this newly developed ecosystem. Analysis was based on ant population trends and the spatial pattern was determined with SADIE system. This study was aimed to assess the changes in ant population due to several practices carried out within the ecosystem. This information was used to put forward the value of ants as ecological indicator within the ecosystem and progress towards achieving sustainable agriculture. The results indicated the abundance and distribution of ant population were only affected by seasonal weather pattern. Generally, ant population was abundant in dry months (March–September). However, its population declined during wet months (October–February). Weeding seemed not to affect ant population. Spatially, ant population tended to be aggregated to certain areas - in low ground in the drier months and at higher elevation during the wet months. This result supported other findings that the ant is a good ecological indicator as it is very responsive to changes in the surrounding environment. It appeared that introduction of morinda into rubber ecosystem had no immediate negative effect on ant population and thus may imply that the ecological integrity in rubber-morinda ecosystem was not disturbed.

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Conservation Coffee: Lessons to Date in CI's Efforts to Integrate Existing Coffee Landscapes into a Regional Biodiversity Conservation Strategy in Southern Mexico

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Since 1998, Conservation International (CI) has been implementing a pilot *Conservation Coffee* [tm] project in the buffer zone of the El Triunfo Biosphere Reserve in the Sierra Madre Occidental of Chiapas, Mexico. This presentation will share key lessons we have learned to date in collaboration with a network of local (ECOSUR, CONANP, AMSA, Fondo Acción, FIRA, COMCAFE) and international (USAID, Starbucks) partners in developing and refining an approach to integrating coffee agroforestry systems into a regional conservation strategy. CI's approach involves working with regional government agencies, research institutions, private companies, service providers, financial institutions, producer organizations and other NGOs to develop and promote the adoption by coffee producers of a set of local *Conservation Coffee Best Practices.* These Best Practices comprise a set of ecologically and culturally appropriate land-use and farm management practices including (among numerous other practices) such things as the establishment of on-farm forest reserves, the diversification of the shade canopy with native tree species and the restoration of degraded lands to either forest fallow or coffee agroforestry. By working with local institutions, government and international market partners to incorporate these Best Practices into their own programs, policies and services, a range of relevant incentives from credit, technical assistance, market access and improved farm gate prices are directly linked to producers' gradual, successful adoption of this biodiversity approach to farm management. The presentation will draw on findings from a recent external evaluation, our own on-going monitoring, as well as on a couple of insightful anecdotes.

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Cacao, Biodiversity and Indigenous People

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In the indigenous reserves of Talamanca, Costa Rica, cacao is grown in small plots under a diverse array of different shade canopies. Many of these agroforestry systems (especially those with a dense and diverse tree canopy) could potentially play important roles for conservation, providing habitat and resources to plant and animal species. However, the degree to which these agroforestry systems help conserve biodiversity depends on the ways in which farmers use and manage these systems. Here we synthesize our research on biodiversity present within cacao agroforestry systems, including studies of birds, bats, dung beetles and mammals (conducted by scientists and local people), floristic inventories of the tree canopies, and studies of hunting activities. Cacao agroforestry systems often have a similar structure to intact forest, but their plant diversity is usually lower and biased towards timber or fruit species of particular interest to farmers. Bird and bat diversity within the systems is often similar to that of intact forest, most likely due to high mobility of these organisms and the high forest cover in the landscape; mammal diversity is generally lower in cacao agroforestry systems but higher than in alternative, non-agroforestry land uses. Unfortunately the high potential for biodiversity conservation in cacao agroforestry systems is severely constrained by heavy hunting pressure. Conservation efforts in these systems must focus on maintaining a floristically and structurally complex tree canopy, reducing local hunting pressure, involving local people in conservation activities, providing environmental education, and developing better strategies for certification and ecological marketing of cacao.

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Palm Diversity and Agroforestry in New Guinea

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As the largest tropical island in the world, New Guinea is positioned at the junction between Southeast Asia and the West Pacific, and is separated from mainland Australia by a gap of only 150 km wide. The island supports a vast and unique assemblage of plants and animals and also is home for ± 500 different ethnic groups. Politically, this area includes the independent country of Papua New Guinea and the Indonesian province of Papua (Western New Guinea). There are about 32 genera of palms that are native to New Guinea, and these have economic importance as sources of food, building materials, and medicine. Sago palm (*Metroxylon sagu*) and betel nut (*Areca catechu* L.) are two most important palms in this area. Sago palm is staple food for people in lowland area in New Guinea. Betel nut palm is one of most popular palms in New Guinea, and is widely cultivated as a cash crop to increase income of households. Species like *Nypa fruticans, Arenga microcarpa, Borassus heinana*, and a few rattans are of agricultural importance and are therefore necessary to be introduced to farming. However, there are still many unknown species of palms which require some assessment in order to be used in agroforestry practices.

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The Use of Native Plants to Promote Agroforestry Program in New Guinea

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Agroforestry program in New Guinea is under expansion. Some exotic plants are used in the agroforestry sector, and have provided income for the local people. Meanwhile, there is lack of knowledge and experience to manage those exotic plants. However, it is important to consider the use of native plants to promote agroforestry practice in New Guinea. Certain native plants like betel nut (*Areca catechu* L.), wild betel nut (*Areca* spp.), sago palm (*Metroxylon sagu*), pandans (*Pandanus conoideus* and *P. julianetii*), and *Dodonea viscose* have great potency in the development of New Guinean agroforestry. It is important to discover more new plant commodities and incorporate their specific environmental requirements as well as local customs to develop an agroforestry model for New Guinea. Examples of homegardens for lowlands and highlands are also discussed in this paper.

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Public Private Partnership to Integrate Ecologically Based Fungal Disease Management Strategy in Cacao – Overview of Current Efforts

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Control of fungal diseases on cacao through the integration of ecologically based methods into existing fungal disease management strategies (IPM) are being researched and implemented in various countries in Africa, Asia and South America through a public private partnership program. Both basic and applied research conducted at USDA and by their collaborators at CEPLAC, Brazil; CABI-Bioscience, UK; STRI, Panama; CATIE, Costa Rica; SENASA, Peru; Rutgers University, USA; INIAP, Ecuador; and IRAD, Cameroon have played an important role in the transfer of biocontrol technology from the laboratories to the field sites. The establishment of biocontrol facilities, organizing scientific workshops, scientific exchange and training of scientists in this new concept has helped in finding ways to integrate some of the biocontrol strategies into current pest management methodologies. Currently field sites in Cameroon, Brazil, Panama, Costa Rica and Peru have been established by various research groups to follow integrated pest management strategies to control black pod, witches' broom and frosty pod rot respectively, the three major fungal diseases of cacao. Initial results have shown that with better biocontrol formulations and application techniques fungal diseases can be reduced and it is economically feasible. Currently, scale-up and transfer of this technology to the farmers are being evaluated.

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Fungal Endophytes Limit Pathogen Damage in a Tropical Tree

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Every plant species examined to date harbors endophytic fungi within its asymptomatic aerial tissues, such that endophytes represent a ubiquitous, yet cryptic, component of terrestrial plant communities. Fungal endophytes associated with leaves of woody angiosperms are especially diverse; yet, fundamental aspects of their interactions with hosts are unknown. In contrast to the relatively species-poor endophytes that are vertically transmitted and act as defensive mutualists of some temperate grasses, the diverse, horizontally transmitted endophytes of woody angiosperms are thought to contribute little to host defense. Here, we document high diversity, spatial structure, and host affinity among foliar endophytes associated with a tropical tree (*Theobroma cacao*, Malvaceae) across lowland Panama. We then show that inoculation of endophyte-free leaves with endophytes isolated frequently from naturally infected, asymptomatic hosts significantly decreases both leaf necrosis and leaf mortality when *T. cacao* seedlings are challenged with a major pathogen (*Phytophthora* sp.). In contrast to reports of fungal inoculation inducing systemic protection, we found that protection was primarily localized to endophyte-infected tissues. Further, endophyte-mediated protection was greater in mature leaves, which bear less intrinsic defense against fungal pathogens than do young leaves. In vitro studies suggest that host affinity is mediated by leaf chemistry, and that protection may be mediated by direct interactions of endophytes with foliar pathogens. Together, these data demonstrate the capacity of diverse, horizontally transmitted endophytes of woody angiosperms to play an important but previously unappreciated role in host defense.

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Indigenous Knowledge, Values and Management of the *Araucaria araucana* Forest by the Mapuche Pewenche in the Chilean Andes: Implications for Native Forest Conservation and Co-management

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Southern Chile has experienced serious deforestation during the last century and it is anticipated that by the year 2025 Chile will be devoid of native forests. One of the most important endemic tree species of the country and at the same time one of the most endangered ones is *Araucaria araucana* (Mol.) C. Koch, the monkey-puzzle tree. It grows in the Andes Mountains, homeland of the indigenous Mapuche Pewenche people who depend on this tree. This study investigated within a participatory and bottom-up framework the ecological knowledge, values, use and management of the *Araucaria araucana* forest by indigenous Mapuche Pewenche based on the socio-cultural, spiritual and ecological interactions they have with the *Araucaria* forest, in order to reveal how indigenous people and their knowledge contribute to sustainable *Araucaria* forest management. A Mapuche Pewenche community located in the southern Chilean Andes Mountains contributed to this study. The study illustrates (1) the complexity of indigenous ecological knowledge of *Araucaria araucana*, and its efficacy in native forest management, (2) the link between the conservation and use of biodiversity by the indigenous people and (3) provides answers relevant to *native* forest management and conservation strategies *ex-situ* and *in-situ* incorporating indigenous knowledge and scientific knowledge, and providing a contribution towards integrative natural resource management.

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Trends of Homegardens in the Coastal Region of Bangladesh

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Of a total population of 129 million, about 38 million live in coastal areas of Bangladesh. The coastal people are heavily dependent on homegardens for their sustenance. Due to the population explosion the homegarden resources, including habitats, are gradually depleting. To identify the trends of homegardens over the last thirty years data were gathered from four villages representing four agro-ecological zones in coastal areas. Multistage random sampling identified representative areas and households for the study. Five homegardens were sampled randomly from each of five categories of farmers, for a total of eighty surveyed. Although the number of homesteads increased by 13%, the effective production area decreased by 4%. Income from homegardens that ranged between 26% and 47% thirty years ago now ranges from 7% to 54%. Evidently, small farmers' income is declining. It is estimated that the rate of loss of habitat is one per cent per annum. Species for new planting include few fruit trees and exotics of high timber value. This resulted in loss of plant diversity, skewed income and employment opportunity, impaired food and health security and degraded the environmental standard of coastal area. Quantitative data on these aspects of homegardens have been generated for guiding the farmers and for impressing on policy-makers the need to improve homegardens. For restoration of plant diversity domestication, sustainable land-use policy and support services are inevitable. In these activities, the affected rural community should be intimately involved since it is they who know best their situation.

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Tree Integration in Homestead Farms in Southeast Nigeria: Propositions and Evidence

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This paper contributes to wider debates on the dominant factors determining the emergence and sustainability of homestead farms in developing countries. The theoretical framework for analysing the evolution and sustainability of tree integration in homestead farms is presented along with three propositions with reference to southeast Nigeria. First, at the household level, livelihood strategies constitute the main determinant of the decision to integrate trees in homestead farms. Second, induced innovation has a wider and significant role at the community level than at the household level in encouraging the integration of trees in farms. Third, the sustainability of observed patterns of tree integration is influenced by the interaction of environmental, ecological, political, economic and social factors. Based on these propositions and using research evidence from two states in southeast Nigeria (i.e., Cross River and Akwa Ibom), the paper analyzes the internal (household) and external (wider community) factors influencing tree integration in homestead farms.

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Agroforestry Initiatives for Rural Livelihoods through Sustainable Management of Medicinal Plants in Central India

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Forests in India are an important resource for nearly 400 million people. Apart from timber, they provide various non-wood forest products (NWFPs), a majority of which are medicinal and aromatic plants including flowers, fruits, seeds, barks, roots, gums, resins, etc. These medicinal plants contribute to nearly 50 per cent of average annual income of about 30 percent of the rural population in India. But a systematised mechanism for sustainable management, harvest and marketing of medicinal plants from the grassroots level to the level of export to international markets does not exist. These medicinal plants remain either undervalued or underutilised due to reasons like: lack of knowledge of sustainable harvesting practices, lack of storage facilities, wastage in harvesting and processing, and non-availability of ready market channels. If appropriate arrangements for cultivation and sustainable management of medicinal plants (on farmlands and community lands) and their marketing are ensured, the livelihoods of the forest fringe and rural communities can be improved to a large extent. The present study is based on medicinal plants availability in a forest village where the forest is being jointly managed by a Joint Forest Management Committee (JFMC). Using surveys, questionnaires, focused group discussions, interviews and secondary data, the paper tries to highlight the potential of sustainable management of medicinal plants for poverty alleviation through rational use, scientific approaches, and people's participation.

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Alley Cropping for Mulch Production: Potential for Organic Farms of Southeastern USA

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Organic farming offers an alternative that can eliminate many of the environmental problems of conventional agriculture. Instead of using petroleum-derived chemicals to fertilize and protect crops, farmers manage their fields so as to take advantage of naturally produced composts and mulches that recycle nutrients and control pests and weeds. However, organic farming is often logistically inefficient, because these organic composts and mulches are bulky and difficult to transport. Certain types of agroforestry such as alley cropping may be able to make organic farming more efficient. Alley cropping is an agroforestry system in which trees or shrubs, often leguminous, are planted in hedgerows between open spaces (“alleys”) where the crop is grown. The hedgerow species are periodically pruned (both above-ground and below-ground), and prunings fall directly onto or into the soil where the crop is growing. These prunings are green manure that add carbon and nutrients to the soil, and that provide mulch that helps suppress weeds The hedgerow species also provide habitat for beneficial insects. Use of prunings reduces the need for composting and hauling manures and mulches, thereby increasing the efficiency by which organic material is supplied to the soil that supports the economic crop. Alley cropping results in Oregon showed annual biomass production to range from 0.9 to 4.7 t/ha, a quantity not sufficiently high to maintain crop production. In Georgia, annual production of prunings reached 18.4 t/ha in the best plots. Alley cropping may be more feasible for organic farmers in the Southeast.

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Scutellaria: A Non-Timber Forest Product of Great Medicinal Potential

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Many countries are endowed with highly rich and diverse biological resources. Such national wealth of resources in these countries provide a wide range of products and services, such as watershed protection, carbon sequestration, eco-tourism, products derived from bioprospecting, intermediate products like natural dyes, colorants, oils, biochemical compounds, medicinal extracts and final products like timber, handicrafts, fruits and nuts, perfumes, nutraceuticals, and medicines. Many of these products are collected for subsistence use. Some products have served as an important source of innovation for the pharmaceutical, biotechnological, cosmetic or agrochemical industries. The skullcaps (*Scutellaria* species; family Lamiaceae), which have been used in the traditional medical systems of China, Korea, India, Japan, Europe, and North America, are herbaceous, slender plants, scattered over the temperate regions and the tropical mountains in different parts of the world. Of the 300 *Scutellaria* species available worldwide, about 90 are found in North America. As many as 20 species of *Scutellaria* grow in Georgia and neighbouring states, but very little is known about their medicinal values. Skullcap has been well known among the Cherokee and other Native American tribes, as a potent emmenagogue and female medicinal herb. Anti-inflammatory activities of the skullcap formulations have been associated with the inhibition of COX-2 (cyclooxygenase-2) enzyme. We are utilizing the *Scutellaria* of Georgia (USA), Uttaranchal (India), and Nepal in order to investigate their ethnobotany, distribution, phytochemical composition, medicinal bioactivity using animal cell systems, and economic value as a non-timber forest product. We will highlight some of these aspects in our presentation.

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Variation in Ray Thickness of Atlas Cedar (*Cedrus atlantica* M.) in Artificial Plantation in Algeria

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The study of the thickness variation of the rays of three artificial plantations of *Cedrus atlantica* Manetti in Algeria permitted an understanding of the growth of this species in different surroundings. Results obtained through analysis (using carrots) indicated good growth of this species in the introduced environments, which can help in knowing impacts of bioclimate (subhumid, humid and perihumid) and soil substrate (schist, sandstone and marnes). The analysis of the individual and global growth curves has a chronology of information for the same plantation individuals but is still meaningful with regard to the middle condition. Finally, our approach goes in the setting of the struggle against the Algerian forest regression to the level of countries in the North of Africa.

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Are Tropical Homegardens Sustainable? Evidence from Central Sulawesi, Indonesia

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Homegardens are generally regarded a sustainable agricultural production system, although this statement has rarely been supported by quantitative data. Out of the suggested indicators for assessing sustainability, “biodiversity” is frequently/usually studied in homegarden research. However, crop species diversity is not static over time and also varies according to ecological and socio-economic factors and/or characteristics of gardens as well as gardeners. In addition to crop diversity and its changes over time, this study aims to assess sustainability indicators like soil fertility, microclimate, and crop yields to value the sustainability of the system “homegarden”. In 30 homegardens randomly selected from three villages adjacent to the Lore Lindu National Park in Central Sulawesi, species diversity and soil fertility were assessed in 2001 and 2003. Microclimate as well as garden in- and outputs have been investigated in selected gardens in 2004. Crop species diversity was high (149 species in 2001) and increased over time. The spectrum was variable due to exceptional climatic events or interventions by development projects, among others. Crop species composition of homegardens from one village, mainly inhabited by migrants, contrasted strongly with those from the other two. In addition, crop diversity (species number and density, Shannon index) was lower in the migrant village, where soil fertility was low, too. Crop diversity appears to be influenced to varying extent by a combination of major factors, e.g. soil fertility, ethnicity, garden size/age, or market access. The sustainability of the homegardens investigated as well as the suitability of sustainability indicators chosen are discussed.

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Ecological Status of Medicinal and Aromatic Plants of Haryana State, India

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The use and popularity of medicinal plants undoubtedly is increasing at a fast pace, world over. Although, being one of the 12 mega-centers of origin of plants species and a storehouse of medicinal plant wealth, we are not aware of the quantum and potential of our treasure. We quite often claim the richness of our plant resource but we fail to identify its degree. We also remain ignorant about regional wealth. Most of the research in medicinal and aromatic plant has been targeted about their active principles, improvement, quality control and marketing, etc. Very little emphasis has been given to the ecological parameters associated with their growth and distribution. Further, hardly any trial has been made to bring in their cultivation especially under Agroforestry systems. This has been so because the richness of the potential with respect to area and the tree species has never been explored. The proposed presentation, an outcome of an R & D project of the government, deals with the ecological status of medicinal and aromatic plants of Haryana state. It is based on actual survey of over 100 sites, 700 locations in 19 districts in different seasons. The parameters covered, include: Density, Abundance, Frequency, Basal area, Dominance, IVI, Indices of Richness, Dominance, Evenness, Similarity and Dissimilarity. The survey was based on quadrat method after determining the appropriate size and numbers of the quadrats at each site and season.

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Galangal (*Kaempferia galanga*) Growth and Productivity Related to Light Transmission in Single-strata, Multistrata and 'No Over Canopy' Systems in Kerala, India

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Galangal (*Kaempferia galanga* L.) is a promising medicinal and aromatic oil-yielding herb grown in the subcanopy of multistrata production systems in the tropics. The effects of differing light transmission levels on its growth, yield, quality and nutrient dynamics under a solitary canopy, six multistrata canopies and 'no over canopy' were evaluated in a randomised block experiment. Coconut palms (*Cocos nucifera*) provided the solitary canopy while coconut+dicot trees (*Vateria indica, Ailanthus triphysa* or *Grevillea robusta* grown in two planting geometries- single row and double row) represented the multistrata environment. Stand leaf area index (LAI) and subcanopy photosynthetic photon flux density were measured when the palms were 17 to 18 years and other trees, 3 to 4 years old. Results show that understorey photosynthetic photon flux density is controlled by tree species and stand LAI. Ailanthus-based treatments consistently registered lower photon flux densities. Mean daily subcanopy photon flux density (50 cm above ground) ranged from 95 to 646 μ moles s^{-1} m^{-2}, as against 968 μ moles s^{-1} m^{-2} in the open. Presence or absence of over canopy, however, seems to have little effect on galangal rhizome yield; as yield response under 'no over canopy', single strata and multistrata systems were similar. Likewise, rhizome quality did not exhibit any remarkable trends with respect to canopy structure. However, 'subcanopy' foliar P and K concentrations were significantly greater than that of 'no over canopy'. Soil fertility assessment suggests that galangal cultivation modestly depressed site N, while K levels recuperated.

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Evaluation of *Inga edulis* and *I. samanensis* for Firewood and Mulch Production in an Organic Corn Alley-Cropping Practice in the Humid Tropics of Costa Rica

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Ideally, a tree species used in alley cropping should create a suitable microenvironment for the companion crop and provide additional income. Legume trees could be used to provide nitrogen for the companion crop and produce firewood. Our objective was to evaluate *Inga edulis* and *I. samanensis* for production of mulch and firewood and for their effects on corn grain yield in an organic alley-cropping practice in the humid tropics of Costa Rica. In 1999, trees were transplanted in rows spaced 4 m apart with 0.5-m spacing between trees and pruned periodically for shaping. In October 2001, trees were pruned and leaves plus twigs were distributed evenly in the alleys for mulch and the branches were removed for firewood. Corn (*Zea mays* L.) was planted in rows 1 m apart and harvested 120 days after sowing. The experiment was repeated 3 months after the corn harvest. The experimental design was a randomized complete block with five replicates. Both tree species were similar for mulch and firewood production, averaging 6.2 and 9.5 Mg ha^{-1}, respectively, for each pruning. Nitrogen content in the mulch averaged 168 kg ha^{-1}. Corn grain yields in the monocrop plots averaged 3.5 Mg ha^{-1} compared to 1.9 Mg ha^{-1} in the alley-cropped plots. At the second harvest, corn yields in the monocrop plots declined to 2.1 Mg ha^{-1} and were statistically similar to the alley-cropped plots at 1.7 Mg ha^{-1}. By the second harvest, the alley-cropped plots were more productive because they produced both corn and firewood.

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Species Diversity and Ecosystem Function in Improved Fallows

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Improved fallows using fast-growing legume species have proved to be a key technology for soil fertility replenishment and have been adopted by many smallholder farmers in east and southern Africa. However, these fallows have been relying on single species, which can pose serious ecological dangers. There has been increasing interest in diversifying species used in improved fallows and their relationship to ecosystem functions. The *species redundancy, rivet and idiosyncratic hypotheses* have been proposed to explain how species diversity influences ecosystem function. According to the *species redundancy hypothesis*, beyond low diversity most species are functionally redundant. According to the *rivet hypothesis*, all species in the system have a contribution, while the *idiosyncratic hypothesis* presupposes that species diversity changes ecosystem functions unpredictably. We conducted several experiments using single-species and mixed-species fallows to test the above hypotheses. Our results showed that mixing some species increased primary production while other mixtures depressed it. Mixing prunings of different quality showed diverse patterns in C and N mineralization. The mixture of *Gliricidia sepium* and *Sesbania sesban* showed less N leaching whilst mixing *Tephrosia vogelii* and *S. sesban* showed increased N leaching. Build-up of the snout beetle, a pest of maize, was higher under mixtures of *T. vogelii*, *S. sesban* and pigeon pea, while *G. sepium* + *S. sesban* mixtures reduced the incidence of *Mesoplatys* beetles on *S. sesban*. The data from this experiment support all the three hypotheses of species diversity and ecosystem function, and the functions will be discussed in greater detail.

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Characterization of Homegardens: A Case Study in Kohkiluye-va-Boyerahmad, Iran

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This is the first study on homegardens in Iran, and concerns the characterization of traditional homegardens of Kohkiluye-va-Boyerahmad province, in the Zagros region of western Iran. These systems contain the experiences of rural people in use of various Agroforestry components at the same time, and are very applicable in new Agroforestry planning. In tours conducted throughout the province, important systems were found, and their properties characterized. Three sources of data were considered: registered criteria of the system, interviews, and primary ecological data. A framework was invented to arrange the results. Four systems were characterized, and compared to the homegardens of other countries. The study shows that these indigenous homegardens have the most compatibility with the need of their users and their climatic conditions.

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Silvopastoral Systems in the Alps: Effects of Cattle Grazing on Biodiversity and Forest Structure

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In the Alps, the multipurpose utilisation of agricultural and forest resources has a long tradition. As there are many settlements in the valleys of the Alps, mountain forests often serve as protection against natural hazards (e.g., avalanches), in addition to timber production. Farmers graze their cattle in mosaics of coniferous forests, open pastures (with diverse herbaceous vegetation) and half open pastures (with dwarf shrubs and young trees), similar to the American Rangelands. Foresters fear that cattle grazing hinders tree regeneration, impairs timber quality and reduces the protective function of mountain forests. Others claim that wood pastures have a high structural diversity, thus positively influencing landscape amenity and biodiversity. The Swiss Federal Institute for Snow and Avalanche Research (SLF) studied both, the benefits of forest grazing for cattle, and the implications on forest structure and biodiversity. The condition of young trees was assessed and the selection of herbaceous species was recorded. Additionally, the digestibility of the herbage was calculated, using the double alkane technique. The long-term influence on forest structure was studied using dendroecology. The results suggest that young conifers are not severely damaged by grazing cattle if stocking density is low and the ranges are sufficiently large, thus enabling the cattle to select herbage plant species of adequate digestibility. Grazed forests have a more open and heterogeneous structure than ungrazed forests. The increased insolation promotes both plant species diversity and tree regeneration. Thus, sustainable management of Alpine silvopastoral systems can combine animal nutrition, biodiversity and avalanche protection.

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Preferences and Indigenous Practices of Fodder Trees by the Rural Agroforestry Farmers in the Flood Plain Area of Bangladesh

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This article focuses on the preferences and indigenous practices of the fodder trees by the agroforestry farmers of randomly selected 40 households sampled in the rural areas of one selected flood plain area of Bangladesh. The study objectives were to find out farmer's ranking of fodder tree species of their choice, their criteria for assessing fodder trees, and uses, management, niches and ways of establishment. *Garuga pinnata* was highest preferred tree species followed by *Erythrina indica* by all categories of agroforestry farmers. The most frequently mentioned criteria for preferences were palatability and the ability of the fodder to satisfy the hunger of the animal among the different animal-related criteria and no dropping of leaves among the tree-related criteria. Fodder trees were mostly used to feed goats and sheep especially during the rainy season. All the households used the top most two preferred fodder species as live stakes and support trees for climber-like vegetable plants, and over 90% of the farmers used these two species as live fences. Most of the fodder trees were found in home compounds established naturally. Satisfactory management techniques for fodder trees were not followed by any household category. The study has helped to identify the species for further research and development activities, with the aim of improving their productivity and disseminating them among the farmers.

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Homestead Agroforestry in Bangladesh: Potential Resource for the Rural Households

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Homestead agroforestry production system has been playing an important role in the rural economy of Bangladesh since time immemorial. The size and structure of homesteads are linked to economic, social, and ecological factors. The size of the homestead is generally small but numbers are increasing steadily with the increases of population. It combines all farming components and forms a highly intensive and multi-strata integrated production system depending on household's needs, preferences and knowledge. Homesteads meet the diversified needs of the rural households through the production of wide variety of fruit, timber, fuel, fodder, vegetable and medicinal plants. Collectively, homestead production systems contribute about 70 percent fruit, 40 percent vegetable, 70 percent timber and 90 percent firewood and bamboo requirement of the country. There is a tendency towards planting quick-growing timber species though fruit trees dominate over other trees. The smaller farmers tend to plant more trees per unit area. Livestock and poultry, which are mostly reared in homestead, are the important source of income aside from supplying meat, milk and eggs. Homesteads also serve as processing centers for the poor households. Homestead being near to the household's residence enables the women, who constitute almost half of the labor force in Bangladesh, to work for efficient management of homestead activities. Planting improved plant species, optimum management of the resources, efficient processing and marketing of the products could contribute significantly to the livelihood of the poor.

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Sustainability vs. Diversity of Homestead Agroforestry: Exploring the Linkages

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An appreciation of homestead agroforestry diversity and its relationship with sustainability has instigated much interest and attention from academic and scientific community in the recent years. Many analysts believe that sustainability of homestead agroforestry is associated closely with its diversity. The basis for their arguments often rests on the fact that diversity ensures a sustained supply of various products, provides a natural safeguard against pests and diseases, represents an invaluable gene pool and confers some degree of stability by arresting soil erosion and contributing to nutrient cycling. Through an extensive review of literature, this article attempts to shed light on the performance of homestead agroforestry with a view to exploring the linkages between its diversity and sustainability.

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Indigenous Agroforestry Systems in Amazonia: From Prehistory to Today

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Recent revisions of Amazonian prehistory have discarded a model of human occupation postulating that environmental factors limited populations to small villages. The rereading of chronicles written by the first European explorers, as well as current archeological research, now indicate a very different scenario. Large population complexes occupied the margins of the main rivers, developing an elaborate material culture and extensive trade networks. These peoples possessed agricultural systems based on a great variety of cultivated plants, including fruit trees, and various food storage technologies. Despite the decimation of the native Amazonian population following European conquest, many elements of these agricultural and agroforestry systems have persisted until today, and continue to be a part of the agricultural practices of indigenous peoples. A review of anthropological and ethnobiological literature from recent decades indicates a great variety of indigenous agroforestry practices, ranging from deliberate planting of trees in homegardens and fields to the management of volunteer seedlings of both cultivated and wild species. These practices result in various configurations of agroforestry systems, such as homegardens, tree/crop combinations in fields, orchards of mixed fruit trees, and enriched fallows. These agroforestry systems constitute a stock of knowledge which developed over centuries, if not millenia, and most likely represent technologies which evolved along with the domestication of wild forest species and their incorporation into food production systems.

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Economic Valuation of Tropical Homegardens: A Case Study in Kerala, India

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Homegardens are traditional agroforestry systems found in the tropics that provide a source of continuous income for the farmer, and are often an important component of the family's food security. Economic studies on homegardens are, however, few. Data were collected from 75 homegardens in Kerala, a small state in southern India, which experiences tropical climate and seasonal monsoons. Based on farmer surveys, plant inventories, direct observation, and market research, an economic cycle has been developed, of inputs and outputs associated with a representative homegarden. Some of the primary inputs were labor, fertilizers and pesticides, land costs, water, and associated transportation costs. The outputs were market produce and goods fulfilling domestic subsistence needs. Intensity of cultivation, in terms of profit per unit area, was highest in the smallest gardens (≤ 0.13 ha), and lowest in those gardens that emphasized commercial production (≥ 0.40 ha). Household labor input also varied with size of garden, ranging from approximately 44 person days/100 m^2/yr in the smallest gardens, to less than 10 person days/100 m^2/ yr in the largest gardens. The Net Present Value (NPV) was calculated using Cost - Benefit Analysis. All homegardens showed positive NPV over the period of one year. A sensitivity analysis, measuring potential changes in prices of labor and market products, yielded no significant changes in NPV, indicating absence of potential risk. A comprehensive financial analysis of homegardens reveals the economic importance of these systems, for the purposes of both subsistence, and market production.

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The Role of Agroforestry in Sustaining *Fagara* Tree and Other Medicinal Plants in Africa: Case Study of Community Perceptions in Western Kenya

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Fagara tree species, which grow widely in Western Kenya, are usually ignored although they have the potential to cure many ailments; some of which have hitherto been incurable with Western medicine. This paper details some of the diseases successfully cured by *Fagara* as epilepsy, schizophrenia, eczema, body wounds, malaria, veterinary diseases and common colds. The author examines the special role of this tree in curing sexually transmitted diseases such as herpes, gonorrhea and infections associated with AIDS. There are other uses in which this tree is applied. Despite this remarkable success, the author cautions that we should not be complacent. There is still a lot that we do not know about the *Fagara* and other medicinal plants and their ability to cure ailments. Future studies are needed to discover other issues of the *Fagara* tree and find cures for snakebites, cancer, diabetes and the dreaded Ebola; all of which continue to debilitate African people. The author discusses the thorny issue of biotechnology and asks: Will genetic engineering of the *Fagara* tree species and others pollute, dilute or strengthen the pool of healing in Africa? The author concludes by analyzing the factors that have led to the wide acceptance of the *Fagara* among the African people and assesses community perceptions of the efficacy of *Fagara* and other traditional medicinal plants in Africa.

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The Potential of Agroforestry Practices in Improving Rural Livelihoods and Biodiversity Conservation in the Mt. Kenya Region, Kenya

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The Mt. Kenya region is essentially a high potential area in terms of farm productivity and natural biodiversity. Despite this reality, poverty among the local residents and biodiversity losses are real and both continue to lose out. Threats to sustainable growth and biodiversity conservation are mainly due to problems related to human population density and their related activities, including inadequacy of land use policies. This paper examines the role of agroforestry in improving rural livelihoods and biodiversity conservation in the region. Agroforestry trees have been identified to provide a wide range of products and services to the people, and equally play an important role in conserving soil and biodiversity within the farmlands. Agroforestry practices, especially those that involve woodlots, improved fallows, live fences, remnant indigenous tree species, as well as farmland sites free from agrochemicals, have particularly been found to play a major role in the conservation of small mammals, avifauna as well as the indigenous tree species themselves which are endangered in the region. The study notes that agroforestry practices will continue to play a leading role in maintaining a balance between farming activities, social development and conservation of biodiversity in rural farmland areas of Kenya.

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Vanishing Valuable Indigenous Trees in Chobe and Kasane Forest Reserves of Botswana

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The continued vicious cycle of population-rural poverty-and-land/forests degradation has been acknowledged in many parts of Botswana. A field study was carried out at Chobe and Kasane Forest Reserves in 2003 to assess the impact of wild fires on valuable indigenous plant species. In both forest reserves ten plots (25-m x 25-m) were established at 100-m inter-plot spacing along a transect of 1 km. Both diameter at breast height (dbh) and height of all trees with at least 3-cm diameter were measured. The average tree mortality rate in Chobe was 60% with *Pterocarpus angolensis* showing the highest proportion (21% tree losses). Out of the 40% living trees, 16.3% were either wounded by fire or elephants. Kasane showed the highest proportion of wounded living trees (26.5%) as compared to Chobe. Chobe gave significantly (P<0.05) higher tree basal area (146.20-m^2 ha^{-1}) and species diversity (H: 7.7281) as compared with Kasane (basal area: 41.93-m^2 ha^{-1} and H: 6.7038). Most of the trees were found in the 21-30 cm (672-stems ha^{-1}) and 41-50 cm (144-stems ha^{-1}) diameter classes in Chobe and Kasane respectively. It is concluded that fire and elephant damage results in increased land degradation and suppressions of natural regeneration and considerable losses of biodiversity. To rehabilitate degraded lands and conserve biodiversity, therefore, fire management plan and policy and elephant populations need to be developed and reduced respectively. Agroforestry practice can also be a way to reduce the rate of fire incidences and their associated greenhouse gases emissions (CO_2) and increase food crop yields.

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Population Structure and Conservation Status of Rare and Endangered Medicinal and Aromatic Plants in the Indian Western Himalaya

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We studied the distribution pattern, population structure and conservation status of rare and endangered medicinal plant species in Kinnaur, Lahul & Spiti and Chamba districts of Himachal Pradesh in the Indian Western Himalaya. The entire study area spreading over 21,000 sq. km. was stratified into 12 landscape zones based on eco-climatic and phytogeographical variations. Exhaustive ground surveys in each of the landscape zones yielded 110 distinct landscape element types (LSEs) potentially distinguishable through Indian Remote Sensing Satellite (IRS-1D) images. The LSE is defined as a patch within a landscape homogeneous in appearance and distinct from surrounding patches. The representative LSEs were randomly sampled for rare and endangered species using quadrats. A total of 26 rare and endangered medicinal and aromatic plant species were encountered, unevenly distributed across the zones with variable density levels under various anthropogenic and natural disturbance regimes. Disturbance factors include collection of medicinal plants for trade and various land use practices, of which grazing of alpine pastures and lopping of forest trees are dominant. There are some village community regulations on the harvest of selected species such as the *Jurinea dolomiaea*. In some of the villages, the harvest of this resource is permissible only once in five years. Such community regulations, therefore, need to be strengthened and promoted towards overall biodiversity conservation efforts in the Himalaya. The attempt may further facilitate working out an overall conservation strategy for protecting, conserving and managing a whole landscape consisted of a mosaic of LSEs or ecosystem components in continuum.

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Participative Regeneration of Agroforestry Biodiversity in the West African Traditional Parklands

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The parklands of the Sahelian landscape are a unique agroforestry system that has evolved over the centuries to incorporate a host of multipurpose trees. These trees offer invaluable fruit for food security, leafy vegetables for sauces, oils, medicines, fodder, fibre and wood for construction and fuel, and also shade. But the parklands system is in trouble due to biophysical, socioeconomic and policy issues. For these reasons, we are undertaking a key study of biodiversity in the parklands system in and around the important historical town of Ségou in Mali, and how best to conserve and promote it in the Sahel. From preliminary results we are able to determine actual levels of biodiversity and how they are related to villages and management units. Although the study is still in its infancy, it is already clear that biodiversity varies between individual villages and different land management units. "*Village fields*" close to the homesteads, have the least biodiversity and lowest tree density. "*Bush fields*" where varying periods of natural fallows are practiced have more biodiversity. The greatest biodiversity and tree density is found in the "*pastureland*", which is unsuited to crop production and is left for grazing and exploitation of forest products. The species are also ranked using farmers' criteria in terms of preference. The most important products for which farmers value trees in the study area are food, medicine, fuel and fodder. This research provides strong basis for the orientation of future research and dissemination activities for rehabilitation of Sahelian traditional parklands.

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Alfalfa Growth, Quality, Maturation, and Root Total Nonstructural Carbohydrate Concentration as affected by Three Light Intensities

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As alfalfa (*Medicago sativa* L.) is the most profitable forage crop in the USA, there is interest in producing alfalfa hay in alley-cropping practices. However, little information is available on how alfalfa responds to shade. A field study was conducted in 1998 and 1999 in an established alfalfa field. Each year the initial spring growth was harvested at first bloom, then shade structures were erected to provide 47 and 63% sunlight. One set of plots was not shaded (100% sunlight). Plots were sampled at 35-d intervals for three harvest cycles each year. Data were taken on yield, maturity, crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF), and root total nonstructural carbohydrate (TNC) storage. In 1998, rainfall was normal and herbage yields in shaded treatments were reduced significantly. In 1999, rainfall was below normal the last two harvests and no differences in herbage yield were observed between shaded treatments and 100% sunlight. At all harvests both years, plants grown in 100% sunlight matured faster, had significantly lower concentrations of root TNC, and similar or less CP. Shaded plants tended to have less fiber in normal rainfall conditions as measured by ADF and NDF; however, in drought conditions, shaded plants tended to have more fiber. Alfalfa may not grow well where sunlight is limiting, as suggested by poor herbage yields and reduced TNC when rainfall was adequate. In alley cropping, alfalfa might best be used with wide tree-row spacings or before tree canopy closure occurs to maximize light.

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Agroforestry Systems Development in Eastern Cambodia

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Cambodia is a country undergoing giant steps in its development. Much effort is directed at resurrecting its agricultural base and protecting its forest resources. However, there is currently very little information regarding agroforestry systems and practice in Cambodia. This paper discusses the potential for agroforestry to contribute to national development. After a brief outline of the current development context, it describes the farming systems and land use constraints in Eastern Cambodia. This description is based on a participatory rural appraisal study undertaken in 2002. The main land uses in Eastern Cambodia are lowland rice, fruit and nut orchards, vegetable gardens, mixed home gardens and degraded forestland. The land and resource use constraints identified include poor soils, insects, disease, lack of livestock fodder, lack of irrigation, lack of labour, and reliance on a heavily degraded forest resource for fuelwood and timber supply. Several agroforestry interventions were identified to meet some of the constraints in the farming systems and these were presented to farmers participating in the study. Farmers were most interested in growing nitrogen fixing trees as living fences around their home gardens and along roadsides to provide firewood, mulch and fodder. Interest was also shown by some farmers in growing woodlots to provide timber and fuelwood. The discussion will consider strategies for furthering the research and development of agroforestry in Cambodia.

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How Trees Determine Nutrient Distribution in Holm-Oak Dehesas of Spain: Effects on Crop Yield

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Dehesas, a type of oak woodland agroforestry system occurring in the western Mediterranean basin, are created from simplification of structure and species, where tree density is cleared, shrub cover is eliminated, and herb layer is favored with cereal culture in large periods of rotation. They are silvoarable systems of extensive utilization, where pastures and trees have a preponderant place. The aim of this study was to know the effect of holm-oak (*Quercus ilex*) on the nutritional concentration in soils and its consequence on the crop yield in tree dehesas of Extremadura, Spain. To quantify crop yield, 1-m^2 crop samples were taken at physiological maturity in three intercropped dehesa farms, with different kind of soil fertility. We sampled nine trees per farm, in two orientations (east and west), and four distances: under the canopy, in the peripheral area, and at five and ten meters from the periphery. For each of these distances we also took a soil sample composed of five subsamples. All samples were analyzed to determine nitrogen and phosphorous concentrations. Soil analysis showed that most of the parameters (total N, available P, CEC) decrease with the distance to the tree following a negative power function. The decrease of organic carbon follows a logarithmic trend. Crop yield increased significantly with the distance to trees only in the most fertile farm, indicating the predominance of the light competition over nutritional facilitation of the trees. By contrast, in oligotrophic soils, crop yield decreases slightly, but not significantly, with the distance.

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Women and Agroforestry in the Mount Cameroon Region – "Lessons from the Field"

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Mount Cameroon, in southwestern Cameroon, rises to a height of 4,095 m and its region covers an area of 2,500 km² with 300,000 inhabitants. It is also a biodiversity hotspot hosting rare and endemic plants and animal species. A conservation project worked in this region for 8 years with local communities to maintain the rich biodiversity so that they could be managed sustainably. Forest clearance for plantation agriculture and food crop farming was identified as a major threat to biodiversity. Alternative ways to improve on farming systems were sought, hence the launching of agroforestry projects. In 1994, Africa 2000 Network and Rainforest Alliance funded tree planting by women because fuelwood and charcoal were becoming scarce and difficult to obtain. Most of the women became interested in fast-growing fuelwood species. This interest served as an entry point to introduce the idea of interplanting. Planting of trees as windbreaks provided protection for their crops and a source of livelihood. Encouraged by fruits from windbreaks, this increased their desire to diversify production. Interview conducted 3 years after, revealed that plantains planted in the farms provide shade to the cocoa/coffee seedlings 6 months after planting, and are ready within a year, which fetches income for the family. Planting of fruits and vegetables helped to boost income. Women also maintain trees planted by men by planting annuals in between. Beehives are installed in farms with other crops. *Women increase yields and conserve biodiversity through crop diversification.*

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Opportunity for Livelihood Enhancement through Agroforestry Practices in Rural Communities in Ghana

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Ghana depends on agricultural production and the exploitation of the forest resources as its economic mainstay. In recent times, there has been a decline in the forest and forest resources, affecting adversely the livelihood of the majority of the people especially the rural poor living in close proximity to the forests. Agricultural lands continue to decline in productivity due to loss in soil fertility and fragmentation. The causal factors for the decline are the effects of traditional farming practices, illegal and excessive logging and occurrence of annual wildfires. The inclusion of trees in all land-based production systems may help reduce land degradation and poverty in rural communities. Thus the practice of agroforestry will enhance the capacity, provide assets and means for communities to meet their welfare needs for today and the future. The paper examines the contribution of agroforestry practices in improving the livelihoods of the people. The study covers three districts in three different ecological areas of Ghana and involves determining the extent of AF practices, assets accumulated and expression of their capacities to meet their needs now and in future. This was conducted using the participatory approach. Many farmers are involved in practices such as boundary planting, fruit trees such as cashew on farms, indigenous and exotic tree plantations and homegardens. These technologies have increased their assets on the land through diversified production systems to promote their capacity to meet their livelihood in a sustainable manner.

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Growth and Yield of Hot Pepper in Hedgerow Intercropping with *Morinda citrifolia* L. during Early Establishment

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Intercropping high-value horticultural crops with tree crops is an economically attractive, but little-studied, agroforestry option in the U.S. Virgin Islands. A study was conducted to evaluate growth and yield performance of hot pepper (*Capsicum chinense* L.) under hedgerow intercropping with Morinda (*Morinda citrifolia* L.), a popular medicinal tree in the Virgin Islands. Morinda hedgerows were established at 5-m spacing forming 5-m wide alley between hedgerows. One year after hedgerow establishment, seedlings of hot pepper cultivar 'Habanero' were transplanted in alleys at 1-m row spacing and 0.60 m plant spacing within rows. Similar spacing was used for plots planted with monoculture hot pepper (no hedgerows). The experiment utilized a randomized block design with four replications. The Morinda hedgerows were not pruned during the cropping year. Data were collected on hot pepper height, number and weight of marketable fruits. Hedgerow plant height and canopy width were also determined at 3-month interval. Treatment effect of hedgerow on growth and yield of hot pepper was compared with monoculture crop. Data analysis indicated that during the early establishment of hedgerows, plant height and marketable yield were not significantly reduced. Differences in height and yield by rows relative to distance from hedgerows were not significant. However, average yield under hedgerow intercropping was slightly lower than monoculture (no hedgerow) crop. This study would indicate that during the early stage of hedgerow establishment, tree-crop competition is not critical in reducing growth and yield of hot pepper. Long-term effects of hedgerows on productivity of intercrops will be further investigated.

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Performance of Wheat Varieties in Organic Based Agroforestry System in India

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Organic farming is a type of agriculture in which emphasis is laid on the soil and environmental health of the production system. However, due to limited resources and poverty, marginal and sub-marginal farmers of India are not able to adopt organic farming as it requires high input as most of organic fertilizers are poor in their nutrient status and also the production is not at par with inorganic fertilizers. Hence, diversification of agriculture is necessary to deal with rather unstable ecosystem. Here, agroforestry can play an important leading role, as it is a form of diversified organic farming. In addition to this, agroforestry is the key to surmount the pressure on forests, conserve environment and reverse land degradation. In view of these facts, *shisham* may prove to be a miracle tree in agroforestry because of its outstanding ability of nitrogen fixation, salt tolerance, hardy growth and good timber quality. It has deeper root system than poplar and eucalyptus, and thus does not compete directly with crops for nutrients. In addition, shisham leaves carry more nutrient that again come to the surface and make soil fertile. Present investigation deals with evaluation of twelve wheat varieties under shisham-based organic agroforestry system with inputs in the form of FYM@ 10 ton/hectare, Neem cake and nutrient were added through shisham leaves. Observations were recorded for yield and yield attributes. A significantly higher grain yield was observed under shisham compared to control in open. Similar trend was also noticed in case of other yield attributes.

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Structure and Economic Viability of Homegardens of Andaman, India

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Andaman group of islands, experiencing a true maritime climate, are located in the Bay of Bengal. After British colonial rule, refugees of East Pakistan, repatriates of Sri Lanka and Burma, landless people and ex-serviceman families of India were rehabilitated in these thickly-forested islands, which led to the development of homegardens. Homegardens, after forests (86%), are the second major land use, covering 4.2% of the total geographical area in the islands. Homegardens are comprised of 5 components, i.e., orchard, poultry birds, livestock, fishpond and home. Orchard includes plantation crops like arecanut and coconut, spices like clove, nutmeg, cinnamon and black pepper, and fruits like banana, jackfruit, mango and pineapple, distributed vertically, which form a multistoried (4 stories) structure. Groundcover of the homegardens is generally not grown for annual crops mostly due to giant African snail menace. Marked intra-and inter-island variability in structure of the homegardens was found due mainly to their multi-ethnic and multi-cultural social structure. Livestock are let to go for free-range grazing in nearby forests whereas chickens are fed among the trees in the orchard. Big fishpond is found in only 8% homegardens. The family members do maximum (56%) labour in the orchard. Total net annual return from the homegarden (1ha size) was an estimated US$2,944 of which maximum 83% was contributed by orchard, 5% by livestock, 3% by poultry birds and 9% by fishpond. Homegardens in the islands maintain stability in their productivity for a longer period of time. Hence, they may be regarded as a sustainable agro-ecosystem.

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Biodiversity and Production in Silvopastoral Systems from Central America

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We aimed at relating meat production with biodiversity level on silvopastoral systems from three sites of Nicaragua, Honduras and Costa Rica. We sampled biodiversity and production indicators at one farm in each of the three countries; these farms had a vegetation cover of ca. 50%. We also studied production indicators on another three farms with no vegetation cover at all. Biodiversity indicators were: Vegetation cover (%), Species richness (S) and Diversity (H') (of birds and mollusks). Production indicators were: Receptiveness, Total stock, Total livestock unit and Stocking rate. The most important conclusions we arrived at, were the following: 1) Obtained results suggest that farms with silvopastoral systems are more profitable than farms without silvicultural uses. This profitability is related mostly with the possibility of facing the summer's drought and even drought seasons longer than expected, without the need of providing nutritional supplies to cattle. 2) Available data suggests that farms with high vegetation cover (40-50%), are self-sufficient regarding cattle feeding, which means that the farmer won't have to spend extra money on food supplies. 3) On silvopastoral systems, the biodiversity indicator with bigger impact on farm productivity is vegetation cover. 4) Regarding biodiversity, we have observed that on silvopastoral systems occur some plant species that play no role in cattle feeding, and are kept by farmers. These plants are allowed to grow up on systems, and somehow rebuild patches with vegetation components similar to the ones of the remnants of primary forests existing on surrounding areas.

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Local Knowledge on Trees and their Uses in Leyte, Philippines

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This study was conducted in four selected sites in Leyte islands, namely Babatngon, Sogod, Maasin and Hinunangan, from April to May 1999-2001. It aimed to determine and document the existing forest and on-farm trees and their uses in the study sites using the local knowledge of upland farmers. A pre-tested interview schedule was used in data collection. Information from the 120 randomly-selected farmer respondents was collected through personal interviews. Results were validated during an organised focus group discussions participated by different sectoral representative in the community. Data were analysed using the preference ranking method and descriptive statistical tools. Results show that there were 136 forest and on-farm trees identified by upland farmers in the study sites. Some of the trees were cared for and domesticated by them in their respective farm lots. According to farmers, each species has its own value and specific uses. They are using these trees both for socio-economic and environmental reasons. Commonly, trees are used as raw materials in furniture industry, lumber for house construction, medicines, fruits, firewood, post, boat keel, shade for abaca (*Musa textiles*) plantation, as wildlife habitat, among others. This implies that farmers' knowledge in terms of diversity is already at certain level, however the information that they have was not recognised and linked to scientific information. Moreover, results of this study strongly recommend that local knowledge of upland farmers has to be considered in the development of a tree domestication program to have an assurance of its adoption and success.

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An Alternative Approach to Enhance Medicinal Plant Biodiversity: Promoting Agroforestry Practices for Conservation and Economic Development

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Bangladesh is rich in both cultivated and wild plants covering a wide array of species, genera and families with enormous genetic diversity. About 5,700 species of higher plants have been recorded so far, and of these, some 260 species are used as crops. The rest of the species are left growing wild in their natural habitats. Of these, wild medicinal plant species have been an important resource in primary health care systems in Bangladesh. But unfortunately, the over-exploitation and destructive harvesting of medicinal plants in the wild have led many plant species to become rare and some are on the point of extinction due to degradation and loss of habitats. Although data on threatened species are scarce in Bangladesh, a large number of medicinal plants are reported to be disappearing rapidly due to destruction of natural habitats. The loss of diversity in medicinal plant genetic resources will undermine productivity in herbal medicines and ultimately affect the lives of poor people. Immediate attention is needed to regenerate and multiply rare and endangered medicinal plant resources in farmers' field to enhance biodiversity outside the forest and to sustain and support the traditional medicinal heritage of Bangladesh. This paper highlights a conservation program of medicinal plants through agroforestry systems that will help provide poor people not only with herbal medicines, food, nutrition, and income, but also help reduce the pressures on natural forests and support genetic conservation.

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Barn Owls as a Sustainable Means of Rodent Control in South Florida Agriculture

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Rodent pests cause an estimated $30 million in damages annually to sugarcane and vegetables in the Everglades Agricultural Area of south Florida. Growers have traditionally relied on chemical rodenticides to control these rodent pests. However, chemical control can be expensive and, depending on the compound, may pose an environmental threat to water supplies and non-target wildlife. The Common Barn Owl (*Tyto alba*) is endemic to Florida and is widely recognized as one of nature's most effective rodent predators. Conservative estimates put the numbers of small rodents eliminated by a nesting pair of barn owls at over 1,500 rodents per year. However, due to a paucity of suitable nesting sites, *T. alba*'s numbers in the Everglades Agricultural Area are well below optimal. A nesting box program to enhance barn owl populations in south Florida was initiated during the 1990s and has proven quite successful in providing barn owl nesting and roosting sites. Nesting boxes, mounted on tall poles, are located along field perimeters and ditch banks. Out in the open, these nesting boxes find ready acceptance by the barn owls and are rapidly colonized. The number of growers participating in the nesting box program and reporting significant levels of biological rodent control by these beneficial raptors has increased in recent years. Several growers have even discontinued the use of chemical control measures.

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Comparative Production Systems of Twelve Native U.S. Woodland Medicinals including Goldenseal and Black Cohosh in Northern Appalachia

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The Appalachian Mountain region of the United States is rich in commercial medicinal non-wood forest products (NWFP), and has one of the highest poverty and unemployment rates in the country. The harvest and trade of NWFPs can contribute needed income to the region's residents. However, harvest pressure and regulations monitoring plant harvest to ensure longer-term preservation of these same species are also endangering the ability of these plants to continue to provide this income. The National Center for the Preservation of Medicinal Herbs (NCPMH) has developed a research and educational agenda to address the sustainability and cultivation needs of a selection of native medicinal plants identified as being over-harvested from the wild to supply the natural products industry. These species were selected based upon their volume supply to the natural products industry, their native range of harvest, their perceived impact on companion species in their native location, and their re-population potential. From 1998 through 2003, the NCPMH initiated forest and field studies on agronomic production and agroforestry models for the species to develop a better understanding of the parameters most influential in bringing the targeted species into cultivation. Results from five species, gathered over a three-year period on black cohosh (*Cimicifruga racemosa*), blue cohosh (*Caulophyllum thalictroides*), goldenseal (*Hydrastis canadensis*), wild yam (*Dioscorea villosa*), and stoneroot (*Collinsonia canadensis*) will be presented. These results include observational data on soil types, percentage shade, plant communities and diseases, and insects identified on native stand sites of these species performed over this period.

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Effect of Agroforestry Technology on Conservation and Improvement of Tree Diversity: Case of Live Hedge in the Sahelian Zone

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A survey of 152 farmers was conducted in the groundnut basin in Senegal and the cotton zone in Mali. The overall objective of the study was to compare species diversity in fields that were enclosed by live hedges and those fields that were not. Species diversity was assessed through inventory by the farmers themselves of species found in their fields. The results of the study showed that a total of 97 species were inventoried in the 76 fields that were enclosed with live hedges compared to a total of 43 species for the 76 fields that were not enclosed by live hedges. Of the 97 species found in the enclosed areas, 39 were unique to the system in comparison to 11 out of the 43 in the plots that were not protected. The species found in the fields enclosed by live hedges were mostly planted and included local fruit trees (*Ziziphus mauritiana,Mangifera indica*, *Borasus aethiopium*, *Anacardium occidentalis*), trees for fuelwood and other wood functions (*Acacia holosericea and Eucalyptus sp*). Natural regeneration of species was also very high in the protected fields (86.3%) than in the fields that were not protected by live hedges (13.7%). Farmers are more willing to plant trees and to allow natural regeneration to occur under conditions of secured land tenure that this agroforestry practice ensures. The results suggest that the live hedge is an ideal practice for conservation and improvement of species diversity in the land use systems prevailing in the study areas.

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Dynamics of Organic Matter in Agroforestry Systems of the Amazonian Region of Brazil

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The organic matter of the soil is all organic fraction, located below the surface of the soil, and it consists of dead matter with 98% of the organic carbon of the soil, and living matter with approximately 4% of the total of organic C of the soil, which comes from plants, microorganisms, of the meso- and macro-fauna, and of residues of animals and microorganisms of the soil. The nature of the humus of the soil can vary substantially with climate, vegetation and conditions of the soil. And the amount and the proportion with that these fractions are found in the soils serves as indicators of quality of the soils in several works, due to strong interaction of the humic substances with the mineral material of the soil. Our study, which examines organic matter dynamics in the the humus of Brazilian soils, has involved the collection of litter samples of two cocoa (*Theobroma* sp.) agroforestry systems, one containing paricá (*Schizolobium amazonicum*) and the other andiroba (*Carapa guianensis*), originating from the municipal district of Tomé-açu of the State of Pará in Brazil. The study showed that agroecosystems containing paricá and cocoa obtained larger relationships of fulvic acid with humic acid and larger amounts of total nitrogen.

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Mangrove Diversity in Andaman and Nicobar Islands, India

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The Andaman and Nicobar Islands are a group of 572 islands, islets and rocks lying in the Bay of Bengal between 6–14° N latitude and 92–93° E longitude. Being volcanic in origin and oceanic in nature, these islands are characterized by numerous bays, creeks and inlets on the landward side and fringing coral reefs on the seaward side. The mangrove vegetation of these islands constitutes 9.4% of the land area occupying 929 km^2 and occurs mostly fringing the creeks, backwater and muddy shores. Along the creeks the width ranges from 0.5 to 1 km. About 27 tree species such as *Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorhza, Bruguiera parviflora, Bruguiera sexangula, Ceriops tagal, Ceriops decandra, Cynometra iripa, Excoecaria agallocha, Heritiera littoralis, Kandelia kandel, Lumnitzera littorea, Lumnitzera racemosa, Rhizophora apiculata, Rhizophora lamarckii, Rhizophora mucronata, Rhizophora stylosa, Scyphiphora hydrophyllacea, Sonneratia alba, Sonneratia apetala, Sonneratia caseolaris, Sonneratia griffithii, Xylocarpus gangeticus, Xylocarpus granatum, Xylocarpus moluccensis,* five shrub species such as *Acanthus ebracteatus, Acanthus illicifolius, Acanthus volubilis, Aegialitis rotundifolia, Aegiceras corniculatum,* two species of palm such as *Nypa fruticans* and *Phoenix paludosa* and a fern *Acrostichum aureum* were found in these islands. All these are belonging to seventeen genera are reported to occur in the mangrove ecosystem of these islands. It also harbors as many as 8 species of mammals, 53 species of birds, 7 species of reptiles, 3 species of amphibians, 253 species of fish, 410 species of polychaetes and 53 species of meiofauna.

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Agroforestry for Income Generation and Conservation in the Eastern Himalayas

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Eleven percent of the land in the Hindu-Kush Himalayas is brought under protected areas. However, pressure on these is high due to the illegal extraction of high value products, firewood, fodder, as well as grazing and poaching. A review of existing agroforestry systems shows that innovations in agroforestry have a high potential to release some of the pressure on both high-value and subsistence forest products. The traditional role of trees in farming systems in this area is to provide soil fertility. Examples of this are the forest fallows in shifting cultivation systems, and the high dependence on fodder trees in the traditional mixed farming systems. Large cardamom-based agroforestry is a traditional commercial system in which cash income is successfully combined with the production of forest products as well as soil conservation. Though originating from Sikkim (India), it has been spontaneously adopted by marginal farmers in the eastern Himalayan region. The Eastern Himalayas are considered one of the ten biodiversity hotspots in the world. The medicinal plant species of the area are used in Ayurveda, Tibetan and modern medicine. Therefore local knowledge is extensive, but so is the risk of extinction due to illegal extraction. On-farm cultivation and product development in a similar way as the large cardamom seems the best option for conservation. However, while government bans on trade of some of the high value species are meant to protect them, they also form a major obstacle for legal income generation through cultivation.

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Agroforestry for Nature Conservation: A Case Study of Javanese Home Gardens in Lampung Province, Sumatra

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Integrating protected areas and community development seems to have great potential for aiding the efforts in preserving the natural ecosystem. Agroforestry, the common farming system practiced by local communities surrounding protected areas, therefore needs to be given more thorough attention. This study tries to quantify the effect of agroforestry as a way of supporting nature conservation. It will include the identification of ecological and economical functions of agroforestry for local community livelihood. The hypotheses were determined as follows: (1) If agroforestry provides sufficient ground cover it will support the protection of the environment; and (2) if agroforestry produces a wide enough range of products in sufficient quantities, it will avoid human disturbances inside the protected areas. The study has been carried out in a village near the boundary of Bukit Barisan Selatan National Park, located in the extreme most southern tip of the island of Sumatra, Indonesia. Its community originates from the neighbouring island of Java and its people conduct an agroforestry system similar to the home garden practices found on that island. In the study, ground covers were measured to estimate agroforestry contributions to the protection of the ecosystem, e.g., slowing down soil erosion and land degradation. Furthermore, the variety of produce and income generated from production were analyzed to examine whether agroforestry is able to provide sufficient support to local people's livelihood as well as contribute to nature conservation.

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The Potential of Legume Fallows in the Reduction of Pest Problems in Rain-fed Maize Production Systems in Southern Africa

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Over 80% of the farm families in southern Africa practice subsistence agriculture with little external inputs on poor soils under erratic rainfall conditions. Traditional cropping systems involving bush fallows and crop rotation which improve soil fertility, keep pest infestations at tolerable levels and give modest maize yields are not practical anymore due to the increase in human population and shrinking landholding size. Soil fertility is declining, pest problems are increasing, and yields of staple food crops like maize are very low. Research conducted in Zambia, Malawi and Zimbabwe has shown that planted fallows using nitrogen-fixing legumes can improve soil fertility. However, the potential of this practice as an integrated soil fertility and pest management strategy has not been studied systematically. We conducted several studies comparing the incidence of soil insects and weeds in conventionally-tilled monoculture maize (*Zea mays* L.), maize grown using traditional fallows and legume improved fallows. Although preliminary, our results showed that (1) short-rotation fallows of *Sesbania sesban* can reduce *Striga asiatica* weeds, (2) pure fallows of *S. sesban* or mixtures of *S. sesban* + *Cajanus cajan* or *Tephrosia vogelii* + *C. cajan* can reduce the infestation of maize by arable weed, and (3) growing maize in fallows of *Leucaena leucocephala*, *Gliricidia sepium* or mixtures of *Acacia angustissima* + *S. sesban*, and *T. vogelii* + *S. sesban* can significantly minimize termite damage to maize compared to conventionally tilled monoculture maize. This paper also discusses the mechanism by which the legume fallows reduce incidence of soil pests of maize.

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Agroforestry and Cropping Pattern as Basis for Land Reclamation in Northern India

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India is an agriculture-based country and so is its economy. Punjab and Haryana, the two northern states, cater to the whole country for its food grain. Cropping pattern of wheat-rice cultivation has stereotyped over the years, which has started to threaten the ecology of the area. Cultivation practices have made the country self-sufficient but this system involves the conscious and deliberate use of land resources especially groundwater for rice plantations. Excessive use of fertilizers has added to soil problems viz., acidic, saline and alkaline soils. Land degradation has affected rich and healthy environment by reducing the basic life support systems. Agroforestry gave a ray of light in the rehabilitation process. As per the suitability and country's need a unique model evolved in Punjab and Haryana and is the only example of its kind in the world. The market economy encouraged some fast-growing tree species like poplar and eucalyptus. The practice of growing commercial timber trees for the wood industry in and around agricultural fields has spread across the region like a storm. Of course the crops growing underneath and in adjoining fields remain a major consideration. Farmers are being made aware of alternative crops. The region experiences widespread hostile environmental conditions. Correct selection of species is thus of prime importance. Highly adapted tree species have been identified for each agroecozone, and the diversification of agriculture, in an effort towards proper land use, will pay off in the long run for the betterment of farmers and the community as a whole.

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A Synthesis of Quarter Century Research on Medicinal and Aromatic Plants in Agroforestry in India

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In nature medicinal and aromatic plants co-exist with various tree, shrubs, climbers and herbs. About 90% of medicinal and aromatic plants are sourced from forests. Exploitation of forest is causing deforestation at a rate of 1.5 million ha per year in India. Multi-location studies in India have been conducted to develop sustainable and economically viable technologies for cultivation of medicinal and aromatic plants in agroforestry. Studies on interplanting poplar (*Populus deltoides*) and eucalyptus (*Eucalyptus hybrida*) based agroforestry with perennial aromatic grasses like palmarosa (*Cymbopogon martinii* var. *motia*), lemongrass (*Cymbopogon flexuosus*) and citronella Java (*Cymbopogon winterianus*) revealed minimal impact of companion crops on tree species. Menthol mint cultivar *Himalaya* and *Kosi* performed well compared to other cultivars in agroforestry. Similarly, successful companion cropping of coriander (*Coriandrum satiavum*), garlic (*Allium sativum*), patchouli (*Pogostemon cablin*), *Nagar motha* (*Cyperus scariossus*), sweet flag (*Acorus calamus*), long pepper (*Piper longum*), sarpagandha (*Rauvolfia serpentina*), ashwagandha (*Withania somnifera*), kalmegh (*Andrographis paniculata*), satavari (*Asparagus racemosus*) or safed musli (*Chlorophytum borivilianum*) were demonstrated in poplar based agroforestry. In a related study, rhizome yield of ginger (*Zingiber officinale*) and turmeric (*Curcuma domestica*) in agroforestry increased by 83 and 145%, respectively, compared to respective sole crop yield. Likewise, significant improvement in land use efficiency (up to 107%) and monetary advantage (up to 94%) was obtained through companion cropping of geranium (*Pelargonium* sp.) in *Eucalyptus citriodora* under semiarid south Indian conditions. These results are discussed in respect of sustainable production of medicinal and aromatic plants, employment generation, utilization of growth resources and environment.

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Dynamics of Chlorophyll in Medicinal and Aromatic Cedars Growing Outside Forests

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Thuja and *Juniperus* are important medicinal plant species for India and internationally. An understanding of environmental impacts on these coniferous species is thus sought to help provide better information regarding their proper conservation and establishment as agroforestry elements outside of forests. Our study investigated chlorophyll dynamics of *Thuja orientalis, Juniperus chinensis, J. prostrata* and *J. variegata* as influenced by various environmental stressors. In present investigations it has been found that chlorophyll contents closely resembled with partial and temporary mobilization of leaf/needle carbohydrates (starch as reserves) contributing to stem elongation and renewable leaf/needle formation. Chlorophyll synthesis was enhanced in spring which intensified process of photosynthesis and reflected in the accumulation of leaf/needle biomass in these conifer species. Chlorophyll starts to decline in winter which reflects decrease in photosynthesis due to lower photosynthetic photon flux density as well as low temperature. This brings about important physiological changes in trees, related to resistance to unfavorable winter conditions. From September leaf/needle biomass decreased gradually and again as temperature rises in spring, the biomass contents in leaf/needle rises as a result of intensified photosynthesis, and various metabolic changes take place shown by extension growth in buds of last season and preparation for bud break and a new vegetation period also starts. Thus the period ending with bud burst is characterized by pronounced chlorophyll degradation with rise in leaf/needle biomass, whereas reserve starch is hydrolyzed during fall and dormant conditions, imparting cyclic adjustments and readjustments during extreme weather conditions in these conifers.

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Cultivation of Medicinal and Aromatic Crops / Plants in Jammu & Kashmir, India: Needs and Priorities

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The need for cultivation of medicinal and aromatic plants is increasing both at domestic and international levels. Average land holding in Jammu & Kashmir State of India is 0.76 ha. About 90% of the total cultivable area lies with marginal farmers among whom the thrust for cultivation of cereals and food grains spares much less acreage for plantation of medicinal and aromatic plants. Medicinal and aromatic plants can be safely integrated with commercial crops in an agroforestry system which not only economise the returns but also conserves tree species and checks soil erosion. Ginger (*Gingiber officinale*), turmeric (C*urcuma longa*), and garlic (*Alluim sativa*) are some of the main crops which are cultivated in Jammu division both for their medicinal and aesthetic values. Other wild grown shrubs like *Adhatoda vesica*, *Cascuta* and trees like neem (*Azadirachta indica*), Bhera (*Herminalia blerica*), Harad and Babul (*Acacia nilotica*) are planted extensively; as a component of agroforestry besides having medicinal value they provide both fuel and fodder for the peasants. Present investigations were carried out in Jammu division of J&K State. Emphasis was made to educate the farmers and to carry out extensive plantation of listed species.

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Adaptive Approach of Three Populations of *Ziziphus lotus* (L.) Desf. by the Slant of the Stomatal Complex, in Southern Algeria

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Ziziphus lotus (L.) Desf. is a very rife species in the arid regions of southern Algeria. It constitutes arbustive stratum to the level of dayas whose arborescent vegetation is dominated by *Pistacia atlantica* Desf. Indeed, it can be seen in protected plantuleses of this last of animals and the violent winds. A phytodermological survey was done to describe three populations of *Ziziphus lotus* (L.) Desf. localized along an increasing aridity gradient: Ain Oussera and Messad (Wilaya of Djelfa) to arid climate and Taghit (Wilaya of Bechar) of the Saharian climate. The observation of epidermises of *Ziziphus lotus* leaves (L.) Desf. permitted counting of stomata of the anomocytic perigenous (T_1) and mesoperigenous types (T_2), anisocytic mesoperigenous (T_3), paracytic mesoperigenous (T_3') and mesogenous (T_4) type. The presence of the paracytic mesoperigenous types (T_3') and the increase of its frequency according to an increasing aridity gradient appears to be an adaptation to the term difficult of the environment. Note that the paracytic mesoperigenous type (T_3') has been described in Chenopodiacaea, as well as two species of *Pistacia*. These last living species exist in the arid surroundings where rainfall is missed.

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Prospect of Domesticating the Forest Floor Private Armies of the Bayuku Snail (*Ryssota ovum*) in Philippine Agroforestry

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The biggest challenge faced by agroforestry advocates dwells on the twin problems of production and conservation. Hence, in the continuing effort to agroforestry development, promotion and advocacy lies the ardent interest to explore non-traditional commodities, enterprises, production systems, wild species of plants and animals that can be grown, produced, domesticated or reared in compatibility with the different agroforestry systems. Such innovation shall contribute to the economic needs of farmers while ensuring a well-balanced environment. In responding to this challenge, this paper discusses the prospects of domesticating the Bayuku, *Ryssota ovum* (Valenciennes, 1854) in agroforestry. Bayuku, an endemic terrestrial land snail to the Philippines has been a traditional diet of many communities in areas where it is naturally occurring. Its meat is among the most sought after snail species and it tastes like chicken gizzard and considered an exquisite food served in various recipes. Moreover, Bayuku snails serve as silent forest-floor private armies - armed with their noble role in nutrient cycling particularly through feeding on decomposing forest debris and excreting fecal matter, which is rich in nutrients for plants growth. Despite their great potential, however, nobody has attempted to domesticate or mass-produce the Bayuku. This paper outlines the attributes of harnessing the prospect of this non-traditional agroforestry product. The paper presents the outstanding features of the species and its attributes as a well-suited commodity in an agroforestry farm. It discusses the economic soundness and ecological benefits derived from this innovative enterprise of Bayuku domestication in agroforestry.

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Role of Traditional Home Gardens on Biodiversity Conservation – A Case Study from Western Ghats, South India

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Indigenous management techniques of traditional home garden and tree resource conservation were investigated in eighteen home gardens of tribal village in Kudremukh National Park, Western Ghats, South India. Data on human and livestock population, land holding, garden size, garden silviculture, management, etc., were collected, followed by measurement of girth and height of the trees and calculation of biomass. Farmers used various types of planting materials collected from natural forest such as seeds, rhizomes, suckers and even seedlings. Regional traditions in growing certain trees in particular locations of the home garden were observed which account not only for shade to the household but also shade for animal dwelling places and nurseries of seasonal vegetables. This region almost resembled the nearby forest in terms of species richness. The gardens occupied a total area of 1.35 ha with an average size of one-fifth of an acre harboring 600 individual trees belonging to 63 plant species of which several species such as *Myristica dactyloides*, *Calophyllum inophyllum* etc., belong to Rare, Endangered and Threatened category of Red data book. The fruit-producing trees such as *Artocarpus heterophyllus*, *Mangifera indica*, etc., occupied the highest portion of total tree population, where tribal peoples are dependent on these for livelihood. This paper aims at understanding the role of these traditional home gardens in carbon sequestration, biodiversity conservation, livelihood improvement of tribal peoples, and in maintaining the soil and water regimes with special focus on Western Ghats.

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Arthropod Communities in Temperate Agroforestry: Theory and Reality

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Interest in temperate agroforestry has increased substantially over the past several years because of its potential as an environmentally positive, sustainable, and potentially profitable set of land use practices. Knowledge of the complex interactions among trees, crops and their associated fauna is necessary to determine the viability of a particular agroforestry practice. While a significant amount of research has been conducted on the ecological interactions among components of tropical agroforestry practices, little information is available on these interactions in the temperate regions of the world. Agroforestry's effect on insect populations, both pests and beneficials, in temperate alley cropping practices is particularly lacking. Theoretically, agroforestry holds promise for increasing insect diversity and reducing pest problems by improving natural enemy complexes and adding competition to pest species. We discuss the theories behind agroforestry's potential to ameliorate pest problems. Examples from our research on alfalfa pests in a temperate black walnut (*Juglans nigra*) - alfalfa (*Medicago sativa*) alley cropping practice demonstrate a reduction in herbivore numbers and an increase in natural enemy numbers for the agroforestry practice versus the traditional agricultural practice.

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Efficacy of Tree Origin Botanicals in Improving Food Grain Yield in Cowpea, *Vigna unguiculata* (L.) Walp.

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To study the efficacy of tree origin botanicals in improving grain yield in Cowpea, *Vigna unguiculata* (L.) Walp., field experiments were conducted in 2000-2001 at Tamil Nadu Agricultural University, India. Eight botanicals, possibly containing secondary metabolites, were prepared from leaves of tree species viz., *Alangium salvifolium* (L.) Wang*., Aegle marmelos* (L.) Corr*., Annona squamosa* (L.)., *Azadirachta indica* A. Juss*., Eucalyptus citriodora* Hook*., Emblica officinalis* Gaertn*., Feronia limonia* (L.) Swingle*,* and *Syzygium cumini* (L.) Skeels*.* Water spray served as control. The experiment was set up in a Randomized Block Design. The botanicals were prepared, stored in ambient temperature for a required time and sprayed on cowpea plants during 30 and 45 days after sowing (DAS). The yield and yield-related parameters were recorded. The data were analyzed statistically for their significance. The study revealed that the highest cowpea grain yield of 920 kg ha^{-1} was registered by giving two sprays of the botanical prepared from *Alangium salvifolium* that was followed by the sprays of botanicals prepared from *Aegle marmelos, Annona squamosa* with yields of 780 kg ha^{-1} and 760 kg ha^{-1}, respectively. Of the eight botanicals tested, *Eucalyptus citriodora, Emblica officinalis* registered least yields than that of control (water sprays). The study indicated that two sprays on 30 and 45 DAS with the botanical prepared from *Alangium salvifolium* could enhance food grain yield in cowpea. The present investigation has thrown a newer dimension on tree species selection for agroforestry situations with eco-friendly and increased food production, on a renewable basis.

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A Look at the Market Chain for American Ginseng (*Panax quinquefolius* L.), and Opportunities for Improving Rural Livelihoods

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Medicinal plants represent some of the largest markets for non-timber forest products. However, very little is known about many of their market chains, demand and supply dynamics, and potential for sustainable development. American ginseng (*Panax quinquefolius* L.) is one of North America's most valuable medicinal plants, long used in Chinese medicine. Although domesticated a century ago, the market for cultivated ginseng has plummeted, while the demand for wild ginseng has outstripped natural production. A case study of American ginseng's historic trade to Asia, and recent efforts to satisfy the demand for wild ginseng with a sustainably grown alternative, sometimes called "simulated-wild ginseng," will be explored from a perspective of market chain, consumer education and popular awareness. This is based on the author's interviews with producers, marketers and importer/exporters in North America and China.

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Integration of Medicinal Trees in Agroforestry Systems of India

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Non-wood forest products like fruit, fiber, gums, leaves, etc. contribute significantly to the economy of the rural people in India. The farmers gather the produce from the forest and village common lands. Naturally growing wild trees, in general, bear fruits of poor quality fetching very low price. Growing of superior genotypes of tree species in the farmers' field along with field crops will not only increase the productivity but will also improve the quality of the produce. This can be achieved by selection of superior genotypes from the wild populations and their propagation through vegetative means. *Terminalia chebula*, *T. bellerica* and *Sapindus mukorossi* are the species, fruits of which have immense medicinal value. Cultivation of these wild fruits has not picked up in the past due to low seed germination, lack of superior planting material and long gestation period of plants of seedling origin. The research conducted has led to the production of true-to-type quality plants for the first time through vegetative propagation. A survey of wild populations in Himachal Pradesh (India) has been conducted and several promising strains have been identified. The plants of *T. chebula* raised through grafting have started bearing fruits just after third year of grafting. The preliminary studies conducted on allelopathic effects of *T. chebula* and *S. mukorossi* have shown no harmful effects on germination and growth of some under crops. Hence, these species offer an opportunity to be integrated with field crops under agroforestry system.

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Ecology versus Economics in Tropical Agroforestry Homegarden Management

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Homegardens and other multistrata agroforests have often been described as ecologically sound, economically viable and socially equitable. As in the majority of sustainable management situations, the reality is not the perfect combination of these three characteristics at their best but a compromise between them. Here, we argue that the development of ecological features of homegardens can be fostered by an adequate economic analysis. If neoclassical economics are used to assess the performance of homegardens, criteria of yield, cost-benefit analysis and net present value may disqualify homegardens when compared to conventional monocropping activities. Alternatively, if ecological economics analyses are applied, the internalization of externalities such as agrobiodiversity management, improved nutrient cycling or integrated pest management may turn homegardens into highly profitable ventures. Economic analysis methods which can integrate the outputs of mixtures of plants with different cycles and allow for the smoothing of long term and patrimonial strategies are definitely required. The merits of homegardens in terms of subsistence food for families, flexibility in crop production or reduced external inputs requirements also need to be taken into account in any ecological economics analysis of homegardens. Similarly, the potential of homegardens for values such as landscape beauty or conviviality for rural societies' life has also to be incorporated in their assessment. All in all, when such an approach is taken, homegardens and agroforests will appear as an ideal compromise of sustainability.

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Kalazeera (*Bunium persicum*) - A Potential Medicinal Herbal Plant in Cold Deserts of North Western Himalayas

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Bunium persicum (Boiss) Fedstsch, Black caraway is a perennial, aromatic spice and medicinal umbellifer (Apiaceae), growing naturally in dry temperate regions (1850-3100 m alms) of northern Himalayas and recently brought under domestication. Its seed and straw both yield cuminaldehyde and p-mentheadiennals rich cumin oil and are in great demand in ayurvedic medicines, condiments and perfumery. Recognizing the need for its conservation to save the plant from over-exploitation and to meet the ever-increasing demands, the author has studied its agro-technology with respect to its phenology, phenotypic variability, methods of its plantation, intercropping pests and diseases of crop. *Bunium persicum* exhibited a wide range of variation for primary, secondary umbels/plant, tuber weight and seed yield/plant. Yield/plant possessed significant positive correlation with plant attributes namely primary and secondary umbels/plant umbellets/secondary umbel and tuber weight /plant. Amongst the insect pest attacking kalazeera, gram pod borer has been found to be the most serious pest of the region with 30-40% infestation. Infested plants lost their umbels and were devoid of grains. However, a recorded inference of various diseases of kalazeera in dry temperate zone of Himachal Pradesh reveals that zeera is infected with a wide range of diseases like blight, powdery mildew and bulb rot infestation during sprouting and bolting stage of crop growth. Bulb rot was a major disease of the crop with 15-35% infestation in comparison to others viz. powdery mildew (2-10%) and blight (7-25%).

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Medicinal Uses of *Detarium microcarpum* in Southern Mali

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Detarium microcarpum Guill. and Perr. is a woody species belonging to the Fabaceae family. It is generally widespread in dry areas from Senegal to Sudan. It is found on the gravelous soils. The aim of this study is to make an inventory of local knowledge on the therapeutic properties of *D. microcarpum*. The survey was carried out near three ethnic groups in the south of Mali using an open and preestablished questionnaire. The study show a diversity of medicinal uses of *D. microcarpum*, variable according to ethnic groups.

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Biodiversity, Watershed Functions and Profitability in Agroforestry Landscapes in Southeast Asia Converted from Tropical Rain Forest: Trade-Offs between Local and Global Functions and Benefits and the Role of 'Rewards for Environmental Service Functions' of Eco-agriculture

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Natural forests are, rightly or wrongly, the global benchmark for both watershed functions and biodiversity conservation – but they don't feed people or provide employment. While environmental service functions can be affected by forest conversion and further intensification of agriculture, the trajectories of both functions are essentially different. Watershed functions can be defined as the way landscapes determine quantity, timing and quality of river flow, given the rainfall that is received. There is only a very partial direct overlap between such watershed functions and the ability to conserve, provide habitat and connectivity for biological diversity in landscapes. We tested a series of hypotheses on the relationships between land use change, watershed functions and biodiversity conservation for internal consistency through the construction and use of quantitative simulation models. Three ASB benchmark areas in Southeast Asia were the focus of this study: Mae Chaem in northern Thailand (intensifying from fallow crop rotations), Jambi (rubber agroforests) and Sumber Jaya (coffee-based agroforestry) in Sumatra (Indonesia), with an annual rainfall of about 1.5, 2.8 and 2.5 m year^{-1}, respectively. Results for quantitative indicators of the main environmental service functions and profitability show that agroforestry mosaics can break away from the clear trade-off between local and global benefits that exists in food-crop dominated systems. On more detailed inspection, however, the environmentally benign forms of agroforestry will lose out from systems such as oil palm monoculture, unless effective rewards are found for the environmental services provided. We are currently testing an array of mechanisms for such rewards.

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Homestead Agroforestry in Andaman and Nicobar Islands, India

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The Andaman and Nicobar group of islands are situated in the Bay of Bengal about 1200 km away from the mainland of India. They form an arc of about 572 islands and isles stretching from Southern Burma in the North to Sumatra in the South between 6° to 14° N latitude and 92° to 94° E longitude. A detailed survey was conducted in 151 homesteads spread over 15 panchayats in North, Middle, South Andaman and in 39 tribal councils of Car Nicobar. The land holding ranged between 0.13 and 6.02 ha. The nutrient status in the home gardens was low in available N (132.5 to 221.6 kg ha^{-1}) and available P (5.6 to 8.4 kg ha^{-1}) and to medium in available K (123.6 to 221.2 kg ha^{-1}). The general composition of homesteads was plantation based, with coconut and arecanut being principal crops intercropped with spices like black pepper, clove, cinnamon, nutmeg and bay leaf. However, fruit crops viz., mango, sapota, papaya, banana, jack, lemon etc., were also found in the homesteads. Among the animal components, poultry ranked first followed by cattle and goat. In certain homesteads, fishery components were noticed where rearing rohu, katla was done in irrigated ponds. In Nicobar groups of islands, apart from backyard poultry, pig rearing is the major occupation. Technological interventions were made in selected existing homesteads, which resulted in remarkable increase in per unit output.

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Austrian Farmers Knowledge and Innovations Related to Traditional and New Silvopastoral Practices with Its Potential for Organic Farming

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In Austria's rural regions traditional practices such as grazed orchards, fodder trees, hedges and forest grazing still exist. In their efforts to optimize and adapt production and working processes to special site conditions, Austrian farmers maintain, renew and integrate traditional practices. Furthermore, they develop new agroforestry methods. Since 1996 we conducted a field survey, covering eleven Austrian farms (nine organic and two conventional). We deployed semi-structured interviews, based on farm management, arrangement of plant species and economic success. The matrix to classify agroforestry practices (Nair 1993) has been adjusted to the field survey results. The surveyed farms integrate agroforestry practices in their contemporary farming practices. The traditional agroforestry practices include grazed orchards, hedges as living fences, ash (*Fraxinus excelsior*) - foddertrees, larch (*Larix decidua*) - meadows and grazed forests. The new, more recently developed techniques are mouflon (*Ovis ammon*) and fallow deer (*Dama dama*) in high stem pear (*Pyrus communis*) and apple (*Malus domesticus*) plantages, Christmastree (*Abies alba*) plantages and Shropshire sheep, pigs in elderberry (*Sambuccus niger*) plantages, wild boar (*Sus domestica*) and domestic pig crossbreeds in spruce afforestation. Main motives for farmers to integrate agroforestry practices are related to raising site productivity, complying with organic standards for animal husbandry and to widen product variety. Farmers listed benefits such as: microclimatic amelioration, higher soil fertility, additional fodder and higher fodder quality, slope stabilisation, animal welfare and additional income. Austrian farmers are well-experienced in agroforestry and are constantly improving their techniques to optimize outputs and sustainability of their specific faming environments.

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Agroforestry Systems for Biodiversity Enrichment: An Example from the Ecuadorian Dry Tropical Forest

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In general, the Ecuadorian Dry Forests of coastal Ecuador have been severely impacted principally by rapid population growth and expansion of the agricultural frontier in this region. To counteract this trend, the Bosque Protector Cerro Blanco, a government reserve administered by the Fundación Pro-Bosque, protects a total of 6,000 hectares ranging from near-primary dry tropical forest to abandoned pasture lands within the reserve, dominated by the exotic African grass *Panicum maximum*. The forest reserve harbors more than 500 species of vascular plants (20% endemic), 53 species of mammals and 211 species of birds. Parts of the forest were previously cultivated as recently as 1999. Subsistence farmers planted *Zea mays* or pasture grass in the uplands. The moister ravines were planted with fruit trees, coffee (*Coffea arabica*) and cacao (*Theobroma cacao*). From 1993 to present, enrichment parcels of native and non-native fruit trees have been established in overgrown and abandoned pastures within the reserve, to enhance populations of native mammals and birds. Species for this purpose include *Vitex gigantea, Citrus spp*., *Anacardium occidental, Persea americana, Inga edulis, Inga spectabilis* and others. Presence of trees in these abandoned pastures facilitates their conversion to forests and permits transit of birds and animals. The plantings link patches of forest in better conditions with abandoned pastures with enrichment parcels and cultivated agroforestry systems (principally corn) with species such as *Gliricidia sepium* and *Ceiba pentandra*, facilitating seed dispersal by animals. Through constant monitoring of permanent plots, overall plant species composition has become more diverse.

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Agroforestry and Watershed Restoration in Western Nicaragua Following Hurricane Mitch

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The Mitch Reconstruction Project was active in 2000 and 2001. One primary objective was restoration of tree cover on agricultural lands, in riparian areas damaged by floods, on sloping lands and along upper stream courses. USDA sponsored technical assistance, small grants to NGOs, demonstrations, and training events for watershed stabilization. Concentrated assistance to the National Tree Seed Center assured quality germplasm for partner groups and reforestation efforts. One of the partners, the Pan-American Agricultural College, Zamorano, accomplished agroforestry and watershed conservation in five geographic departments. A critical watershed focus allowed the ProCuencas project to connect areas where farm families adopted sustainable agricultural practices, soil and water conservation techniques, and reclamation of agricultural lands. The project managed tree seedling nurseries in each watershed to revegetate riparian areas, support agroforestry, and supply fruit trees for homegardens. Management focused on trees native to the region and adapted to the habitat conditions. USDA technical assistance for nursery practices, seed collection and storage, compost and soil mixes, and site-species compatibility improved species diversity, seedling vigor, and plant survival. Within the ProCuencas watersheds, in 106 communities during the first year of the project, there were just over 1,400 nurseries producing from 44 to 575 thousand tree seedlings of up to 25 species. The second year, restoration activities used 45 tree species and over five times the number of seedlings produced the previous season. Post-Mitch USDA support for mycorrhizal inoculation increased seedling survival and adaptation to stressful growing conditions in difficult edaphic settings of critical watershed sections.

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III. Biophysical Aspects

Includes topics related to sessions on:

Biophysical Interactions,
Carbon Sequestration and Landscape Ecology in Western Europe,
Carbon Sequestration and Environmental Benefits,
Decision Support Tools,
Environmental Amelioration,
and Climate Change

Carbon Dynamics in a Temperate Agroforestry System in Southern Ontario, Canada

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A study was conducted at the University of Guelph Agroforestry Research Station to quantify carbon sequestration in a tree-based intercropped system and in an adjacent conventional agricultural system. Two tree species, hybrid poplar (Clone DN-177) and Norway Spruce (*Picea abies*) were intercropped with barley (*Hordeum vulgare* L.). In the conventional agricultural system, barley was grown as a sole crop. Carbon inputs and outputs in both systems were quantified in order to understand the carbon dynamics in these systems. Inputs via litterfall, crop residue, root turnover, and sequestration in trees and soil were quantified. Outputs via soil respiration and water leaching were quantified. In the poplar intercropping system, total C input was quantified to be 2.33 t ha^{-1} yr^{-1}, and total input in the spruce intercropping system was 0.89 t ha^{-1} yr^{-1}. The sole cropping system (barley) input was 0.47 t ha^{-1} yr^{-1}. The total soil organic C pool for the intercropping system was 50 t ha^{-1} and was 46.5 t ha^{-1} for the sole cropped system. This soil organic C pool difference was observed over 13 years. In the poplar intercropping system, C input was 5 times more than the sole cropped system and 2 times more in the spruce intercropped system when compared to the sole cropped system. Total soil organic C pool for the intercropping system was 7% more than that quantified in the sole cropping system. It could therefore be concluded that intercropping trees with crops could significantly enhance carbon sequestration in agroecosystems.

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Data Management for Decision Support Systems (DSS) in Agroforestry

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There is growing demand for computer-based tools which can support and simplify the research process. The organisation, storage and handling of experimental data are critical parts of this process. The most appropriate tool for facilitating this is a relational database implemented using the structured query language (SQL) available within modern database software. SQL bypasses the barriers between different software and operating systems. The same database can be managed by ACCESS running under MS Windows on a personal computer or by MySQL running under Linux on a mainframe server. This implementation also allows researchers to make data available on web sites and directly to simulation models of varying complexity, by translation routines. A further advantage of using databases implemented by SQL is the relative ease of writing query reports, which supply data as output in any desired format (e.g., in a standardised data code such as ICASA Standard V 1.0). Such facilities are not available in databases constructed in spreadsheets. While it is advisable that data collection is carried out in a spreadsheet, which allows direct checking and handling of data, the structure of the sheet should be already “normalised” with the database structure by removing redundant data within and between tables. The use of database software running on a PC, which provides tools for designing input and query forms for the end-users of the database, can be a step in-between the spreadsheet and implementation on a mainframe server. This research is part of the Silvoarable Agroforestry for Europe (SAFE) Project.

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Development of Online Computerized Databases as a Decision Support Tool for Agroforestry Systems in India

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Agroforestry, while an age-old set of practices, is becoming more important due to its diversity of applications. However, information on agroforestry systems and practices is often limited and inaccessible to farmers, extension workers and other end users. With the rapid development of the Internet, it is now possible to put agroforestry information in electronic format so that it can be conveniently retrieved. The present investigation is being carried out in order to develop a comprehensive online database of agroforestry information entitled “agroforestryBASE”. This database would contain information on various aspects of agroforestry under four independent modules, namely multipurpose tree species (MPTS), research projects, economic analyses, and agroforestry interventions/innovations. The component databases are being designed in MS Access 2000 and standard query language (SQL), active server pages (ASP), HTML, and DHTML, which has been used to create the dynamic pages of the database. The software runs on a HTTP Server and serves the request of a client on any computer connected to Internet and having a graphic web browser. The database has been equipped with interactive web pages to browse information on on-going/completed agroforestry research projects in India, detailed information on multipurpose tree species being used for agroforestry, economic analyses of agroforestry case studies, and agroforestry interventions/innovations for specific regions of India. The “agroforestryBASE” system is thus designed to disseminate scientific information on agroforestry in India. The major constraint faced during its development was a lack of information on AF technologies suitable for specific soil and climatic conditions.

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Carbon Sequestration by Amazonian Agroforestry Systems

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In the Peruvian Amazonian region during the latter part of 2000, we evaluated the volume of carbon sequestered by six agroforestry systems and/or land-use systems: primary forest, regeneration forest, coffee+shade, pasture+trees, pasture, and homegarden. In three ecological situations (blocks), we evaluated a) tree biomass, b) herbaceous and arbustive biomass, c) litter, and d) soil. About the total carbon, the parameter primary forest, stored 465.8 tC ha^{-1}, overcomes in 58% to the treatments: homegarden and coffee+shade, in 74.3% to the fourth: pasture+trees and 80% to the other parameter, pasture. However, those ones plus regeneration forest are statistically similar and less than the primary forest ($p<0.01$). The soil was the most stable drain ($p<0.01$), retaining in all cases –except primary forest- more than the half of total carbon. The increments are proportionally inverse between the tree and soil drains, depending on the tree covering with which they count; the contributions of the rest of vegetative biomass (herbs, shrubs and litter) varied from 1 to 2%; the amount provided by dead trees was considerably high but changeable in treatments: primary forest, regeneration forest and coffee+shade. Thus, the differences depend exclusively on the proportion of the arboreal biomass ($p<0.05$).

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Beer's Law, Darcy's Law, and the Exponential Decay of Organic Matter in Soils: Important Implications for Agroforestry

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The microclimates created by tree-crop associations offer unique opportunities for understanding important biogeochemical processes governing the distribution of light, water and nutrients. This study looks at the current state of knowledge on three such processes—Beer's law, Darcy's law, and the exponential decay of organic matter in soils—to derive a clearer picture of how these processes operate within microenvironments such as agroforestry. Specifically, this study provides mathematical and graphical descriptions of each concept, compares the similarities and differences among these concepts, and explains the application of these principles to agroforestry. Each process is seen to operate within a range of similar and predictable mathematical relationships, depending on specific environmental conditions. Observations from this study suggest that characteristics such as PAR interception, LAI, hydraulic conductivity, and C:N ratios, are important in conferring differential growth and yield among single species and multi-species plant communities. An understanding of these relationships is foundational to the design and modeling of agroforestry systems.

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Plant-insect Interactions in Temperate Agroforestry Systems

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Plant-insect interactions are a largely unstudied but important factor in the design of agroforestry systems, as variations in tree-crop combinations and spatial arrangements may have an effect on insect population density and speciation. Agroforestry is a potentially useful technology for reducing pest problems because tree-crop combinations provide greater niche diversity and complexity than monocultural systems of annual crops. Various studies have shed light on plant-insect interactions. Studies with pecan (*Carya illinoensis*) have looked at the influence of ground covers on arthropod densities in tree-crop systems. Research has looked at how cover crops (e.g., annual legumes and grasses) sustain lady beetles (*Coleoptera: Coccinellidae*) and other arthropods that may be useful in the biological control of pests in pecan. The competitive activity of belowground pests is another important consideration in agroforestry design. This paper will review recent findings in agroforestry and related literature as they relate to arthropod density, speciation and control in agroforestry systems. Specifically, this paper will examine how spacing and tree-crop combinations in agroforestry systems may alter, disrupt, decoy, repel, or otherwise change the growth, feeding and reproductive activity of arthropod species.

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Tree-Crop Competition for Nutrients in a Pecan-Cotton Agroforestry System in the Southeastern USA

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Trees in agroforestry systems may potentially remove excess N, P and other nutrients from agricultural soils. We are testing this "safety net" hypothesis in a pecan (*Carya illinoensis*)-cotton (*Gossypium* sp.) alley cropping system in Jay, Florida (30°47'N, 87°13'W; fine-loamy, kaolinitic, thermic Rhodic Kandiudult). The system is delimited into three treatments, achieved through the installation of a polyethylene root barrier in randomly selected plots: barrier (tree roots excluded), nonbarrier (tree roots included) and control (pecan monocrop). Temporal changes in applied fertilizer (inorganic vs. poultry manure) were quantified from 1 m soil cores and from soil water extracted from vacuum lysimeters at 0.3 and 0.9 m depths. Nitrate concentrations in soil under nonbarrier were similar to control, particularly below 15 cm, possibly due to tree root uptake. Monthly nitrate concentrations in soil water decreased at 0.9 m depth early in the season and also varied by rainfall and crop nutrient demand. Soluble reactive phosphorus (SRP) in topsoil after fertilizer application was higher for organic manure than inorganic fertilizer, but was minimal for all soils below 15 cm, indicating adequate P retention. DPS comparisons for 2002 and 2003 indicate that P losses would be greater with organic manure due to its higher P:N ratio. Lastly, nitrate leaching rates below 0.9 m were significantly lower in nonbarrier compared to barrier treatment (16 vs. 44 kg N ha^{-1} yr^{-1}, respectively). This reduced loss of N and possibly P suggests that the tree-crop system would be more effective at containment of these nutrients on-site.

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Carbon Sequestration in Pasture, Agropastoral and Silvopastoral Systems in the American Tropical Forest Ecosystem

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Forest-to-pasture conversion has been the major land-use change in tropical America in the last 50 years. After deforestation and pasture establishment, many pasture areas become degraded due to mismanagement. Improved, well-managed pasture systems (agropastoral, silvopastoral, agrosilvopastoral) play a key environmental role in recovering these areas. Our C-sequestration project aims to demonstrate that improved pasture systems are not only socially and economically attractive to farmers, but also show C accumulation comparable to that of native forests. This paper presents results of the first two years where soil C-stocks (SCS) were evaluated in long-established pasture systems in commercial farms, in 3 sub-ecosystems of the Tropical Forest Ecosystem, and compared with native forest (+control) and degraded soil (-control). A soil sampling design controlling factors affecting SCS (site conditions, slope gradient, land-use system, and soil depth) was used. In Colombia's Andean hillsides, native forest SCS (t/ha/1m) were statistically higher (262 and 214 for space reps 1 and 2) than those of the signalgrass (Brachiaria decumbens) pasture (213, 165) and degraded pasture (183, 171). In contrast, improved Brachiaria pastures (alone and associated with legumes) in the humid tropical forests of Colombia's Amazonia showed statistically higher SCS (167-422) compared with native forest (155). Similar rankings were found with agroforestry systems in Costa Rica's sub-humid tropical forests. Preliminary findings suggest that (1) the soil sampling design is appropriate for estimating SCS with minimum variability; (2) SCS are affected by site altitude/temperature, system's land-use history, soil depth and texture; and (3) improved pasture systems prove attractive for C-sequestration.

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Edaphologic Attributes Related to the Coeso Layer in Brazilian Coastal Tableland Soils under Different Land Uses

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The Atlantic Forest of Brazil has undergone deforestation resulting in various agricultural uses, to the point that only about 8% of the original forest remains. Soil degradation, including loss of soil organic carbon (SOC), has often been associated with deforestation. In extensive areas previously occupied by Atlantic Forest the soil has a naturally compact subsoil horizon called the *coeso*. This layer challenges root development and plant productivity, especially when dry. A variety of agroforestry systems are used on these soils, particularly for cocoa production. The purpose of this study was to investigate the changes that occur in the soil profile when under the influence of the native forest and associated agricultural practices following conversion from native forest. The land uses were a native forest, a rubber tree plantation, a pasture and a farm with annual cropping. These land uses are common in the area, as are their combination in agroforestry systems. Two locations in the soil profile were evaluated: 0 to 15 cm depth (A horizon), and 35 to 50 cm (coeso horizon). Management influenced both the SOC concentrations and bulk densities. The result was that the SOC content was not significantly changed by any of the land uses following harvest of the Atlantic Forest. This supports the type of annual cropping system adapted by small landholders. Interestingly, the amount of SOC found in the coeso was substantial and suggested the potential to sequester SOC in these subsoil horizons. All other soil chemical changes were related to liming and fertilization.

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Three-dimensional Tree Architectural Analysis and Modelling to Study Biophysical Interactions

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Architectural analysis allows us to understand the successive phases of plant development, from seedling to the adult stage, as well as the arrangement of morphological structures in the course of plant ontogenesis. After a qualitative and quantitative analysis with AMAPmod, botanically-correct 3D tree architectural computer models which evolve through time from plantation to the end of the rotation can then be built through the AMAPsim software. To study temperate and tropical agroforestry systems, field-scale biophysical models (WaNuLCAS, HyPar, SAFE) generally describe trees in relatively simple forms. Detailed 3-D AMAPsim mock-ups have been developed to serve as reference descriptors of the use of space by trees of several species in France and in Indonesia. Different plot variables are simulated, with some degree of stochastic variability, which then provide “virtual experiments” to calibrate the simplified modules of field-scale models, which are simpler, less time-consuming and less memory-requiring. Such validations are performed for radiative balance on young Teak (*Tectona grandis*), and for biomass distribution and below-ground processes on hybrid Walnut (*Juglans nigra x regia*). The parameters of the tree modules of field-scale models are currently being improved, based on the present findings. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) and SAFODS (Smallholder AgroForestry Options for Degraded Soils) collaborative research projects, partly funded by the EU: contract number QLF5-CT-2001-00560 and ICA4-CT-2001-10092. The support is gratefully acknowledged.

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Carbon Sequestration in Rural Communities—Is It Worth the Effort?

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Climate change is one of the major global environmental problems. This paper will discuss the possibility of developing agroforestry/forestry projects that can sequester carbon and at the same time provide income to rural communities from the sale of carbon credits. There is now a possibility to develop such projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Carbon sequestration and income generation from forestry/agroforestry projects were studied in Nepal, Uganda, Ethiopia and Tanzania. Carbon sequestration in regrowth of a natural forest in Nepal was 2.6 t C ha^{-1} yr^{-1}considering both soil and biomass carbon. Woodlots and improved fallows of *Sesbania sesban* (L.), *Eucalyptus* and *Alnus* in Uganda sequestered 7-9 t ha^{-1} yr^{-1} in biomass and soil. Net Present Value (NPV) in the different land-use systems was calculated with and without a carbon value (US$10 per ton of C). Adding a carbon value increased NPV by less than 10%. The other benefits from carbon sequestration projects such as timber, fruits and fodder by far outweigh the value of the carbon credit. There are also costs in relation to registration of the project under the CDM, measuring of carbon during project lifetime, and validation. The project will in addition lose flexibility, as CDM projects will have restrictions on changes in land-use. The conclusion is therefore that the price of carbon will need to increase significantly if rural communities are to benefit from carbon sequestration projects.

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Light Intensity Effects on Growth and Nutrient Uptake and Use Efficiency of Erect Leguminous Cover Crops

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In plantation crops such as cacao (*Theobroma cacao*), cover crops have tremendous beneficial influence on improved soil fertility and productivity, reduced erosion and leaching losses, and control of weeds, diseases and pests. Because cover crops are grown as understory plants, light intensity has major implications on the growth, development and survivability of these plants. Information is lacking on the growth performance and nutrient needs of these crops at low light intensities. An experiment was undertaken in a climatically controlled growth room to assess the influence of photosynthetic photon flux density (PPFD) on growth and macro-micro nutrient uptake parameters (concentration, uptake) and nutrient use efficiency in erect leguminous cover crops. Two PPFD levels (200, 400 µmol s^{-1} $m^{-2)}$ were achieved by constructing mini shade frames covered with varying layers of plastic cloth. Nine cover crops used in this study include: joint vetch (*Aeschymomene* sp.), sunhemp (*Crotalaria juncea*), slender leaf rattlebox (*Crotalaria ochroleuca*), showy crotalaria (*Crotalaria spectabilis*), hairy indigo (*Indigofera hirsuta* L.), lablab (*Lablab* sp.), sesbania (*Sesbania* sp.), cowpea (*Vigna* sp.), and tropical stylo-fabaceae. Higher PPFD enhanced the growth and nutrient uptake parameters and nutrient use efficiency. Cover crops used in this study showed interspecific differences in growth, nutrient uptake and nutrient use efficiency at both PPFD levels. Cover crops tested are sensitive to low light intensity. Shade and fertilizer management are very critical in plantation crops to achieve the maximum potential benefits of cover crops.

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Loblolly Pine Growth and Warm/Cool-Season Forage Performance under Thinned Tree Canopies in North Florida

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A mid-rotation thinning is amendable for a pine plantation to silvopasture conversion, provided adequate forage growth conditions are created under thinned canopies. To test this, wood and forage production and forage quality are being quantified in a North Florida study. Eighteen-year-old loblolly pine (*Pinus taeda* L.) stands were thinned from the original 726 trees per acre (TPA) (1 ac = 0.4 ha) and 180 ft^2 (1 ft^2 = 0.09 m^2) of basal area (BA) to: (i) 160 TPA and 60 BA (conventional 5th row thinning), and (ii) 80 TPA and 30 BA, in summer 2002. Two spatial tree configurations resulted from thinning to 80 TPA: (a) paired tree row sets with 50 ft (1 ft = 0.3 m) wide alleys between sets, and (b) "random" tree placement after heavy 4th row thinning. Stands were then prescribed burned, disked and seeded with forages, after weed control with Roundup herbicide. Various warm/cool-season forage combinations are being evaluated under two tree canopy conditions: 'Argentine' bahiagrass (*Paspalum notatum* Fluegge) alone, and with 'Jumbo' ryegrass (*Lolium multiflorum* Lam.) (B x R), B x R with 'Dixie' crimson clover (*Trifolium incarnatum* L.), B x R with 'Cherokee' red clover (*Trifolium pratense* L.), and B x R with both varieties of clovers. An open pasture with the same forage combinations, and the 5th row thinned stand, serve as controls. Tree growth, summer and cool season forage yield, and estimates of laboratory nutritive value, are discussed in relation to tree canopy geometry and intercepted Photosynthetically Active Radiation (PAR).

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Micrometeorological Influence on the Performance of Yam Bean (*Pachyrhizus tuberosus*) as Alley Crop in West Bengal, India

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An investigation was carried out to study the influence of different micrometeorological parameters on the growth and yield of Yam bean under agroforestry, situated in the New Alluvial Zone of West Bengal, India during 2001-2003. Yam bean (Var: RM-1) was grown as an alley crop under different shade tree species. The LAI, transmission coefficient, extinction coefficient, and mean leaf angle of the shade trees were estimated, as these factors influence the micrometeorological parameters underneath. Variations of ambient temperature, soil temperature and PAR under different shade trees were measured and their impact on the yield of Yam bean was worked out. It was observed that the alley crop performs the best under *Albizia lebbeck*, having PAR interception capacity of about 50%, relatively higher than *Gliricidia*, *Casuarina*, *Dalbergia*, *Gmelina* and *Eucalyptus*. Moisture depletion rate from 0 to 60 cm soil-layer was relatively lower in case of *Albizia* than other tree species, which may affect the yield also. Such study can be used as a guideline to introduce new crops as per their micro-environmental requirement, which can be modified through adoption of agroforestry system, in a particular agro-ecological region.

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Separating Tree-soil-crop Interactions in Agroforestry Parkland Systems in Saponé (Burkina Faso) using WaNuLCAS

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Competition and complementarity in resource use between the components of parkland systems need to be better understood and managed to sustain and/or improve the production of these systems. Thus, the effects of crown pruning of *Vitellaria paradoxa* C.F. Gaertn and *Parkia biglobosa* (Jacq.) Benth. on above and belowground interactions with associated crops of *Pennisetum glaucum* (L.) and *Sorghum bicolor* (L.) Moench were investigated in an agroforestry parkland system in Burkina Faso. Three treatments of crown pruning (total-pruning, half-pruning and no-pruning) were applied. Three-year crop production was analyzed in relation to resource capture and utilization. Crop performance did not increase as light supply increased going from the tree trunk to outside the canopy. However, when light supply was increased, by removing the tree crown, crop performance was improved up to eight-fold showing that this factor is the most limiting one. A further exploration of these data with the WaNuLCAS 2.0 model showed that for karité, with a relatively shallow root system, water limitation dominated for 25%-29% of the simulation period whereas water limitation occurred for crop growth under this species during 20%-24% of the simulated time. For the néré the main limitation was P both for trees (16 to 60% of the simulation time) and crops (22 to 51% of the simulated time). The WaNuLCAS model overestimated crop performance but it appeared to be a good tool for efficiently synthesizing experimental information on tree and crop interactions, allowing further separation of the effects of growth factors, compared to classical statistical tools.

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Productivity and Resource Capture in Fruit-Based Agroforestry Systems of Highland Guatemala

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Agroforestry systems based on apple *(Malus*), peach *(Prunus*) and pear *(Pyrus*) are common in northwest Guatemala as low intensity homegardens. This study evaluates the productivity of mixed cropping of fruit trees with annual crops as influenced by biophysical mechanisms. Of the three common deciduous species, pear was selected for the study because of its greater apparent potential as a system component. The on-station experiment included the following: sole crops and additive intercrops of maize (*Zea mays* L.) and fava (*Vicia faba major*), and clean cultivation without crops as understory treatments, and eight-year old pear trees or shade structures resembling tree canopies as overstory treatments. Growth and yields of both annual and perennial components were measured during 2002 and 2003. Tree water use, soil water status, and radiation capture were also assessed daily. Management followed smallholder practices except for improved weed control. Mixed cropping of fruit trees with annuals showed significant advantages (land equivalency ratio and area time equivalency ratio) over maize + fava intercropping, which was superior to sole cropping of the same species. Annual-crop yields were generally unaffected by overstory treatments making fruit yields an additive benefit. Tree height, but not diameter, was increased in the presence of associated species. Associations of pear with fava resulted in improved yields of top-grade pears with no reductions in total mass or sugar content. The results suggest that gains in small farm productivity and fruit quality can be made through careful association of fruit trees with annual crops.

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The Future of Agroforestry: Reconnecting Urban and Rural Communities

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During the past two decades, the developed land in the Kansas City metro area has increased by approximately 37%, more than twice the population growth rate. As experienced world-wide, this pattern of development is fragmenting the landscape, resulting in a plethora of environmental, economic, and social problems. Polluted runoff, habitat loss, visual blight, and lack of accessible markets for agricultural products are just some of the problems created and shared between urban and rural land uses. Agroforestry technologies offer a means to create viable living linkages that can minimize these problems and promote opportunities between rural and urban land uses. The Mid-America Regional Council (MARC), in partnership with the USDA National Agroforestry Center (NAC) and others, has embarked on an initiative to adapt agroforestry technologies into *Working Green Infrastructure* in the Kansas City region. To support the planning process, tools developed by NAC are being used to pull together stakeholders with varied interests and meld concerns and objectives that occur at various scales. GIS-guided assessments, economic evaluations, and visual simulations of agroforestry design alternatives are some of these tools being used in the decision-making process. Through this effort, rural and urban stakeholders are working together to address the region's problems and identify opportunities for cooperative solutions using agroforestry technologies that extend beyond the jurisdiction of a single city, county, or state.

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Equations of Life: Using Biophysical Models to Describe Interactions in Agroforestry

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A brief report of principal equations of biophysical models includes heterogeneous sources but any science of heterogeneity. Agroforestry presents cases of advantageous heterogeneity. What set of equations may predict or represent well this result, limiting the space to the least diverse unit (LDU)? A LDU combines a tree or a fraction of its crown and a fraction of soil left to cultivation by the neighbouring trees. Water and nutrient availability to plants, light use and growth analysis were evaluated and reviewed. Michaelis Menten (Biochem. Z., 49, 33- 1913) equation was developed for quasi-irreversible chemical equilibria in solution but may represent changes in soil permeability and plant water uptake that are modified by plant density and diversity (HilleRisLambers et al., Ecology, 82, 50- 2001). Light use should account diffuse light effects to a sparse tree vegetation and its understory. Photosynthesis increases of 50% when sky is partially overcast by either clouds or trees were estimated (Roderick et al., Oecologia, 129, 21- 2001). This component may add a high value to penumbra and to diffuse light and can be accounted on the basis of incident fluence map variations in 3 hr intervals at crop level. Growth models can include carbon density, photosynthesis and respiration in relative growth rate expression (Masle and Farquhar, Plant Phys., 82, 32-1988) and any change in these variables due to heterogeneity can be a deterministic cause of variation in Chapman and Richards senescence functions (Brack and Wood, Dept. of Forestry site, ANU Canberra, Australia).

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Smallholder Agroforestry Provides Local and Global Benefits in Northern India

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Smallholder agroforestry is an increasingly important alternative land-use system replacing conventional rice/wheat systems on traditional green revolution lands in India. It is estimated that up to one million hectares are currently planted to poplar-based systems (*Populus deltoides*). This represents a significant and fundamental land-use change in the Ganges Basin, with implications for local and basin level hydrologic regimes, and income security for smallholders. These tree-based alternatives to the rice/wheat systems provide options for management of increasingly significant cropping system-induced productivity constraints, including irrigation-induced shallow water tables, secondary salinization, and off-site impacts such as non-point source pollution. Results show that the poplar agroforestry system, properly managed, can increase smallholder income and food security, and allow for profitable utilization of marginal lands, while maintaining or even improving environmental security. Synergistic effects are not only local, but also include global benefits of increased carbon sequestration, biodiversity preservation and enhancement, and ecosystem resilience. In particular, farm forestry in India significantly reduces pressure on the remaining and now protected forests of the highly biodiverse Himalayan foothills. An investigation undertaken in Uttar Pradesh and Haryana states in India sampled 500 sites in four districts, to understand the dynamics, extent and rate of adoption of the poplar-based agroforestry system in terms of incentives provided by biophysical productivity, economic profitability, socio-economic constraints, new opportunities, and major driving factors. This complex of issues is described along a salinity gradient, ranging from fresh groundwater, to moderate salinity, in areas where adoption of the poplar system is prevalent and increasing.

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Enforced Reverse Phenology for Dry Season Productivity in Trees

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Naturally occurring reverse phenology is a well known phenomenon in some tree species, e.g., *Faidherbia albida*. However, reverse phenology can be imposed upon a wider range of tree and shrub species by a regime of pruning. Presence of leaves in the dry season has advantages for agricultural systems that require green material during these periods, such as for livestock production. This paper brings together results from a range of experiments conducted on four tree species (*Prosopis juliflora*, *Acacia nilotica*, *Gliricidia sepium* and *Senna spectabilis*) in Nigeria, Malawi and Kenya, to understand the physiology of enforced maintenance of green leaves in the dry season. It was found that in response to shoot pruning during the wet season, in some species rooting profiles changed in the dry season to enable water extraction to continue, and thus they were able to transpire as effectively as in the wet season. There were indications that different species had different strategies for coping with the imposed stress. It is suggested that tree and shrub species suitable as fodder supplies should be screened for their potential for surviving such a management regime. In some circumstances there may also be scope for using reverse phenology to reduce competition with crops in the wet season, whilst producing mulch in the dry season.

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Diurnal Effects on Nutritive Value of Alley Cropped Orchardgrass Herbage

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Nonstructural carbohydrates, crude protein, and in vitro dry matter digestibility (IVDMD) are important indices of herbage nutritive value and can exhibit diurnal variation in 'conventional' agronomic systems. Our objective was to determine diurnal trends of nutritive value components in alley cropped orchardgrass (*Dactylis glomerata* L.) herbage harvested daily from 1-15 June 2001 and 2002 at three times (0500, 1100, and 1700h, CST), from three environments: unshaded control, loblolly (*Pinus taeda* L.) pine alleys, and shortleaf (*P. echinata* Mill.) pine alleys. Diurnal effects were defined as the presence of a regression response (P<0.10) with time. Total nonstructural carbohydrates (TNC) and water soluble carbohydrates (WSC) increased linearly in the control and shortleaf pine environments, but not in loblolly pine alleys. Starch increased curvilinearly in pine alleys but not in the control environment. In pine-shaded environments, maximum carbohydrates at 1700h were only 64 to 75% of the control. Crude protein and IVDMD did not exhibit diurnal responses within or across environments. However, mean crude protein decreased and IVDMD increased between AM- and PM-harvested herbage. Shaded orchardgrass herbage averaged 27 to 33% more crude protein, 1 to 2% more IVDMD, 28 to 34% less yield, and 27 to 34% less nonstructural carbohydrates than the unshaded control. Differential responses of nutritive value components among environments were attributed to altered amount and temporal distribution of solar irradiance. The study showed that conventional and alley crop environments elicited different temporal responses in orchardgrass herbage.

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Influence of Alley Crop Environment on Orchardgrass and Tall Fescue Herbage

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The design of agroforestry systems requires a thorough understanding of biological interactions that might complement or constrain production. The objective of this study was to examine effects of alley crop environment on persistence, herbage yield, and nutritive value of two shade tolerant herbage grasses. The experiment was conducted for 3 yr in orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), and a 1:1 binary mixture (tall fescue and orchardgrass) in 4.9 m-wide alleys of 10-yr-old loblolly pine (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.), and the unshaded control at Booneville, AR. Loblolly pine was 1.5 m taller and had twice the canopy cover as shortleaf pine (52 and 25% canopy cover, respectively). Averaged across harvests, orchardgrass persisted better in loblolly pine alleys (72% stand) than in the control (44% stand), while tall fescue persisted better in the control (30% stand) than in loblolly pine (13% stand). Persistence in shortleaf pine alleys was intermediate for both herbage treatments. Yields of orchardgrass and the binary mixture did not differ in pine alleys (1300 kg ha^{-1}), and were usually greater than tall fescue yields (<700 kg ha^{-1}). Crude protein was higher in loblolly pine alleys (172 g kg^{-1}) than in the control (141 g kg^{-1}). Producers should consider using orchardgrass monocultures or binary mixtures with tall fescue for pine alleys in the mid-south USA.

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Environmental Services by Agroforestry Systems: A Local Approach

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According to its contemporary importance and global tendencies, agroforestry is examined in our study according to its ability to provide environmental services. In chapter one, the concept is defined in the context of environmental economics, more specifically in the internalization of externalities; the environmental services are defined and derived according to their functions, underlining their economic and environmental potentialities. The article continues with the protocol followed by the theme in global agreements, trends and conflicts, topics considered and transference mechanisms; the idea is completed with basic concepts of agroforestry and its capacities to meet these demands. Chapter two focuses on technical details about synchrony among agroforestry and two key environmental services: biodiversity preservation and carbon sequestration. In the first topic are focused its principal functions (production and preservation), and the more convenient agroforestry practices are detailed according to their comparative advantages in comparison to the orthodox systems. For the second topic, in agreement to its different treatment, is detailed the state of the art of the investigation, the awaiting investigation hypotheses, and some proposals to obtain them: conflictive issues, technological options, technical troubles, pending research, and so on. Finally, chapter three discusses briefly some technical and theoretical topics that should be saved to concrete a real proposal.

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Agroforestry Systems as an Alternative to Pure Forest Plantations for Timber Production on Arable Lands in Italy

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Current interest in agroforestry in Italy relates mostly to the wider general focus on sustainable agriculture for environmental protection. This focus is often in great contrast to the urgent economic needs of rural people. A partial solution to this problem has come through funding from the European Union for sustainable agriculture and afforestation of arable lands. Trees, mostly valuable broadleaved (hardwood) species like walnut, cherry and ash, were planted back into farmland using public funds and with the aim of producing high quality timber, which is in very short supply on the Italian market. More than 100,000 ha of agricultural lands were afforested in Italy during the '90s. A significant proportion of those plantations were unsuccessful due to poor site quality, wrongly chosen tree species and/or poor tree care. Alternative and new cultural models, such as agroforestry and mixed models, were studied for replacing hardwood plantation forestry. These studies are in connection with the Mediterranean tradition of mixed cultural systems, which are now marginal. Researches show that both cultural models have numerous advantages in comparison with traditional forestry plantations. Tree growth and timber quality are often improved due to enhanced tree care, better site quality and synergisms among plant/system components. Technical advantages are augmented by ecological ones, such as improved biodiversity, soil erosion control and reduced fire risk. Farmers' reactions to innovative agroforestry systems have also been studied. Agroforestry can be more effective than pure cultivation for the restoration of degraded agro-ecosystems and for the preservation of rural landscape.

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A Soil Food Web Model of N in a Georgia Alley Cropping System

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A soil community food web model was used to study the short term nitrogen mineralization pattern from green manure and roots in an alley cropping system in the Georgia Piedmont. During one growing season, the N release patterns of *Albizia julibrissin* leaves, prunings and roots, and *Alnus rubra* prunings were monitored. The temporal dynamics of biomass of bacteria, fungi, protozoa, nematodes and microarthropods were also determined. C/N dynamics, initial contents of lignin, cellulose and hemicellulose, and crop plant N uptake rates were estimated. These data were incorporated into a food web model to simulate the dynamics of N mineralization as a response to the interaction between temporal behavior of C/N ratio of organic matter and the biochemical composition of the initial substrate *with the soil populations.* Simulations to study the effect of C/N behavior, initial substrate quality and the size of organisms' biomass pools were performed. *Albizia* leaves and *Albizia* roots treatments showed the highest mineralization rates. Although their mineralization patterns are very similar, *Albizia* roots N release was more gradual and steady. Contribution of Alder to soil mineral nitrogen was significantly lower than that of *Albizia*. Organisms' contributions to mineralization varied through the season. The simulations highlighted the enhanced relative role of fauna and fungi when substrate quality is low. The suitability of the different substrates as soil amendments can be evaluated and explained by a combination of their utilization pattern by bacteria, fungi and fauna and the degree to which their mineralization pattern matched the plant nitrogen demand.

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Evaluation of Mixed Planted-Fallows of Non-Coppicing Tree Species on a Ferric Luvisol in Zambia

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Improved fallows using mono-species of *Sesbania sesban, Tephrosia vogelii* and *Cajanus cajan* (L.) for soil fertility replenishment have been adopted by most small-scale farmers in eastern Zambia. However, these fallows can pose a serious ecological danger in terms of pests. It was also hypothesized that mono-species fallows may not effectively replenish soil fertility for optimum crop growth. Therefore, an experiment was conducted using mono- and mixed-species fallows to test the above hypothesis. A field experiment was conducted at Msekera, Zambia from 1999 to 2002. The treatments were sole *sesbania, tephrosia* and *cajanus*, and mixtures of *sesbania + tephrosia*, *sesbania + cajanus* and *tephrosia + cajanus* and the controls of natural fallow, continuous fertilized and unfertilized maize (*Zea mays* L.). Two maize crops were grown subsequent to the fallows. At the end of two years, mixed fallow of *sesbania + tephrosia* produced the greatest total aboveground biomass which also added more N to soil than mono-species fallows. Higher preseason and wet season nitrate-N was recorded under sole *tephrosia* and *sesbania + cajanus* fallow respectively, in the first post-fallow year. High initial infiltration rates were recorded under mixed fallows compared to mono species fallows after two years of growth. Mixed species fallows produced more maize yields than mono species fallows in both post-fallow seasons. Results show that mixed fallows are more superior to mono species fallows in terms of tree biomass production and soil improvement.

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Electromagnetic Field Influence in Oak Seedlings (A Study in Romania)

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Since electromagnetic radiation represents a ubiquitous environmental factor for the whole biosphere meaning a putative constraint for all plant species including trees, we focused on the influence of electromagnetic waves in trees. Pedunculate oak (*Quercus robur* L.) was chosen as a species widely spread on the planet having significant economic and ecological uses. Young oak seedlings of uniform genotype, aged 3 months, were repeatedly exposed to ultra-high frequency (UHF) electromagnetic waves; then the levels of chlorophyll a, chlorophyll b and carotenoid pigments were measured using an appropriate spectrophotometric device. The most remarkable change was recorded in chlorophyll **a** content as well as in the ratio of chlorophyll a/b where a significant diminution in most of the samples was noticed. Carotene pigments appeared as the less sensitive to the magnetic electromagnetic exposure. The energy level of a UHF photon is approximately a million times lower than the energy required to break a covalent bond, however, biophysical interactions could occur in the tylakoid membranes. We need to consider also the role of light harvesting protein complex of photosynthetic system II (LHC II). Encoded in the nucleus it is known to exhibit remarkable structural flexibility upon changes in the environmental conditions (such as, in the present case, the electromagnetic environmental component). Consequently, the chlorophyll a/b ratio, much dependent upon the LHC II content in the thylakoid membranes, can be affected by microwave exposure, at least during the very early ontogenetic stages of vegetal organisms.

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Model to Describe Light Distribution, Yield and Growth in Agroforestry Systems with Pejibaye (*Bactris gasipaes* H.B.K.)

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Agroforestry systems (AFSs) can give growth and yield advantages compared to sole cropping, due to their soil and environmental protective role, especially in the Amazon where soil fertility is a major constraint. Pejibaye (*Bactris gasipaes* H.B.K.), or peach palm, has been planted in the Amazon under a number of AFSs with success. However, little is known about the biophysical interactions in these systems. The aim of the present study was to identify the effect of radiation on yield of pejibaye and to adapt and to evaluate a mathematical model to estimate the light availability for this crop and its yield and growth under AFSs. A field experiment in randomized block design was conducted in Manaus-AM, Brazil, from March, 1999 to August, 2000, on a clayey Xanthic Ferrasol. Approximately every four months, in every harvest, pejibaye trees were evaluated in terms of total above ground dry matter, fresh weight. The neighbor trees to the pejibaye in the AFSs treatments were assessed in terms of plant height and crown length and width. The relative irradiance (Ir) reaching the pejibaye canopy was estimated using the mathematical model:

$$Ir = ½ * \{ \text{sen} [\text{arctg} ((d_1 – (cw_1^2/d_1))/Hr_1)] + \text{sen} [\text{arctg} ((d_2 – (cw_2^2/d_2))/Hr_2)]\}$$

A linear relation between light availability and growth ($p<0.05$, $r^2=0.76$) or yield of palm heart per pejibaye tree ($p<0.05$, $r^2=0.62$) was observed. The proposed mathematical model generated an accurate estimation of light availability to the growth and yield of the intercrop in the studied AFSs.

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Evaluation of Contour Hedgerows as a Means of Ensuring Sustainability of Tea Yields in the Sloping Highlands of Sri Lanka

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Contour hedgerow intercropping (CHI) is an agroforestry practice introduced to arrest soil fertility decline and sustain tea (*Camellia sinensis*) yields on sloping terrain in central highlands of Sri Lanka. Our objective was to quantify the positive and negative effects of hedgerows and determine their net impact on tea yields and soil fertility parameters. Two on-farm experiments were conducted in the high-elevation (945 m), high rainfall (2500 mm yr^{-1}) zone. Effects of six hedgerows species (*Calliandra calothyrsus, Cassia spectabilis, Euphatorium innulifolium, Flemingia congesta, Gliricidia sepium* and *Tithonia diversifolia*) on the long-term yields of mature tea (i.e., in the second pruning cycle) and young tea (i.e., first pruning cycle) were quantified. Totals of continuous tea yield measurements were analyzed over a three-year pruning cycle from November, 1998 to October, 2001. In both experiments, tea in CHI showed significant yield reductions as compared to sole cropped tea, thus indicating significant resource competition. The only exception to this trend was mature tea under *Euphatorium* hedgerows. Mulching of respective hedgerow prunings significantly increased yields in comparison to unmulched tea. The major soil nutrients (N, P and K) were lower in CHI than in the control. However, the opposite was observed for cation exchange capacity and soil organic matter. Multiple regression analysis showed that variation in soil properties explained 87% (mature) and 98% (young) of the observed tea yield variation. We conclude that incorporation of tree hedges into tea crops has to be done with caution as it could decrease yields due to excessive resource competition.

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Potential of Contour Hedgerow Intercropping for Ensuring Sustainable Annual Crop Production on Sloping Lands in the Upper Mahaweli River Catchment in Sri Lanka

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Soil erosion and loss of fertility is a serious problem in sloping lands of the Upper-Mahaweli River Catchment of Sri Lanka. Contour hedgerow intercropping (CHI) has been proposed as a solution to this problem. Our objective was to quantify tree-crop interactions in CHI and determine whether it is biologically sustainable in this catchment. Contour hedgerows of *Gliricidia sepium* and maize (*Zea mays* L.) were grown in a hedgerow intercropping system on a sloping (35%) land in mid-elevational (479 m), humid (2,000 mm yr^{-1} rainfall) zone. The treatments were two hedgerow intercrops with (H_m) and without (H_o) hedgerow prunings added as mulch and two sole maize crops with (S_m) and without (S_o) mulch. Fertility (F) and Competition (C) effects were estimated as respective yield differences ($S_m - S_o$) and ($S_m - H_o$). Tree-crop interaction (TCI) was estimated as (F – C). All estimations were standardized by yield of S_o. Over a three-year period, cob fresh weights of maize yields increased from 198-383 kg ha^{-1} in 1999 to 1,474-6,328 kg ha^{-1} in 2002. The highest and lowest yields were in S_m and H_o, respectively. F (24-94%) outweighed C (0-67%) in all seasons. Therefore, TCI was positive and ranged from 8% to 27%, showing that CHI was biologically sustainable in this catchment. Hedgerows reduced soil erosion and run-off by 43% and 19%, respectively. Mulching decreased soil nitrogen and potassium depletion and increased soil phosphorus enrichment and pH during cropping season. We conclude that CHI has the potential to ensure sustainable annual crop production in this catchment.

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Silvopastoral System using Black Wattle and Warm-Season Pastures in Southern Brazil: Wood Production and Beef Steer Performance

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A silvopastoral system consisting of black wattle (*Acacia mearnsii*) and perennial warm-season grasses was conducted under subtropical conditions of southern Brazil in Tupanciretã, RS, from October 1995 to May 2003, to evaluate wood production and beef cattle performance under grazing. The experimental design was a completely randomized factorial (tree density and forage species), with two replications. *Eragrostis plana*, *Brachiaria brizantha* cv. Marandu and *Panicum maximum* cv. Gatton were the forage species evaluated during the first four years (1996-99). In December 2000, tree populations were thinned to 50% of the original densities (1666 and 1000 trees/ha). *Panicum maximum* cv. Gatton, *Panicum maximum* cv. Aruana and *Digitaria diversinervis* were the forages used thereafter. Wood volume was determined annually in March. Animal liveweight (LW) gain was evaluated in the spring of 2002 and summer of 2003, totaling 144 grazing days. No arboreal density x forage species interaction was observed, but a significant effect (P<0.05) of arboreal density was found. The highest wood production (166 m³/ha) was obtained at the highest density (1666 trees/ha). Average annual wood volume growth rates were 23.7 and 20.4 m³/ha for 1666 and 1000 trees/ha, respectively. Beef steer liveweight gain was not significantly affected (P>0.05) by forage species or tree density, or by their interaction. Beef gains from *Digitaria diversinervis*, *Panicum maximum* cv. Aruana and *Panicum maximum* cv. Gatton pastures were 248, 228 and 203 kg/ha, respectively. Average daily gains ranged from 0.420 to 0.821 kg/steer/day.

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Hydrodynamics of an Experimental Silvopastoral Field in the Ozark Plateau of Northwestern Arkansas, USA

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Water available for plant growth can be highly variable in karst terrain; thus the establishment of a silvopastoral system is dependent on site hydrology. A 4.25 ha (10.5 acre) field in the Ozark Plateau was monitored between March and September 2002 and 2003 to characterize the hydrology of a young silvopastoral site consisting of separate 1.2 ha (3 acre) zones of Red Oak (*Quercus rubra)*, Eastern Black Walnut (*Juglans nigra* L.), and Pecan (*Carya illinoensis*) with orchardgrass (*Dactylis glomerata)* as the dominant forage crop. Piezometers were installed to monitor water-level fluctuations throughout the vadose zone to the epikarst. Surface microtopography was mapped, wells were geo-referenced, and a GIS database established for hydrologic monitoring. Based on 21 sampling events, the oak zone exhibited the least hydrologic variability, where 16 of 20 wells had a mean water table level (WTL) < 1.0 m beneath the surface and subsurface fluctuations were low to moderate with 14 well ranges varying from 0.02 to 0.7 m. The walnut zone occupies the most hydrologically-challenging tract, where 13 of 18 wells had mean WTLs from 0.5 to 0.9 m below the surface and the range of subsurface fluctuations was the highest in the entire field, varying from 0.1 to 3.2 m. All wells in the pecan zone had a mean WTL > 1.2 m beneath the surface; subsurface fluctuations, for most wells, were high, varying from 1.7 to 3.1 m. Near-surface hydrologic variability impacts the growth and productivity, and ultimate success, of silvopastoral systems in karst landscapes.

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Integrating Tree-crop Dynamic Interactions with the HiSAFE Model

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During the last decade, modest progress was made towards the dynamic modelling of the integration of both competitive and facilitative mechanisms in silvoarable agroforestry systems. While the mechanisms of partial competition for water, light or nutrients are now well described, their interaction in a dynamic system under control by climate hazards and farmer management decisions are not fully understood. HiSAFE was designed by a team of biophysical modellers in Europe, and intends at predicting dynamically the interactions between trees and crops in silvoarable systems. Compared to previous integrated models such as HyPAR or Wanulcas, HiSAFE includes a full 3D approach to modelling the spatial heterogeneity induced by tree-crop competition both above-ground and belowground. HiSAFE includes exclusive features such as a light competition module based on a fully disaggregated tree canopy, a water and nitrogen competition module using a minimisation of energy extraction algorithm, and a dynamic tree root module based on the voxel cellular automata concept. It allows the simulation of many management options including tree root pruning. First validation results will be presented using data from poplar-cereals and walnut–cereal systems. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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A Voxel Cellular Automata for Modelling Opportunistic Tree Root Systems in Agroforestry

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The simplistic representation of the shape and density of tree roots in agroforestry systems was identified as a major weakness of many models. A subtler means of simulation would require that the tree must colonise the most favourable areas of soil, taking account of the influence that neighbouring crops and trees exert on the development of its root system. A universal root growth module is suggested, which combines a degree of genetic control and the local pedo-climatic conditions affecting root growth. This module adopts a 3-D voxel automata approach to modelling the fine roots at the day time-step. Coarse root topology is deduced from the colonisation patterns predicted by the fine root automata. This module allows an easy way of modelling management decisions such as root pruning or various tree-crop distances. The module is incorporated in the HiSAFE model. It aims at providing a realistic tree root growth modelling in a 3-dimensional heterogeneous soil. It should be able to model the opportunistic growth of tree root systems, reacting to local soil conditions for root proliferation, colonisation and death. Split-root container grown trees provided data for a first calibration of the module. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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The Role of Biological Improvement in the Building of an *Atriplex*-based Silvopastoral System in the Senegalese Saline Ecosystems

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Ground secondary salinization is one of the main threats to agroforestry systems and to on-going agricultural productivity. This situation confronts about 25% of the earth's land surface and about one million ha in Senegal. This situation aggravates land partitioning for the increasing population (3% per year). Therefore, one of the next challenges for agroforestry research is to address the sustainable use of saline soils. Mycorrhized halophytes genus could thus be an economical alternative in this regard. Non-inoculated and inoculated saline-stressed *Atriplex lentiformis* plants were respectively monitored during three years in the field and 13 months in jars. In-jar salt concentrations ranged from 0 to 186 g l^{-1}. Results showed that non-inoculated plants had an average survival rate of 7% in salty and fairly acidic soils, while survival (90%), growth, production, leaf persistence, water absorption, and 'keeping back' were improved by mycorrhization. The strong mortality explanation is made complex because the mortality rates are higher upstream (salinity 5-6, pH 5-6) than downstream (salinity 3-4, pH 4-5). The sodium contents were 3-8 times higher in leaves than roots. In a basic controlled environment, 5.7mS.cm^{-1} is a lethal salinity. These results encourage a building of silvopastoral systems based on biologically improved *Atriplex* plants in association with long-lasting herbaceous species on the basic soils in different granulometries.

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Forage Production Under and Adjacent to *Robinia pseudoacacia* in Central Appalachia, West Virginia

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Pasture is the dominant agricultural land use in Appalachia because steep, dissected terrain limits large-scale or mechanized agricultural practices. Management systems compatible with steep terrain could help diversify farm income sources. Silvopastures that incorporate black locust (*Robinia pseudoacacia*) trees into pasture can provide fuel, fence posts, and honey in addition to forage for grazing animals. Our objective was to define the impact of microclimate variation within a black locust silvopasture on forage production within a steep pasture watershed. Harvest plots were superimposed on the forage sward parallel to 12 m spaced tree rows and were harvested for three growing seasons, when trees were 9, 10 and 11 years old. Total yield, botanical composition, and forage quality were determined. Photosynthetically active radiation (PAR), surface soil temperature, soil moisture, and light quality were measured across the site. There were no significant soil moisture gradients among plots. Surface soil temperature was 5°C cooler under trees during dry periods but similar to plots in unshaded conditions during wet periods. For most harvest periods there was no significant difference in total forage yield between plots unshaded during midday compared to plots under tree canopies although the latter received about 20% of the daily PAR of the former. Plots unshaded during midday had substantially more clover than did plots under tree canopies. Data suggest that black locust silvopasture provides income-generating opportunities for steep pastures without compromising traditional forage production.

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Farming Carbon: An Economic Analysis of Its Viability for Rural Landholders in Western Australia Accounting for Environmental Benefits of Reducing Dryland Salinity

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In Western Australia there is increasing recognition of the importance of trees to the long-term environmental health of the landscape. The widespread removal of native trees from the agricultural zone and their replacement with annual crops and pastures is a major cause of dryland salinity in Western Australia. It has been recognised that much of the landscape needs to be replanted to trees in order to prevent salinity. However, for much of the agricultural zone, generating profit from trees is not an option due to low rainfall and lack of suitable tree species. The emerging carbon market may provide a new option for landholders. Potentially, trees could be grown to sequester carbon dioxide from the atmosphere. The carbon stored by the trees is then sold to companies requiring carbon permits. This paper presents a cost-benefit analysis of growing trees to sell carbon credits, for two regions in Western Australia. Environmental benefits of this practice, particularly in relation to reducing groundwater recharge and preventing dryland salinity, are explored. These benefits are accounted for in the economic analysis. The analysis finds that growing trees for carbon can be a profitable alternative for landholders, depending on both carbon price and sequestration rate. For landholders in higher rainfall areas, the minimum carbon price for positive returns is less than in low rainfall areas. However, adoption of this enterprise will depend not only on whether it is profitable but its profitability relative to other landuse options. This concept is explored for the two agricultural regions.

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Use of the “Taungya” Agroforestry System in Guinean Classified Forests

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The Government of Guinea has taken action to improve the vegetative cover of selected national forests located in important watersheds in the Fouta Djallon region, considered the ‘Water Tower of West Africa’. Preceding the introduction of appropriate agroforestry systems which promote protection of natural regeneration of timber and fruit trees, nearly all trees were destroyed at the time of clearing of fallow lands for cultivation. The Taungya agroforestry system adapted in Guinea favors natural vegetative regeneration by maintaining a minimal density of 100 seedlings (of variable thickness) per hectare. This system is less expensive and easier to establish than traditional Taungya regeneration systems, as production of seedlings and reforestation is not required. Selected healthy trees remaining on cleared fields, regardless of their thickness, do not adversely affect agricultural production, and at the same time grow during fallow periods, and are partly harvested at the time of clearing. Biomass surrounding these trees remaining on cleared fields is removed in order to reduce the risk of their mortality during burning. Charcoal is produced from this collected biomass. Long-term environmental impacts such as soil protection and stabilization of the CO_2 cycle are coupled with economic gains like short-term timber, charcoal and firewood production. Additionally, farmers who have tested this agroforestry system in classified forests (as part of their co-management contract between the state and the population), have adopted similar practices on their privately owned lands.

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Sustainable Development in Watershed Areas of Ropar District of Punjab, India

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Under the Integrated Watershed Development Project (IWDP), attempts are being made to judiciously use the land, water, plant and animal resources. The study was conducted to ascertain the people's participation in IWDP and the impact made in Doluwal and Jhandajiki Rao watershed areas, of Ropar district of Punjab State in India. Data was collected from 50 farmers and 30 farm women representing ten villages. The constituted Village Development Committees (VDCs) develop plans and monitor progress of the works of a micro watershed. Eighty-six percent of respondents revealed that in the VDCs, women stakeholders participated effectively compared to other rural institutions. Of the total respondents, 67.5% practice mixed farming with agroforestry and dairying. For soil and water conservation, measures like vegetative barriers, terracing, earthen dams and water-harvesting structures have been constructed. For regenerating the depleted forest cover and promotion of agroforestry, trees of *Populus ciliata*, *Phyllanthus emblica*, *Eucalyptus hybrida*, *Tectona grandis*, *Acacia arabica*, etc., have been planted. For capacity building various trainings were organized. Adoption of learnt dairy technologies led to more milk production. In Chikna village, urea molasses mineral blocks as feed for dairy animals are being manufactured at commercial scale. The gain in knowledge and skills of the beneficiaries influenced them to actively participate in the activities. As IWDP is in operation until 2005, to ensure continuing holistic sustainable development in areas where topography is irregular, water is scarce and job opportunities are less—various development agencies should start planning to link up the existing VDCs with other institutions.

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Root Competition for Phosphorus between Coconut Palms and Interplanted Dicot Trees Along a Soil Fertility Gradient

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Asymmetric competition is an intrinsic feature of mixed species systems, where plant traits and resource availability are crucial. Yet, competition for belowground resources between woody perennials in mixed species systems (e.g. homegardens), has been seldom studied. We tested the hypothesis that root competition in multispecies tree-based systems depend on tree traits rather than resource availability. Three dicot trees (*Ailanthus triphysa*, *Grevillea robusta* and *Vateria indica*) were interplanted in a 14 year-old coconut (*Cocos nucifera*) plantation (palm+one dicot tree in single or double hedge), on an experimental N-P gradient (high, medium and low fertility). High and medium fertility blocks received N, P_2O_5, K_2O, organic manure and lime at 0.5, 0.32, 1.2, 25 and 1 or 0.34, 0.17, 0.68, 15 and 0.5 kg palm^{-1}, while the low fertility block received none. At eight years after interplanting, the nature and extent of root interactions between coconut and interplanted trees were studied by ^{32}P soil injection. Despite significant variations in soil fertility along the gradient and tree traits, differences in foliar recovery of ^{32}P by palms were not significant. Presence/absence of dicot trees also did not affect it, signifying non-competitive nature of the interplanted trees for P. Interplanted trees (root spread: 163-to-469cm), however, absorbed considerable radio-label. Although differences among competing tree species in resource acquisition are probable, after canopy closure, such differences vanish and the positive feedback between growth and nutrient cycling stimulate complementary interactions. Interplanted trees presumably absorb nutrients that the main crop is incapable of utilizing, thus increasing nutrient use efficiency.

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Alley Cropping as a New Land Use Form for Post-Mining Landscapes

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In the temperate zone Agroforestry systems come into focus increasingly as they integrate the production of woody biomass for energy transformation purposes, crop production and the societal requirement for multifunctional landscape utilization. Post-industrial landscapes provide a considerable areal potential to establish agroforestry systems. To test the suitability of agroforestry systems for the reclamation of post-mining landscapes under Central European conditions, an alley cropping system was established on sandy quaternary overburden sediments. Four different tree species or clones were planted in rows (*Robinia pseudoacacia* L., *Salix viminalis* L., and two clones of *Populus maximowiczii* Henry x *Populus trichocarpa* Torr. et Gray). Between the tree rows, arable crops such as *Medicago sativa* L. were grown. Overburden sediments were marked by high pH values, the virtual absence of soil organic matter, an extremely low nutrient availability and a low water holding capacity. Among the tested tree species and clones *Robinia* showed the largest biomass accumulation (approx. 6 t ha^{-1} yr^{-2}). The annual yield of *Medicago* test area was comparable to the regional level (20-30 t ha^{-1}) of this crop grown on undisturbed substrate. Investigations of above- and below-ground interactions between tree (*Robinia*) and arable crop (*Medicago*) gave no indication for a negative competition between both species. Accumulated yield of the alley cropping test system was similar to that of other land use systems. Thus, alley cropping is supposed to be an alternative production practice for the reclamation of post-mining landscapes.

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Windbreaks and Risk Reduction from Spray Drift and Transgenic Pollen Movement in USA

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Windbreaks provide many benefits to agriculture and the environment including erosion control, yield enhancement and reduction (up to 90%+) in pesticide spray drift. The effects of spray drift and transgenic pollen on off-site habitats has become a critical aspect of risk management for agriculturists. Spray adjuvants, buffer zones, and windbreaks as well as application technology are all important tools for the management of spray drift. Research at Ohio has summarized world literature on windbreaks and spray drift reduction and demonstrated differences in spray capture between conifers at 3-4 fold greater than broad leaf species. Mixed vegetation buffers also create greater capture of spray drift. Pollen movement is also dependent upon pollen size, winds, turbulence and buffer vegetation macrostructure. A pollen dispersion model amplifies the potential usefulness of windbreaks to modify pollen movement. Measurement of windbreak porosity continues to be a serious constraint to characterizing windbreak barriers to modify movement of spray drift into vulnerable environments. Recent data on optical porosity (quantum sensor) suggests optical porosity is related to drift reduction by various barriers but is modified by wind speeds and turbulence. The potential for a low cost optical porosity sensor to easily characterize and predict barrier usefulness in reduction of spray drift/pollen movement is significant but must be integrated with drift mitigation nozzles/techniques in order to be fully optimized. This potential for an integrated drift mitigation strategy with the use of windbreaks remains underutilized in the United States.

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Changes in Belowground Carbon Stocks during the Rotation "Tree Improved Fallow – Crops" in the Dry Tropics of Cameroon

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Belowground C stocks in the 0-20 cm soil layer were evaluated in a tree fallow/crop rotation on an alfisol in Northern Cameroon (1050 mm annual rainfall). Belowground C was separated into soil C (SOM of 0-2 mm size) and root C. Three separated fallow systems planted with Acacia polyacantha (N2 fixing species), Senna siamea and Eucalyptus camaldulensis were compared to a spontaneous herbaceous fallow. The fallow period lasted 5 years and was followed by maize (Zea mays L.) cultivation. After 5 years of fallow, the root C (1 t ha-1 under the herbaceous fallow to 8.7 t ha-1 under A. polyacantha), was the main contributor to the increases in belowground C stocks and the only significant increase of the soil C occurred in the A. polyacantha fallow (+ 2.5 t ha-1, + 28%), mainly due to particulate macro-organic matter (50 to 2000 µm size fraction). After tree logging, slash and burn, the roots of the fallow vegetation decomposed rapidly within the first two years of cropping, mainly through macrofauna activities, especially termites. By contrast, soil C stocks showed little changes during this period. Only the A. polyacantha fallow resulted in a net increase in maize grain production over two seasons, in relation to greater soil N availability than in the other fallows. In leguminous tree fallow systems, low C sequestration in SOM may be associated with high root mass and fast C turn-over linked with increased nutrient flows and storage, which results in maintaining crop production in the long term.

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Nitrogen Dynamics and Nitrate Water Contamination in a *Coffea arabica - Eucalyptus deglupta* Agroforestry System in Southern Costa Rica

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The study was carried out from April 2002 until March 2003, in an Ultisol in the low wet Pacific southern zone of Costa Rica (600 masl and 2700 mm annual rainfall). We evaluated the effect of Eucalyptus deglupta, introduced as a shade timber tree in Coffea arabica plantations, on N loss from the system through leaching, run-off, emissions of N2O and coffee harvest. Coffee plots in full sun and under E. deglupta shade received 180 kg N ha-1 as chemical fertilizer. Mineral N losses in surface runoff and N2O emissions were very low (less than 5 kg N ha-1 per year). N export in coffee harvest were 34 and 25 kg ha-1 in full sun and shaded coffee, respectively. Lysimeters located at 0.6, 1.2 and 2 m below the soil surface in full sun coffee, detected mean NO3--N concentrations of 16.5, 9.2 and 2.3 mgl-1 respectively. For the same depths in shaded coffee, mean NO3--N concentrations were 12.6, 6.1 and 1.2 mgl-1 respectively. NO3--N concentrations in soil solution at 2 m soil depth and in spring water were close. Nitrate lixiviation estimated at 2m depth, was about 22 and 12 kg N ha-1 in full sun and shaded coffee, respectively. The strong decrease in NO3--N concentrations with depth and the low N leaching were mainly attributed to nitrate adsorption in soil layers below 80 cm depth. This process might be more common than formerly thought. Nevertheless, the sustainability of this process is not presently known.

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Accelerated Agroforestry Rotations for Salinity Prevention and Control in Western Australia

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The salinization of land and water resources is a major environmental problem in Australia, with up to 17 Mha of farmland likely to be affected. This hydrologic imbalance has been caused by the replacement of deep-rooted natural vegetation by shallow-rooted agricultural plants, and reforestation is thus required. The hydrologic effects of trees in these dryland-farming systems are often localized, and belts of trees can compete with crops. Another approach is to insert short rotations (3-5 years) of trees into existing agricultural systems on a 20-25 year cycle. The premise is that the trees will rapidly de-water soil profiles to several metres depth and thus create a buffer of dry soil, with this being refilled during the subsequent agricultural phase. Following modelling which suggested that the system would work in deep (>20 m) soil profiles, but not areas with free water tables, we examined 15 existing *Eucalypt* plantings across south-western Australia There was evidence of soil water depletion to 10 m depth after 7 years across a range of soil conditions. In a field experiment (400 mm annual rainfall) we manipulated species, planting density and fertility to accelerate the rate of water depletion, and hence rotation length. Soil water beneath *E. occidentalis* planted at 4000 trees ha^{-1} was depleted to 4 m depth after only 2 years. This paper discusses these results, and the technical and economic issues that need resolution before extension of this agroforestry system.

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Fusing Regional Soil and Climatic Data with Pedotransfer Functions to Estimate Wood Production, Carbon Sequestration and Recharge Reduction

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There is strong interest in encouraging the reforestation of dryland (rainfall 300-600 mm/year) farms in southern Australia to protect soil, water supplies and biodiversity from the onset of salinity, caused by landscape hydrologic imbalance. Up to 17 Mha of land may be affected by 2050. A particular challenge is to identify profitable products from agroforestry systems, so that they are rapidly implemented by private rather than public investment. Apart from wood and bioenergy there is interest in marketing non-wood environmental products such as sequestered carbon and reductions in recharge to groundwaters.

Prior to developing markets for these products it is necessary to determine their distribution with respect to existing infrastructure. For a 24 Mha area in south-western Australia, we combined regional scale (1:100,000) soil-landscape mapping, pedotransfer functions describing tree survival and growth and groundwater recharge and existing land tenure data. This analysis indicated broad areas where agroforestry was either unlikely to succeed, or was not required. For those areas suitable for agroforestry, pedotransfer functions were combined with climatic data to estimate risk, total yields and spatial distribution of wood, carbon sequestration and recharge reduction. This approach provided an estimate of where investment in wood and environmental products will be most profitable and may be applicable for other areas with extensive land use.

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Tree Foliage Polyphenolics and Nitrogen Use in Crop-livestock Systems of southern Africa: Strategies for Increasing Efficiency

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Integrated livestock and crop production systems predominate the agricultural systems of southern Africa. Integration with trees for increased system productivity and resilience in these drought-prone areas has, of late, gained more importance in the research and development agendas of the region. The trees are potential sources of locally available, low cost nutrients, especially N. Polyphenols, found in most of the priority species, have been shown to influence N use efficiency in the soil-crop-animal continuum. Foliage from exotic and indigenous trees and shrubs has been evaluated for its ability to improve the rumen ecosystem function and, subsequently, increase feed intake and animal productivity. While the effects of tannins on forage intake were variable, their influence on rate and extent of protein degradability in the rumen and digestibility post-rumen was clear, tannin level being negatively correlated with these parameters. In the soil, rates and extent of foliage N mineralisation and subsequent plant growth is affected by polyphenols, the effects varying with type of soil, tree species and method and level of foliage application. The type of polyphenols affects these interactions but the mechanism is not fully understood. Foliage harvesting, preservation and feeding/application techniques and strategies that increase N use efficiency have been evaluated in both the crop and ruminant systems. This paper synthesizes research on the effects of polyphenols on N use by crops and ruminant livestock, highlights similarities and differences between the two systems, and discusses the underlying principles of strategies that are available to farmers to improve N use efficiency.

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Agroforestry Systems for the Restoration of Ecological and Economic Functions of Marginal Lands in Western Europe

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In the industrialised countries the demand for production and use of woody biomass for energy transformation purposes has significantly grown throughout the last decade. Especially in rural areas the production of solid biofuels may provide a stable source for a decentralised generation of heat and electric power. To reach this aim, it is claimed that the total area dedicated to bioenergy production has to be extended and that alternative land use systems are needed which are supposed to integrate social, economic and ecological requirements of the local population. To test the suitability of agroforestry systems for this purpose under central European conditions, an alley-cropping system was established on quartanary mine spoils. Four different tree species and clones, respectively, were planted (Black Locust, Willow, and two poplar clones *Androscoggin* and *Hybride* 275) in a randomised block design. Three and six years after planting, pruning was carried out for each tree species on a selected number of plots. Different crops were tested on the inter-croppings. The productivity and nutrient status of treatments were monitored on an annual basis. The root distribution at the hedgerow/intercropping interface was investigated to look for effects of either competition or synergism between root systems of crops and trees and possible impacts on the productivity of both. In addition, the soil chemical status and the formation of soil organic matter were studied periodically to investigate the influence of different (N-fixing) tree species and crops on the development of soil ecological functions in the initial state of soil formation.

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Temporal Changes in Carbon and Nitrogen in Cacao (*Theobroma cacao* Linn.) Multistrata Agroforestry Systems: A Chronosequence of Pools and Fluxes

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The conversion of forests to agroecosystems produces many biological and chemical process changes. Agroforestry, a tree-based agroecosystem, has shown promise with respect to enhanced system nutrient accumulation after land conversion as compared to sole cropping systems. Previous research on tropical agroforestry systems has revealed increases in soil organic matter and total organic nitrogen in the short term. However, research is lacking on long-term system level sustainability in terms of nutrient cycles and storage, specifically in traditional multi-strata agroforestry systems. This study, conducted in Ghana, West Africa, focused on carbon and nitrogen dynamics in a twenty-five year chronosequence of cacao (*Theobroma cacao* Linn.) plantations. Three treatments, 2, 15 and 25-year-old plantations were selected as on-farm research sites. Soil carbon varied between treatments (2 years: 22.6 Mg C·ha^{-1}; 15 years: 17.6 Mg C·ha^{-1}; 25 years: 18.2 Mg C·ha^{-1}) with a significant difference between the 2 and 15 and the 2 and 25-year-old treatments (p<0.05). Total soil nitrogen in the top 15 cm varied between 1.09 Mg N·ha^{-1} and 1.25 Mg N·ha^{-1} but no significant differences between treatments was found. Nitrification rates, litter fall, and root quantity increased significantly with treatment age. However, Photosynthetically Active Radiation and soil temperature showed a significant decrease with age. No difference was found between decay rates of litter at each treatment age. Results suggest that by 25 years, system sequestrations rates were 3 Mg C·ha^{-1}·yr^{-1} and system-level attributes progress towards those of a natural system.

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Runoff, Sediment and Nutrient Losses as Affected by Alley Cropping in North Alabama, USA

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Alley cropping was tested as an alternative to conventional pipe-outlet terraces for soil and water conservation on a 6.5% slope in Cullman, Alabama. Alley cropping treatments with hedgerows of Mimosa (*Albizia julibrissin*), Blackberry (*Rubus ursinus*) and Switchgrass (*Panicum virgatum*), were compared to conventional pipe-outlet terraces and a no-barrier control in a rotation of Sweet corn (*Zea mays*) – Rye (*Secale cereale*) –Cowpea (*Vigna unguiculata* (L.) Walp.) from Summer 2002 to Summer 2003. One replicate consisted of plots measuring 0.05 ha, each of which was instrumented for measuring and sampling runoff and sediment. Three replicates consisted of plots measuring 0.02 ha for yield determinations. Hedgerows and terraces were established in April-May 2002. Runoff and sediment data were collected over the fall 2002, winter, spring and summer 2003 and analyzed for nutrients. Mimosa was pruned in July 2003 and pruning left on the field. During fall, total runoff and sediment yield were highest with mimosa, followed by control, switchgrass and terrace. No data were available on blackberry plots. Between January and August 2003, runoff decreased in the order: control>mimosa>blackberry>switchgrass>terrace. Sediment yield was highest with Blackberry followed by control, mimosa, switchgrass and terrace. Total P yield was highest in mimosa and control, followed by terrace and switchgrass during fall; during spring-summer the order was: blackberry>control>mimosa=terrace=switchgrass. Highest nitrate yield was in control and mimosa followed by switchgrass and terrace during fall and control>mimosa>blackberry>switchgrass=terrace during spring-summer. Terrace and switchgrass appear to be the most effective in limiting sediment and nutrient losses followed by mimosa.

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Carbon Sequestration in Woody Biomass of Fallows in Soudanian Zone of Senegal

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In traditional land-use systems of Tropical Africa, the maintenance of soil fertility was based on rotations of cultivation and fallow phases. The fallow phase allowed the increase of soil fertility due to a return to shrubby or arborescent savanna. In soudanian zone of Senegal, farmers do not take out trees stumps during the cultivation phase. Fallows thus allow a rapid production of a significant amount of biomass and play an essential role in agrosystem carbon dynamics. The aim of this study is to estimate carbon stocks in woody biomass of various ages of fallows, and to follow their dynamics in a sustainable agrosystem production perspective. The study of carbon pools in tree compartments (leaves, branches and stems) provides an understanding of carbon dynamics. The evolution of total biomass carbon in fallows shows a rapid increase in the first years to reach 25 tons of Carbon per hectare in 7 years. After 7 years, growth slows until reaching a high level between 20 and 25 years (approximately 35 tons ha^{-1}). Carbon dynamics are different according to the tree compartments considered. A share of root carbon is recycled with the decomposition of dead roots. Carbon in leaves and branches takes part in litter composition. In the absence of fire and wood cutting (human action), stem carbon improves until the clearing. During the clearings, all above-ground carbon is lost by the system (firewood, burning). Stump carbon is the most stable pool in terms of dynamics during the phases of cultivation and fallow.

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Hedgerow Pruning Effects on Alley Cropped Maize: Light Interception, Water Relations, and Yield

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Competition between year-old mimosa (*Albizia julibrissin*) hedgerows and maize (*Zea mays*) was assessed under alley cropping in Shorter, AL. Treatments consisted of presence or absence of pruning at 30, 30+60 or 30+90 days after planting (DAP) and at two heights (5 cm and 50 cm). To minimize competition for nutrients, 189 kg N ha^{-1}, 9 kg P ha^{-1}, and 73 kg K ha^{-1} were applied. Water status in plant and soil were assessed using a porometer and time domain reflectometry (TDR), respectively. Reduction in photosynthetically active radiation (PAR) was assessed periodically. Rainfall was abundant throughout the season and there was no significant difference in soil water content among treatments. Significant treatment and row differences in stomatal conductance (SCD) and transpiration (TR) for maize leaves were observed only after the 3rd pruning. Rows close to trees had high SCD and TR, which suggest water loss that might reduce final yields. Light interception was lower in rows nearest to hedgerows than in adjacent rows especially at the 2nd pruning (silk stage). Pruning increased light interception, maize grain and stover yields compared to unpruned plots. There were no significant differences in grain yield among pruning treatments. Rows next to hedgerow had 24% lower yield than did adjacent rows. Interaction of treatment by row was not significant. It appears that in this season, competition for light was more important than competition for other factors.

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Above and Below Ground Interactions in Morus-Wheat Based Traditional Agroforestry System in Western Himalayas of India

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Above and below ground interactions of morus (*Morus alba*) and wheat (*Triticum aestivum*) were investigated by selecting a single scattered tree on the farmland. Wheat crop was evaluated for its growth and yield performance in rainfed conditions by laying out sample plots at 1 m, 2 m, 4 m, 6 m and 8 m distance towards the outer canopy of the tree. To quantify the resource use characteristics viz., water, nutrient and light, observations were recorded for soil moisture, soil temperature, nutrient content, relative illumination and beneath-canopy temperature at sowing, tillering, panicle initiation, milking and harvesting stages of wheat. Growth and yield of wheat crop was negatively influenced below the tree crown while it increased with increase in distance from the tree trunk. Soil moisture, soil nutrients, soil temperature and beneath-canopy temperature were reduced considerably at 1m and 2m distance during all the growth stages of wheat. Apart from this, nutrient concentration at panicle initiation and harvesting in wheat were also severely affected below the tree crown due to nutrient stress in the soil. Further, morus did not pose any competition to wheat for light at sowing and tillering. However, at panicle initiation, milking and harvesting of wheat light was reduced considerably below morus. Thus overall, competition for moisture, nutrients and light were the major contributing factors toward the reduction of growth and yield of wheat.

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Selection of *Irvingia gabonensis* Strains for Production and Service Functions in the Congo Basin

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Agroforestry is now recognized as a dynamic sustainable land-management system that can provide ecological, economic, and social benefits. In the Congo basin, *Irvingia gabonensis* has become a highly valued agroforestry species. This tree provides both a source of food, medicine and timber (i.e., products), and a means of increasing C sequestration, limiting soil erosion, and protecting surface and ground waters (i.e., services). Progeny genetic tests were established in nurseries in three different countries of the Congo basin (Cameroon, Gabon and the Democratic Republic of the Congo) in order to select the best strains for increased bio-fixation of C. This parameter was assessed indirectly by biomass production. Growth measurements of the progeny (e.g., height, root collar diameter, volume and dry biomass) were evaluated to provide an estimation of the breeding value of the parental stock. This information will aid the selection of individuals for use in future genetic improvement programs in the Congo basin. Estimation of variance components and heritability were also assessed. The potential use of this species in agroforestry systems for production and services will be discussed.

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Carbon Sequestration by Citrus-based Agroforestry Systems in Veracruz, Mexico

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In the citrus (*Citrus* sp.) production zone of Veracruz, Mexico, we compared the carbon-sequestering ability of three strata drains (trees, shrubs and litter), in the most important agroforesty systems: Citrus+banana (Ci+B), Citrus+coffee (Ci+Cf), Citrus+coffee+banana (Ci+Cf+B), Citrus+goat (Ci+G), Citrus+covering (Ci+Co), and the control Pasture (P). Capture of more arboreal carbon was seen in the Ci+G system with 73.38 t C ha^{-1} and the least in the P system with 0.0, with no statistical difference ($p<0.05$) among the other four systems. For the herbaceous drain, the difference favors the parameter P ($p<0.05$) that concentrates its production on the herbaceous stratum, and in the case of the litter, it is superior in the treatments Ci+B and Ci+G ($p<0.05$) for the residual foliage. An adjustment of 99% exists between the sum of all drains and the arboreal one; and according to that, the contributions of inferior drains (with the exception of the control P) oscillated between 2 and 5%. The carbon stocks did not vary significantly in the evaluated land-use-systems; the stratum in which we should concentrate is the arboreal one (specifically *Citrus* sp.), for its higher contribution, dynamic of variation and feasibility for anthropogenic administration. The considerations to understand Agroforestry Systems like drains should be reformulated in the framework of LULUCF (Land use, land-use change and forestry), particularly in the topics, through: establishment of base-lines, dynamics of accumulation, and management and monitoring of activities (frequency and intensity).

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Using 3D Architectural Models for Evaluation of Smallholder Coconut-based Agroforestry Systems

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The association of various food and cash crops with coconut is a key issue for the sustainability of coconut-based agroforestry systems in the humid tropics. Crops can be associated at various coconut development stages, but the effects of above-ground competition for light and below-ground competition for water and nutrients throughout the coconut cycle, which lasts several decades, must be taken into full consideration to optimise such associations. New modelling tools are used here to simulate light distribution under coconut stands and root-free soil volume for food and cash crops. Modelling of light transmission through coconut stands is based on three-dimensional coconut models and a numerical light model which simulates the shade cast by these 3D models on underlying crops. This approach was validated in Vanuatu on standard coconut plantations against in situ hemispherical photographs and was extended to evaluate smallholder situations. Root-free soil volume is assessed with a 3D coconut root system model. The light quantity and distribution as well as root-free soil volumes available for food and cash crops were analyzed for 6, 20 and 40 year old coconut trees in smallholder plantations. The possibility of using open places created as a result of coconut mortality was then assessed for different planting patterns and tree densities. Realistic predictions were achieved using a very simple data collection strategy. This approach is useful for drawing up recommendations about tree patterns and planting densities as well as associated crop management in most sunlit areas with minimal root competition.

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Carbon Sequestration of Agroforestry Systems in Southeast Asia: Potentials for the Clean Development Mechanism (CDM)

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Agroforestry systems offer a great potential for carbon sequestration in Southeast Asia. The first part of the paper reviews the potential of agroforestry systems in the region to sequester carbon, including recent research results by the author. Carbon stocks and rate of sequestration of agroforestry systems in the Philippines, Indonesia, Thailand, Malaysia, and East Timor are presented. These include among others, alley cropping, various multistory systems and improved fallow. Data is presented on the various carbon pools: aboveground, belowground, necromass and soil carbon. In general, agroforestry systems have ≤ 50% of the carbon stocks of natural tropical forests. However, they have much higher carbon stocks than grasslands and shifting cultivation farms (with annual crops). The potential benefits of agroforestry systems as an option under the Clean Development Mechanism (CDM) are analyzed. In addition, the environmental and socio-economic threats posed by using agroforestry in the CDM are discussed. Finally, research directions are suggested to enhance the use of agroforestry systems for carbon sequestration.

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Policy Support for Agroforestry in the European Union

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Agroforestry is a traditional land use in many parts of the European Union. In some places, for example the silvopastoral Dehasa or Montado systems of Iberia, it continues to thrive. In others, such as the poplar silvoarable systems in Italy's Po Valley, it is no longer profitable. However farm profitability in the EU is dictated by levels of Government support. Both silvoarable and silvopastoral systems have significant potential to enhance rural landscapes and livelihoods in the EU, but new plantations are discouraged by the way in which agricultural and forestry regulations are interpreted by Member States. This paper focuses on common impediments to agroforestry: a) separation of rural planning and support between agriculture and forestry departments; b) exaggerated reduction of agricultural area payments if trees are present in a field; c) non-payment of income-support grants for plantations when only part of cropped area is tree-covered; d) large pro-rata reductions in tree planting grants when the cost per tree for agroforestry is, in fact, higher than for conventional plantations; e) ineligibility of agroforestry for most 'agri-environmental' payments; e) permanent classification of agroforests as 'forest' land for tax and planning purposes. Despite these impediments, EU regulations (e.g. 1257/99) are extremely flexible and allow scope for 'subsidiarity' of interpretation in different countries and regions. This paper identifies different approaches to agroforestry in the four component parts of the United Kingdom, and in five other European countries, and contrasts these to the more constructive interpretation now adopted in France (Liagre et al., this meeting).

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Carbon Sequestration in Soils under Agroforestry

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Carbon sequestration in soils is an important topic with regard to discussions about mitigation of the anthropogenic greenhouse effect. This paper examines the potential of agroforestry systems to increase carbon stocks in soils and to contribute to carbon sequestration or carbon trading. A survey of the carbon stocks in agroforestry systems suggests that carbon content in soil can be significantly increased by trees in rotation or in spatial combination with crops. However, carbon increases in response to an introduction of agroforestry are low in comparison to carbon losses upon land use conversion from primary vegetation to agriculture and occur in the labile organic matter fractions. While labile carbon pools are valuable for nutrient release, they are not likely to lead to significant long-term sequestration, as they are mineralized relatively rapidly. These arguments seem to make agroforestry inappropriate as a means for carbon sequestration under the current management techniques. New techniques have to be developed which lead to the stabilization of added organic matter without decreasing nutrient availability. Charring techniques recently proposed as an alternative to slash-and-burn, conversion of low-nutrient containing organic matter such as branches which can not be sold or used as fire-wood to charcoal provide stable organic matter to soil and may additionally act to stabilize labile organic matter added to soil through agroforestry. We will examine the evidence for this management practice and consider the implications for greenhouse gas emissions.

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Developing New Tools for the Management of Tropical Associated Crops: Contribution of Satellite Very High Resolution Mapping for Coffee Plantations Assessment in Uganda

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Recent access to sub-metric resolution data on which individual trees can be identified provides new opportunities in agroforestry management. Newly developed mapping methodology adapted to this new technology, and its relevance to extract information on crop conditions, are presented in the context of coffee plantations. Quickbird image (0.65m/pixel) was acquired in November 2002 near Mukono in Uganda (0°30'N-32°48'E), where coffee is largely cropped at different scales in complex associations (under shade, intercropped with banana, overlaying life-support crops…). Characteristic vegetation cover patterns were recognised by photo-interpretation based on field knowledge, some of those corresponding to replications of given spatial distributions of trees. A classification by maximum likelihood was then performed on the height textural indexes derived out of the cooccurrence matrix of the image, for different sizes of neighbourhood. Representative classes correspond to ten different structures of tree crops including coffee (banana, eucalyptus…) and six "flat" surfaces (grass, vegetables, soil…). A map of the different types of agricultural systems was then produced, helping the detection of orchards and especially of well developed coffee crops. An industrial coffee farm growing under shading trees can clearly be identified, which intra-plot analysis provides information on the crop organisation: shade amount and spatial distribution, coffee trees density, missing trees localisation, or even coffee foliage development. This product could then provide information related to the farm production, especially if integrated in a Geographic Information System. Very high resolution imagery thus provides new relevant tools for coffee farm management even under the agroforestry system.

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Understanding the Spatial Structure of Agroforestry Systems using Very High Resolution Remote Sensing: An Application to Coconut-based Systems in Melanesia

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Quickbird provides the highest spatial resolution images currently available via satellite, with metric precision that allows detection of individual large trees and analysis of the intra-plot organisation of complex mixed woody plantations. This was a preliminary study aimed at developing mapping tools to help characterise Melanesian coconut-based agroforestry systems, using both field and remote sensing data. Quickbird data were acquired in January 2003 over 64 km^2 on Malo island in the Vanuatu Archipelago (15.4°S-167.1°E). Pan-sharpening of the multispectral data was done by applying a Brovey transform to produce an image with 0.65 m/pixel resolution in the four spectral bands. Coconut trees are clearly distinguishable on these images thanks to their specific "star" shape in the canopy, but no spectral signature could be assigned to this or any other species. An unsupervised classification was then performed with 64 classes defined by a K-means analysis, thus enabling preliminary deciphering of coconut population density, canopy development, undercover type and density, and shadow distribution. It is concluded that the spatial distribution of the different vegetation classes could be an indicator of the type of plantation system. Landscape classification was thus performed, comparing the histogram of each pixel neighbourhood with those of reference landscapes pre-selected by photo-interpretation based on field knowledge. Five different coconut-based systems, corresponding mainly to different levels of canopy closure, could be recognised and mapped automatically with satisfactory reliability. Very high resolution remote sensing could thus be an effective tool to map coconut-based agroforestry systems and also to analyse their intra-plot structure.

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Sustainable Forest Management: Stakeholder Approach to Strategic Forest Management Planning in Chobe Forest Reserve, Botswana

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The goal of this study is to explore the feasibility of incorporating stakeholders' preferences in Chobe Forest Reserve management planning. Research on the preferences of stakeholders over forest management provides an opportunity to develop a focused insight into issues that arise with participatory programs. The method focuses on the quantification of the human opinion, preferences and perceptions, which are investigated after research on local population of Chobe Enclave. Both quantitative and qualitative information will be collected using participatory methods and formal surveys. Application of decision making analysis tools, specifically Analytic Hierarchy Process will be used to analyze stakeholders' preferences. By applying this approach, valuable information can be obtained about public values and their effects on the choice of management strategies/options as well as about possibilities to attain a compromise between conflicting interests. More detailed knowledge of stakeholder preferences (or wants) may permit the Forestry Section to resolve conflicts in a more efficient and systematic manner. Tradeoffs between different management alternatives will be evaluated and that could be useful in guiding policy makers in designing future forest management strategies.

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WOCAT as a Tool for the Assessment and Evaluation of Soil and Water Conservation Practices

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The World Overview of Soil and Water Conservation Approaches and Technologies (WOCAT) program, which was launched in 1992 by the World Association of Soil and Water Conservation (WASWC), has developed a standardized framework for the assessment and evaluation, as well as promotion of exchange of knowledge, of soil and water conservation (SWC) technologies and approaches world-wide. WOCAT results and outputs are accessible via the Internet (www.wocat.net), in the form of books and maps, or on CD-ROM. WOCAT examines advantages and disadvantages of SWC systems and why technologies were accepted or rejected by local users. The WOCAT database, overviews, and maps provides a useful framework and a tool for decision makers and project planners responsible for SWC project design, implementation, monitoring and evaluation. Through the global network involving international and national institutions and programs, the valuable knowledge on SWC is being exchanged and made available. In the Philippines, PHILCAT is based in the Bureau of Soils and Water Management, Department of Agriculture and in the University of the Philippines Los Baños. It is an interagency committee of ten member agencies/institutions and two professional societies/organizations for WOCAT. In Thailand, THAICAT is based in the Land Development Department, Ministry of Agriculture and Cooperative, while in China, CHOCAT is based in the Soil and Water Conservation Monitoring Center and Fujian Soil and Water Conservation Center. The presentation and the paper will demonstrate the program, its tools and how they can be applied, and some of the results obtained from different countries in the world.

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Farm Forestry and Agroforestry Research in Australia – the Joint Venture Agroforestry Program

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The Joint Venture Agroforestry Program (JVAP) is a partnership between four Australian federal government agencies: Rural Industries Research and Development Corporation, Land & Water Australia, Forest and Wood Products R & D Corporation, and Murray Darling Basin Commission. Established in 1993, JVAP has funded research projects ranging from biodiversity in commercial native forest and plantations, to silviculture and tree breeding, and exploration for new products from lignin and essential oils from eucalypts. A driving influence on research is the increasing salinity of large portions of the Murray Darling Basin in southern Australia, and the wheat belt in south-western Western Australia. One of the major solutions to remediation of these lands is broad-scale planting of trees, to lower the water table and draw salt lower down into the soil profile. Approaches currently under investigation include phase farming and alley farming with mallee eucalypts, and planting catchment recharge areas with either conservation plantings or plantation species. Water use by trees and competition with crops and pasture is important for all these models. Because much of the saline area coincides with low rainfall (<800 mm p.a.) and high evaporation, growth of plantations is currently sub-commercial. Achieving multiple products and markets for ecosystem services offers the scope to increase returns to commercially-viable levels. There is strong need to better coordinate farm forestry and natural resource management research in Australia. We are currently inviting more partners to become involved in the concept “Agroforestry Australia”, to achieve more coordinated determination, funding and delivery of research priorities.

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Long-term Impact of Gliricidia-maize Simultaneous Intercropping Systems on Carbon Sequestration

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Agroforestry systems may sequester carbon in soil and standing biomass thus reducing the carbon dioxide concentration in the atmosphere. A study was undertaken in two gliricidia (*Gliricida* sp.)-maize (*Zea mays* L.) simultaneous agroforestry systems; one experiment was 7-years old (coded MZ21) and the other was 10-years old and coded MZ12 to increase our understanding of Carbon sequestered in and CO_2-C evolved from the system. The study was conducted in sole maize cropping (Sole-Maize), Gliricidia-maize simultaneous intercropping (Gs-Maize) and a 7-year old grass fallow (Grass-F). All the crop residues were incorporated within each system at the beginning of each season. Gliricidia prunings were incorporated at each time of tree pruning in the Gs-maize. Amount of organic carbon recycled in the systems via incorporation of crop residues varied from 0.3 to 1.0 t C ha^{-1} per annum in Sole-Maize and 0.8 to 7.5 t C ha^{-1} in Gs-Maize. A net decrease of soil carbon of 6 and 7 t C ha^{-1} in the topsoil (0-20 cm) relative to the initial soil carbon was observed at MZ12 and MZ21 respectively. In Gs-Maize, up to 5 t C ha^{-1} was sequestered in the topsoil (0-20 cm) after 10 years of continuous application of tree prunings. Grass-F had higher organic carbon sequestered in the top 0-40 cm than Gs-Maize at MZ21 but much lower in the sub-soil (40-200 cm depth). Carbon dioxide evolution varied from 10 kg ha^{-1} day^{-1} to 28 kg ha^{-1} day^{-1} in Sole-Maize and 23 to 83 kg ha^{-1} day^{-1} in Gs-Maize.

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Financial and Technical Viability of Agroforestry Systems for Carbon Sequestration in Small Farm Areas in Northwest Mato Grosso, Brazil

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This study evaluated the financial and technical viability of agroforestry models for carbon sequestration in the Northwest area of Mato Grosso state, Brazil, with participation by small and medium rural producers and their local associations. Agroforestry alternatives were sought that could optimize carbon sequestration jointly with income generation. With revenues originating from sale of carbon credits, such producers would be enabled to finance planting of perennial crops within agroforestry systems, for which they are rarely able to receive official credit. To undertake the viability study, agroforestry diagnostic workshops were accomplished in the region, involving specialists and rural producers, as well as an international literature review. The potential areas for establishment of agroforestry systems relevant to criteria of the Kyoto Protocol (i.e., deforested prior to January 1990) were identified, and four agroforestry treatments were proposed. Two of the designs include agriculture and tree species, incorporating coffee and palm tree cultivation. A third model integrates pasture with tree species plantings, while the final model is a perennial home garden system. The baseline carbon stock was defined and the costs of the agroforestry systems' establishment and maintenance, and incomes from products and carbon credits projected over a 21-year period, assuming a regular flow of carbon benefits. The cash flow analysis suggests favorable net returns from agroforestry systems when discounted at 12%, and an improvement in IRR from 12.5% to 16.1% in the respective scenarios without and with carbon credits, when carbon is valued at an expected market rate of US$12.85 mt^{-1}.

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The Influence of Soil Physical-chemical Characteristics and Husbandry on the Growth of Three Tree Species in Farmer-managed Agroforestry Plots (Rondônia, Brazilian Amazon)

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Farmer-managed agroforestry plots in the Brazilian Amazonian (Itapuã do Oeste, Rondônia) were used to study the influence of soil physical-chemical characteristics and husbandry on the height growth of peach palm (*Bactris gasipaes* Kunth), cedar (*Cedrela odorata* L.) and *freijó-cinza* (*Cordia goeldiana* Huber). Path analysis was used with tree height, 5.5 years after planting, as the dependent variable, and soil characteristics and weed control intensity as explanatory variables. Peach palm showed better growth in more clayey soils, with moderate phosphorous, potassium and magnesium levels, and its growth was stimulated by better weed control. Cedar grew better in soils with less silt and more sand than clay. Cedar height was negatively influenced by higher values for organic matter, calcium, magnesium and pH, while in the better-weeded plots height growth was favored by higher levels of phosphorous, calcium, magnesium and pH. *Freijó-cinza* showed good adaptation to medium texture soils. More intensive weeding had a strong positive influence on height growth of *freijó-cinza*.

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Phosphorus and Nitrogen Dynamics in Silvopasture, Open Pasture and Rangeland in South-central Florida, USA

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It has been suggested that a silvopastoral system may reduce runoff and leaching of chemicals compared to an open pasture and thereby improve environmental quality, but little research has been conducted to substantiate these claims. We are currently monitoring movement of N and P through the soil at a silvopasture site compared with open pasture and native range at Ona, Florida (27°23'N, 81°57'W). Soil is a Myakka fine sand (sandy, siliceous, hyperthemic Aeric Alaquod). Both pastures are bahiagrass (*Paspalum notatum*) with the legumes *Desmodium heterocarpon* and *Vigna parkeri*, with silvopasture planted to slash pine (*Pinus elliottii*) at 500 trees ha^{-1}. The open pasture has been fertilized annually with 56 kg N ha^{-1} for the past 15 years. Silvopasture has received 5 kg P ha^{-1} for the past 5 years, and the open pasture 4 kg P ha^{-1} once (2003) in the past 20 years. Grazing density for pasture is 1 cow/calf pair ha^{-1} for the past 20 years, and for range is 1 cow/calf pair $7ha^{-1}$ for the past 60 years. Soluble reactive phosphorus (SRP) concentrations in the 0-100 cm depths varied in the order: pasture > silvopasture > native range. Environmental indicators, such as the Florida P-Index show that pastures fall under the MEDIUM category (75-150), and thus can use an N-based nutrient management program. Silvopasture appears to be more efficient in removing P from the soil profile than open pasture, and therefore might contribute in reducing non-point source pollution.

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Managing Competition for Water between Crops and Coppicing Fallows under Dry Land Conditions

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Coppicing fallows are recommended for biomass accumulation in cropping systems; however, the potential for competition for water may exist during dry periods. The objective of this study was to evaluate the effects of pruning frequencies in *Acacia angustissima* and the effects of conventional tillage (CT) and no tillage (NT) on biomass production, soil water retention and maize yields on a kaolinitic sandy soil. Soil water retention was measured by sampling for soil profile water in plots where one, two and three week pruning regimes were practiced. Samples were collected to a depth of up to 100cm and were immediately analyzed for soil water after sampling. Biomass pruned from plots was oven dried and weighed before being returned to the field. Soil profile moisture was significantly different between pruning regimes; it was highest in one and two weeks pruning regimes and least in three weeks cutting regime. Total biomass productivity was significantly higher in plots under three weeks pruning regime, (3.6 t ha^{-1}), relative to <2.7 t ha^{-1} in one and two weeks pruning regimes. Maize yields were not significantly different for one and two week pruning regimes (2.1 t ha^{-1}), but were significantly lower under the 3 week pruning regime (1.8 t ha^{-1}). There were significant tillage effects on maize yields. The results showed that increasing pruning regime to two weeks could increase soil water and crop yields relative to longer pruning regime of three weeks, which result in reduced soil water for plant uptake and reduced yields.

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Soil and Water Conservation Using an Improved Fallow – Maize Rotation System in a Sandy Soil Subjected to Conventional Tillage (CT) and No Tillage (NT)

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Research on improved fallows has concentrated on soil fertility benefits neglecting possible benefits to soil and water conservation. The effects of improved fallows and tillage management on soil and water conservation were investigated in October 2000 using simulated rainfall of 35 mm h^{-1}, applied onto plots where a 2-year planted fallow-maize rotation was practiced since the 1992/93 cropping season. Treatments evaluated were planted fallows of *Acacia angustissima* and *Sesbania sesban*, natural fallow (NF) and continuous maize. Fallowing resulted in high infiltration rates, >24 mm h^{-1} relative to continuous maize which was 5 mm h^{-1} at fallow termination (October 2000). After 2 cropping seasons steady-state infiltration rates remained >14 mm h^{-1}, in fallows and were unchanged in continuous maize. These results corresponded with results for runoff losses, double-ring infiltration measurements, tension infiltrometer measurements and aggregate stability, which remained high in fallows relative to continuous maize. Improved fallowing also resulted in higher soil water retention, increased pore sizes and pores per unit area during the cropping phase. Improved fallowing also resulted in increased maize yields relative to NF and continuous maize, from October 2000 to October 2002. Conventional tillage resulted in a faster loss of the benefits of fallowing relative to NT. These results show that improved fallows improved soil structure during fallowing and resulting in improved infiltration rates, pore sizes, soil water retention and reduced runoff and soil losses during the cropping phase. However, these benefits decreased from fallow termination with the introduction of tillage.

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Consequences of Dehesa Management on Tree-understory Interactions in Spain

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Dehesa is a multi-purpose agroforestry system in Spain with widely spaced holm oaks (*Quercus ilex*). Dehesa landscape consists of a mosaic of scattered trees combined with crops, pasture and shrubs, resulting from a mix of different management practices, namely agriculture, livestock husbandry, forestry and hunting activities. We studied the distribution of light, soil and air microclimate, soil water content, soil fertility (total N, available P, base cation, CEC and organic carbon) and tree and herb fine root length density around trees, in four dehesas with three types of combinations: trees with cereal crop, trees with natural grasses and trees with abundant shrub. Additionally, we measured crop and pasture yield, tree leaf water potential and CO_2 assimilation rate, tree growth and acorn production. In this paper, we analyze the dominant interactions in three types of tree-understory combinations. Contrary to the general assessment for the Mediterranean ecosystems, soil water did not play an important role in productivity of either trees or crop in dehesas. The holm-oak water status and photosynthetic rate were significantly higher in dehesa than in forest, especially during the dry period. This could be explained by the great amount of soil explored by tree roots, which reach more than 20 m distance from the tree and more than 4 meters depth. On the other hand, both microclimate and soil fertility improved significantly in the vicinity of the trees, but only in less fertile soils did they contribute to increase crop or pasture productivity with respect to the open areas.

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Carbon Inputs and Soil Carbon Pools in Tropical and Temperate Agroforestry Systems

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Organic matter inputs in agroforestry systems help to maintain levels of soil organic matter and sequester soil C. The objective of this study was to determine and compare annual aboveground C inputs, soil organic C turnover, and soil C pools in a 19-year old Erythrina poeppigiana alley crop in the humid tropics to a 12-year old hybrid poplar alley crop in the temperate zone. Soil C turnover was determined by quantifying aboveground organic matter inputs and amount of accumulated soil C. In the humid tropics, soils received C input from crop residues and from tree prunings, and from autumnal litterfall and crop residues in the temperate zone. Carbon input from E. poeppigiana tree prunings was 400 g C m-2 y-1 in the humid tropics compared to 117 g C m-2 y-1 from litterfall at the temperate site. Carbon inputs from crop residues were not significantly different between alley and sole crops. In the humid tropics, soil organic carbon was significantly greater ($P<0.05$) in E. poeppigiana alley crop (9536 g C m-2) compared to sole crop with a turnover rate of 44 years. In the temperate zone the SOC pool, to a 20 cm depth, was quantified to be 10,200 g C m-2 with a turnover rate of 55 years. Crop residue inputs are not different between the two biomes, although the tropical system has two cropping seasons. Despite greater input of organic material in the tropical system the soil C pool is smaller due to a faster turnover rate.

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Agroforestry Systems' Evaluation Tools

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Currently, there are vast agroforestry systems which simultaneously and primarily provide socioeconomic upliftment and conservation of the integrity of the environment. This dual function of agroforestry systems harmonizing the production and protection aspects as sustainable land management shall only be realized through the implementation of site-specific suitable agroforestry systems. Hence, the Institute of Agroforestry (IAF) has been pro-active in developing tools to assess fitness of agroforestry systems towards being potentially sustainable. The evaluation tools were the Methodology for Evaluating Agroforestry Systems (MEAS) and the Agroforestry Land Capability Mapping Schemes (ALCAMS). ALCAMS determines the biophysical suitability of the agroforestry system in specific sites vis-à-vis some biophysical aspects of the environment such as slope, existing vegetation cover and soil fertility. Meanwhile, MEAS has sustainability indicators which address soil conservation, land productivity, farm income and social acceptability based on defined threshold levels. ALCAMS entails production of slope, transect and soil fertility maps. These maps are overlayed wherein each combination has corresponding suggested agroforestry systems, soil and water conservation measures and land-use. MEAS, on the other hand, requires keeping of records of the agroforestry-related inputs and outputs, and provides the level of sustainability. In this connection, said tool can only indicate the potential sustainability of the current agroforestry practice. Institutionalizing these tools as an integral part in agroforestry systems could enhance the services elicited from the Agroforestry practices. Moreover, it shall ensure a continuous monitoring of the agroforestry system which is an inevitable process in coping with the inherent dynamism of agroforestry systems.

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Integrating Economic and Environmental Indicators to Assess Silvo-Arable Agroforestry Options for Europe

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Agroforestry has been proposed as an alternative land-use system for European agriculture for about a decade now. Yet, the uptake is still marginal. A larger uptake depends (i) on farmers being informed on the productivity and rentability of agroforestry and (ii) on policy makers being informed on environmental benefits that could justify an adaptation of the subsidy system in favour of agroforestry. The project 'Silvo-arable agroforestry for Europe' strives to contribute to answering these questions. In 21 test regions throughout Europe a bio-economic plot based modelling approach is scaled up to 4 x 4 km quadrats and the long-term profitability of silvo-arable agroforestry scenarios with *Juglans nigra* x *Juglans regia*, *Populus* spp., *Quercus ilex*, and *Prunus avium* is assessed. The impacts of agroforestry adoption on water recharge, soil erosion, nitrate leaching and landscape diversity are also simulated in a geographic information system (GIS). The resulting economic and environmental indicator values are processed in a multicriteria analysis in order to identify optimum solutions for farmers and policy makers on future strategies to adopt. Preliminary results will be presented which show that silvo-arable agroforestry can contribute to protect the natural resources of Europe's agricultural landscapes and how the subsidy system would have to be altered to promote the uptake of agroforestry. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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LULUCF: Strategies for the Future

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A comprehensive use of land use, land use change and forestry (LULUCF) options is critical to many developing countries and to a sound approach to using LULUCF to address climate change. This paper briefly explains why the Kyoto Protocol restricted use of LULUCF, why this restrictive approach is not sound, and why a comprehensive approach would be more beneficial, particularly for many developing countries. Reduction of emissions from fossil fuels was the primary focus of climate change negotiations, addressing climate change through LULUCF was very controversial, and agreement to include LULUCF was reached in the final hours. These factors plus adoption of absolute quantity targets led to gross-net accounting and to a restrictive approach to LULUCF. Although developed countries are permitted to include all LULUCF options, only one – a/reforestation – is available to developing countries through the Clean Development Mechanism (CDM). Use of a/reforestation alone makes it extremely difficult to address competing land-use needs, particularly the need for food; and immense economic pressures will tend to undermine any environmental gains. A comprehensive approach can support high per acre agricultural yields, the key to sustainable a/reforestation and forest preservation, with their attendant surface-temperature moderation and water quality and supply benefits. In much of the developing world emission reductions from energy projects are limited, but only a comprehensive approach to LULUCF will offer the substantial credits needed to attract industrial investment. Finally, inclusion of all LULUCF options is sound because the atmosphere responds to all LULUCF changes.

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Inorganic and Organic Phosphorus Pools in Earthworm Casts (Glossoscolecidae) and a Brazilian Rainforest Oxisol

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We investigated the effect of large earthworms (Family Glossoscolecidae) on soil phosphorus (P) pools by comparing earthworm casts to an Oxisol in a 10 year-old upland agroforestry system (AGR), pasture (PAS), and secondary forest (SEC) in the Central Brazilian Amazon. AGR and PAS both received low-input fertilization and SEC received no fertilization. We found that earthworms increased organic hydroxide P, whereas fertilization increased inorganic hydroxide P. Inorganic P was increased by fertilization, and organic P was increased by earthworm gut passage and/or selection of ingested materials, which additionally increased available P (sum of resin and bicarbonate fractions) and moderately available P (sum of hydroxide and dilute acid fractions), and P fertilizer application and land-use increased available P. The use of a modified sequential P fractionation produced fewer differences between earthworm casts and soils than were expected. We suggest the use of a condensed extraction procedure with three fractions (Available P, Moderately Available P, and Resistant P) that provide an ecologically-based understanding of the P availability in soil. Earthworm casts were estimated to constitute 41.0, 38.2, and 26.0 kg of total available P stocks (sum of resin and bicarbonate fractions) in the agroforestry system, pasture, and secondary forest, respectively.

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Improving Productivity, Profitability and Sustainability of Degraded Forest Margins through Tree-based Land Use Systems in the Philippines

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This study aimed to quantify and analyze the productivity, profitability and sustainability of alternative land uses in degraded forest margins using a bio-economic modeling approach. The study was conducted in Claveria, Misamis Oriental in Mindanao, Philippines. Results of bio-economic analysis showed that tree-based land use systems have significantly higher financial profitability and environmental benefits than farmers' practice of continuous maize annual cropping. Environmental benefits were measured in terms of higher carbon sequestration, reduced soil erosion, and sustained soil nutrients relative to current farmers' practice of maize cropping. Despite these, survey results showed the extent of tree farming remains low (<10% of land area).The risk analysis indicated that while timber-based systems earned the highest net present value (NPV), they seemed to be the most risky options as reflected by the high coefficient of variations of the NPV ranging from 164% to 205%.

The study recommended measures to reduce price risk and the need to improve risk management capability of farmers to promote expansion of smallholder tree farming. Provision of relevant and timely price information and price risk insurance are such possibilities. It is also suggested that payments to farmers for environmental services like carbon sequestration be explored to encourage expansion of tree-based land use systems.

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Best Practices and Recommended Guides in Implementing Agroforestry Programs: A Compendium of Lessons Learned in the Philippines

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Donor organizations are still struggling in search of the best solutions in the management of agroforestry programs. Until now, a "rolling design" or a "trial and error" method is still being practiced in agroforestry programs because of the lack of good implementing models. This has resulted to the eventual failures of these programs. In most cases, solutions to land management and organizational problems are addressed on a piecemeal basis rather than on a comprehensive manner. Ironically, local communities have less participation in decision making and ownership of the programs. While agroforestry is popularly growing as a strategy to address sustainable land management, measures to promote best practices to scale-up adoption of successful farm models are not effective in some aspects. It is important to draw strategic lessons and learn from the failures and successes of past agroforestry programs, as these can give insights and increase chances of success of future initiatives. The successful implementation of agroforestry projects is based on good design and effective management. This paper will provide donors and implementing organizations an overview of successful models based on a broad range of community-led experiences of varying agro-ecological zones, cultures, and farmers' social status. This paper will guide current and future agroforestry programs on how to address basic issues of people's participation, technology adoption, farmers' extension, policy formulation, organizational development, income generation and marketing. Learning from experiences and adopting best practices will increase the rate of success for the eventual sustainability of program interventions.

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Utilizing Community Participation in Data Gathering and Data Analysis for Effective Strategy in Agroforestry Monitoring and Evaluation Design

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Scientific and technical approaches in monitoring and evaluation of agroforestry programs have resulted to confusions and have been unacceptable to farmers. Oftentimes, communities are not involved in monitoring and evaluation, particularly in the identification and selection of indicators observed as mostly donor-driven. Social scientists and consultants from academes and development programs are employed to do program evaluation to avoid biases in program outcomes. These experts have a limited knowledge of the over-all program operations. In most cases, evaluation results do not capture changes in the biophysical characteristics and social behaviors of farmers and communities. Also, the positive and negative effects of agroforestry programs to gender issues and women's participation and decision-making are not measured as important indicators. Evaluation results and feedback are not shared with communities. This paper aims to promote an effective design of a participatory community-based approach to monitoring and evaluation of agroforestry programs. This model has been gained from various experiences and lessons learned in successful agroforestry programs in the Philippines. This will share an effective strategy that utilizes farmers, local leaders, women and other stakeholders. Communities have been proven to have skills and be capable of performing monitoring and evaluation functions that are more cost-effective and sustainable. With proper training and incentives, they can be effective to gather, analyze and exchange quality data vital to decision making. Thus, communities are an effective instrument in data gathering and analysis and can provide quality decisions to implement courses of action toward the achievement of program goals and objectives.

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Assessing the Role of Agroforestry Systems in Mitigating Climate Change in the Philippines

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In the Philippines, agroforestry system is the most popular strategy being adopted in rehabilitating degraded lands. High adoption of the technology is due to the many benefits the farmers derive from the system. The beauty of practicing agroforestry is its ability to address the concern of the farmers, i.e., ready income from the cash crop or agricultural component of the technology and at the same time its capacity to make the system more stable, productive and sustainable. On the global scale, agroforestry systems have significant role to play in mitigating climate change because they can be sources and sinks of carbon dioxide (CO_2). Carbon stocks assessment made on agroforestry systems in the Philippines revealed that carbon density ranges between 93.25 t/ha to 214.95 t/ha. Currently, there are a total of 5.4 Mha of agroforestry areas in the Philippines (FMB, 2001). Using the mean carbon density of 155 t/ha, a total of 837 M tons of carbon are found to be stored in the various agroforestry systems in the country. These results reveal that agroforestry systems have potential in providing global benefits through carbon sequestration. Thus, appropriate policies must be put in place to enhance the role of agroforestry systems in addressing the issue of climate change.

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Are Intensive Teak Plantations in Agroforestry Practices Environmentally and Ethically Sound?

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Agroforestry and teak has generated a high level of enthusiasm in recent years, especially among those concerned with tropical land-use systems. Although it is true that the scientific principles of agroforestry are only now being examined, and hence understood, the practice has been in existence since early times, especially with forest organizations growing teak under taungya system. However, the teak plantations established in the past have fallen short of their potential, and thus a new approach is demanded. The paper examines the possibilities of growing teak under taungya, spatial agroforestry system (agrisilviculture system), silvopastoral system and home gardens. Possibilities of growing some suitable crops and grasses have also been examined. How the biophysical factors like light, water, nutrients and root behaviour play a role in increasing tree productivity has been discussed. Tree improvement activities for small holder farmers, particularly in Chhattisgarh, are discussed. Moreover, a financial analysis of a small-scale teak improvement programme in Raipur, Chhattisgarh is described. The programme consisted of a seedling seed orchard, made up of ramets of plus-trees. *The analysis demonstrated the annual planting rates between 31 ha per year (at 20% genetic gain in volume) to 125 ha per year (at 5% genetic gain) over 30 year life of the orchard are economically justifiable.* The results demonstrate that the tree improvement above the seed stand intensity should be more widely adopted in support of small-holder tree planting. The implementation of such small-scale, locally-based programmes by community-based or locally oriented organizations is justifiable.

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Proper Utilization of Waste Aqua-terrestrial Ecosystem for Conservation and Development through Agroforestry Ecosystem in Indian Sub-tropics

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Emphasizing the importance of waste unused aqua-terrestrial ecosystem for the development of carboniferous environment as well as production of foods, a case study with the principles of agroforestry was undertaken in the coasts and northeastern plains of Indian sub-tropics through the cultivation of popular aquatic food crops (water chestnut, *Trapa bispinosa* Roxb.; makhana, *Euryale ferox* Salisb. – are rich in protein and starch materials) and plantation crops (forestry, fruits and vegetables) in an aqua-terrestrial land situation. The study revealed that the physico-chemical properties of both aqua-terrestrial ecosystems (pH, organic carbon, available N, P and K) as well as quality of water (pH, EC, BOD, COD, CO_3^{2-}, HCO_3^-, NO_3 N, SO_4^{2-} S, and Cl^-) were remarkably influenced due to crop variables and exhibited significant improvement of soil health. The carboniferous environment was more pronounced, particularly under the semi-permanent water body in a given year (flooding during rainy season of 2.0 ± 1.0 m water depth and drying during summer season) due to prevalence of both anaerobic and aerobic condition alternatively, which enhanced quick decomposition of huge biomass so accumulated in the system. This soil rich in humus, is effectively utilized in situ and succeeding arable crops successfully, saved a substantial amount of fertilizer nitrogen along with other essential elements for the plants. Besides increasing N use efficiency (NUE) of the system, it also produced foods significantly (water chestnut, makhana), fossil fuels and vegetables, suggesting the best utilization of waste aqua-terrestrial ecosystem for the benefit of farmers in these regions and eco-environment as well.

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Evaluation of *Gliricidia sepium* Provenances in an Alley Cropping System with Maize in Sri Lanka using Vector Competition Analysis

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Interactions to acquire resources in agroforestry are competitive or synergistic depending on factors such as species mixture, climate conditions, soil conditions and management regime. In my study Vector Competition Analysis (VCA), a bi-variate model developed to investigate both growth and nutrient relationships in plants grown alone or in mixture was used to elucidate interspecific growth and interactions in an agroforestry system in Sri Lanka. The productivity of an alley cropping system comparing three provenances of *Gliricidia sepium,* originating from Sri Lanka and each of the wet and dry zones of Guatemala was evaluated in sole and mixed crop combinations. The objectives were to investigate growth and nutrient relationships and interactions in the alley cropping system of *G. sepium* provenances with maize (*Zea mays*) and recommend the most effective *G. sepium* provenance to improve crop productivity and soil fertility. The trees were planted with maize on the same soil in the intermediate agro-ecological zone. Yield measurements revealed that the growth interactions were synergistic except in alleys with the dry provenance of Guatemala. Both crop and tree yields exceeded sole cropping yields, and the major limiting factors of productivity were identified as nutrients, particularly nitrogen on VCA. The wet provenance of Guatemala was recommended for use in agroforestry systems for the intermediate zone of Sri Lanka, because of (i) its superiority in biomass production and soil fertility enrichment (associated with high nitrogen fixation and mulching capacities) and (ii) its low underground competition with the companion crop due to deeper rooting habits.

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Water Use Efficiency for Cotton Grown in an Alley Cropping System, Under 50 Year-Old Pecan Trees, and in a Monoculture System

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A field study was conducted in 2003 in Florida to investigate the water use efficiency of cotton (*Gossypium* spp.) grown in an alley cropping system and in a conventional monoculture system. The objective of this study was to determine if cotton grown in alley cropping systems would have lower foliar transpiration and/or photorespiration than cotton grown in the monoculture system. The cotton in the alley cropping system was planted under 50 year-old pecans (*Carya illinoensis*), and was subjected to moderate to heavy shade. The three treatments included 1) cotton grown between pecan trees that were trenched to prevent tree roots from competing with cotton roots for water and nutrient resources, 2) cotton grown between untrenched pecan trees, and 3) cotton grown under monoculture conditions. Photosynthesis, stomatal conductance, and transpiration were measured for ten plants in each treatment, over a three week time period in September 2003. A photosynthetic:carbon dioxide response curve was also generated for each of the treatments. Estimated photorespiration rate and water use efficiency were calculated. Water use efficiency of C_3 plants, such as cotton, may be overestimated due to high photorespiration rates inflating the apparent carbon dioxide assimilation rate. Photorespiration may consume as much as 25% of the assimilated carbon dioxide for cotton exposed to full sunlight. Results from this study will compare the transpiration rates on a plant level between the three treatments.

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Target Regions for Silvoarable Agroforestry in Europe

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In Europe today, agroforestry is not supported by subsidies, whereas agriculture and forestry receive government support in all countries. Still, agroforestry in arable landscapes can reduce problems, e.g., soil erosion and nitrate leaching, while enhancing landscape and biodiversity. In this study we identified target areas for silvoarable agroforestry systems with *Pinus pinea*, *Juglans* spp., *Populus* spp., *Quercus ilex* and *Prunus avium*. Target regions were defined as the intersections between (i) regions where productive tree growth in an agroforestry setting is possible and (ii) regions where environmental or socioeconomic problems exist that agroforestry can help to solve. The investigation covers the entire European continent. GIS techniques were used to integrate data on soil, climate, relief, biodiversity, land cover, and agricultural farms. Although limited by constrained data availability, the study shows that the implication of trees in arable landscapes in Europe would be possible throughout all climatic zones (from the south of Spain to the north of UK). In addition, 21 case study regions were randomly selected in Spain, France and The Netherlands. The effects of the implementation of silvoarable agroforestry on soil erosion, nitrate leaching and landscape diversity are investigated by means of scenario calculations and landscape modelling. Preliminary results will be presented. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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Effects of Tree Shading on Corn and Soybean Gas Exchange, Photosynthesis, and Growth in a Temperate Tree-based Agroforestry Intercropping System in Southern Ontario, Canada

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In 1987 a large field experiment was established to investigate intercropping trees with agricultural crops. Corn and soybeans were intercropped with hybrid poplar (*clone-DN-177*) and silver maple (*Acer sacharrinum*) at a within-row spacing of 5m and between-row spacing of 12.5 or 15 m. Soybean yields were 71% and 75% of that of a no-tree control in the poplar and maple intercrops, respectively. Generally, tree competition significantly reduced the growth of individual plants growing nearer (2 m) to tree rows, and often reduced the size of plants furthest (6 m) from competing trees in comparison with controls. Poplar competition reduced corn photosynthesis more than maple, whereas the two tree species appeared to reduce soybean photosynthesis equally. Daily rates of carbon assimilation were generally lower near the trees where competition for light was the greatest, which resulted in the lowest yield. Growth characteristics of individual plants were significantly correlated with available PAR and net assimilation, but poorly and non-significantly correlated with midday water potential. It was concluded that competition for light, and not water, within 6m to the tree rows was the main factor that detrimentally affected corn and soybean yields. Although growth reductions were not significantly correlated with plant water stress, the lowest plant water potentials observed were for maple intercrops. Concurrently, much higher intrinsic water use efficiencies were observed for maize compared with soybeans, and were highest for maple intercrops. Collectively, these findings suggest that maple and maize may compete more vigorously for available soil moisture than poplar and soybeans.

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Coffee Water Use in Agroforestry System with Rubber Trees in Southeastern Brazil

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Water uptake and use by plants are essentially energetic processes that can be largely modified by percentage of land cover, kind of plants, foliage area and its distribution, phenological stage and many environmental factors. One-year-old coffee plants (*Coffea* spp. Cv. Obatã IAC 1669-20) were submitted to different shade conditions in an experiment at Piracicaba, in southeastern Brazil (22°42'30" S, 47°38'00" W; altitude 546 m). Coffee plants in spacing of 3.4x0.9 m inside and aside of a 12-year-old rubber crop (*Hevea* spp.) were evaluated in a function of the following distance from the trees, counting from the border: (inside) -5.7m, (aside) 1.5; 4.9; 11.7m and in the coffee monocrop. In December/2002 and February/2003 – middle of summer – the reflected and transmitted light available to the coffee was measured using tube solarimeters (Delta-T) at the rows of coffee plantation. At the same positions the sap flow were measured by the technique of heat balance (Dynamax Inc.). Relative light availability was, respectively to those distances, 35%; 45%; 80%; 95% and about 100%. Coffee plants under shade showed a greater water loss per unit of incident irradiance. On the other hand, plants in monocrop (full sun) exhibited the smallest water loss per unit of incident irradiance. For the evaluated positions the average water use was: 58.14, 77.76, 47.59, 22.16, and 20.12 g $H_2O.MJ^{-1}$ on December 2002 and 149.36, 53.28, 23.94, 35.55, and 17.82 g $H_2O.MJ^{-1}$ on February 2003. This may be attributed to the higher stomata sensitivity of the coffee plants under more illuminated conditions.

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Measurement and Simulation of Light Availability Related to Growth of Coffee Plants in Agroforestry System with Rubber and Pejibaye Trees in Southeastern Brazil

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Light is an important factor for plant growth, but its availability to understory crops is strongly modified by trees in agroforestry systems. Coffee (*Coffea* spp. – cv. Obatã IAC 1669-20) was planted 3.4x0.9 m under 12-year-old tree crops of rubber (*Hevea* spp.) and pejibaye (*Bactris gasipaes* H.B.K.), at Piracicaba, in southeastern Brazil (22°42'30" S, 47°38'00" W; altitude 546m). One-year-old coffee plants were evaluated at the following distances from the border of the tree crops: (inside) -13.7; -10.3; -5.7; -2.3m; (aside) 1.5; 4.9; 8.3; 11.7; 15.1; 18.5; 21.9m and compared to the coffee monocrop. Light availability to coffee was measured with a tube solarimeter at the same positions. Growth was estimated by trunk diameter measurements related to above-ground biomass. Leaf area index (LAI) was estimated in respect to crown projection. The relative light availability was, respectively to those distances, 25%; 30%; 35%; 40%; 45%; 80%; 90%; 95% and about 100% to the 3 farthest positions. Its estimate by the Bernardes *et al.* model: $I_r = \{ sen\{arctg [(d-(cw*cw/d))/hr]+slope\}+1 \}*I_0$, where: I_0 – radiation above trees; hr – tree relative height in respect to coffee height; cw – crown width; slope – terrain slope; and d – distance from the tree, fitted the measured data. Coffee tolerates 50% decrease of light availability without reduction in growth and LAI. Further reductions in light availability resulted in lower LAI, thus poor ground cover and light interception, resulting in growth reduction.

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Ecological Functions of Shelterbelts in Agricultural Landscape Management in Poland

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The provision of shelterbelts in the landscape is not expensive and could provide economic benefits. The modifications of the energy fluxes, water flows, control of ground water pollution by shelterbelts was documented in the long-term studies carried out in the Research Centre for Agricultural and Forest Environment in Poznan, Poland. Shelterbelts use about 40% energy more for evapotranspiration than wheat fields, while the wheat field diverts approximately three times more energy for air heating than the shelterbelts. In a dry year the difference between latent heat (energy used for evapotranspiration) of shelterbelt and field for whole vegetation season is as much as 586 $MJ \cdot m^{-2}$, while in the wet year this difference reaches only 298 $MJ \cdot m^{-2}$. Nitrate concentrations decreased substantially when ground water carrying them from under fields passed under shelterbelts or meadows strips. The main mechanism of NO_3-N withdrawal is nitrogen holding in the internal recycling between plants and heterotrophs (soil animals and microbes). Uptake of NO_3-N and NH_4-N by plants from ground water seeping through the tree's root systems and subsequent formation of NH_4 ions during biomass decomposition play a crucial role in regulation of nitrogen cycling in shelterbelts. The large pool of internally recycling nitrogen, which is evidenced by very high NH_4 production rates during biomass decomposition, determines the holding capacity of shelterbelts. The release of nitrogen into atmosphere in denitrification processes or storing in wood or humus is much smaller. The shelterbelts also provide good refuge for many invertebrates and vertebrates.

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Effect of Soil Sampling Distance from *Cordyla pinnata* on Soil and Crop Yield in Senegal

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In agroforestry parklands, litter from trees represents an important source of nutrient transfer from woody vegetation to soils. Productivity of millet and peanut plants grown on soils sampled at different distances from *C. pinnata* trunk (R/2, 1R, 2R, R being the crown radius), a tree legume, has been studied, using a bioassay. Height growth, aboveground and belowground biomass, and total biomass of millet plants increased on soils sampled at R/2, compared to 2R, same as root length, stem, leaf, pod, root and total biomass of peanut plants. Therefore, foliar litter of *C. pinnata* revealed a potential in modifying tropical ferruginous soil properties and both crops yield and nutrient concentrations.

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Interaction between *Cordyla pinnata* and Crops in an Agroforestry Parkland System of Senegal

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Agroforestry parklands are land use systems where trees are mixed with crops on the same unit of land. These tree-crop associations can have positive, negative or no effects on the soil or on the growth and yield of the plants. Foliar biomass production of the tree, *Cordyla pinnata*, was estimated to be 337 kg ha^{-1} in a parkland located in the southern part of the peanut basin of Senegal. Effects of crown volume, orientation, distance from the trunk and pruning intensity of *C. pinnata* on soil physical and chemical properties, nutrient contents, and millet and peanut growth and yield were studied. *C. pinnata* was not associated with any differences in soil physical properties (texture, bulk density or humidity). Soil organic C, total N, extractable P, exchangeable Ca and CEC were respectively 57%, 61%, 47%, 22% and 15% higher under the canopy than in the open. For all pruning intensities combined, millet grain biomass (-18%) and total millet biomass (-0.5%) decreased significantly under *C. pinnata.* The biomass of peanut pods was also reduced (-25%) under canopy compared to the open. Under the control (non pruned trees), total biomass of peanut plants increased with distance (1486, 2084, and 2110 g m^{-2}) while under completely pruned trees, total biomass of peanut plants decreased with distance (2177, 1829, and 1787 g m^{-2}). The removal of 1/3 of the crown volume increased the overall peanut yield in the system.

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Growth and Radiation Use Efficiency of the Assai Palm in Agroforestry Systems of Brazil

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Juvenile assai palms (*Euterpe oleracea* L. Mart) were studied under different agroforestry systems, at Piracicaba-Brazil (22°42'30" S, 47°38'00" W; altitude 496 m). Relative irradiance (I%) available to the assai varied from 6-10% under canopy of the cocoa, guarantã and leucaena trees, to 18-39% under rubber trees and to 28-33% at 1.5m, 52-54% at 5.5m, 62-70% at 9.5m, 78-86% at 15.5m, 85-93% at 23.5m, 88-97% at 33.5m aside from the border of a rubber alley. Growth as aboveground dry matter (DM), leaf area (LA), trunk diameter (D), plant height (H) and radiation use efficiency (RUE), were evaluated in function of the available irradiance, six, twelve and eighteen months after planting. Maximum values of DM, LA, D and H of 327.32g, 1.12m^2, 0.031m and 0.45m and 792.05g, 2.85m^2, 0.056m and 0.59m, occurred between the relative irradiance of 52% to 67% and 60% to 89%, twelve and eighteen months after planting, respectively. The differences were negligible under all the available irradiance, six months after planting. In the systems with less than 20% of irradiance, RUE of 0.1g.$MJ.m^{-2}$ was almost ten times higher (P<0.0001) than in other systems, six months after planting. Maximum RUE increased and moved to higher irradiance with age, being of 0.2g.$MJ.m^{-2}$ at 40% of irradiance twelve months after planting and 0.3g.$MJ.m^{-2}$ at 62% of irradiance eighteen months after planting. Very small growth rates were observed under relative irradiance below 10% and above 86% along the eighteen months. (Granted by FAPESP).

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Agroforestry for Poverty Eradication: Opportunities with Clean Development Mechanism (CDM)

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Climate change is one of the most pressing environmental issues of today, and the rising levels of greenhouse gas emissions are a major source of concern. Many people working in land use and forestry sectors are becoming increasingly aware of the inclusion of these sectors in international policy deliberations on climate change. The Land Use, Land Use Change and Forestry (LULUCF) under Clean Development Mechanism (CDM) of United Nations Framework Convention on Climate Change (UNFCCC) provides exciting opportunities for developing carbon mitigation projects and agroforestry as an opportunity to optimize benefits from CDM for the benefit of rural communities. CDM can offer developing countries an opportunity to promote and attract investment in sustainable agroforestry and land restoration projects. Agroforestry plantations create rural employment and provide secure commercial and subsistence outputs contributing to the socio-economic development of rural areas. The CDM would provide an avenue to obtain technology (for high yields), to promote agroforestry strategy aimed at meeting the domestic biomass demands as well as to reduce CO_2 emissions. Agroforestry models facilitate application of sustainable agricultural production systems and may offer some of the highest livelihood benefits than afforestation. The paper illustrates some pilot agroforestry projects being implemented in southern India, Mexico, etc. Environmentally-sound and socially-equitable climate change mitigation projects in the agroforestry sector will require a strong enabling environment both at national and international levels. A holistic approach is recommended to integrate carbon sequestration objectives with improving livelihoods to achieve the ultimate goal of sustainable development coupled with poverty eradication.

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N and P Assimilation in a Silvopastoral System Receiving Poultry Litter or Inorganic Fertilizer

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A silvopastoral demonstration/research site was established to quantify differences in N and P cycling due to nutrient source (poultry litter or commercial fertilizer). Northern red oak (*Quercus rubra*), eastern black walnut (*Juglans nigra*) and pecan (*Carya illinoensis*) were planted at 15 m row spacings on a 4.25 ha site near Fayetteville, Arkansas, USA in 1999-2000 and alleys were seeded to orchard grass. Beginning in 2001, one-half of the site received a single 4.5 Mg/ha poultry litter application each spring and the other half received 56 kg/ha N as commercial fertilizer each spring and fall. Monitoring results indicate consistently greater concentrations of NO_3-N in both soil water and ground water samples collected from the area receiving commercial fertilizer. Average NO_3-N concentrations for the soil water samples were 7.9 and 5.2 mg/L for the fertilizer and litter-treated areas. Ground water samples displayed the same trends, as average NO_3-N concentrations in ground water samples were 9.4 and 7.0 mg/L for the fertilized and litter-treated areas. Nitrate N concentrations were greater in the spring with maximum concentrations exceeding 20 mg/L in both soil water and ground water. Very little change in soil P concentrations were observed as both litter-treated and fertilized areas averaged ~35 mg/kg P as measured by the Mehlich 3 extract. However, P concentration in forage harvested from the litter-treated area had consistently greater (~0.05%) total P. Tree, forage, and environmental monitoring to quantify nutrient and C cycling components will continue and intensify as the trees mature.

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Agroforestry: Finding a Bio Solution for Every Environmental Problem

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This article explains that actually our world faces every day the new and more complex environmental problems, such as natural resources degradation, genetic degradation, and enormous kinds of pollutions. This is the main challenge of our time. Facing this challenge, it is possible to have two reactions: 1) Diminution and limitation of activities that create this situation, which can be done by changing the life system and in this new vision of life, we can increase the place of trees in our production system, so AF takes a more important role and become a solution for our problems. 2) Designing the methods for controlling and removing the situation, in these solutions agroforestry takes an important place and presents two priorities: (a) By its nature and structure, is capable to have all bio components comprising macro and micro, natural and human adapted flora and fauna. (b) By all traditional AF systems, human beings have a rich heritage, in time and space, of varied AF systems, that are not simplified, because they were not used as a current way for development up to last decades, and it is possible to adapt them for our days or create the new complexes within them by the way of normal researches and D&D. So today, Agroforestry is the strongest bio instrument that is able to resolve our environmental problems. In this article the authors try to bring the different cases and examples to show better such an argument.

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Modification of Microclimate in an Alley Cropping System in Northern Sudan

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Field experiments were conducted in semiarid regions of Northern Sudan to study the effect of alley cropping microclimate on productivity of different agricultural crops. The influence of micro-environmental elements on growth and yield of some winter crops (wheat, faba bean and common bean), off-season summer crops (carrot and sweet pepper) and an autumn crop (sorghum) was investigated in 6.0 m wide alley cropping system. Above-ground interaction was examined by installing a series of weather stations in different zones of the alleys and control plots for monitoring microclimatic changes. These changes included solar radiation, wind speed, relative humidity, maximum and minimum temperatures. In addition, shade behaviour (direction and length) was regularly monitored in a systematic way. During the winter season, shade in the southern alley caused a relative decrease in crop yields; however, the substantial part of increase of yield in the central alley, as a result of optimum solar energy, compensated this reduction. Consequently, the average yields of wheat, faba bean and common bean had increased in the alleys by 69, 15 and 10% over control plots respectively. During the summer season, where the decrease in solar energy was advantageous to off-season, yield of carrot was increased by 487% over control. Alley-cropped sweet pepper produced 5,833 kg ha^{-1} of fresh fruit /plot, while all plants in control plot died during vegetative stage. Similarly, during autumn, changes in alley cropping microclimate significantly increased fodder maize crop in alley cropping plots by 179% over control plot during the two consecutive cropping seasons.

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Enhancing Carbon Sequestration by Improving Productivity in Agroforestry through Franchise Mechanism

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Uttar Pradesh, in north India, largely consists of fertile gangetic plains, with a forest cover of 7% and a tree cover of 4.46%. Farmers in the region prefer agroforestry practices compared to agriculture. However, the Forest department is not raising sufficient seedlings of species attractive to farm-forestry. This has led to establishment of private nurseries on a very large scale. On average, private entrepreneurs are raising more than ten million seedlings of Eucalyptus, Poplar, *Anthocephalus cadamba*, *Dalbergia sissoo*, etc. in the Saharanpur district. If we consider the whole state, large volume of seedling production is from poor quality seed and planting material. There is thus a scope to improve the quality of more than 700–800 million seedlings per annum. The farmers do not have quality planting material. Market is available for the technology and people want to pay for the quality but it is not available. Forest department of the UP state has the technology but is unable to reach the private entrepreneur due to inefficiency. Also, none of the research institutions are able to reach out to farmers to provide technology. Due to scale-backs in agroforestry seedling production by state government, the farmers are depending on private nurseries for seedlings. Establishment of demonstration nurseries to disseminate the technical knowledge to private entrepreneurs requires financial input. It will be better to identify franchise mechanisms to disseminate the technology. The productivity could be enhanced from 5 m³/year/ha to 20 m³/year/ha or more so that carbon sequestration is enhanced 4-5 times.

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Bush Bean as an Associated Crop for Commercial Apple Orchards in Guatemala

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Apples (*Malus domestica*) are grown in homegardens and commercial orchards in Guatemala's northwest highlands, providing income and fruit for regional producers. Most fruit is consumed domestically although some export occurs within Central America. Regionally, orchards are of medium to low density (approx. 400 trees ha^{-1}) and in these conditions between 35 and 45% of the orchard is underutilized. Apple orchard floor management varies in intensity from clean cultivation to ring weeding or minimal control of weeds. To evaluate potential for improved land use and farm profitability, we investigated bush beans (*Phaseolus vulgaris* vars. *Altense*, *Texel*, and *Hunapú*) as a crop associate within orchards. This study was conducted in two commercial orchards near Quetzaltenango (approximately 2400 m). Three bean varieties were sown at 39,000, 79,000, or 124,000 plants ha^{-1}. Bean yields, yield components, and capture of photosynthetically active radiation were measured. Additionally, grower opinion of the technology was assessed. Yields were highest for *Altense* and lowest for *Texel*. Bean yields were relatively unaffected by association with apples as compared to monoculture controls. Planting density was responsible for most of the yield variability within varieties and little effect from fruit tree shading was observed. Producers' opinions of understory cropping were favorable and the highest density plots were preferred. Cultivation of bush beans provided acceptable bean yields and improved orchard floor management without obvious impact on fruit production. This agroforestry technology merits further evaluation with a broader array of growers and additional assessment of impacts on fruit yields in this region.

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Possibilities for Agroforestry Development in Bulgaria: Outlooks and Limitations

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Current conditions in Bulgaria are favorable for the development of agroforestry due to socio-economic incentives and environmental necessities. As a scientific theory and practice, agroforestry is less familiar in Bulgaria. Hence, to ensure successful agroforestry development in Bulgaria, four necessary movements (or collective national 'moments') are here described. 1) The first initiative is wide-scale popularization. Popularization of agroforestry's fundamental tenets is needed, including its nature as a production system, types of agroforestry systems, structural components, methods for design, construction, support and management, advantages and disadvantages, and possible applications in Bulgaria. 2) The second movement is the conducting of massive and comprehensive research on agroforestry, in terms of research areas such as: high-tech selection of plant and animal species suitable for agroforestry technologies (including cultivation of lesser-known indigenous species that may be better suited to local conditions); studies of how to balance the biophysical interactions of agroforestry species to optimize and conserve natural resources (e.g., sunlight, soil, water, microclimate, etc.); knowledge of best cultural practices (e.g., fertilization, irrigation, IPM), and economic analyses of various agroforestry systems. 3) The third movement involves education and preparation of interdisciplinary specialists for the development of this new economic direction. 4) The fourth movement is the realization of special government policies to enhance and encourage the development of agroforestry in ways that are economically appropriate for the nation. These policies should include long-term development strategies, national and regional program plans and structures, financial incentives (loans, substitutions, tax reductions, security, awards), and establishment of agroforestry demonstration sites.

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Estimation of Timber Volume of Rubber (*Hevea brasiliensis*) Small Landholding in Malaysia Using Landsat TM

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Natural rubber areas cover 1.24 million ha in Malaysia, and within this area, 87% are small landholding areas. The form of rubber (*Hevea brasiliensis*) small landholding management occurs in both monoculture and agroforestry systems. In many developing countries, rubber tree crops play pivotal roles in providing natural rubber, sources of wood products, and other benefits that support basic human needs and economic development. Despite their importance, little attention has been given in timber inventory and assessment of the crops. Effective management for these resources requires reliable information on forecasts of resource availability. This promoted research into supplementing ground-based survey methods with satellite remote sensing information. This study was conducted to establish and evaluate models for estimating timber volume of rubber small landholding in Malaysia. The 76 sampled rubber stands were split randomly into two independent groups, with 49 stands for building the models, and the remaining 27 stands for validating the models. Regression analyses were used to explore relationships between rubber stand volume and Landsat TM reflectance. Statistically significant models for estimating timber volume of rubber stands were obtained with the R^2 values were all higher than 0.70 and standard error of the estimate (SE_E) values were lower than 54 m^3 ha^{-1}. The inventory information is needed for effective resource management planning aimed at maximizing the potential benefits of rubber tree crops for wood and natural rubber supply in Malaysia or other countries with similar resource management issues and constraints.

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Forest Floor Litter Production and Decomposition in Ten Tropical Hardwoods – Tamil Nadu, India

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The quantum of accumulating litter on the ground under ten tropical hardwoods viz., Artocarpus heterophyllus, Albizia lebbek, Acacia mangium, Acacia auriculiformis, Senna siamea, Casuarina equisetifolia, Eucalyptus tereticornis, Gliricidia sepium, Tamarindus indica and Tectona grandis were assessed on monthly basis for two years and the litter production for per season and per annum studied. The age range of the plantations was 9 -11 years. The decomposition rate of the litter for each species was assessed using field weight – dry weight method. The study indicated that maximum litter of 10.0 t ha^{-1} $year^{-1}$ was recorded by Acacia auriculiformis and was followed by Senna siamea (8.56 t ha^{-1} $year^{-1}$). The minimum litter production was registered in Tectona grandis plantation. Regarding the decomposition of litter, Senna siamea litter decomposed easily followed by Albizia lebbek litter. Casuarina litter had a very slow decomposition rate.

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Tree Growth, Carbon Sequestration and Nutrient Allocation in *Gmelina arborea* Roxb. Stands Grown in Monoculture and Agrisilviculture Systems in Central India

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Growth, biomass, carbon storage and nutrient (N, P and K) variations in 1 to 6-years-old chronosequence plantations of *Gmelina arborea* were studied in three degraded red lateritic sites in central India. Growth parameters varied significantly due to difference in age and site quality. Stand biomass ranged from 3.94 (1-yr-old) to 53.67 Mg ha^{-1} (6-yr-old) and stand carbon in 6-year-old plantations ranged from 24.12 to 31.12 Mg ha^{-1} at different sites. Among the tree components, the stem wood accounted for maximum C (56.25% at site 1) followed by branches (19.8% at site 3), roots (18.51% at site 2) and foliage (7.01% at site 3). Mean annual C accretion at 6 years age of plantation was highest in site 3. Quantity of nutrients increased with age. Total nitrogen accumulation in 6-yr-old stands at the three sites ranged from 212.9 to 279.5 kg ha^{-1} and total K ranged from 170.8 to 220.5 kg ha^{-1}. Phosphorous accumulation was lowest with a mean storage of 16.75 kg ha^{-1}. *Soil organic carbon increased from 8.46 to 14.02 Mg ha^{-1} within 6 years.* At soil depths 0-20 cm, 21-40 cm and 41-60 cm, available N enhanced by 14.85%, 11.98% and 11.25%, K by 10%, 9.13% and 10.63%, whereas phosphorous declined by 26%, 23% and 20%, respectively. *At 6 years, G. arborea stands sequestered 31.37 Mg ha^{-1} carbon.* The nutrient management strategies in relation to carbon accretion in *G. arborea* stands on degraded lateritic sites are discussed.

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Mapping Shifting Cultivation Fields in Karen Area, Bago Yoma, Myanmar

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Taungya system, classified as a typical type of agroforestry, originated in Myanmar (Burma). Taungya, stemming from the Burmese terms *taung* (hill) and *ya* (cultivation), means temporary cultivation on hill land, which has been practiced in Bago Yoma, the homeland of the Karen people. Originally used for the establishment of teak plantations by the colonial government in the 19th Century, shifting cultivation is still practiced by the Karen people. This study aims to examine, through GPS mapping, interviews and participatory observation, the present state of shifting cultivation in the Karen area by focusing on the vegetation of fallow lands and the fallow periods. The field survey was conducted in SN village, Oktwin township, Toungoo district, Bago division of Myanmar. In 2002, 58 HH opened 60 plots for shifting cultivation. Village area, aggregate 60 shifting cultivation plots and average size of plot were 39,706,181 m^2 (A), 1,614,606 m^2 (B) and 2.69 ha, respectively. Based on these figures, the maximum potential fallow years can be 24.59 years (A/B). The first year fallow was covered with *Eupatorium odoratum*, which was replaced by bamboo (*Bambusa polymorpha* & *B. tulda*) in several years. After 12 years, tree species such as Pinkado (*Xylia dolabriformis*) gradually dominated the fallow lands. Despite the longer maximum potential fallow period, the actual fallow period was 17.88 years on average. This is attributable to the fact that fallows covered with trees and bamboo, 12 to 18 years of fallow period, are easy to open and provide good burning for shifting cultivation.

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Soil Conservation Role of Forest Shelterbelt Systems in Agro-landscapes: A Study from the Ukraine

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Investigations were carried out on an experimental farm located in the southeastern region of the Ukraine. The region is characterized as continental, with occasional droughts, and the soil is subject to erosion and loss of fertility. Some years ago, a system of soil control measures was introduced on the farm. Main elements of the system are forest shelterbelts in combination with simple hydrological constructions. Our research was focused on the elementary watersheds and windbreaks situated on the farm territory. The main idea of our investigations is that windbreaks, in combination with other soil control measures, are natural barriers for reduction of wind and runoff. Therefore, they promote an accumulation of materials from the soil erosion and deflation. At the same time, they could be used as points for studying of the processes. Results showed the regularity of the runoff and washed-away soil distribution on different elements of the agro-landscape, and the process of chemical exchange between field and windbreak caused by the soil depletion. Using equations derived from observed data, a description of the dependence of the soil sedimentation in windbreaks on different factors under the influence of the soil erosion and deflation, was created. In sum, we concluded that the system of forest shelterbelts with optimal organization could decrease soil loss to 0.5 t ha^{-1} per year.

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Hydrologic Influences on the Growth of Young Grafted Black Walnut Trees in Arkansas, USA

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An Eastern Black Walnut (*Juglans nigra* L.) plantation consisting of 91 trees was established in the Fall of 1999 at a site in Northwestern Arkansas. Two-year old seedlings (pre-grafted to cultivars selected for superior nut quality) were transplanted with a spacing of 9.1 m within and 15.2 m between rows. Tree girth at 25 cm above the graft (N=52) was determined at the conclusion of the growing seasons in 2002 and 2003 for all surviving trees with surviving grafts. Each tree position was mapped and growth data were linked to a GIS database (ArcView 3.2a) established for the shallow ground water monitoring of a 4.25 ha silvopastoral field. Eighteen wells with depths varying from 0.51-3.48 m beneath the land surface datum were installed (from 2000-2001) in this 1.22 ha zone. Monitoring efforts (N=21) during the last two growing seasons (March-September 2002-2003) have revealed that 13 out of 18 wells have mean water table levels of less than 1.00 m beneath the surface, which challenges the characterization of “dry upland site”. Four wells have hydrodynamic ranges in excess of 1.50 m (with subsurface fluctuations varying from 1.69-3.20 m); young trees in the vicinity of these wells are exhibiting substandard growth due to water deficit stress (with negative departures within 1-3 standard deviations from the mean 2-year girth increase of 15.4 mm). Preliminary geospatial analyses suggest that young trees emplaced in areas where the mean water table ranges from approximately 0.8-1.3 m are exhibiting the best growth on the plantation.

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Carbon Fixation in an Agrosilvipastoral System with Eucalypt in the Cerrado Region of Minas Gerais, Brazil

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The objective of this work was to quantify the carbon fixed by the agrosilvipastoral system with eucalypt established in the Cerrado region of Minas Gerais. The system comprises a joint planting of eucalypt (*Eucalyptus* spp.) with rice (*Oryza sativa*), soybean (*Glycine max*), and braquiaria grass (*Brachiaria brizantha*), in a suitable timing scale, to produce wood for fuel and sawing, agricultural crops and beef. The 3-PG model with the aid of the normais 2.0 Program was used to estimate the biomass of eucalypt. The factor of 0.49 was adopted to transform dry biomass into carbon. For the carbon determination, randomized samples of rice and soybean from plots of 1.0 m x 0.5 m and pasture from plots of 0.3 m x 0.3 m, were collected. The plots were distributed within 3 spacings from the eucalypt line (1.0, 2.8 and 4.6 m). At the end of an 11 years cutting cycle, the carbon fixed by the eucalypt in the agrosilvipastoral system was 80.68 ton.ha^{-1}, including the litter. At the beginning of the first year the rice fixed 2.18 ton.C.ha^{-1}, and the soybean, at the beginning of the second year fixed 1.08 ton.C.ha^{-1}. The pasture fixed 3.71 ton.C.ha^{-1}.year^{-1}, from the third to the eleventh year. The carbon fixation capacity of the agrosilvipastoral system throughout the cycle was an average 11.66% greater than that of eucalypt monoculture (3 m x 2 m). The results showed that the agrosilvipastoral system can become an alternative within the Clean Development Mechanism activity.

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Interfacial Root Densities and Soil Moisture in a Soybean Alley Cropping Practice

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Agroforestry cropping practices have been introduced recently in temperate climatic regions for many purposes including the improvement of water quality and soil erosion control. The objectives of this study were to evaluate the effects of an agroforestry alley cropping practice on infiltration, change in antecedent soil moisture, and interaction of roots at the interface of soybean (*Glycine max* (L.)) and tree-grass strips. Study site soils are primarily Putnam silt loam. The 4.44 ha agroforestry watershed includes six, 4.5 m-wide buffer strips consisting of redtop (*Agrostis gigantea* Roth), brome grass (*Bromus* spp.), and birdsfoot trefoil (*Lotus corniculatus* L.) established at 36.5 m intervals. Pin oak (*Quercus palustris* Muenchh.), swamp white oak (*Q. bicolor* Willd.) and bur oak (*Q. macrocarpa* Michx.) were planted at 3 m intervals in the buffer strips in 1997. Campbell soil moisture sensors were installed at 5, 10, 20, and 40 cm depths in crop and buffer areas to examine soil moisture changes with the information fed into a field-based data logger. Soils were sampled to a 1 m depth to determine root densities. Volumetric soil moisture contents at all four depths were lower in buffer areas than in the crop areas. The moisture contents appeared to be similar after several large precipitation events. Buffer areas contained deep roots and root densities that were several times greater than those in crop areas. Differences in infiltration and antecedent soil moisture resulting from the presence of tree-grass strips have the potential to reduce non-point source pollution and improve water quality.

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Biophysical Interactions between Shade Trees and Coffee in Central American Agroforestry Systems

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With the financial assistance of the European Union (ICA4-CT-2001-10071), research has been undertaken for the last 3 years on coffee and tree associations in Central America (www.casca-project.com). Its purpose is to promote coffee agroforestry systems in the region and to improve farmer's income through diversification (timber production), production of high quality coffee and payment of incentives for environmental services in order to compensate the current low coffee prices. Intensive measurements have been undertaken to model light and water partitioning between coffee and trees. The impact of shade trees on microclimate, coffee physiology and quality has also been investigated. Especially under sub-optimal conditions, the results show that tree shade creates more favorable microclimatic conditions for coffee and improves coffee photosynthesis. They demonstrate that coffee transpiration is lower under tree shade (*Eucalyptus deglupta* or *Terminalia ivorensis*) than in full sun. Nevertheless, they indicate that water competition can take place during the last weeks of the dry season. These results demonstrate that adequate shade (20-40%) decreases coffee productivity by 15-25%. However, this lower productivity can be financially compensated by an increased proportion of larger beans suitable for export and the premium paid for higher cup quality. Indeed, shade lengthens by up to 6 weeks the maturation of coffee berries resulting in better bean filling and beverage quality. These investigations indicate that modelling the effects of agroforestry practices on microclimate, resource partitioning, coffee physiology, productivity and quality is required to provide adequate recommendations for selecting and managing associated trees according to local ecological conditions.

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Uncertainty Analysis of Agroforestry Models

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Models for productivity and resource use in agroforestry systems are needed for land use explorations and support of management decisions by farmers and policy makers in European agriculture. Alternative or complementary avenues for building predictive models are available, ranging from parameter-sparse models, containing not more than some dozens of parameters and only few dynamic equations, to parameter-rich models with hundreds of parameters, based on detailed descriptions of ecophysiological processes and covering many pages of code. The strength of parameter-sparse models lies in their transparency and amenability to mathematical techniques for reduction of uncertainty and improvement of predictive capacity. The strength of parameter-rich models is their biological realism and suitability for studying intricate trade-offs in agroforestry systems at short temporal and detailed spatial scales. In both classes of models, problems are faced in parameterization and the containment of uncertainties in model predictions. Parameter-sparse models require long-term data sets for model calibration and evaluation of uncertainty. Such data sets are rare. Parameter-rich models contain many parameters that do not have a significant impact on long-term model predictions; moreover, they are cumbersome to develop and maintain, understand and document. This presentation will focus on how these problems are being dealt with in a European-wide research project aiming at evaluation of possibilities of agroforestry systems as a rediscovered component of sustainable land use in Europe.

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Climate Change: Linking Adaptation and Mitigation through Agroforestry

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The agricultural sector is particularly vulnerable to climate change. We know that international conventions will not stop the drivers of climate change and adaptation will be inevitable. Many of the improved practices for increasing the sustainability of smallholder farming can have a positive impact on the atmospheric accumulation of greenhouse gases. The IPCC Third Assessment Report indicates that conversion of degraded agricultural land to agroforestry has a huge potential to sequester carbon. This paper reviews the work of ICRAF on smallholder agroforestry. We review the evidence and identify the gaps in knowledge regarding the mitigation potential of agroforestry. We have good numbers for carbon in a number of systems, but are sorely lacking data on N_2O and CH_4. Worldwide, agroforestry systems can sequester between 12 and 228 Mg C ha^{-1}. In the humid tropics, tree-based production systems have large above-ground carbon stocks compared to arable crops. In the subhumid zones much of the storage potential is in the soil and the nature of the soil largely determines how much can be stored. Under current situations climate shocks are a major source of setback for smallholder farmers and are a leading cause of farmers falling into poverty. As climate changes and extreme events become more common, we anticipate increasing difficulties for these farmers. There is anecdotal evidence suggesting that agroforestry systems are more resilient to climate variations and extreme events. Quantifying this potential is one of the major challenges in agroforestry and climate change research.

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Limiting Factors for the Establishment of Agroforestry Schemes with Mayan Homegarden Species on Calcareous Soils in Yucatán, México

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In Northern Yucatán, the huge area of abandoned sisal plantations, now assigned to the communities, requires agroforestry management strategies that generate income for farmers and are adapted to the mosaic of different soils and the limiting rainfall. To meet this management challenge, we planted the indigenous multi-purpose tree species *Cordia dodecandra* (Siricote), which produces fruit and valuable timber, in combination with the food colorant bush *Bixa orellana* (Achiote). Our objective was to determine survival, growth, and the interrelation between nutrient and water availability on the two dominant soils.

We planted alternating 4 Siricotes and 4 Achiotes on 192 plots of 7mx7m on red Cambisol and black Litosol. To these, we applied 7 fertilizer treatments in minus-one-trials (minus N, P, K, Mn, and Zn), with and without irrigation. Soil was sampled. Growth of seedlings was measured. Leaf samples were collected twice during the rainy season. Foliar nutrient levels of the same species from homegardens were assessed for comparison. First results showed that with sporadic irrigation at the peak of the dry season only, seedlings of both Achiote and Siricote had high survival rates. Siricote seedlings, planted in July 2002, survived hurricane Isidore in September 2002. Growth rate of Siricote was high on both soils.

Our study will improve the understanding of soil-water-plant interactions in Northern Yucatán and provide farmers with a promising agroforestry management strategy. Interest by the Mexican Federal Forestry Commission (CONAFOR) will ensure that the study will have an impact on recultivation schemes on the Peninsula.

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Productivity and Competition Vector Changes over Two Decades in a Temperate Alley Cropping System in Midwestern USA

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Alley cropping systems in the temperate Midwestern USA have the greatest economic potential when tree plantations of high-value veneer wood are intercropped with annual cash crops in order to offset tree establishment costs early in the production cycle. Opportunities for managing resource availability in the cropping alley are limited to those methods which maintain veneer wood production goals. In this study, several walnut tree (*Juglans nigra* L.) plantation management activities were examined for their impacts on tree and maize (*Zea mays* L.) production including thinning (years 9 and 15), aboveground branch pruning (year 17), and belowground root cutting (year 11). Thinning in years 9 and 14 resulted in the highest tree diameter growth across the period, but had little effect on reversing declining crop yields. Tree root cutting immediately improved crop access to nutrients and water so that there was little difference in crop yields observed between middle and edge crop rows. This response dissipated by year 16 when crop production declined by up to 96% as trees continued to grow and light became limiting across the 8.5 m wide alley. However, aboveground branch pruning in year 17 returned crop yields to up to 81% of year 11 values. These results indicate we have the ability to manage plant competition to aid crop production and the financial return of these systems. Additional data from year 16 and 17 will be presented revealing how trees impacted the nitrogen and water cycles and reduced fertilizer and nitrogen leaching in soil drainage waters.

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Competition for Light between Pecan (*Carya illinoensis* K. Koch) and Cotton (*Gossypium hirsutum* L.) in an Alley Cropping System in Northwest Florida, USA

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In temperate regions, agroforestry is recognized as an alternative land-use practice for intensive production of agricultural crops. Widespread adoption, however, is hampered by limited understanding of the competitive vectors affecting productivity and sustainability of such systems. In an alley cropping system, temporal, spatial and ecological interactions between the tree and crop components are inevitable. It is hypothesized that reduction in light transmittance caused by trees decreases productivity of associated crop in alley cropping. A three-year study is being conducted at the University of Florida to investigate temporal and spatial patterns of aboveground competition for light in an alley cropping system involving pecan (*Carya illinoensis*) and cotton (*Gossypium hirsutum* L.). This study specifically investigates how shading affects photosynthetic rate, transpiration, stomatal conductance, biomass production and lint yield of cotton with and without (by trenching) the belowground competition for water and nutrients. Daily diurnal variation of light was measured to determine the pattern of light distribution in the system. Physiological parameters, including light response and A-Ci curves, were measured using a LICOR-6400 portable infrared gas analyzer. Results indicate a reduction in photosynthetic rates, transpiration, and stomatal conductance of cotton both spatially and temporally and with belowground competition. Results of the study will help to improve our basic understanding of ecological interactions in temperate agroforestry systems so that better systems can be designed to optimize productivity.

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Plasticity in Root Morphology of Cotton (*Gossypium hirsutum* L.) in Response to Interspecific Competition with Pecan (*Carya illinoensis* K. Koch) in a Pecan-based Alley Cropping System in Northwest Florida, USA

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Plant-to-plant interactions in agroforestry systems can involve a complex mix of competitive and facilitative processes. However, *competition* is much more prevalent than *facilitation* in mixed systems like alley cropping. The development of suitable temperate alley cropping systems requires the understanding of belowground processes to determine the key interactions influencing production. In temperate alley cropping systems, little attention has been given to studying root morphology of agronomic crops as a result of interspecific competition. A study is being conducted at the University of Florida to investigate root morphology and root development of cotton (*Gossypium hirsutum* L.) under pecan (*Carya illinoensis*) trees. Specifically, this study investigates how cotton root morphology responds to shading and belowground competition for water/nutrients. Parameters of interest include root diameter, root length, root length density, root surface area and root-shoot ratio, among others. Root sample collections are done monthly and analyzed using the Winrhizo software. Preliminary results show that there are significant differences in root morphology of cotton under different environmental conditions. The result of the study will provide vital information needed to quantify and model belowground competitive interactions.

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Integrated Soil Conservation with Agroforestry Progressive Terraces in Highlands of Congo-Nile Crescent

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Soil erosion is a major constraint to natural resources management and sustainable agriculture in the great lakes region of Africa, particularly in the Congo-Nile crescent highlands where average annual soil loss is estimated at 30 tons ha^{-1}. Several approaches such as radical terracing are being implemented to control this phenomenon. However, most of these approaches require inputs far beyond the reach of rural poor farmers who make the majority of the population. Progressive terracing, a method that uses agroforestry multipurpose trees and shrubs in combination with grasses on contour lines to form terraces, has proven to be particularly affordable and effective on soils with slopes ranging from 20 to more than 40%. Contour edges of *Calliandra* and *Leucaena*, combined with fodder grasses, fruit and medicinal trees (in upper story) were evaluated for their effectiveness in soil conservation and system productivity. Results indicate that soil loss can be reduced by 60% to 80% within 4 years. At the end of that period, average terrace height ranged from 60 to 80 cm. In most cases, terraces were formed and stable after six years. System productivity was enhanced and diversified, yielding equivalent income of USD $300-500. In addition, the number of deadly landslides as well as swamp pollution was reduced. Major advantages of this option include affordability (little investment), replicability, and crop yield stability compared to other options. This approach requires collective and synchronized interventions, which requires local community involvement and organization, thereby opening avenues for strengthening and building those communities from within.

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Afforestation of the Waste Banks in Donbass, Ukraine

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In the territory of Donbass, Ukraine, coal has been extracted for more than 200 years in underground coal-pits. During the exploitation of coal-bed there is also rock extracted with coal, which pours out on the surface as waste banks of different forms. There are more than 1,500 banks in the region. They not only occupy fertile lands, but also pollute the surrounding environment. Since 1984 we have been researching different methods of afforestation on conical and flat banks as a way of struggling against their harmful exposure. The method elaborated by Donetsk Botanical Garden consists in lowering the height of conical dumps by one-two thirds, in applying fertile soil to the flat summits and in landing plants on the summits and slopes. According to this method a large amount of fertile soil is necessary. We propose to substitute river silt for soil. We have carried out several vegetation tests (barley and robinia have been grown on the blends of silt and rock) and received good results as to the silt application to the amelioration of the bank rock. The precise dependence of the length of the sprigs and roots of barley and robinia is observed from the correlation of the silt and bank rock. In specimens with correlation 2:1 and 3:1 the length of the sprigs and roots is two times longer. The number of the germinating robinia seeds is two times greater in samples with correlation 3:1.

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Ameliorative Efficiency of Forest Shelterbelts on Agricultural Lands in Steppe Zone of Ukraine

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The insufficient amount of annual precipitation (300-450 mm), and its unproductive loss through runoff and evaporation, are factors limiting increase in agricultural productivity in the steppe zone of Ukraine. A creation of the forest shelterbelt systems is regarded as one of the most effective methods of stabilizing soil and preventing evaporation in this zone. Since 1983 we have been studying the effectiveness of various systems of contour and parallel shelterbelts in the agricultural enterprise “Udarnik”. Long-term researches show forest shelterbelts render a wide ameliorative influence on the adjoining territory. They absorb the moisture and prevent the snow from being blown out. Shelterbelts provide a territory protection within a distance of 6-7 up and 11-13 their heights down the slope. The snow cover in this zone was 11.4 cm higher than in unprotected fields. The safety of snow moisture in unprotected fields was 60.5%, but within the system of shelterbelts – 87% to the amount of precipitation. The additional moisture supply was 22 mm. The additional yield in a zone of shelterbelts ameliorative influence amounted to 0.4-0.5 ton of grain ha^{-1}. Equations of yield increase dependence on distance from shelterbelts were obtained. The algorithm of a choice of the optimal distance between the shelterbelts is elaborated. Therefore, forest shelterbelts are a weighty factor in productivity increases of agro-landscapes under conditions of insufficient and unstable moisture.

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IV. Economic and Social Aspects

Includes topics related to sessions on:

Economic Analysis,
Land Tenure and Gender Issues,
Local Agroforestry Knowledge in Global Context,
Policy and Institutions,
Scaling up of Agroforestry Benefits,
and Mechanization

Comparison of Eight Dryland Agroforestry Systems with Agricultural Land Uses in Australia

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Biophysical problems such as salinity and soil erosion combined with the prospects of income diversification are encouraging research and development of commercial woody perennial crops in Australia. This paper is a summary of a project funded by the Joint Venture Agroforestry Program (JVAP) of the Australian Government. It compares the economics of some existing, emerging and prospective agroforestry systems with conventional agricultural land uses in the dryland zones of the states of Western Australia and New South Wales. Business analysis techniques were used to compare alternative land use scenarios accounting for the biological and economic temporal and spatial interaction effects of trees on agricultural enterprises. The profitability, cash flows and debt associated with each of the projects are reported. Eight agroforestry case studies are compared to agricultural land uses. The Western Australian (WA) case studies included oil mallees (*Eucalyptus kochii* subsp. *plenissima* and *E. polybractea*), tagasaste (*Chamaecytisus proliferus*), maritime pine (*Pinus pinaster*) and wattle (*Acacia* spp.). The New South Wales (NSW) case studies included blue mallee (*E. polybractea*), narrow-leaved peppermint (*E. radiata*), jojoba (*Simmondsia chinensis*), and river red gum (*E. camaldulensis*). An economic analysis tool was developed to assess the likelihood of new land use systems meeting the economic requirements of farmers. This tool, named *Imagine*, is an automated spreadsheet application. It has proven to be a highly useful partial budgeting tool for analysis of alternative land use systems. The generic database and computational framework underlying *Imagine* make it applicable globally to a diverse range of edaphic and agroclimatic situations.

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The Role of Agroforestry in the Income Generating Activities of Selected Women's Self-help Groups in Ghana

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In Ghana, self-help groups which involve cottage industries play an important role in the livelihoods of rural women. However regular supplies of fuelwood to these cottage industries are usually taken for granted. A study was conducted of selected women's self-help groups in the Ashanti region of Ghana in order to provide an improved understanding of the socio-economic implications of declining fuelwood supplies, and the current awareness of agroforestry and tree planting. The study also sought to examine the potential for the adoption of agroforestry practices and technologies, and how they could be introduced and adapted to suit the socio-economic structure of the self-help groups, especially those engaged in rural cottage industries that require the use of fuelwood. The groups have well-organised structures with activities organised on a weekly basis. Markets exist for products both within and outside their localities. Leaders are selected amongst members who voluntarily opt for positions. Participation in activities is satisfactory though a few would not co-operate for various reasons. Fuelwood acquisition is changing from the gathering of preferred species to the purchase of any type of wood that is available. In the past, common fuelwood sources included gathering from farms, fallow vegetation, backyards and nearby villages. Increasingly, fuelwood is purchased from sawmills, chainsaw operators and fuelwood contractors. Most groups were aware of the benefits of tree planting but awareness of agroforestry was low. However, after discussion, the women were able to identify potential niches for agroforestry, and examples of this are described.

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Agroforestry and Soil Fertility Management Technologies in Southern Africa: Farmers Knowledge, Attitudes and Practices

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Based on a multi-stage stratified random sample of 302 households in five districts in Zambia and 300 households in five Extension Planning Areas in Malawi, a field survey was carried out to establish farmers' Knowledge, Attitudes and Perceptions (KAP) of agroforestry and several other soil fertility management options. The objectives of the survey were to (i) assess how farmers perceive AF in relation to other soil fertility management options, (ii) identify factors that systematically shape farmers' perceptions about different soil fertility management options over several years, and (iii) evaluate opportunities and constraints to the scaling up of AF based on current levels of farmers' KAP in southern Africa. Results showed that declining soil fertility, and non-availability or high cost of fertilizer, rank as the highest constraints facing agriculture in the two countries. Farmers' preferences for specific agroforestry species are based on various criteria: ease of establishment method; length of "waiting period" before obtaining benefits; ability to produce large quantity of marketable seeds within a short time; tolerance to livestock and fire; and compatibility with oxen-drawn ploughs during field operation. Although improved fallow species are primarily designed to improve soil fertility and increase farmers' income indirectly through improved yield, farmers clearly showed preference for plant species that both improve the fertility of their soil in the longer term and also increase cash income directly in the immediate term. For effective scaling up, the development of soil fertility management options should take into consideration the multiple objectives expressed by farmers.

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Agroforestry Systems Implantation in Amazon Region through Agroforestry Districts Creation

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In the present work whole detail is described related to agroforestry systems establishment in the Amazon area through a proposal of agroforestry districts creation. Agroforestry districts would be areas in the Amazon forest ecosystem, in rural settlement projects, designated by federal and state government. The implantation of an agroforestry district would reconcile, at the same time, investigation projects and concrete actions in family agriculture domains, natural resources management and property administration. It is presented the districts concept, details on public politics for its establishment: association and cooperative society mechanisms, agrarian reform: establishment project, research and rural extension, rural credit: specific lines, market information, agricultural industry and commercialization, and building infrastructure for the agroforestry district.

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Starting Where the People Are: Innovative Capability Building Approaches for Community Self-Reliance

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Aside from providing needed knowledge and skills, capability building helps individuals and organizations in realizing their potentials for exploring and creating opportunities, establishing linkages, and taking control of their own destiny -- paving the way for self-reliance and eventually empowerment.

This was the guiding principle of the Agroforestry Support Program for Empowering Communities Towards Self-Reliance (ASPECTS) in the sustainable development of the Philippine uplands. People's organizations, agroforestry schools, government and non-government organizations, and other institutions were organized as managers of pilot sites in Luzon, Visayas and Mindanao, utilizing the concept of multi-sectoral partnership. ASPECTS harnessed the potentials of the agroforestry schools to assist partner communities in creating their own farmer training centers and providing their own Community-Managed Agroforestry Extension Services (CMAFES). CMAFES facilitated linkages with adjoining communities, line agencies, and other sources of assistance to collectively sustain development efforts in the uplands through agroforestry. Agroforestry training fellowship enabled institutions to address problems of partner communities by implementing action plans. Faculty members were granted scholarships for agroforestry education programs. The farmer leaders, farmer-trainers and potential farmer-trainers were trained in agroforestry and appropriate management skills. Farmer-to-farmer training, cross-farm/site visits, and demonstration farm and nursery establishment for training purposes were also undertaken. These capability-building approaches enabled partner communities to improve their agroforestry farms, develop their pool of agroforestry farmer-trainers, form training-management groups, and strengthen their networking capabilities. The collaborating schools, meanwhile, developed their pool of agroforestry faculty/staff members, in- and off-campus agroforestry field facilities, and enhanced their agroforestry education, research and extension programs.

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Traditional Practices and their Hindrance to Agroforestry Development in Northern Ghana

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Agroforestry is a key to ecological land use for sustainable development in the world. It provides habitats for hosting the diversity of life and sustaining ecosystem architecture for a serene atmosphere, as well as the survival and sustainability of flora and fauna in every society. For some time now, traditional practices in some northern parts of Ghana have hindered the smooth development of agroforestry. A research survey conducted at Damango, Savelugu and Yendi sites in Ghana revealed that most lands there were owned by the community and were used for shallow mining, fish farming, charcoal production and the brewing of "Pito" (a local alcoholic beverage). It was therefore difficult for an individual to make decisions about a land and decide whether to use it for a long term project like agroforestry. Due to some traditional beliefs, certain lands were described as sacred areas preserved for the gods of the community and their ancestors. Therefore people cannot have the lands and use it for agroforestry purposes, since they are afraid that their gods and ancestors would punish them. Traditional practices like shifting cultivation, bush burning for hunting and festival purposes, tree cutting for traditional medicine, among others, are causing serious problems such as gradual desertification in such areas. Our study concluded that much education and restrictive forest laws and regulations are needed in order to increase cultural acceptance of agroforestry in the region.

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Financial and Risk Evaluation of Multi-strata Agroforestry Systems in Rondônia, Eastern Amazonia, Brazil

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The difficulties in establishing agroforestry systems (AFS) in tropical forests are quite numerous. AFS have been promoted for their biophysical, ecological and socioeconomic advantages; however, studies need to add financial and economic risk analysis aspects to reinforce AFS advantages. The objectives of this study were to analyze the financial return and the risk of investing in AFS traditionally used in the State of Rondônia, in the western Amazon region of Brazil. Financial analysis was based on the following forestry enterprise evaluation methods: Net Present Value (NPV), NPV for Infinite Horizon Planning (NPV*), Annual Expected Value (AEV), and Benefit/Costs Ratio (B/C). Data were analyzed considering the respective cash flows of each AFS. Risk analysis for the AFS with better financial results was carried through the Monte Carlo simulation technique and processed by @RISK software, considering different levels of the harvesting costs, management operations, price of fruits and wood, and internal rate of return. The following multi-strata AFS, set in a clayey Oxisol, were tested: T1: Ca+Ba+Pm+Cp; T2: Fr+Ba+Pm+Cp and T3: Pu+Ba+Pm+Cp. While all the production systems were considered economically viable, T1: Ca-Ba-Pm-Cp showed the best profitability indicators, due to higher incomes provided since the first year of the horizon plan. Management operations and harvesting costs represented more than 70% of the total cost composition. Although these AFS incurred a high cost in terms of establishment and management, the investment may be considered of low risk, according to the use of the proposed methodology.

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Reaching Sustainability by Mechanization: Introduction of Mechanized Mulching Technology to Replace Slash-and-Burn Techniques in Tropical Fallow Systems

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In eastern Amazonia, Brazil, forest-based fallow systems including slash-and-burn practices are still the most important small farmer land-use systems. Intensification of land-use while keeping the traditional agricultural practices, leads to a decrease of the system´s productivity. A key factor of this degradation are the losses of organic matter and nutrients during slash burning: carbon and nutrients stored in the fallow biomass are released into the atmosphere by volatilization. If not burned, however, the fallow biomass can contribute considerably to the management of the soil organic matter in order to improve the physical, chemical and biological properties of the soil. Therefore, a tractor-propelled bush chopper was developed to replace the slash-and-burn practice with a fire-free chop-and-mulch technology by transforming the fallow vegetation into manageable mulch. Two chopper prototypes have been tested so far on small farmer land and the feasibility of the new technology could be proven. Additionally, a commercially available forest mulcher was also tested. Financial analyses revealed the economic viability of the chop-and-mulch approach, compared to the traditional system. Even though the newly developed chopper was designed for the transformation of fallow vegetation into mulch, new fields of application have emerged such as landscape conservation or biomass harvesting.

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Pursuing the Development of Sustainable Farm Management Systems in East-Africa: A Follow Up of a Human-Ecological Case Study

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Successful (i.e., sustainable) farm management schemes are fundamental to work towards poverty reduction, food security and natural heritage conservation - all of which are pressing targets to be pursued by global society in the 21st Century. Within this context, female farmers play a key role as they are the main providers of the agricultural subsistence products, not only in East-Africa. A case study conducted between 1998 and 2002 investigated 18 successful partly female headed smallholder farms located in three project areas by focusing on the following research questions: *'What kind of successful schemes are available?' 'What are the causes of variations (which 'success indicators' can be identified)?'* And *'What impact do successful schemes have on the natural, socio-cultural and economic environment?'* Great variations between the selected agri-environmental schemes due to different interconnected factors have been assessed. Furthermore, the study revealed various positive trickle-down effects resulting from the farmer's activities and a wide range of success indicators. 'What happens to these systems over time?' A follow-up shall investigate the development of the selected farms over the years. What has changed, which positive processes can be seen, where are weaknesses and problems? The lack of process-oriented impact-assessment studies is generally regarded as a critical aspect within the development context: Generally, natural resource management systems are dynamic and react in a time-space interaction on innovations and changes undertaken. The study can be a valuable contribution to trace development processes of farm schemes and by this to contribute to the improvement of development efforts.

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Intertemporal Sustainability for the Economic Viability of Agroforestry Systems in the Amazonia

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Agroforestry is an economic and ecological system that may respond closely to the postulate of the concept of sustainable development expressed by UNCED 92, which is to "meet the needs of the present without compromising the ability of future generations to meet their own needs". This research identifies that it is the long-term *intertemporal sustainability* of an agroforestry system that will secure the economic legitimacy and viability of this forestry model of land use. Agroforestry systems are undergirded by two sets of interconnected values: non-market values (i.e., those non-tradable benefits or goods generated by the system), and market values (i.e., those tradable benefits or goods). However, these values interfere with each other. Specifically, they interfere at the formation of the cost of opportunity of each activity yielded by the production unity and, also, at the final allocation of monetary or in-kind incomes gained by the family. The main contribution of this intertemporal model is in *creating income expectation at each temporal stage of agroforestry management*. Thus wise, the family may obtain benefits and incomes through the production of short-rotation crops (corn, rice, beans, tubercles, vegetables, etc.), and, in the meantime, derive increasing returns from livestock and perennial crops of short, medium and long rotation (especially from high-value timbers such as mahogany, cedar, rosewood, etc.). In sum, the Achilles' heel of agroforestry systems has been to articulate a balance between that which is technically desirable with that which is desirable in terms of income expectations and the well-being of the family.

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Is Agroforestry Development a Particular Form of Land Tenure and Management? (A Study from Sénégal)

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In Senegal, administrative decentralization and the devolution of political power to local communities in West Africa is revealing new social dynamics between various actors for land tenure and management. In the groundnut Basin of Senegal, where the land is strongly degraded, agroforestry adoption aimed at improving the agronomic value of a parcel, is in fact contributing to the modification of the social relationships between owners and other users in the territories concerned. The live hedges and windbreaks are particular forms of land layout which change the agronomic and economic value of the land even in terms of its legal boundaries and laws. The results of our work show that land parcels are often enclosed by peasants to mark the limits, to reduce the conflicts of delimitation between parcels and to secure the users. Does that raise the question of how adoption of live hedges is related to the need for land securement within the specific framework of a forthcoming law on the land and of decentralization? Does this social and agronomic change require the exclusion of certain social categories to the detriment of others? In what aspects of the agroforestry movement do stakeholders take part in the official recognition of the rights of users, and in securement of land title?

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Economics of Eastern Black Walnut Agroforestry Practices: Nut Production in Relation to Genotype and Tree Size

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Eastern black walnut (*Juglans nigra* L.) is a prime tree species for agroforestry practices in the USA. Nut production may be an important component of sustainable agroforestry practices. The relationships between tree size and nut production are poorly understand. Two sets of studies are reported here. First, data (annual nut production, 1941-1946, and average trunk diameter, dbh, for over 150 trees) reported by Zarger (1946) were re-examined. The R-square for equations relating nut yield to tree dbh ranged from a low of 0.04 to a high of 0.18 when data from individual years were analyzed. Averaging nut yields over two consecutive years did not improve R-square. However, the R-square increased to 0.33 when nut yield data from four to six years were averaged and then regressed against average dbh. In the second set of studies, nut yields per tree were determined for 14 plots (10-50 trees per plot) in 2002 and 2003. R-squares of 0.25 and 0.34 were obtained for the regression equations between nut yield and tree dbh for data collected in 2002 and 2003, respectively. R-square increased to 0.45 when the two-year averages for dbh and nut yield were regressed. R-square was greater for the regression equation generated from native tree stands as compared to improved cultivars (0.57 versus 0.27). The results indicate that data from at least two consecutive years are needed to assess a tree's nut yield potential, and the relationship between dbh and nut yield may differ between native and improved cultivars.

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Agroforestry Systems in Space and Time: Modelling Household Decision-making by Subsistence Farmers in Cameroon

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Shifting cultivation is the primary means of livelihood for subsistence farmers in the Congo Basin of central Africa. This agroforestry system, which depends on long periods of forest-fallow to maintain soil fertility as well as for provision of non-wood forest products, is under pressure as populations increase. Where long fallows are no longer possible, productivity declines in the absence of intensification of production or the forest frontier is further pushed back as new land is brought into rotation. Conversely, where the system is in balance, the landscape is characterized by a stable mosaic of land use that provides an adequate rural livelihood. The landscape- and household-level impacts of shifting cultivation and *ex ante* assessment of alternative agroforestry systems are best captured by a model that accounts for spatial and temporal factors. This paper outlines an approach to modelling household decision-making that effectively simulates the spatial and dynamic mosaic of land use characteristic of shifting cultivation. This approach explicitly accounts for the differing relative importance of various non-economic decision criteria in the household's choice of location to cultivate in any one year. It combines these with recent developments in spatial modelling of resource use and the usual economic factors associated with productivity and labour constraints used in household modelling to address some of the weaknesses of previous bio-economic modelling approaches. Decision criteria are linked to socio-economic characteristics of households making it possible to simulate the impact of differences or changes in decision criteria on both the landscape mosaic and household livelihoods.

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Local Knowledge on Indigenous Trees in Central Philippines

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The main objective of the study was to identify the most promising indigenous timber and fruit tree species for on-farm domestication based on local knowledge. Local people especially farmers possess a remarkable knowledge about indigenous trees. The study shows that resource knowledge goes with resource status. Without a good documentation this indigenous knowledge will be lost with the extinction of the resource base. Between 100 to 200 indigenous timber and fruit species were identified in each of the study villages in Central Philippines. Molave (*Vitex parviflora*) was the most preferred species for domestication. Other top preferences included *Securinega flexuosa, Shorea contorta, Syzygium brevistylum, Hopea manquilingensis, Pterocarpus indicus, Shorea almon, Sandoricum koetjape, Lansium domesticum, Shorea negrosensis, Triphasia trifolia, Shorea astylosa* and *Melia dubia*. The remarkable wood quality and durability of indigenous species over exotics was unanimously acknowledged. Most of the identified indigenous timbers were confined to natural forested areas which is indicative of non-domestication of such for a long time. Main constraints in growing the indigenous trees were lack of planting materials and lack of technical skills in growing them. Potentials of promising and preferred indigenous tree species for on-farm domestication have to be thoroughly assessed. Tree growers have to be sufficiently educated on species-specific tree farming technologies. Government policies on tree growing and utilization have to be reviewed. Good documentation, data storage and retrieval on the rich local knowledge on indigenous trees, is highly called for.

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Valuation and Conservation of the Philippine Tropical Forest

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The tropical forests of the Philippines provide a range of tangible and intangible benefits. However, forest resources are undervalued as both the market and government fail to measure non-commercial benefits and determine the total economic value (TEV) of these natural resources. The TEV of benefits derived from a typical tropical forest was estimated using different valuation techniques. The study area was the Makiling Forest Reserve (MFR), well known for its unique and diverse ecosystem. A total of 1,524 visitors to MFR, and over 542 farmers living inside and outside MFR, served as survey respondents. Total economic value of MFR includes both market and non-market benefits. Data analysis indicates that the capitalized value of the benefits derived from MFR ranges from P16.38 million (US$0.41 million) for market-based forest products to P28,857.68 million (US$721.44 million) per year for the value of biodiversity protection. Estimates of the study show a capitalized total economic value of MFR to be approximately P31.72 billion (US$0.8 billion). Total value of opportunity cost of MFR is estimated at P13,072 million (US$327 million) which generated a 2:1 ratio of benefits to opportunity costs of preservation. The study demonstrates that MFR is a valuable asset worthy of conservation. This should exert sufficient pressure for the government to change political priorities to afford appropriate protection and to introduce policy measures that would mitigate the impacts of intensive use of MFR for agricultural production. It should also raise awareness among farmers to enhance sustainable production of community benefits through collective conservation efforts.

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Values of Forest Products in the Makiling Forest Reserve (MFR), Philippines

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MFR is an important forest reserve and contains valuable and diverse products, which are of economic importance. These non-timber forest products (NTFP) include fuelwood, food and fruits, seeds, fodder, rattan, bamboo, vines, ornamental plants, medicinal plants, and wildlife. Since some of these products are not being sold in the market but are locally consumed by gatherers, there are no available market prices. In cases where market prices of a particular NTFP were not available, shadow prices were used. Forest products benefits for MFR are estimated to be P386 (US$10) per hectare per year, with wildlife products making up the highest proportion (31 percent), followed by fodder (27 percent), then ornamental plants (17 percent) and seeds and planting materials (14 percent). Other products that have low percentage values of the total NTFP are bamboo (4 percent), fuelwood (3 percent), vines (2 percent), and rattan (0.4 percent). The income derived by a household from NTFP in MFR is about P1,490 or US$37 per year, representing only about three percent of the total annual household income of MFR farmers. Although the contribution of NTFP to the value of MFR is modest, these products are economically important to the local community. Moreover, the ecological effects of unregulated gathering may have repercussions with respect to sustainability of NTFP gathering.

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Scaling Up the Benefits of Agroforestry in a Developing Country Setting: Emerging Lessons from the Philippines

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Agroforestry has considerable potential to address the twin problems of rural poverty and environmental degradation in the Philippine uplands. The World Agroforestry Centre (ICRAF) has been promotinig agroforestry by working with a range of partners including local governments and communities. In particular, ICRAF helped initiate the Landcare Program, a successful farmer-led extension program based on community landcare groups, in the Municipality of Claveria in the Southern Philippines. The Landcare Program has resulted in widespread adoption of soil conservation and agroforestry practices and, as a consequence, has been scaled up to several other sites to achieve wider adoption of agroforestry. We present initial results of five case studies to assess the effectiveness of different modes of scaling up, each with different institutional and resource requirements. It was found that Landcare was associated with rapid adoption of soil conservation and agroforestry technologies in the different sites, due to the strong latent demand for the technologies. However, social and institutional processes were more difficult to scale up. Landcare groups were the key to success but required on-going support to function well. Reliance on local governments as the 'lead institution' tied the program to political and budgetary cycles, undermining sustainability. The case studies indicate that a balance has to be sought between community-initiated change, partnerships with local governments, and promotion of technological and institutional innovations by external actors, this balance depending on a range of contextual factors. Hence, rapid scaling up of Landcare and other community-based agroforestry programs will not come easily.

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Indigenous Knowledge and Agroforestry Practices in the Eastern Himalayas, India

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Agroforestry is one of the basic traditional occupations of millions inhabiting the Himalayas. Both the categories of agroforestry, simultaneous and sequential, are practiced in the Himalayas. While simultaneous systems such as boundary planting, alley-cropping and silvopastoral systems are common in the drier heights of the northern and western Himalayas, the humid eastern and southern Himalayas inspire shifting cultivation, *taungya* system and multi-strata system. Hundreds of Himalayan tribes living in as many enclaves have almost institutionalized agroforestry practices, particularly in the eastern Himalayas where forests have vigorous growth. The indigenous knowledge of mountain dwellers in terms of plot selection, crop selection, crop rotation and timing of shift from one plot to another has often proved to be far superior to that of a specialist. In the Himalayas, forests are part of the agro-pastoral continuum. Most Himalayan tribes use grasslands and forests as common property and practice collective tenure system. Utilization of land by spacing crops and trees, management of resources by alternate phases of agriculture, and regeneration of forest in same plots are collectively supervised by the indigenous communities who rely heavily on oral tradition and experience. The traditional practice of *Jhum* (slash-and-burn clearing of forests) cultivation by East Himalayan tribes is widely recognized as the most viable farming practice in humid tropical forests. Besides, the multi-strata system combining the plantation of large cardamom (*Amomum subulatum*) (lower stratum) and *Alnus nepalensis* (upper stratum) adopted by the inhabitants of Sikkim Himalayas has been proved to be sustainable as well as highly profitable.

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Trends in Agroforestry in the Eastern Hilly Regions of India

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The Eastern Ghats of India, a semi-circular chain of mountains along the eastern coast, is a unique bio-geographical region in terms of physiography, flora and anthropological features. It is inhabited predominantly by indigenous people and boasts about 2000 species of angiosperms. Agroforestry has been influencing the livelihood of these highlanders since the evolution of shifting cultivation. The regional ecology, climate and the people together hatch a favorable niche for this land-use system. Over the years, the landscape of this region has undergone massive transformation along with the agroforestry practices and the role they play in shaping the regional livelihood. The early focus on temporal and home garden systems has been now shifting towards introduced-species based commercial agroforestry interventions. The perennial species richness and diversity in the home gardens and in the sinking shifting cultivated patches has narrowed and new introductions are dominating the landscapes. The temporal and spatial change in rights regime and access to land resources has also greatly affected the vegetation structure and composition on the toposequences across landscapes. The growing environmental lobbies, market forces, institutional factors as well as the policy regulations are transforming the regional agroforestry mosaics. The influence of these developments on sustainability of this land-use system and the livelihood of the landless and marginal farmers are discussed in the paper.

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Sustainability Indicators for Assessing the Impact of Agroforestry Development Projects in Tunisia

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Overuse of forest resources due to excessive human population pressure has led to widespread degradation of woodlands, despite state efforts aimed at the conservation and expansion of forest areas. During the last decade, the forest administration initiated a new orientation towards the implementation of integrated development projects stressing the necessity for local participation in the management of appropriate land use systems. For impact assessment of forest development projects, the locality of Zilia, northern Tunisia, was used as a case study for the identification and quantification of pertinent local *indicators of sustainability assessment*. *Four sets of changing indicators over time were distinguished and they included social and economic well being, the maintenance of ecological integrity, and institutional consolidation*. Zilia's development project, which was implemented between 1998 and 2001 at a cost of $ 0.61 mil., targeted a total area of 253 ha, comprised of 170 ha of forests, 51 ha of pastures, and 32 ha of croplands. Main project investments included the improvement of basic infrastructure, animal husbandry, pasture establishment, vocational training and apiculture. Stratified inquiries and interviews with the different partners involved in the project were used to collect data in order to make multiple comparisons between 1997 and 2002. Results *showed little changes in the behavior of local communities in dealing with the use of forest resources*, and a great deal of dependence on the forest administration for employment and income. It was also noticed that only a few sustainable activities in forests were developing, particularly apiculture.

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Interrelation between Peasant Tree Planting and the Creation of Private Land Property in Laos – Case Studies From Vientiane and Xieng Khouang Provinces

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The socio-economic development of largely subsistence-oriented rural areas is a prominent policy objective in Laos. The diversification of farm production through cultivation of commercial trees on extensively degraded sloping land is acknowledged as a successful option. Three villages have been investigated that differ with regard to scarcity of land for permanent agriculture, the evolution of land tenure, and the level of socio-economic development. The explorative field research followed a specifically elaborated mix of methods. The distribution of land use and land cover types was derived from an analysis of remote sensing data and ground checks. Furthermore, the land capability was assessed based on slope and soil type. Empirical social research tools such as interviews and observation were conducted to collect primary data of the peasant households. Triangulation preferably referred to various sources of data. The spatial analysis revealed that woodlots are generally established on abandoned slash-and-burn areas. Afforestation facilitates the adjudication of legally recognized titles on these land parcels, since customarily claimed but abandoned upland plots are barely transferred into private property. A shortage of high-quality arable land limits afforestation to less favourable sites, while an extensive land reserve supports tree planting on productive land as well. Large individual land holdings claimed on a customary or legal basis favour tree growing. Similarly, the generation of alternative off-farm income allows for an increased afforestation. In general, tree growing could be proved to establish and safeguard individual land property.

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Private Tree Growing and Its Market Development for Sustaining Rural Livelihoods and Poverty Reduction in Nepal

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The decreased supply of forest products as a result of increased forest degradation has considerably raised interest of rural households towards tree growing in Nepal. A study using participatory tools has been conducted in the Terai (flat plains) and Hills of eastern Nepal where rural households are more innovative in comparison to other parts of Nepal. The households' perceptions and attitudes towards tree growing and the socio-economic factors that influence their decision-making to grow trees were analyzed. The study found that trees are an integral component of rural farming systems and are increasingly perceived as an important source of income, particularly in areas having a good market access for tree based products. The choice of trees and their extent and location on farmlands depends upon their market values and usefulness. Households' socio-cultural and economic characteristics and some government policies also have influenced households' decision-making towards growing trees. The study reviewed the present government policies, rules and regulations regarding the cultivation and marketing of trees on private farmlands. It was found that development of tree resources on private farmlands and their commercial utilization aspects are not yet fully explored to their potential. The study found that sustainable development of tree resources could help reduce poverty in eastern Nepal provided that they are wisely used and marketing efficiency is enhanced.

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Making Farmers as Partners in Agroforestry Technology Development (Experiences from the ASEAN Korea Environmental Cooperation Project in the Philippines)

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The On-Site Agroforestry Research is part of the ASEAN Korea Environmental Cooperation Project (AKECU) launched by the Korean Government through its Ministry of Environment in July 2000. Philippines is one of the six ASEAN countries participating in this project, with Mt. Makiling, as one of the on-site field research areas. One of the studies being conducted is entitled "Development of Appropriate Agroforestry Technology through Farmer's Participation in Sitios Tigbi and Karay, in Pansol, Calamba City, Laguna". The project aims to 1) develop an appropriate agroforestry technology by the farmers; 2) develop support livelihood enterprises until such time that the system becomes mature and productive; and 3) ensure cooperation among the community members in carrying-out the project activities rather than completely be pre-occupied in their own source of non-farm income. The application of agroforestry based on the participation of local people and consideration of the biophysical and socio-economic conditions of the locality is chosen as one of the strategies to achieve the goals and objectives of AKECOP. From a community with no cooperation and each farmer is working on his farm all by himself, a community nursery has now been established in the area. The nursery serves as venue for cooperation and camaraderie among the farmers in the area. Also, farmers are establishing their own backyard nurseries that produce their own planting materials' needs. As a result of the asexual propagation training attended by farmers, they are now performing asexual propagation even on their outplanted seedlings.

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Developing MPT Information System and Agroforestry Models Based on Local Knowledge in South India

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Agroforestry systems and tree plantations constitute an omnipresent component of the South Indian rural landscape, from its degraded arid and semiarid lands to its highly populated coastal and mountain areas. Unfortunately, little is known about the diversity, functioning and economic and ecological importance of these systems although their potential to contribute in sustainable development and poverty alleviation is considered very high. In this perspective, to promote the right trees and serve the design of appropriate models, a comprehensive database of the South Indian multipurpose trees was developed at the scale of the different agro-ecological zones of South India, through on-farm surveys and inventories. A total of 260 species with their main botanic, dendrometric, management, and utilization traits, including iconographic data, compose the basis of this information system, MARAM (a Multipurpose tree database for Agroforestry Research and Adaptive Management). Developed as a multimedia tool (CD Rom), it includes all the needed geographical and agro-ecological characterization and retrievable statistics resulting from data analysis, notably on tree management and uses. Finally, it provides the researchers and development actors with primary information on tree attributes and management from local knowledge under well defined agro-ecological conditions to design viable agroforestry models through adaptive management practices.

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Agroforestry Interventions for Watershed Development in India: A Perspective for the Next 25 Years

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India is blessed with vast natural resources of land, water and vegetation, yet confronted with poor quality of life. The country with a population around 1.4 billion by 2025 will require annually 380 million tons of food-grain, 650 million tons of dry- and 1,170 million tons of green-forage for cattle and 346 million m^3 of fuel wood. A demand-driven agricultural policy calls for a quantum jump in production from 212 million tons at present from the net cropped area of 142.22 million ha and 67.55 million ha of forest cover. To meet the challenges of deficits of food, fodder, firewood, employment generation and ensure sustainability of production systems in future, a two-pronged strategy is envisaged. One is yield enhancement through efficient utilization of land and water resources and crop diversification in irrigated areas, and another is holistic development of 97 million ha of rainfed areas following watershed approach. Agroforestry, with the active involvement of watershed communities, is playing a crucial role in the holistic and sustainable development of rainfed areas through watershed development programs. Considerable progress has been made in agroforestry research and extension in the country during the last two decades. It has resulted in identification of suitable multipurpose trees/shrubs and their improvement; prioritization of agroforestry systems (AFS) for different agro-climatic regions; and use of agroforestry practices for reclamation of degraded lands/problem soils. These AFS, strengthened with subsidiary sources of income with sericulture, apiculture and fisheries, will provide opportunities for all-round development of local communities without degrading the environment.

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Reclamation of Degraded River Affected Lands by Women: A Case Study of Kair Khola, Chitwan, Nepal

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Women in agroforestry play a very important role—as much or more so than men—in many settings. However, they face many problems related to social norms, values and unequal distribution of wages, all of which limit their ability to participate in the community development process as active and powerful decisionmakers. The case studies described in this presentation helped in understanding the role and status of poor women in rural households of Nepal. Even though generalizations are difficult to draw on the basis of one case study, it was possible to get the feel of the socio-economic status of poor women in selected households of the study area. This paper presents the findings of four case studies, namely, a case study of Somali Chaudhary, a typical female agricultural worker of Inner Terai. Our paper also looks at the pattern of time budgeting by rural women in two situations, as well as the pattern of child labor in rural Nepal. Women and farm forestry activities in Nepal are also described.

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Towards More Effective Business Development Services for Rural Eco-Enterprises

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International markets offer unique opportunities for eco-enterprises committed to environmentally sound production and socially responsible commercialization of agriculture and forestry products. Driven by increased consumer awareness of health and environmental issues, these markets reward enterprises able to innovate, diversify production, and maintain high quality standards throughout the production process. However, most eco-enterprises must overcome specific deficiencies to fully capture the economic benefits of participating in international markets. Major impediments include high transaction costs, inability to routinely comply with quality and quantity requirements, and large cultural gaps with foreign buyers. Strengthening the competitiveness of eco-enterprises requires access to effective business development services (BDS). The majority of BDS providers are not-for-profit that maintain extended contacts with rural producers. These providers have proven effective in leading groups through pre-enterprise development; however, they often lack appropriate concepts, methodologies and tools for developing self-sustaining businesses. Specialized, for-profit service providers would potentially respond more effectively to needs of eco-enterprises. However, a commercial sector has yet to emerge due to low ability and willingness-to-pay for BDS by eco-enterprises, combined with the 'crowding out' effect caused by subsidized services offered by not-for-profits. In this paper, we present a concerted approach to BDS market development, delineating the appropriate spheres of intervention between not-for-profit and commercial service providers. Not-for-profit provider would specialize in pre-business development services, while contracting out potentially commercially-viable services, such as business linkages and market intelligence. Access to effective BDS would increase the likelihood that producer groups develop into eco-enterprises, exhibiting stronger ability and willingness-to-pay for BDS.

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Silvopasture: A Touch of Philippine Experience

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It is surmised that with increased demand for beef and other livestock products, *silvopasture* would, sooner or later, be an integral part of *multiple use forestry* and/or *agroforestry*. Advantages of integrating livestock production with forestry and the basic steps involved in silvopasture establishment as regard the Philippine experience will be highlighted in the paper.

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Agroforestry Development in Cuba

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This study will present an evaluation of developments in the forestry industry in Cuba over the past 30 years. The analysis will identify the principal problems, strengths and weaknesses, threats and opportunities within the overall sector, and examine each major line of development (e.g., agroforestry initiatives, soil fertility management strategies, eco-agriculture, etc.) within the sector in detail. The assessment will include consideration of the implications of changes in international trade of forestry and agroforestry products for Cuba's industry and an evaluation of the long-run economic potential for the sector as a whole.

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Institutions and Competing Demand for Renewable Natural Resources in Kenya with Focus on Wood Supply from Farms, Forests and Woodlands to Construction Wood Markets in Mombasa and Kisumu: Implications for Policy and Enforcement

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Sufficient supply of construction wood at affordable prices in fast growing African cities is a key issue while considering needs and possibilities for sustainable management of natural resources in rural areas. The paper aims to identify measures and policies that would facilitate the resource management thus benefiting the actors of the wood market. The work is accomplished through applying the Institutional Analysis and Development (IAD) framework on the resource end of the wood supply chains to two cities, Mombasa and Kisumu, in Kenya. The paper evaluates the effectiveness and credibility of exchange markets by focusing on inter-linkages between the formal institutional setting formed to regulate the exchange and the "rules-in-force" used by actors. It is anticipated that a necessary and inevitable condition for a 'credible' institutional setting and low-cost transacting—i.e., the "should be state" best contributing to socio-economic development and sustainable use of natural resources—would be met under institutional conditions that harmonize with actors' ideological attitudes and perceptions. It is concluded that there is an obvious discrepancy between the current policy framework and the practices carried out. A possible as well as desirable route towards long term sustainability is suggested by two means: (i) improving the rights and responsibilities of local people to take part in the resource management and utilisation, and (ii) restructuring the state forestry organisation and its means for enforcement of forestry-related activities in a way that provides cost-effective actions while minimizing the impact of 'politics' on licensing, permitting, excisions and replanting issues.

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Spatial and Technological Factors Influencing Cattle Production and Intensification in Costa Rica

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This paper develops an application of a Tobit with selected sample Model to explain how geographical and spatial features may explain cattle production types in Costa Rica, and how farms and technology characteristics affect intensification. The paper uses GIS-derived variables and Von Thünen's original ideas on land rent. This was a reference case to carry out a critical application of this methodology for the development of regional descriptives and explanatory models for territorial order in Costa Rica. The resulting models indicate the effect of the economic and biophysical variables on the probability of cattle activity type. A first model, Logit model, was developed to consider cattle activity type (dairy or beef) as a function of access costs to dairy market, and incorporating site attributes. The capacity of prediction was 84%. The second models were Tobit Models, one for beef farms and the other for dairy farms. These models considered intensification, using animal stocking as a proxy. They explain intensification as a function of farm characteristics, technology, and geographic and spatial features. These models contribute to guiding the formulation of policies to order land use according to biophysical condition and to the demands and necessities of producers. Finally, land use models show the importance of including the space dimension in explicitly economic analysis. Advances of GIS contribute substantially to giving a geographic expression of the decisions of economic agents on the location of their activities. This research was sponsored by the Cerbastan Project.

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Scaling Up the Impact of Agroforestry: Lessons from Three Sites in Africa and Asia

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This paper assesses recent lessons in scaling up agroforestry benefits, drawing on three case studies: fodder shrubs in Kenya, improved tree fallows in Zambia and natural vegetative strips coupled with the Landcare Movement in the Philippines. Each innovation is being used by over 15,000 farmers and the main factors facilitating their spread are examined. Ten key elements of scaling up are presented and the use of each element in the case studies is examined. The key elements contributing to impact were a farmer-centered research and extension approach, a range of technical options developed by farmers and researchers, the building of local institutional capacity, the sharing of knowledge and information, learning from successes and failures, and strategic partnerships and facilitation. Three other elements are critical for scaling up: marketing, germplasm production and distribution systems, and policy options. But the performance of the cases on these was, at best, mixed. As different as the strategies for scaling up are in the three case studies, they face similar challenges. Facilitators need to (1) develop exit strategies, (2) find ways to maintain bottom-up approaches in scaling up as innovations spread, (3) assess whether and how successful strategies can be adapted to different sites and countries, (4) examine under which circumstances they should scale up *innovations* and under which circumstances they should scale up *processes*, and (5) determine how the costs of scaling up may be reduced.

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JICA's Cooperation in Forest Conservation through Agroforestry Activities: Focusing on Empowerment of Farmers

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The Japan International Cooperation Agency (JICA) provides technical cooperation under the Japanese Government's Official Development Assistance (ODA) program to developing countries in Asia, Latin America and Africa. Its activities vary from technical training of overseas participants, project-type technical cooperation including dispatch of Japanese experts, to development studies. Throughout these activities, a suitable balance of natural resource conservation and agricultural production has been one of the rising themes in accordance with sustainable development, which has resulted in the increase of forest conservation projects with agroforestry components. JICA has been implementing forest conservation projects with agroforestry activities in Kenya, Nepal, and Panama, and also its development studies with pilot projects in Madagascar, Malawi, and Dominican Republic. Approaches of the projects can be categorized into four by *direct targets* (Community group or Model farmers) and *type of support* (Technical-transfer or Participatory capacity building). Projects in Category A (Community group with Technical-transfer) introduce new agroforestry technique to farmers by displaying and providing training at project's farms. Category B (Model farmers with Technical-transfer) is currently without a project due to its lower trajectory for reaching many people. Projects of Category C (Community group with Participatory capacity building) involve participatory planning of agroforestry activities. Projects of Category D (Model farmers with Participatory capacity building) expect repercussion effects from selected model farmers' success of agroforestry to farmers living around them. JICA will continue promoting these projects, focusing on the participation and learning process of farmers, in order to ensure sustainability of agroforestry activities after project phase-out.

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Starting Small: A Safer Approach for the Promotion and Implementation of Agroforestry Projects

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Developing countries have problems of such magnitude that at times only large scale efforts seem to be the only approach to their resolution. Problems stemming from the degradation of nature, including deforestation, soil erosion and loss of biodiversity, are so severe and widespread that government agencies and NGOs often tend to design projects whose goals and activities are often too ambitious. Although our aspirations should be big, experience has shown that starting projects on a large scale very frequently does not achieve the desired concrete results. The purpose of my presentation is to share ideas on using a "small" approach for the promotion and implementation of agroforestry projects. Several examples of projects that started at the small level are presented with electronic photos. Most of those examples are based on the experiences of United States Peace Corps Volunteers who have provided technical assistance throughout Ecuador in many projects sponsored by both government agencies and non-governmental organizations.

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The Boom of Living Fences with Teak (*Tectona grandis* L.F.) in Venezuela: Silvicultural and Financial Aspects

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Recently, the establishment of living fences with teak (*Tectona grandis* L.F.) in the Venezuelan western Llanos has become an activity of major interest for the local people. This is due to the good incomes currently obtained by farmers who established living fences with teak 15 years ago. Some evaluations have been done about growing and economics of this activity: as an example, 100 linear meters of 12 year-old teak can produce six cubic meters of sawn wood as well as 178.35 m of beam longitude and 314.41 m stick longitude, with a gross income of $US 1,200 for the serrate volume timber, $US 57 for the beam longitude and $US 57 for the stick longitude (Barrios, 1999). Despite the interest in living fences, genetic and silvicultural aspects have not been considered, and that is why poor bole shapes and unpruned stems are observed. The establishment of living fences should be the result of a technical program promoted by the Public sector (Ministries of Agriculture and/or of the Environment and Natural Resources), in order to provide farmers with information about genetic quality and seed sources, nursery management and other silvicultural aspects such as weed control, spacing and pruning. Marketing information should be clear and readily available. We propose that a strategy should be implemented, either by the Government and/or the Universities, in order to promote the establishment of teak in living fences as a profitable and sustainable agroforestry land-use form. A financial profitability analysis of living fences with teak is presented.

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Economic Analysis of the Mediterranean Agroforestry Systems

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One of the main problems found in range management when applied to Mediterranean pastures owned by the Public Administration is, in fact, the lack of any kind of plan for management. Nowadays a large extension of public land in Mediterranean Region (Spain) holds tenants livestock numbers that exceed the pastureland carrying capacity. Consequently, the pastures are impoverished, shrubs and tree regeneration damaged and hence, farmers are obliged to feed the animals with external forage or fodder in extensive systems throughout the year, including the grazing season. Some likely reasons for this extreme situation are a very low pasture rental rate by hectare – computed regardless of the livestock numbers -, an inadequate policy of agrarian subsidies, and a general lack of inversion in agroforestry systems in public land. This situation brings up the need for range management plans, which include: (1) an analysis of the pastureland potential carrying capacity as an ecologically viable option, adequate for the animal's health and compatible with other land uses (essential aspect in Mediterranean agroforestry systems), and (2) a complete livestock inventory (current pastureland carrying capacity) with an economic analysis of the main types of farms. This paper shows a complete methodology to make an adequate economic analysis of the Mediterranean Agroforestry Systems and the results in a region with a significant livestock tradition.

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A Comparison of Computer-based Models of Silvoarable Economics

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Computer-based models of silvoarable economics seek to simulate the economic behaviour of silvoarable systems. The literature describing such models is sparse, compared to that on biophysical models, and this creates difficulties for the development of new or existing models. A framework for characterising such models is described in terms of: the model background and purpose, the systems modelled, the objective of the economic analysis, the viewpoint of the analysis, the spatial and temporal scales, the generation and use of biophysical data, the model platform and interface, and the inputs and outputs. This framework was used to provide a coherent approach for comparing five models from Europe, Australia and New Zealand. Each of the models could produce a partial budget to compare the profitability of a silvoarable, arable or forestry system at a one-hectare level using discounted cost-benefit analysis. Two of the models could also be used to examine the feasibility of silvoarable systems on an existing business, and to determine the effects of heterogeneous land types and phased planting. The framework provides users and modellers with a basis for selecting and developing new or existing models. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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The Development and Application of Bio-economic Modelling for Silvoarable Systems in Europe

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In recent years, the European Union has introduced measures to promote the integration of trees within farm businesses. Whereas the introduction of silvoarable systems in Europe provides an opportunity for farmers to engage in this process, the implications at a plot- and farm-scale are not well understood. Since 2001, the Silvoarable Agroforestry for Europe (SAFE) project has been developing computer-based tools to evaluate the biophysical and economic performance of a range of silvoarable systems for different European regions. This paper describes the approach taken to assess impacts arising from introducing silvoarable systems at a plot, farm and regional scale. A simple biophysical model was developed to predict long-term tree and crop yields, based on light partitioning and water competition for given sets of climate and soil conditions. A triple quadrant approach was used to indicate nutrient budgets implicit in annual yield predictions. These outputs were then used in a spreadsheet-based economic model to represent their profitability. Both models were calibrated and evaluated for contrasting agroecological zones in Europe. The analysis suggests that a modest restructuring of the amount and delivery of agricultural subsidies would increase the attractiveness of silvoarable systems. The implications of adopting these systems in the context of natural resource protection and equity issues in world trade are also discussed. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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The Development of an Economic Model of Arable, Agroforestry and Forestry Systems

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A computer-based economic model of arable, forestry and silvoarable systems was developed as part of the 'Silvoarable Agroforestry for Europe' project. The process of developing the model is described in terms of: the model background and purpose, the systems modelled, the objective of the economic analysis, the viewpoint of the analysis, the spatial and temporal scales, the generation and use of biophysical data, the model platform and interface, and the inputs and outputs. The objectives of the economic analysis are to compare silvoarable, arable and forestry systems at a one-hectare scale, and to determine the feasibility of silvoarable systems at a farm-scale. At a one-hectare scale, a partial budget is used to undertake a discounted cost-benefit analysis. The farm-scale analysis allows for heterogeneous land types, multiple enterprises on each land type, phased planting, and farm fixed costs. The model runs on an annual time step and requires biophysical data. It operates in a commonly available spreadsheet and works in different European language versions of the software. The description of the model and the process of development should be useful for future users and those embarking on their own modelling projects. This research was carried out as part of the SAFE (Silvoarable Agroforestry for Europe) collaborative research project. SAFE is funded by the EU under its Quality of Life programme, contract number QLF5-CT-2001-00560, and the support is gratefully acknowledged.

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Women and Agroforestry Adoption in the Northwest Himalayas, India

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Traditionally, women have played a key role in maintaining agroforestry systems in the northwest Himalayas. The socio-economic transformation has been responsible for change from traditional subsistence farming to intermediate to commercial agroforestry systems. Agri-horticulture and horti-pastoral have emerged as dominant agroforestry systems in which temperate fruits and vegetables are grown for cash returns. Women play dominant roles in grass, fodder and fuelwood collection, canopy management of trees, tending of livestock and specified agricultural activities like weeding, sowing, etc. The hill women have much knowledge about the types of trees suitable for firewood, medicines and fruits as a result of continuous interaction with their environment. The relatively small nuclear family, with emphasis on independent dwellings, and improved educational and occupational status, represent deviations from the generally perceived role of women in households and production status in the hills and form of contribution women make in the change scenario. The study analyzes the role of women in the existing hill production system and women's contributions to the maintenance, sustenance and adoption of transformed agroforestry systems. The study also emphasizes that to sustain the present livestock population, grass production should be enhanced by introducing high-yielding perennial grasses in place of traditional low-yielding grasses in orchards through adoption of horti-pastoral systems. It also recommends beekeeping to increase production of orchards and honey. The study recommends organization of women into self-help groups having common interests, to take advantage of the new technologies to increase their cash income from adopted agroforestry systems.

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An Economic Analysis of Poplar based Agroforestry Systems in India

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Poplars (*Populus* spp.) are fast-growing, deciduous, short-rotation trees which as a result have found favor within agroforestry systems. Population growth and industrialization has drastically enhanced the demand for wood and other forest products in India. The ubiquitous presence of poplars in the farmlands of North and Northwestern states of India demonstrates a successful development of poplar-based agroforestry systems. The evolution of these systems is traced to 1970s and onwards. The success has been attributed to adoption of *Populus deltoids* clones viz., G48 and G3, which was recognized as a promising short-rotation species, and its integration with high-value agricultural crops. Scientifically-managed poplar plantations at 8-10 year rotation have an average increment of 15-20 m^3/ha/year. Agricultural crops grown with poplar include sugarcane, wheat, paddy, vegetable, fruits (pineapple, strawberry), and grass for essential oil, fodder and aqua-forestry. For sustainable agroforestry, it is necessary to ascertain economic viability of growing poplar and advise farmers and concerned agencies accordingly. Poplar is a good companion of agricultural, horticultural and medicinal crops due to its fast growth, and easy-to-propagate poplars have gained popularity in both plantation and agroforestry systems. Further, development of local markets and poplar wood-based industries has made poplar growing viable. Integrated approaches for development of poplar-based agroforestry can play a crucial role in overall regional development. Poplar is found to be suitable for integrated land use, ecologically stable, economically lucrative, industrially supported, socially acceptable, and financially viable where high yields are achievable, making it one of the promising agroforestry tree species.

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Policy and Legal Constraints for Agroforestry Development in the Northwest Himalayas, India

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Agroforestry has traditionally been an integral part of the complex, highly interactive and substantive farming systems of the Indian Himalayas. Farmers maintain different tree species on their lands and practice mainly need-, economy- and/or environment-based agroforestry systems. The national forest policy (NFP) in India aims for a minimum of one-third of the total land area under forests with two-thirds of it in the mountains. NFP does not highlight the importance and relevance of agroforestry even though agroforestry provides multiple products and services and has immense potential to support local economy and poverty reduction. The existing policy and legal provisions on control, use and management of forests and lands are scattered over several acts, rules, settlement reports, notifications and government orders. The paper discusses the acts relating to the management, harvesting, transport and marketing of trees grown on private lands in the northwest Himalayas. The study explores that the current policies, legal provisions and operations of various acts create unnecessary disincentives for the growing of trees and constrains the development of agroforestry. The existing forestry legal framework is a major deterrent to the agroforestry development as the legal provisions are found to contain conflicting and contradictory provisions. The relaxation of rules and regulations that encourage people to promote and adopt agroforestry is required. Similarly, policies with regard to forest and land management instead of being complementary to each other are found to have conflicting provisions. There is thus a need for coherent national and state wise agroforestry policy.

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Economic Evaluation of Agroforestry Investment in the South Basin Watershed of Lake Managua, Nicaragua

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The Managua basin is environmentally "threatened" and is in the process of deterioration due to six threats: overuse of agriculture, deforestation, soil erosion, floods, environmental contamination, and disordered urban growth. Managua, as well as the urban infrastructure and highways, is at risk due to the hydrological deterioration of the basin. This study had as objective to evaluate the economic viability of Agroforestry Projects and channel control in the basin. The methodology integrates a method that combines soil loss estimations and environmental economics. The increment of productivity per hectare generates benefits of $229,500 in four years. With agroforestry systems, soil retention in 2,700 ha was 148,230 m^3/ha/yr. Soil retention and B/C ratio were higher at the upper level of the watershed with 80,844 m^3 and 4 respectively, at the middle part the soil retention was 153,787.00 m^3 and the B/C 3. At the lower level, 323,032 m^3 and the B/C was 1. In general the B/C ratio was 50 with 557,661 m^3. The retained volume of soil in channels was 153,800 m^3 with a cost of US $1.28/$m^3$. The volume of soil without sand in channels and micro-dams was 323,000 m^3 with a cost of US $4/$m^3$. Therefore, about $196,730 was spent in soil loss prevention, but about $599,771 could have been spent in removing the sand from the soil. This generates avoided costs or social benefits of $403,041. This result of B/C ratio is important in relation to B/C financiers, hence use of economics to assess stakeholder incentives is justified.

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Credit based Agroforestry Projects for Rural Prosperity in India

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NABARD provides credit for sustainable agriculture, village industries and Agroforestry for integrated rural development. National Agriculture policy has advocated Agroforestry for efficient nutrient cycling, nitrogen fixation, organic matter addition and drainage improvement. Planning Commission proposes to bring 33% land under tree cover, for which 28 million ha need to be brought under Agroforestry. To achieve this, new Agroforestry projects must be promoted. NABARD had promoted Cottonwood (*Populus deltoides*) under Agroforestry in 1980s in Punjab, Haryana and Uttar Pradesh. It was highly successful and brought tremendous rural prosperity in the areas. The wood is used by plywood industries and successful agrocrops are wheat, mustard, potato and chillies. In 1990s, we promoted Eucalypts and *Anthocephalus chinensis* which were very successful. To promote more projects, NABARD undertook studies in 2001 and found *Leucaena leucocephala* and *Casuarina equisetifolia* most promising and promoted credit-based agroforestry projects in Andhra Pradesh. Encouraged by success, Government liberalized its policy by creating agriculture marketing committees, NABARD brought Agroforestry under automatic refinance and reduced interest rate. Now, we are promoting *Bamboos* in Aassam and Tripura. Agroforestry is NABARD's priority area of investment. It also provides grants for Agroforestry research besides holding workshops for promotion. Its projects have helped in improvement of rural livelihoods and food security. However, major constraints are: lack of enthusiasm among tree farmers, quality planting stocks and marketing avenues; high interest rate and lukewarm approach of bankers for financing Agroforestry projects and nonavailability of land with industries. NABARD has so far invested US $62 million under Forestry/Agroforestry.

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Modeling and Transitions of Land Use Strategies among Small Farmers in the Amazon

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While shifting cultivation has often been regarded as a 'villain' in accelerating tropical forest deforestation, agroforestry systems have been welcome as a 'panacea' for sustainable land use. Both systems, however, are similar, being characterized as self-sustaining land use systems, to the extent that they make the maximum use of nutrient cycles and environmental functions provided by forest formations. These systems contrast to heteronomous land use systems, represented by conventional agriculture, which is supported by permanent inputs of nutrients and disease control materials. The difference between shifting cultivation and agroforestry systems entails extensive/intensive employment of land and capital. While shifting cultivation is land intensive and capital extensive, compensating the lack of financial capital for vast tracts of forest resources, agroforestry systems are land extensive and capital intensive, compensating relatively small land availability for higher productivity through capital inputs in the formation of artificial forests. In terms of attaining high productivity, agroforestry systems resemble conventional agriculture, which is characterized as a heteronomous, capital intensive land use system. Based on the above modeling, the transitions of land use strategies among small farmers in the Brazilian Amazon were reviewed and analyzed, involving a field survey conducted in Marabá region in the eastern state of Pará. The results showed that, as initial capital is available in financial and technical assistance, small farmers are increasingly adopting more land intensive land use strategies based on agroforestry systems for economic benefits, departing from land extensive land use strategies, represented by shifting cultivation and pasture development.

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Successful Extension Models of Animal Production in Silvopastoral Systems in Cuba, Mexico and Panama

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Three extension models on animal production in silvopastoral systems in Cuba, Mexico, and Panama are analyzed. All were developed as projects of public institutions, and in the case of Panama and Mexico with support of the Food Agriculture Organization of the United Nations (FAO). Extension tools included training leader producers, workshops "learning by doing", and the establishment of demonstration modules in selected farms. The Cuban models developed by EEPF "Indio Hatuey"-MINAG promoted dairy and beef cattle models, which included fodder trees (especially *Leucaena leucocephala*) planted in rows within improved pastures, and sugarcane (*Saccharum officinarum*) as an animal feed supplement in the dry season. This agroforestry system currently occupies over 16,000 hectares in several provinces. In Panama, FAO-MIDA promoted goat modules with confined animals and Mulberry (*Morus alba*) fodder banks as the main feed, fertilized with goat manure. Government's goals include the establishment of over a thousand modules country-wide for goat milk production and its derivates. In Veracruz, Mexico, a model of dairy farms was promoted by FAO-INVEDER, which includes fodder trees of *L. leucochephala* associated within pastures, and supplemented with protein banks of *M. alba.* Preliminary results indicate milk production increases, and the system's rapid adoption by dairy producer associations for quality cheese production. In all three countries the goal of substituting grain concentrates for fodder trees as the main source of animal feed, while maintaining or increasing the same levels of animal production, has been achieved.

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Mechanisation of Pruning in Agroforestry Systems: The Potential of Portable Motor-driven Tools

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In tropical agriculture, agroforestry systems play an important role in improving soil fertility, restoring organic matter in resource poor soils, mitigating land degradation processes, providing fuel wood and other services. Farmers, however, reject these systems despite their benefits and services they supply, complaining about the tremendous work load they face when hedgerows have to be pruned occasionally. Often, pruning coincides with other important field or farm activities, thus competing for labour force. Portable, motor-driven tools such as bush cutter, hedge trimmers, extended length hedge trimmers and edgers are already used for pruning in various cropping systems, forest thinning and cut-back of natural vegetation along roads. Using these tools in pruning of coffee plantations led to a considerable reduction in work load and improved coffee production economically. There is evidence that these tools are perfectly suited for application in agroforestry systems as they shorten the bottle neck of labour demand which may contribute to a better acceptance by farmers. Experiences from Indonesia showed good results. This presentation outlines how results and experiences from other cropping systems can be applied to agroforestry systems and discusses the potential of mechanization for improving the economic output and the acceptance of these systems by farmers.

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Indigenous Agroforestry Practices in Bangladesh

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Age-old indigenous agroforestry practices in Bangladesh follow reasonably stable land use systems combining woody perennials, agriculture, and livestock in response to physical, biological and socio-economic environments. Based on spatial arrangement or temporal sequence, agroforestry practices are found in variety of systems as cropping system, livestock production system, crop-tree production system, fisheries production system, etc. The farming system is the result of farmer's response to the immediate environment in accordance with his (her) understanding, goals, preferences and resources. The country's 15 million homesteads, occupying about 0.3 million hectares, are under indigenous agroforestry practices and the integral components of the same farming system include production, management and utilization. Agroforestry products are used in innumerable ways to fulfill the family's daily requirements and social needs. Agroforestry practices are linked with key elements like food production, fodder production, fuel supply, cash income generation and other functions. Other functions include variety of necessities like timber for construction and furniture, use of branches as props and trellis for creepers and soft-stem crops, hosts for silkworms, shade in tea gardens, etc. Farmers' traditional wisdom has the potential to make important contributions in poverty alleviation and environmental improvements; but, analysis on the existing linkages among agroforestry practices, dissemination of effective ones and innovative improvements still remain at a rudimentary stage.

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Economics of a Novel Temperate Agroforestry System in Pennsylvania: The Potential for Integrated Land Management

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Forest farming, as an agroforestry system, is becoming more popular as farmers and landowners seek alternative income sources. Perhaps the most lucrative forest crop in Pennsylvania is American ginseng (*Panax quinquefolius*), a perennial herbaceous forest plant whose root has been collected for centuries in Pennsylvania and surrounding Appalachian states. The cultivation of ginseng in forested areas provides an opportunity for income from both timber and the ginseng. This paper examines the financial returns of a temperate agroforestry system that integrates simultaneous and complementary overstory (timber) and understory (ginseng) crop management. The objective is to compare the monetary returns from a variety of timber stands common to Pennsylvania with that which might be earned from American ginseng on an equal area basis. Six forest types that are conducive to ginseng are selected and typical timber yields and prices are calculated for an 80-year rotation on an acre (1/3 ha) basis. In addition to a regeneration cut at the end of the rotation, an improvement thinning is carried out at 50-years on each forest type. Using the same unit area, ginseng costs and returns are examined at three stand densities ranging from one plant per 1 ft^2 (high labor and capital inputs) to one plant per 100 ft^2 (low labor and capital inputs). In addition to planting densities, other ginseng price variables will be addressed such as market realities, different husbandry intensities, and alternative product scenarios. A matrix is developed showing discounted net returns for alternative timber and ginseng production scenarios.

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Colombian Coffee Agroforestry

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The production and market of coffee beans (*Coffea* spp.) has been traditionally important for the development of Colombia. This crop has been grown in mountainous areas where most of the population and commercial activities are concentrated. Any change or effect in coffee production or market, has effects on Colombian economy, society and environment. The Colombian coffee agro-industry, most of the time, has taken the coffee beans to international market, as unique source of foreign currencies; leaving for the internal consumption the rest of the products of this typical agroforestry activity. Diverse internal and external factors have influenced the dynamics of land use. Certain temporary changes toward an intensive cropping system for coffee showed undesirable effects, mainly due to environmental effects; however, these have been overcome by mean of agroforestry practices. There are other social and economic reasons that are changing the Colombian coffee industry policies, as the crisis of the coffee international market. Nowadays coffee plantations are associated with other species such as plantain, walnut, oak, flowers, fruit trees, beans, corn, aromatic and medicine plants, etc., producing a variety of products for the local and for the international market. With these practices, many soil erosion areas have been recovered and also the water balance for the watersheds has been improved.

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Sustainability of Colombian Sugarcane Agro-industry through Agroforestry Practices

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Colombian sugarcane agro-industry is basically concentrated on the Cauca river valley, where at the present time are about 200,000 hectares of sugarcane (*Saccharum officinarum*) and about 3 million people. This region reaches one of the highest sugarcane production levels by hectare in the world, due to the concurrence of technological and environmental factors. Most of the rural population is poor and a high percentage of highlands population is living under extreme poverty levels. During the last 12 years, efforts to improve the population conditions have been increased through extension programs, land and water management projects, soil amelioration, protection of water sources, etc., using agroforestry techniques and producing beneficial externalities for the sugarcane production. According to the social and environmental conditions, there are different agroforestry techniques applied and different products obtained: protection areas, wood, nuts, fruits, flowers, food, etc. As a result of the agroforestry practices, there are improvements of the watershed's cover vegetation, increase of products variety and better environmental effects as the improvement of the hydrological response of the watersheds. Due to the benefits of these alternatives, the program has been applied to the highlands of most sugarcane production watersheds. Also it is recommended to apply most intensive and extensive agroforestry techniques to the lowlands, where sugarcane is by far the dominant crop.

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Devolution of Powers to Communities to Manage Forest Resources in North-East Namibia

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Namibia faces several land degradation problems, including deforestation. As part of government's decentralization policy, the Ministry of Environment and Tourism has put in place policy and legal framework, to empower communities to manage resources sustainably to reverse this trend. Management has been devolved to the communities who in turn have established different institutions to manage forest, water and wildlife resources. This paper presents activities of Namibia-Finland Forestry Programme of the Directorate of Forestry, who facilitate the process of devolution of powers for community-based forest management. Community institutions and stakeholder partnerships have been established in line with the Forest Act. The process culminates into the declaration of community forests; where, resource rights, ownership and management are fully devolved to communities. In North-East Namibia, the process has taken about three years due to legal requirements and inherent community dynamics. Nevertheless, some lessons learnt are that, stakeholder commitment and active community participation are factors which auger well for resource management. Consultations and close collaborations with the communities also serve to indicate the governments' commitment to the devolution of powers to the communities. The experience shows that the process of devolution can be made faster by accomplishing basic critical aspects such as establishment of community structures to manage the resources, technical aspects to provide basis for planning and capacity building to equip communities with appropriate skills.

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Approaches to Expand Agroforestry Program Outreach

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Nongovernmental organizations (NGOs) are widely recognized for their success in designing and implementing locally effective agroforestry programs. But despite their effectiveness at solving local problems, most NGOs are small, scattered organizations that often lack the ability to generate large-scale change. In response to demands for expanded services over larger geographic areas, many NGOs attempt to expand their agroforestry program outreach. While many NGOs attempt expansion, only a few succeed in retaining on a large scale the very attributes that fostered their local successes. Such NGOs are caught in an apparent dilemma. They can stay small and achieve few large-scale impacts, or they can expand their operations and become less effective at the local level. This paper examines how NGOs successfully achieve large-scale outreach, yet remain relevant to local needs. It draws on a survey of 168 NGOs from 42 developing countries on four continents that had expanded their agroforestry program outreach or that operated large agroforestry programs, and from indepth interviews of NGO administrative and field staff in eight developing and developed countries. It examines the complexities of the expansion process, and identifies critical elements to consider in expansion efforts. It documents eight approaches used by surveyed NGOs that work well on a small scale yet can be transformed and incorporated into large-scale strategies, structures, and systems. These include: capacity building, networking, organizational growth, program replication, organizational multiplication, influencing, intermediary arrangements and partnerships.

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Market-Driven Conservation: Diversifying North American Farm Enterprises by Producing Specialty Woody Crops in Agroforestry Systems

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Producers in the North American Midwest and Great Plains are expressing considerable interest in growing “alternative crops” such as specialty forest products for the food, medicinal, decorative floral and handicraft markets. Many of these commercial products can be produced in temperate agroforestry plantings such as windbreaks, alleycropping arrangements, and riparian buffers, providing both environmental and financial benefits to the producer and to society. Extensive national and international markets worth millions of dollars exist for specialty woody crops, including florists for woody florals; jelly, jam, juice and manufacturers for small fruits; ice cream, confectionary, oil and nut companies for tree nuts; nutraceutical, pharmaceutical, food supplement and tea companies for botanicals and medicinals; and craft supply companies for specialty woods and other handicraft products. This paper summarizes extensive and newly available data on cultivar selection, production, performance, prices and markets derived from replicated on-station and on-farm agroforestry field trials, market assessments and product sales in both the United States and Canada. It presents costs and returns for selected woody crops produced in agroforestry systems, and identifies the multiple benefits and challenges of producing specialty woody crops in these integrated systems. Fundamentally, this paper presents strong support for a new field-tested, profit-driven model for accelerating producer adoption of more sustainable agroforestry systems.

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Community Based Tourism (A Case Study from Bagmare Community Forest, adjacent to Royal Chitwan National Park, Mid-low land, Nepal)

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A study was carried out during 2001 and 2003 at Bagmare community forest located at buffer zone of Royal Chitwan National Park, Nepal. The present paper mainly highlights on the potentiality of community forest with entrepreneurship development like NTFP-related industries, agroforestry program and other income generation activities with special tourism industries through the public participation of user group members towards community forest management. Management of community forestry not only helps to meet people's daily needs for fodder, fuel wood and timber but also conserves biodiversity of the area as well as equally holds potential for drawing direct economic benefits through community based tourism. It also conserves local resources, helps to increase household income and generates employment opportunities for the local people. Thus, it provides for restoration of natural forest resource base and for benefits from integrated conservation and development activities of community based tourism. Data were collected through primary and secondary sources.

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Greenery in the State of Kuwait

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Kuwait is a desert country characterized by harsh climate, poor soils, and scarce water resources. Several attempts are undertaken to combat desertification in the arid country of Kuwait. These include the emphasis on the native plants through mass plantings of local plants to be further used in the desert rehabilitation, where seeds from the desert are being collected to be used for the natural re-vegetation process. Other attempts include the introduction of exotic ornamental plants that can endure similar harsh climatic conditions. Several studies are being conducted to enhance the greenery and beautification of the country. More than 150 ornamental plants have been introduced and naturalized within Kuwait and yet around 200 more species are being examined for further introductions. A new study that was also conducted to enhance the re-vegetation of the country was the remediation of the oil-contaminated soil that resulted form the Iraqi invasion on Kuwait. In attempts to retain the soil's productivity, physical, chemical and biological methods of remediation were earlier studied. The biological method was recommended for agricultural purposes. Local and newly introduced ornamental plants were experimented using bio-remediated soil. After a thorough study of the plants' performance the results proved that there were no major differences in the plants' survival and vegetative growth in both soil types.

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Agroforestry: Policy and Institutional Issues in the Indian Context

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Relevance of agroforestry in the Indian context with prime focus on food security can hardly be overemphasized. In the scenario of competing basic landuses like crop husbandry, grazing, forestry, mining and urbanization driven by unavoidable needs of different or overlapping sections of the population with small per capita land availability of 0.32 ha, integrated landuses like agroforestry assume added significance being suited to the social, economic and environmental aspirations of the people. However, despite its suitability and relevance to the Indian environs, agroforestry has not received due attention in the matter of policy and institutional support for attaining its potential. The paper outlines suggestions for achieving the target of bringing one-third of the land area under tree cover as laid down in National Forest Policy (NFP) to meet the requirement of environmental stability without compromising on food security and the reasonable demand for fuelwood, fodder and timber. The paper attempts to quantify extent of wastelands and agricultural lands to be brought under agroforestry to achieve the NFP target. Strategies for dealing with different landholding sizes are also suggested. The need and relevance of evolving an 'Agroforestry Policy' independent of the National Agricultural Policy (NAP) and National Forest Policy (NFP) to give required thrust to development of agroforestry are dealt with logically. The paper also dwells upon components of the proposed policy and its institutionalization aspect. The policy and institutionalization issues of agroforestry described in the paper are relevant as well to developing countries especially in the Asia-Pacific and African regions.

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Influence of Tenure Regimes on Management of Tree Resources and Landscapes Adjacent to Protected Areas: Some Examples from East Africa

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The extent to which tree resources are conserved in many parts of the world is in part a consequence of ecological characteristics of the sites in question, historical human and forest resource interactions and evolved management systems. Where strong traditional regulatory systems exist and resource-partitioning strategies are developed, sustainable use regimes are possible. These people-resource interactions are best seen in the typology of livelihood systems observed in landscapes within or adjacent to protected areas. The diversity of landscapes in various ecological zones of East Africa and associated tree species represent on one hand a rich ecological heterogeneity and on the other a resource use continuum. Although forest resource dependence was in the past largely subsistence driven in most parts of East Africa, this has changed in recent years as commercial interests are becoming a significant part of rural economic lifestyles. Shifts from traditional resource use systems to more diversified forms of economic livelihood and concomitant land and resource tenure changes amongst most rural communities has triggered considerable stress on forested landscapes and tree resources. Unless alternative systems are developed that respond sufficiently to the socio-economic and cultural realities of local populations, it is very likely that random non-reversible degradation trends will continue to occur in such landscapes. To counteract likely negative effects of these anthropogenic activities, strategies optimizing economic and other benefits from a combination of land-use options are needed, informed by well articulated national forest policy guidelines as well as clearly defined resource tenure and institutional arrangements.

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Ecological and Economic Effects from Forest Shelterbelt Introduction in Lugansk Region of Ukraine

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The investigations were carried out in Lugansk region. This region is situated in the Eastern part of the Ukraine Steppe zone. Soil erosion is a cause of severe damage in agriculture of the zone. Decreases in soil fertility and the areas under cultivation, incomes of producers, taxes paid, and the opportunities for solving social problems, are the main results of soil erosion. In connection with this, the regional ecological and landscape system of crop farming and the program for development of it have been worked out. The program determines the stages of development of the system. The program is realized in one of the pilot agricultural enterprises “Roduchist-2000” Markovsky district. The enterprise has 3,657 ha of land. The elements of this system are the structure optimization of farming and arable lands and planting of forest shelterbelts. The realization of these elements is being carried out according to the location of natural landscape borders. The state and regional budgets and financial resources of producers are the sources of the primary stage of fulfillment of the system. The emphasis has been made on economic basis of the system realization. General ecological and economical effects include, in monetary terms: prevented soil losses from erosion, additional agricultural output from ameliorative influence of forest shelterbelts, expenditures for planting of forest shelterbelts, decreasing of output from reduction area under forest shelterbelts. The active positive effect of forest shelterbelts will be shown from the fifth year. All the expenditures will be compensated in nine years.

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Value Addition to the Agroforestry Tree Species through Vermitechnology

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Eucalypts, Poplars and Leucaena – all fast growing, non-native, agroforestry tree species in India – have lately acquired a controversial character because of their strong allelopathic interference potential in agroforestry and plantation systems. Stories in support and strong opposition to these trees are rather common. The trees are accused of causing loss to biodiversity under plantation systems. Because of low LER (Land-Equivalence-Ratio) they are accused of causing economic loss under agroforestry systems. After over two decades of working on ecological interactions and economic aspects of such agroforestry species, we have devised a novel vermitechnology technique of adding economic value to the biomass of such species. It is proposed to share the state-of-art and to present and compare the ecological and economic evaluation of some of the Agroforestry species.

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Legal Issues involved in Agroforestry Development in Himachal Pradesh State, India

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Agroforestry has been practiced since ages past in India in general and in Himachal Pradesh in particular. In Himachal Pradesh (H.P.) major species grown on private lands in lower and mid hills mainly include *A. catechu, D. sissoo, M. indica* and in the higher hills species such as *P. roxburghii, A. pindrow, C. deodara, P. smithiana* are grown. The existing legal framework for regulating agroforestry practices in H.P. is however fast becoming redundant and obsolete. In the era of liberalization, privatization and globalization the State control and restrictions ought to be made compatible and conducive to creating favourable atmosphere for strengthening agroforestry practices and saving the forests from rapid degradation and to enhance income of local people. Locals should be encouraged to adapt private forestry. Time has come when provisions of Acts and Rules such as H.P. Land Preservation Act (LPA), 1978 and Rules, 1983, the H.P. Forest Produce (Regulation of Trade) Act 1982, Timber Distribution (TD) rights be overhauled and modified. The guidelines issued by Hon'ble Supreme Court of India regarding felling of trees on private lands also need some revision. The exclusion of six species from the provisions of LPA etc. recently is a step in this direction. Since forestry is a long gestation activity, there must be long term consistency in the rules, regulations and policies framed by both central as well as H.P. Government. The paper makes an attempt to identify impugned and obsolete provisions under different laws and to suggest the probable and necessary amendments.

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Women in Agroforestry: Issues and Lessons Learned from Himachal Pradesh State, India

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India resides in villages and women nourish villages. It is very common to find rural women carrying heavy loads of firewood, clearly depicting one of the major female roles in forest resource management in Himachal Pradesh (H.P.). However, due to population pressures that have led to over-exploitation and depletion of forest resources, women have to travel more and spend more time to collect firewood and fodder (up to or more than 6 hours daily), thus neglecting livestock and interrupting their children's education. They also have the responsibilities in preparing and using firewood for cooking and home heating, rearing livestock and taking care of their children. To meet ever-increasing demand for forestry products, deforestation takes place, leading to soil erosion and reduced agricultural productivity. Therefore the people suffer socially, economically and ecologically. These problems, to a large extent, can be sorted out by growing an appropriate combination of agricultural crops and forest trees. There is a need to increase forested area and to stabilize the ecosystem and environmental conservation in addition to supplying local demand for firewood and food. This paper highlights the issues that concern womenfolk in Himachal Pradesh with special reference to Agroforestry. These issues include availability of forest per capita, low productivity of forest, closure of forest areas for regeneration, large-scale weed infestation of forest floor, low investment in forestry sector, participatory forest management and the necessity of practicing agroforestry practices. It is largely based on the author's own field experience in several parts of the state.

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Combining Farmer Indigenous Knowledge and Participatory Methodologies to Evaluate Agroforestry Species for Various Uses in Eastern Zambia

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Farmers' Indigenous Technical Knowledge (ITK) and participatory methods are rarely used in evaluating agroforestry tree systems in Eastern Zambia. We conducted a participatory study with 112 farmers in on-station agroforestry germplasm screening in four districts of eastern Zambia. Farmers used their ITK to identify indicators that they used to rate 11 agroforestry trees using a '*bao'* game for soil fertility replenishment, fuel wood, fodder, light construction material and poles production. From the eleven (11) tree species: *L. collinsii* 45/85, *G. sepium*, *A. angustissima, C. calothyrsus* (ex Embu), *S. siamea, L. escurenta* 52/87, *L. pallida, L. diversifolia* 35/88, *L. diversifolia* 53/88, *S. spectabilis* and *L. escurenta* (Machakos), the later four rated low for all the benefits mentioned above, and can be dropped early in the research process to reduce on costs. The simple indicators developed by farmers to select species can stand as proxies for chemical tests used by scientists. N concentration of leaves can be estimated on basis of their leaf colour. Tannin or polyphenols can be determined by tongue test and fibre content by crushing leaves. If a leaf can be crushed to powder it has low fibre content. These methods need to be tested with many farmers. If these indicators are robust across many species and across agro-ecological zones, then decision trees can be made to select species for various uses. This will allow rapid screening in farmers' fields and communication between scientists and farmers in participatory research and development projects.

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Institutional Incentives and Agroforestry Parklands Dynamics in North-Cameroon

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In the sudano-sahelian zone of North-Cameroon and for more than a century farmers have been building multipurpose agroforestry parklands, which are either cropped, under fallow, or grazed, and provide various products. Until the 90's, technical advisory structures have ignored these parklands, and even encouraged tree clearing from field, for trees hamper animal draught or mechanical tillage for cotton cultivation. From 1985 onwards research stressed the interest of local agroforestry species; but only in 1996 did the DPGT (Farmer's Development and Territory Management) project attempt to induce tree (*Faidherbia albida*, *Prosopis africana)* resettlement in the fields, by subsidising retaining of every new tree. The study shows that farmers hold firm knowledge of tree and parklands management, and that tree retaining and parkland area increase. However, this evolution hangs on the ability of local organisations to take over from DPGT for subsidy management and to reach agreement with the Forestry Administration on how to rule and control tree cutting or pruning by peasants. Tree management will be improved by: (1) pursuing research on thinning, pruning and cutting practices and supporting it by modelling of dynamics of village tree resources, and (2) considering parklands as part of community forests in order to transfer management responsibility to local population, like the forest law allows it. Institutional action based on incentives to farmers can thus sustain agroforestry systems in African savannahs, thereby increasing production, biodiversity and even carbon storage.

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Study-circle Promotion of Agroforestry Techniques among Zambian Small-scale Farmers

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On-farm scaling up the adoption of agroforestry depends upon several factors, including processes through which farmers share information and seeds. One such process that has been successful in central Zambia is the study-circle method, a form of non-formal adult participatory education that has been practised in Sweden for over 150 years. The staff of Kasisi Agricultural Training Centre, with support from the Swedish Co-operative Centre, has written several manuals for small-scale farmers to use in study circles. Seven to twelve farmers come together to form a study circle group and meet nine times to study agroforestry from the Agroforestry Study Circle Manual. There is a group leader, who need not be an expert in the subject matter, who is trained in study-circle leadership skills, and whose task it is to animate the group. All participants contribute to the learning process. At each meeting the participants cover the material in one of the nine chapters of the Manual. Each chapter ends with a set of questions or suggested practical exercises to stimulate the participants' discussion and sharing of information. An example of a practical exercise is the establishment of a tree nursery by the group. The tree seedlings that the group raises are eventually shared among them for planting in their own fields and at community sites such as a rural health clinic or an information centre. The participants report that the study circle is a very good method to learn about agroforestry techniques and to share information about solving problems.

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Technological Innovations Oriented to High Value Timber Production through Mechanization in Chile

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Diversification of species and of cultivation techniques is desirable because it has important social, economic and environmental impacts and it represents an alternative to reduce the monoculture's problems (more than 2 million hectares in Chile). Several actions have been implemented looking for a productive innovation: modalities for cultivating non-traditional species, or new ways of cultivating traditional cultures. The severe crisis can be overcome mainly by productive innovations. One of these innovations is high value timber production, which can be produced in association with other agricultural products. In this context the use of common walnut or other fruit-bearing species that possess valuable wood constitutes a feasible alternative to be incorporated in the rural agricultural productive systems. Walnut is par excellence as an agricultural species, making the incorporation of the forest component an interesting complement to the property economic activity. Timber markets demand logs ideally 3-4 m long, right, without defects, with regular growth rhythm. Longer logs get much higher prices, this being reason why some owners have been developing a new technique called *high pruning*, which is characterized by being intense, costly during the first 4-6 years, and dependent upon mechanization. Interesting results have been obtained, that are presented in the paper. Through this technique it is possible to harvest logs up to 9 meters long, oriented to special markets (for expensive and specific uses), using special tools and equipment. Costs are economically justified.

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Farmer Participation in Scaling-up of Agroforestry Technologies in Zambia

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Agroforestry has been identified as having the potential to mitigate the problems of soil degradation, shortage of food, animal fodder, timber and fuel wood. Among the various agroforestry options tested, the improved fallow technology addressing soil fertility problems has been widely tested by farmers. However, one of the obstacles to scaling up of this technology has been perceived to be lack of an effective dissemination pathway. Recently research on dissemination pathways has been done. Three pathways namely farmer trainers, agricultural extension officers and local leaders have been considered. Farmer trainers have emerged a quicker way to disseminate agroforestry technologies to achieve impact within a short space of time. Attempts have been made to use farmer trainers through other organizations such as World Vision International and the District Women Development Associations to reach more farmers. It has been realized that farmer trainers in the past have had a knowledge gap which has hindered them from effectively disseminating the technology. In an attempt to build capacities among the trainers, ICRAF with financial assistance of the USAID decided to scale-up agroforestry to other areas that have not been reached by other partners in order to accelerate use and uptake of agroforestry. Farmers are trained in aspects of the technology stage by stage and are allowed to implement what they are taught before the next stage training. This poster shares the experiences from the TARGET project, which works at different prongs of scaling up and discusses sustainability of farmer trainers as dissemination pathway.

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Farmer Tours and Exchange Visits as Impact Tools for Agroforestry Technologies

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Over the last decade, improved fallows have been developed as a means to combat problems of decreasing agricultural productivity and environmental degradation. By providing nitrogen to crops, tree fallows can help farmers increase their incomes and help the nation to improve its food security. In Zambia, both on-station and on-farm studies have shown that improved fallows of 2-3 years of *Sesbania sesban*, a nitrogen-fixing legume, can increase maize (*Zea mays*) yields significantly. On-farm research trials started in 1991. Since then, the number of farmers planting improved fallows has been increasing rapidly. Farmers that have been involved with improved fallows have been easily convinced that the technology works. There are however, those farmers that have not seen the results of such research and thus find it difficult to believe the results when it is theoretically explained to them. Farmer tours and exchange visits seem to be beneficial for such farmers. These are visits by farmers to other already practicing farmers of a particular technology, in this case agroforestry. It is an experiential learning tool, which combines 'seeing', 'hearing', and 'doing' in helping the farmer acquire new knowledge and skills. Farmer tours and exchange visits create awareness and help influence farmers to take up a technology. The poster will therefore share views of the farmers that participated in the tours and exchange visits, and illustrates the benefits accruing to both the hosts and the visiting teams.

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Planting Trees around Poultry Farms: A Proactive Environmental Initiative

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Increasing urban encroachment and issues relating to emissions from poultry houses are challenges facing the poultry industry. Neighbor-relations concerns are exacerbated when residential homes are in close proximity and downwind of poultry farms. With rapid adoption of tunnel and windowless-type poultry housing systems, planting trees around the perimeter of poultry farms may offer the following benefits: i) filter emissions from houses (e.g., odor, dust, ammonia and feathers; surface and groundwater nutrients), ii) provide a visual screen to improve neighbor relations, and iii) potentially improve energy efficiency and biosecurity on the poultry farm. In response to growing odor-related and environmental concerns, stakeholders on the Delmarva Peninsula met to draft preliminary guidelines for the implementation of a program of using trees as vegetative filters around poultry farms. With support from the USDA Natural Resources Conservation Service and local conservation districts, cost-share programs have been established for this practice in the region. With support from various organizations and agencies, the University of Delaware has implemented numerous projects to evaluate the efficacy of trees in filtering emissions, the fate of nutrients captured, survivability of different tree species when placed in close proximity to high-capacity exhaust fans, and an assessment of possible production benefits of trees around poultry farms. The preliminary results from these studies, potential barriers to implementation, details and status of local cost-share programs, and the industry response to this proactive environmental initiative will be discussed.

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Lacandon Maya Agroforestry in Chiapas, Mexico: Nematode Concentration and Plant Community in Traditional and Non-traditional Plots at Three Successional Stages

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The Lacandon Maya of Chiapas, Mexico practice a system of agroforestry that mimics the surrounding ecosystem and its successional stages. Their fields rotate through grass (milpa), shrub (acahual) and forest stages that regenerate soil, nutrients, and seed banks. Each successional stage, including the fallow stages, produces as many as 60-100 types of crops, raw materials, and medicines. By comparing traditional and non-traditional systems, and examining fields of different ages, our goal is to discover how management methods used by the Lacandon result in sustained production and fertility with limited outside resources. In contrast to traditional methods, non-traditional Lacandon farmers do not regularly weed their fields or utilize as diverse a polyculture in their systems. Analysis of soil nematodes and plant communities conducted during 2003 showed significant differences between the traditional and non-traditional Lacandon fields, and between field stages. Traditionally managed milpas had lower densities of weeds and a greater biodiversity of cultivated species compared to non-traditional milpas. Total nematodes per 20-gram soil sample averaged 19 for traditional milpas and 26 for non-traditional milpas ($P<0.005$). Plant parasites averaged 2 for traditional milpas and 4 for non-traditional milpas ($P<0.05$). In the traditional system the quantity of total nematodes and plant parasites were found to be greater in the forest stage compared to the milpa ($P<0.001$ and $P<0.005$, respectively). Bacterivores and fungivores also appeared to follow these trends. An understanding of soil and plant community ecology will lead to the identification of Lacandon management practices that result in sustainable agroforestry.

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Privatizing Forest Encroachments as Small or Agro-Forests in India

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The Worldwatch Institute estimates that the *world is losing 22.53 ha (FAO estimates 26 ha) of forest land every minute*. In India, this loss is 4 ha of forests per minute due to encroachments and cultivation. This paper presents a case study of the loss of forests in the highly populated, but forest-poor Gujarat State of India. Total forest area lost in Gujarat state in 16 years is 154,050 ha, out of which area lost for agriculture is 61%. Statistically, this puts the loss of forest at 26.74 ha per day, or 185 sq. m per minute. The *causes* are mainly related to *food security, poor agricultural production, and lack of education, training and employment opportunities* for the tribal people. Their only insurance is possession of land, even though it may be forest encroachment. Additionally, forest management has failed to maintain the rich biodiversity the tribal people were dependent on. Political decisions based on electoral favors have also contributed to increased cultivation in forest areas. What is the way out? Instead of treating unauthorized cultivation as encroachment, the paper suggests that they be converted as Private Forests or as small Agro-Forests. It will have many benefits as some trees will always be maintained and tribals can have agriculture too. The example of existence of private forests in many European countries, USA and Japan over more than a century is a clear guide for another success story to follow.

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Optimal Combination of Trees, Pasture and Cattle in Silvopastoral Systems in Costa Rica

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The paper's main objective is to estimate the optimal combination of trees, pasture, and cattle in Silvopastoral Systems located in the tropical dry forest of Costa Rica. Three different kinds of farms, representing the main cattle production systems in this area, were modeled. Two agroforestry arrangements were considered, i.e., dispersed trees (DT) and live fences (LF). The model only accounts for timber as the main use of trees, but shade (the other important use of trees in animal production) is discussed in the conclusions. A discrete-time bio-economic model, solved by non-linear programming, was used to estimate the optimal path for a 20 years time period. For each type of farm, three models were estimated—DT, LF and a combination of both—for a total of 9 models. As an example, for the medium-size farmer, the estimated models are DT only, LF only, and the combination of both. The objective function is to maximize discounted net revenues from livestock revenue and timber harvesting, while the equations of motion of livestock, pasture and tree resources are the restrictions. Three hypothetical farms were constructed in order to estimate the models. Technical data was obtained from a one-year monthly monitoring of 20 farms. Future cattle and timber prices were estimated with econometric models. Forest information came from an empirical census of dispersed trees and live fences, as well as aerial photographs. The model used available literature information (for tropical dry forest) to obtain the shade-grass interactions and the tree growth rates equations.

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Economic Development and Ecosystem Management through Agroforestry – A Case Study from Kerala, India

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Biodiversity faces serious challenges in developing nations like India. The State of Kerala in South India is rich in biodiversity. But, the existence of many rare and costly trees and plants of high medicinal and commercial value are under threat from the population growth, and changes in socio-economic and environmental conditions. Plantation crops replaced vast areas of natural forests, wiped out certain plant species, and also lead to seasonal water crisis. Rules to protect the green cover produced adverse results because of slow government machinery and corruption. Cutting and selling of certain trees such as sandal and rosewoods require Government permission and people hesitated to plant them in their premises. However, worldwide recognition of Ayurveda, increased export of medicinal and aromatic plants and their extracts and new findings on the commercial use of certain plants (for example, bio-diesel from jatropha plant) have recently provided a new encouragement. As condition in the State is not favourable for industries, adoption of agroforestry is a viable alternative for economic growth. The 'Western Ghats' of Kerala, one of the 18 recognized global biodiversity hot spots, is ideal for large-scale agroforestry. It is imperative that the Government is planning to amend certain rules and to promote planting of medicinal plants. The present paper is a detailed investigation on the possibilities of agroforestry as a key development factor in Kerala. Detailed study of the hydroclimatology of the region has been carried out, for delineating the suitable regions. Guidelines for an appropriate forest policy have been suggested.

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Prospects for Agroforestry Development in the Marshall Islands (Micronesia, North Pacific)

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The main problems in the agroforestry systems in the Marshall Islands are coastal erosion, infertile soil, mal-practices resulting in loss of agrodiversity and deforestation, complicated land-tenure system, and limited agriculture development. Consequently, the agroforestry practices focus on sustainable development. Specific attention is given to (i) low-cost organically-based technologies to improve atoll soil productivity, (ii) the protection of land resources from both agricultural and non-agricultural activities, (iii) the multiple uses of trees, crops and livestock including their by-products, and (iv) the promotion of community-based food crops, livestock and industrial commodities in the atoll farming systems. Marshallese people have benefited a great deal from agroforestry systems, which provide them with a rich variety of products and services. Products include food, drink, medicines, perfumes, building materials, dyes and glue, oils, tools, forage for livestock and much more. Services provided by agroforestry include, shade, wind protection, improvements in soil fertility, erosion protection, cultural and spiritual enrichment. Coconut, breadfruit and pandanus are the major multipurpose trees and play a central role in the agroforestry systems. Coconut is source for drink, food, wood for canoe building, cooking oil and copra cake for fertilizer. Breadfruit is a main staple crop and provides food, leaves for mulch, wood for fuel and canoe building. Pandanus provides significant amount of food, in addition to shade and material for handicrafts. The challenge faced is to find a balance between conservation and development in the atoll environment to improve the quality of life through appropriate scientific programs in agroforestry.

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Development of a Hawaiian Agroforestry System Utilizing Native and Culturally Important Plants to Control Invasive Species and Encourage Restoration of Native Biodiversity

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The drastic decline in abundance of native Hawaiian plants has ecological, cultural and economic consequences in Hawaii. Changes in land-tenure and habitat destruction have reduced forest cover and degraded existing native forests. Combined with invasion of non-native species, these changes have resulted in the extinction of one in nine endemic Hawaiian plant taxa. The ecological, cultural and economic importance of many native species and their diminishing accessibility has led to great interest in finding ways to increase native plant populations. Development of an agroforestry system in which the understory of existing forests is enriched with plantings of desired species offers a solution. In Hawaii, agroforestry systems have the potential to actually complement restoration activities by replacing alien invasive species with economic and culturally important native species. Additionally, they may potentially favor the reestablishment of rare and endangered non-target species. By combining native species restoration and invasive species control with non-timber forest products, agroforestry systems also provide an incentive for local people to get involved with restoration and give them economic alternatives to agricultural conversion. This research addresses the need to recognize the restoration potential of creating agroforestry systems that utilize native and culturally important species while also providing economical benefits in the form of sustainably harvestable plant material with cultural and economic value.

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Financial Viability of Eucalypt Woodlots and Revenue Distribution among Stakeholders: A Case from Guraghe Highlands, South-Central Ethiopia

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Smallholder households of the Guraghe region of Ethiopia grow eucalypt as a major species in the highly fragmented landscape. Although the main goal is meeting household requirements for construction wood, fuelwood, farm tools/utensils, etc., some households generate additional cash incomes from sales of tree products. Results of the socio-economic survey and participatory observation reveal that eucalypt woodlots are mainly grown on marginal lands furthest away from the homegardens and farm fields. They are financially superior to all other land-use units under the prevailing production systems. Farmers' negative valuation of profitability of eucalypt woodlots is attributed to the long gestation period of the woodlots and the more psychological esteem for food crops. An equivalent of one hectare of eucalypt woodlot generates 514% of the total compounded profit of teff (*Eragrostis tef*) over seven-year rotation age. In the Chayanovian financial calculation, eucalypt poles resulted in 1758% of the compounded profit of teff production per ha over the same period. The analysis indicates that incomes from eucalypt woodlots constitute about 28.5% of the total cash revenues generated from sales of tree/shrub products. By and large, farmers make only 2.5% and 0.2% of the total cash profit from eucalypt poles of respectively the two dominant intermediate brokers. Poor marketing infrastructure, weak institutional support, and biophysical limitations still undermine the financial benefits of eucalypt woodlots and other tree/shrub plantations. Expansion of market-oriented eucalypt woodlots on marginal lands is expected to improve farmers' financial income and thus increases access to modern farm inputs.

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Fundamental Causes of Deforestation and Degradation of the Forests in Central Africa

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There are certain people who support the idea that itinerant agricultural practices and forestry development approaches are the causes of the deforestation and the degradation of the tropical forests in general, and of Central Africa in particular; for others it is poverty and the strong demographic pressures. Actually, the principal cause of the deforestation and the degradation of the forests of Central Africa resides primarily in the difficulty which tests the decision makers to conceive and to implement at the same time coherent policies of rural development, intended to satisfy the human needs and compatible with the regeneration and outputs for the forest resources. Other quoted phenomena, namely itinerant agriculture, the forestry development, the demographic pressure are in the majority of the cases, either of the secondary or apparent causes, or of the consequences of a major evil, or finally of the aggravating circumstances. Admittedly, an itinerant agriculture or a forestry development practiced in a context of controlled rural development would not cause as much damage to the environment. While a rural development articulated evil delivering the rural populations to themselves can only lead to the disaster for the forest resources. The populations of the forest belts during millennia lived off the gathering, hunting and itinerant agriculture. That did not create serious ecological disturbances as long as these populations lived in an economy of closed substance and in balance with their medium.

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Institutional Reform of the South African Forestry Sector

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The introduction of the small-scale forestry concept in South Africa (SA) by means of small-scale timber production by rural communities during early and late 1980's was a great innovation. It represented a revolution in the South African forestry sector. However, more than two decades after its inception, the expected level of change in small-scale growers' involvement in the forestry sector affairs has not been realized. Achieving this situation presents one of the greatest challenges to small-scale forestry in SA, and has generated exceptional interest locally and internationally. The rational overhaul of the forestry sector's institutional representation in 2002 opened the way for small-scale timber community involvement in the industry's affairs. The story which this paper tells is that, despite the enormity of the challenges, the future success of small-scale forestry very much depends on the ability of the country to reform its forestry sector institutionally. Furthermore, it should be noted that institutional reform process takes time, and demands tenacity and long-term commitment.

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Local Knowledge of the Functional Attributes of Trees in Multistrata Cocoa Agroforests in Cameroon

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The conservation function of the shade cocoa (*Theobroma cacao*) agroforests of Cameroon is often cited as a major contribution for maintaining biodiversity. These multistrata agroforests appear to act in many parts of Cameroon as a reservoir of tree species richness and diversity. This paper investigates farmers' ecological knowledge and management relating to tree diversity of cocoa agroforests in four contrasting localities of southern Cameroon distinguished by agroecological zone, population density and market access. The results show detailed understanding of tree attributes related to competitive, complementary and facilitative interactions with cocoa for over 40 tree species. The tree diversity recognised and managed by farmers approaches the species richness found in ecological surveys but far exceeds ecological science in terms of relating attributes of the different species to agroecosystem function. The implications of this sophisticated and detailed local knowledge of trees for the development of multistrata cocoa systems and the livelihoods of farmers are explored.

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Research Work on Afforestation in Lebialem Region of Cameroon for Future Sustainable Development

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Within the *Lebialem* division (region) of Cameroon is a zone of transition between Savannah Land and forest regions which constitutes one of the most unique and threatened ecosystems, where afforestation is difficult to manage. The government of Cameroon, through the Ministry of Environment and Forestry (MINEF), and some NGOs such as World Wide Fund for Nature (WWF), are trying to educate the population on how afforestation can be implemented. In this study, we are attempting to show how we can protect the environment and conserve its natural resources. To achieve this, conferences, mass media, educational materials and forest visits would be organized to accommodate information on the role that the local population should play in the management of their forest, problems faced and benefits they will derive from the project. They will know the economic and traditional uses of the forest. For this project to succeed so that the population can be able to derive the desired profit, they need to be educated.

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Agroforestry for Integrated Natural Resource Management in Australia

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This poster will describe the broad picture of how agroforestry is used within the context of integrated natural resource management in Australia. It presents the framework of a new online university-level course developed under the aegis of the Cooperative Research Centre for Plant-Based Management of Dryland Salinity. The environmental functions served by agroforestry systems are in their ability, in varying degrees, to mimic natural ecosystems with balanced water use and biodiversity while protecting soil, crops and livestock and enhancing the amenity value of landscape. The productive functions of agroforestry systems are in their provision of sawlog, firewood, pulpwood, fodder and a uniquely Australian range of specialty tree products and integrated production systems. The implementation of agroforestry in Australia is supported by wide range of design and evaluation tools, and institutional arrangements to facilitate agroforestry adoption.

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Agroforestry Practices in Congolese Mayombe: Study of Behaviour of Three Crops associated with a Forest Tree, *Terminalia superba*

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Agroforestry is a cropping pattern that associates agricultural crops and forest species. In the Congo, this practice is already a common one and has been used by small farmers for a long time. In the Congolese Mayombe, re-timbering in Terminalia superba has been done since 1954. The reduction of agricultural space resulting from it brought smallholder farmers to place agricultural crops within Terminalia superba stands. A study has been done in order to make the inventory of types of agroforestry associations used by smallholder farmers in Mayombe. It evaluated the behaviour of all types of associations and suggested solutions for improving their effectiveness. Other experiments could then be tried.

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Profitability and Problems of Agroforestry Adoption in Selected Areas of Southern Philippines: Its Implications toward the Attainment of the Program's Objectives

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A study was conducted in six municipalities among four provinces of Mindanao Region, Philippines, to determine the profitability and problems of agroforestry adoption and its implications toward the attainment of the program's objectives. A total of 200 agroforestry farmers organized by the DENR, the implementing agency of the government, and the PICOP, a private company, were selected as respondents employing random sampling. A questionnaire and an interview schedule were constructed as research instruments to obtain the relevant data. A benefit-cost analysis revealed that agroforestry farming is economically profitable. The factors of production that significantly affect farm profit are the operating expenses and the amount of labor. Lack of capital, low market price, farm distance to market, high transportation cost of harvested products, poor knowledge on cropping pattern, unavailable farm supplies within the locality, lack of technical and legal assistance, unavailability of immediate labor and credit facilities, and unfavorable peace and order situation in some areas were the major problems experienced by program beneficiaries. The continued adoption of agroforestry in these selected areas was attributed to the fact that farming is the only source of livelihood among the technology adopters. The prime objective of the program on socio-economic upliftment of the rural farmers showed achievement in some groups of adopters particularly those strongly organized by PICOP, as demonstrated in the increase of their annual income and some changes in their way of life after adoption. However, those adopters lacking technical assistance and obtained weaker community organizing, remain to be economically poor.

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Agroforestry Adoption by Gender in Southeastern Nigeria

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The paper analyzed the adoption of agroforestry practices by gender in Southeastern Nigeria. Data were collected from 240 randomly-selected male and female farmers from Imo and Abia States of Nigeria, through interview schedule and observations during transect walk round the communities. Data analyses utilized descriptive statistical tools pictorials, and Ordinary Least square regression technique. From the results, multi-storey home garden recorded the highest adoption rate of 97% and 92% by male and female farmers respectively with a mean crop combination of 23. A modified version of alley cropping that involves scattered planting of leguminous trees and other multipurpose trees in crop farms recorded higher adoption rate by women (42%) than men (37%). More males (43%) than females (12%), adopted wildlife agroforestry practice for bee pasturage, snairy, and cane-rat production. Among other agroforestry practices adopted by both gender groups are, live fencing, the taungya system, planting of multipurpose trees and shrubs along flood plains, and around houses, etc. Some of the reasons given for agroforestry adoption are for fuelwood, human and animal food supplements, soil fertility improvement, and boundary demarcation. Factors such as sex of the farmer, land ownership title, population of the area, extension contact, primary occupation, and educational attainment had positive and significant effect on the rate of adoption of agroforestry practices. Farm size, gave negative but significant relationship. It is recommended among others that extension education on agroforestry practices be conscious of the gender, and location-specific agroforestry needs of farmers.

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The Fundamental Challenges of the Forestry Sector in Gabon

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Gabon mobilizes important human and institutional resources to secure the sustainability of its natural resources. Its forestry domain, in particular, covers an area of 20 million hectares, which represents 75% of the national territory. Nevertheless, Gabon's forestry sector must face *three major challenges* to maintain its economic and environmental efficiency. The first challenge of our forest concerns *biodiversity conservation*. Gabon has more than 7,000 flowering plants, 190 species of mammals and 675 bird species. This biodiversity is endangered by two main anthropogenic activities: the tendency of overexploiting forests and the development of illegal poaching. The second major challenge is the *generalization of forestry management units* and of viable means of forest management. These technical assets would enable to limit the actual disequilibria between forest exploitation and its regeneration capacity. Finally, the third challenge is *the participation of all stakeholders* in decision making in relation to forest resources, and on the other hand the need to address sustainably the socioeconomic needs of the rural population. In this regard, the actual experimentations of agroforestry practices in forest management show an improvement in the standard of living of these populations.

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Indigenous Ecological Knowledge in the Management and Use of Mixed Agroforestry Systems in Talamanca, Costa Rica

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The thesis proposed presents an investigation into Indigenous Ecological Knowledge (IEK) of the BriBri and Cabecar tribes of Talamanca (southeastern Costa Rica). The purpose is to investigate how agroforestry systems can be appropriately managed while acknowledging the importance of IEK and how it informs and/or integrates this knowledge with scientific knowledge. The objective of this ethnography is to learn about the indigenous farmers with regard to their values, beliefs and knowledge of cultivation, management of mixed agroforestry systems (AFS), and examine the manifestation of how IEK is used to make decisions and influence prevailing land-use practices. An iterative database of IEK will be generated using WinAKT© (Agro-ecological Knowledge Toolkit) software. For the study area, a purposive sample of six key informants (gatekeepers) will facilitate data gathering from a larger snowball sample of 30 informants across 6 communities. Knowledge acquired from participants will also be evaluated in terms of its representativeness, the extent to which it is used by the indigenous farmer and the extent to which it was complementary and/or contradictory to professional knowledge held by researchers operating in the study area. Survey results will provide baseline information for emerging knowledge-profiles by ranking levels of knowledge of practice and ability to implement practice as dependent variables, against a set of independent variables, to determine how IEK is used to make decisions and influence current agroforestry-based land use practices.

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Land Management and Food Production Efficiency in the Rainforest Belt of Nigeria

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Food insecurity and rural poverty have resulted into inadequate use of land in many Sub-Saharan African (SSA) nations. In Nigeria, agricultural intensification is now common with drastic reduction in soil conservation investments. In this paper, an attempt was made to determine the current pattern of land use, and estimate the impact of some major cultural practices on efficiency of farmers. Data used were collected from 161 farmers by the use of multistage random sampling. Average age of the farmers was 53.23 years, while 76.39 percent were male. Using the *Rutherberg's index*, average land-use intensity was 59.16 percent, and most of the farmers reported that their farmlands have somehow degraded. Frontier 4.1 version was used for efficiency estimation, and the production function Maximum Likelihood Estimates (MLE) result has the coefficients of labour, fertilizer and land being positive and statistically significant at 1 percent level, while only seed has negative sign that is significant at 10 percent level. Computed average economic efficiency is 53.15 percent. Land-use intensity and family size both have negative and significant effect on efficiency, while farming experience and use of organic manure have positive and significant effect. Use of crop rotation, clean clearing, mulching and farmers' education do not significantly affect efficiency. To address farmers' inefficiency and ensure sustainable agricultural production in Nigeria, there is need for development of research in line with the challenges of agricultural intensification and increase in adoption of soil conservation practices like crop rotation, agroforestry, and organic manures.

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Crotalaria juncea in Maize-based Systems: An Economic Assessment from the Northern Guinea Savanna of Nigeria

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An on-station trial was established on a degraded soil to assess the economic impact of incorporating *Crotalaria juncea* in maize rotations over three seasons, 2000–2002. Treatments were: sole *Crotalaria juncea* followed by maize in the second season, *C. juncea* relayed into maize at 3 weeks after planting (WAP), *C. juncea* relayed into maize at 6 WAP, and sole maize. Annual economic returns were calculated from maize grain outputs and the sale of woody stems of *C. juncea* as firewood during the dry seasons. Cumulative average net returns varied among treatments with *C. juncea* relayed into maize at 6 WAP significantly outperforming sole maize and increasing returns from $1,833 to $2,361/ha. Thirty percent of income from the most efficient treatment was from firewood sales. Alternatively, the *C. juncea* biomass could be used as mulch to improve maize growth, soil nitrogen status, and suppress weeds. Studies have shown that 66% of the *C. juncea* biomass could survive until the subsequent planting season and be available for mulching. Relaying *C. juncea* into maize at 6 WAP instead of 3 WAP allowed the farmer to enjoy higher net returns at the same costs. It is concluded that maize systems including *C. juncea* are likely to be economically viable and more sustainable than sole crop maize.

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Self-organizing Systems, Indigenous Agroforestry Land Use and Adaptive Practices of NRM in the Central Africa Region: Lessons Learned from Southern Cameroon

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The Central Africa region (CAR) accommodates the Congo Basin, an 'eco-region' representing the world's largest rainforest after Amazonia. Its importance for biodiversity conservation, livelihoods, human well-being, research and policy-making is actually well known. This paper is located at the intersection of the above-mentioned issues. Based on research conducted in Southern Cameroon since 2000, the paper describes and characterizes the way people manipulate forest elements in agricultural mosaics within the forest agriculture interface. In the eco-region, the agricultural mosaics are symbolized by both their 'diversity' and their 'unity'. The paper shows how the dynamics of land use are embedded in the interactions between people, agro-biodiversity and forest components. It tries also to document given aspects of the social ecology of local communities in the CAR. It argues that this "epistemological asset" could be "strategic knowledge" for researchers, practitioners and program formulators. Ultimately, the paper recommends that scientific knowledge should unify with local knowledge, in order to generate a strategic material for adaptive practices and collaborative efforts.

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Forestry Policies: From the Outcomes to the Hypotheses

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The case of policies regarding rainforest protection will be under scrutiny in this paper. Our aim is to construct a system of hypotheses that can explain the policies on forestry that are put in place by different collective agents. In particular, our hypothesis should allow to explain differences and regularities in policies across countries. Policies, and their outcomes, are observed in Costa Rica, Mexico and Brazil. Volitional efforts, by collective action agents (the state, NGOs, international organizations), to protect forests are analyzed identifying the main tools in forestry policies and the trends along which these policies have evolved. Finally, the policies, put in place in order to protect the forests, are analyzed from the point of view of the objectives that are intended by the actors who created them and compared with the goals that standard economic analyses (commonly understood as the science of choice) would expect from policy makers and would identify as proper ones. Regularities and differences are, more or less, expected or surprising, given our set of economic knowledge, and a set of hypotheses is considered as possible *explanandum* of these outcomes. These hypotheses are analyzed with the intent of improving political economy approaches to forest policy and to identify the determinants of these policies.

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Certification of Agroforestry Production

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Certification is a market tool to promote changes in production systems towards a desired reference. Most of the certification initiatives aim to move systems towards sustainability or a higher level of environmental or social performance. Credibility of certification depends on its transparency, independence, volunteer purpose and quality and social recognition of the evaluation standards. ISO 14.000 could be applied to any kind of production systems, but it considers procedures instead of performance. However, there are consolidated initiatives that deal with social and environmental performance of forestry and agricultural production. Organic and fair trade systems could be applied either for forestry or agricultural systems. The Forest Stewardship Council (FSC) system focuses on forests while the Sustainable Agriculture Network deals with crops. All the systems have similarities, but differ in approaches, standards and changes to promote. Agroforestry is not the core of any of these initiatives, but could be benefited by all of them. Use of agrochemicals, management or cultivation of trees or non-timber forest species and the socio-economic aspects of the operation, are criteria for deciding which system and set of standards would be more appropriate for the assessment of an agroforestry operation. Certification may contribute to the scaling up of agroforestry but there are conceptual and practical issues to consider before its wide use. The best system for farmers will depend on the production system and market opportunities.

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Gender and Agroforestry in Africa

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Over the years, ICRAF and partners have integrated gender dimensions into its work, including diagnostic studies, technology testing and assessment research, and adoption and impact analyses. This synthesis draws lessons from this large body of work. The research questions to be explored include: is the promotion of multipurpose trees good or bad for women, are women more successful in planting trees when the primary use is as an input into farm production rather than a direct tree product, what characteristics of agroforestry systems promote or constrain their attractiveness to women, under what household situations are women increasingly able to assert preferences in planting trees, and what methods of dissemination are particularly effective in reaching women. This synthesis draws from research conducted by ICRAF and collaborators in over 12 African countries. One of the conclusions is that women are planting and managing trees for soils and livestock at rates near those of men, while they lag considerably behind when it comes to trees for marketed products such as timber or poles. Another is that because women are not able to fully control their schedules, they prefer to have multiple and sustained sources of information on agroforestry. The paper concludes with best bet approaches for increasing the participation of and benefits to women with agroforestry.

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Land Tenure and Smallholder Tree Planting in Africa

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This is a synthesis of a wide body of research conducted by ICRAF, the Land Tenure Center, and others in recent years. The synthesis covers quantitative and qualitative studies from Kenya, Uganda, Burundi, Rwanda, Malawi, Zambia, Ghana, Togo, and Burkina Faso. The following land tenure variables are analyzed: size of farm holding, level of fragmentation of farm holding, mode of land acquisition, community versus individual rights to land, rights of use, transfer, and exclusion to agricultural land, rights to plant trees and benefit from tree products, access to trees off farm, and gender distribution of rights. It will also explore the hypothesis that the planting of trees itself may enhance individual land rights. The paper will also examine how these tenure variables may have different impacts according to the type of agroforestry system or primary purpose of planting (e.g., for soils or for timber). General lessons are that customary tenure systems in Africa generally do not inhibit the planting and management of trees at the household level. There is evidence to suggest that in most settled areas, rights to plant trees are well established, while in other areas planting trees is still used as a strategy to acquire individual land rights. Small and fragmented holdings do impinge on the types of trees that are planted. The more widespread problem concerns the lack of unfettered rights of women to plant and manage trees. The paper concludes with some promising approaches to reduce the possible adverse effects of tenure.

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Growing *Gliricidia* under Coconut for Generation of Dendro-Thermal Power in Sri Lanka: Costs, Benefits and Adoption

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Use of wood for generating Dendro-thermal Power (DtP) is a relatively novel concept and an emerging technology in Sri Lanka. Converting biomass into electricity has potential for sustainable energy generation, environmental benefits and rural development. Hence, cultivation of *Gliricidia sepium* in the coconut region is emphasized to produce good quality wood materials for generating DtP. The study is based on data and information that were collected through secondary data, field observation and a field survey. Cultivating *gliricidia* for the DtP is financially viable even without considering the intangible benefits. The NPV is Rs. 200,026.54 (2,000 US$) per hectare for 20 years at 9% benchmark interest rate and the IRR is 32% with a pay-back period of 8 years. The ratios between percentage of land extent and the percentage of small-, medium- and large-holders are 16:45, 46:43 and 38:12, respectively. The size of holdings makes a significant difference in that the small-holders are willing to grow while medium- and large-holders are reluctant to grow *gliricidia*. The willingness to grow *gliricidia* is significantly increased with the productivity of coconut (*Cocus nucifera*) lands. Education level and willingness to grow *gliricidia* is negatively correlated. Experience in coconut cultivation has no significant influence to grow *gliricidia*. Availability of labor and capital are the significant limiting factors particularly for large-holders. The market is not competitive and dominated by intermediaries. However, growing of *gliricidia* has a low risk. Hence, growing of *gliricidia* could be popularized through an extension program assisted with supporting services.

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Incorporating the Value of Reducing Soil Erosion in the Competitiveness of Maize-Hedgerow Intercropping Systems in the Philippine Uplands: A Policy Analysis Matrix Application

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Many economic assessments have been conducted to evaluate the profitability of the upland maize production technologies at farmers' perspective or using financial competitive measures in the Philippines. In Claveria however, none of these studies examined the social competitiveness of upland corn production under hedgerow intercropping systems. While the economics of soil conservation in hedgerow systems are fairly understood, the policy dimension of the technology is largely ignored and the value of reducing soil erosion was estimated using private prices. Since maize is a tradable commodity that can be imported, policy makers are currently debating options for maize production that are economically efficient and sustainable. This paper aims to determine the social profitability of agroforestry-based technologies, particularly on maize-hedgerow intercropping in the uplands of Claveria, using an extended policy analysis matrix (PAM) incorporating the user cost of soil degradation; and analyze the impacts of policy shifts on the financial and social competitiveness of maize production under hedgerow intercropping systems. Results show that where the financial profitability of maize-hedgerow intercropping is minimal, its social profitability is considerably high. Incorporating the user value of avoided soil erosion under hedgerow systems further increases the social profitability of the systems. Government may then have a strong incentive to provide policy support for these systems to enhance adoption of the technology. It also indicates that the system cannot be widely adopted without price policy and incentive structure changes. Policy implications of the impact of policy shifts on the divergence between private and social profitability are discussed.

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Tree Growing Investment Decisions of Smallholder Farmers in Claveria, Northern Mindanao, Philippines

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This study aimed to identify the factors that help explain land use decisions by smallholder farmers. Specifically, the study aimed to analyze the factors influencing smallholder farmers' decision to invest in tree-based land use systems, and draw policy implications that may enhance adoption of tree-based land use systems among smallholder farmers. The study was conducted in Claveria, Misamis Oriental, Mindanao, Philippines. It made use of interviews from 192 farmer-respondents, 86% of whom practiced tree-based farming systems and the rest planted short-term cash crops, with corn as the dominant crop. Tobit regression results revealed that high relative price variability deters tree planting. Farmers' tree-growing decisions also depend on: (1) current price levels and forecast price changes; (2) socio-economic characteristics such as household size, age, and education; (3) farm characteristics given by cultivable land-man ratio and farm size; (4) land tenure; (5) knowledge about tree-based land use systems; and (6) membership in landcare association. The study recommended that since price risk appears to be the major deterrent to expansion of tree farming, measures to reduce said risk or to improve risk management capability of farmers should be analyzed. Provision of relevant and timely price information and price risk insurance are possibilities. The influence of landcare association on farmers' decision to adopt tree-based land use systems implies the need of this local initiative to be further enhanced and developed in other areas through extension and training support.

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Local Ecological Knowledge about the Sustainability of Multistrata Tea Agroforests in Northern Thailand

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Multistrata tea agroforests are found extensively throughout northern Thailand and play an important role in maintaining tree cover and biodiversity in upper watersheds. Knowledge was elicited from farmers associated with their management of tea production and their understanding of the interactions occurring between tea trees and the other biotic components of the system. Local knowledge was elicited from repeated and detailed interviews with 34 key informants. The information was recorded and assessed using knowledge-based systems methods. A wider validation survey involving 100 randomly selected farmers was then used to confirm the representativeness of the knowledge. The research demonstrated that farmers' decision making was based on ecological concepts developed through their own experience. Biodiverse, multistrata tea stands were maintained because farmers understood that the forest ecosystem, including the ground flora and litter components, increased the quality and quantity of tea leaves produced. Farmers were able to demonstrate detailed understanding of the role of forest trees and ground flora in: providing shade, controlling erosion, maintaining soil moisture and cool air temperature and cycling nutrients. Farmers explained the central importance of managing tree cover and cattle grazing, to maintain appropriate ground flora. The local knowledge complements scientific understanding and displays interesting similarities with other multistrata agroforestry systems in Asia and Africa, in the types of observations that farmers made and their interpretation. The implications are discussed in respect of forest conservation in northern Thailand and global trends in incorporating local knowledge and perspectives in agroforestry development.

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Agroforestry-Based Microfinance as Entry Point in Enterprise Development: The Guimaras, Philippines Experience

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Micro-enterprise is the springboard toward sustainable economic livelihoods in agroforestry programs. Yet, it is given the least intervention focus, as emphasis is given more on the large-scale adoption of farm technologies where farmers are not trained to become farm entrepreneurs. This paper will present successful micro-finance models introduced in agroforestry programs to address the more immediate and growing demands for financial support to farm production, processing and marketing. The experience of the Agro-Environmental Productivity Programme supported by the Netherlands Development Organization and Save the Children in Guimaras, Philippines used agroforestry as a strategy to improve land management for economic empowerment. It serves as a good model to promote micro-finance in agroforestry programs. It also shows that giving people the decision to manage their funds results to significant changes in their participation and accountabilities. Micro-finance in this experience was conceived by the demand for continuous production support and financial sustainability beyond the donor's support fund. A distribution and repayment system of farm inputs for research and farm production that farmers have developed are proven workable and can encourage ownership of funds. This scheme eliminated the "dole-out" approach that is still practiced in several development programs. With access to financial resources, farmers and their wives participated actively and had improved accountability in economic activities utilizing agroforestry by-products. With the growing need for financial assistance to agroforestry programs, micro-finance is a good entry-point tool to propagate financial sustainability, reduce pressures on resource extraction, and enhance farmers' organizational and management activities.

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Promoting Good Governance in Agroforestry Programs

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Agroforestry is most often viewed as a technology-fixed solution, rather than a people and institution-centered mechanism to attain food sufficiency, promote an ecologically-sound environment, and achieve sustainable development. Many agroforestry programs focus more on pilot-testing and large-scale adoption of commodity-based technologies to increase farmers' income and improve agro-ecological researchable areas. However, farmers' indigenous knowledge and decisions are oftentimes ignored in favor of prescribed institution-driven models. Agroforestry requires a comprehensive crosscutting theme to interact with various forms of agro-silvo-pastoral technologies and social infrastructures that put people at the center of development. While conserving the resource base, it should acknowledge that people must have ownership of decisions in agroforest farms that concern their broad-ranged socio-economic needs. Farmers and other stakeholders are important in the development process. Agroforestry programs must promote genuine participation, transparency, accountability, and responsibility in the management of natural resources to address the broad dimension of poverty alleviation and land-use management system. It is perceived that, in the future, agroforestry farms will be the sources of income of farmers and government both through direct and indirect economic benefits and taxes. The attempt to foresee events after the success of agroforestry in shaping the landscape of economic gains and the plan for a best policy-oriented approach will be advantageous to people and support institutions. Thus, it is imperative that stakeholders such as farmers, local organizations, NGOs, donor institutions, and local and national governments must encourage promoting good governance of agroforest farms and natural resources.

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A Strategy to Promote a Comprehensive Agroforestry Program in the Departments of Agriculture, Environment and Natural Resources and Agrarian Reform in the Philippines

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The Philippine Government promotes agroforestry only within the mandates of the Department of Environment and Natural Resources (DENR), involving only public lands. It is because of the misconception of top-level planners and policy makers that agroforestry is an integrated hilly-land technology suitable only for upland areas and designated ecological zones. While agroforestry is concerned with food security and ecological balance as strategies to address rural poverty and sustainable development, the Departments of Agriculture (DA) and Agrarian Reform (DAR) which also promote integrated farming systems, have no comprehensive programs for agroforestry development. Their technicians are not well-versed in agroforestry practices. They are involved only in promoting planting of annuals and commodity-based crops that have declining yields and no sustainability. Also, lowland farmers who comprise the large majority of the agriculture industry and successful planters of forest gardens have not been oriented about agroforestry trends and practices. In fact, the DENR has no regular funding assistance for agroforestry in its devolved district offices, except for technical assistance to upland farmers. This paper presents a policy development framework for the integration of agroforestry with the mandates of the DA, DAR and DENR. It aims to use a two-pronged approach: (1) to promote the large-scale adoption of agroforestry practices among farmers, regardless of land ownership and ecological zones, to be assisted by these departments for wider impact; and (2) to develop a mechanism to stimulate support from decision makers and planners for comprehensive long-term programs toward agroforestry development.

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How Can We Feign Sustainability and Development of Agricultural Lands through Agroforestry Practices in India ?

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The last two decades have seen an upsurge of interest in seeking out ways and means of managing Indian landscapes in order to ensure a perpetual stream of multiple products and services. The traditional mixed farming systems have been replaced by monocultures of high yielding varieties. For a variety of biological, social, cultural and economic reasons, benefits from such approaches have often proved illusory. A number of approaches do appear encouraging for managing land in ways that are ecologically and economically sustainable. The practice of agroforestry and the notion of a critical mass strategy are among those that offer promise. How far agroforestry approaches have been successful in achieving sustainability of agricultural lands has been studied. The study area includes arid (Rajasthan), semi-arid (Haryana) and humid (Chhattisgarh, M.P.) regions of India. Three case studies (*Gmelina arborea*, *Populus deltoides* and *Prosopis cineraria*) are presented to highlight approaches for sustainability in agrisilviculture systems. A reflection on the past two decades of research by the author raises several issues. *Research efforts started with traditional systems and experimental approaches have been able to reveal that through agroforestry practices sustainability could be achieved only if one is able to select a right type of tree species, crop and the system is managed intensively.* The tree-crop interaction data revealed that the general notion that tree roots under agroforestry systems go deep and do not compete with crops, is refuted. However, the potential of agroforestry as a development vehicle and alleviation of poverty has not been fulfilled.

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Economic Analysis of Stakeholder Perceptions on Land Use Options in the Peripheries of Tropical Dry Deciduous Forests in Southern India

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The interface of dry deciduous forests and agricultural landscapes in Anaikatty region of southern Western Ghats of India is characterized by a multitude of land uses and increasing fallow lands. Primary stakeholders are native marginal farmers (adivasis) who live nearest to forests. Livelihood base of native farmers was being destabilized by soil degradation, drought, wild animal attacks, and declining access to forests. Economics of feasible land use options among stakeholders was examined to identify appropriate land use strategies. Existing land use patterns were identified to understand long-term impacts and possible improvements. This was followed by a survey of primary stakeholders to gather occupational and livelihood patterns, costs, benefits and prices associated with land uses. The survey enabled an interactive elicitation process for arriving at a set of feasible land uses for Economic Benefit Cost Analysis (BCA). All cash transactions associated with selected land uses as well as other costs and benefits like opportunity cost of fodder, firewood, family labour, household consumption of farm produce, productivity changes and net carbon sequestered, were quantified in BCA. Though there was lack of incentives for tree planting among adivasis, gradual realization that certain agroforestry practices could drought-proof their livelihoods was reflected in the choice of feasible land use options. Economic rational behind these were examined with and without social and long-term benefits, at 5%, 8% and 12% discount rates. Results showed superiority of millet-based dry farming systems with perennial fruit trees when social, ecological and economic factors were taken into account.

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Linking Social and Ecological Dimensions of Agroforestry Projects: A Case Study from Central Quintana Roo, Mexico

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In an effort to begin to build new models and practices in agroforestry research that combine social and ecological factors in the same analytic framework, the research presented examines selected aspects of agroforestry promotion in the Mexican state of Quintana Roo since the mid-1990s. It compares and contrasts the political and social origins, organizational strategies, and ecological dimensions, particularly with respect to pest control and plant diversity, of two different agroforestry initiatives in two case study communities in central Quintana Roo. The findings presented demonstrate how political processes and institutional motives have influenced land use decisions regarding agroforestry extension and promotion of each agroforestry initiative. The different patterns of extension have led to different levels of plant biodiversity and pest infestation within sampled agroforestry plots, showing clear relationships, if not causal links, between policy, social dimensions such as extension, and certain ecological dimensions of agroforestry projects in the state.

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Potential of Agroforestry Research in India

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The present paper is based on the salient research achievements of the All India Coordinated Research Project on Agroforestry, being carried out at 37 coordinating centers under different agro-climatic regions of India since 1983. Based on the results of Design and Diagnosis survey, two MPTS have been allotted to each center to work on evaluation, collection of germplasm and genetic improvement. The germplasm of many important tree species like *Azadirachta indica, Acacia nilotica, Populus deltoides,* and *Eucalyptus* and *Prosopis* species has been collected; superior clones and lines of these species have been identified and are being evaluated at different centers. Promising agroforestry systems for different agro-climatic regions have been developed and evaluated, like Poplar based systems for Indo-Gangetic regions, *Hardwickia binata, Emblica officinalis* based systems for semiarid and arid regions, *Casuarina. equisetifolia* based system for sodic lands, and a *Dichrostachys cinerea* based silvopastoral model for arid regions. Crops and cropping sequences which can be grown successfully in association with forest and fruit trees have been identified. Successful efforts have been made to stabilize the yields of selected crops under tree canopies through agronomic manipulations and tree canopy management practices. Even varieties of crops having synergistic association with trees have been identified. Successful efforts have been made to improve the productivity and quality of natural grasslands through the introduction of promising leguminous trees on dry degraded lands. Lands earlier producing only 2-3 t/ha/year biomass are now producing 8-10 t/ha/year high quality biomass.

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Nature, Problems, and Prospects of Tree and Land Tenure in Marshall Islands Atolls

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Land was, and still is, the fundamental basis of Marshallese culture and society. Atoll dwellers developed highly developed systems of sea and reef tenure to manage and conserve their marine resources. To exploit their rich marine resources they required land-based resources such as wood, fiber and food plants, which in turn depend on availability of fresh water and nature of atoll sands. The total land area of Marshall Islands is 181 km^2, having 1,100 islets, and single islands, that surround the lagoons of the 29 atolls. Single land holdings called 'wato', average only one to two hectares, and extend across the islet from the lagoon to the ocean. This provides the resident family with all or most of the resources present in a coral setting. The lagoon reef offers a great variety of marine life, the lagoon strand bears coconut (*Cocos nucifera*) and pandanus trees (*Pandanus* spp.) and a sheltered place for family living, the interior is usually planted with breadfruit trees (*Artocarpus* spp.) as well as hardy beach shrubs which are exposed to salty spray from ocean surf. However, this traditional system has been changing due to great western impact and increasing population pressure. Problems of maintaining clear boundaries have intensified, owing to increased value of land for copra production; land disputes have become more common and costly. Dispersed holdings within the same family or co-ownership group have further intensified the problem at this time when increased productivity is greatly needed to help country's developing economy.

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Rural Planning in India for Sustenance: Need of the Hour

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Two-thirds of the Indian population live in rural areas. The true face of India can be seen in its villages, which indicate the progress and prosperity of the nation. Agriculture and allied activities are the main source of livelihood for rural people but the production from such lands is too low even for two meals' sustenance due to low productivity, low soil fertility, and small and marginal holdings. At present, there are 116 million operational holdings, of which 80 million are comprised of small and marginal farmers with an average land size of 1.41 ha only. Twenty-six per cent of our population live below the poverty line and the majority of them live in rural areas. Agriculture's share in the GDP is 24% compared to the population share of 67%. This indicates unequal income distribution in favor of non-farming occupations. To improve the economic condition of rural masses, planning and execution of rural development works should be made a priority, giving the agricultural sector the first preference. Profitable cultivation can be taken up on principles of contract farming, small holdings should be grouped together, and packages of agricultural practices should be made using community decisions, which will boost overall production. NGOs, SHGs, and cooperatives need to be formed at the village/block level, which may help in smooth and profitable marketing for their produce. Allied ventures and small industries should be set up in villages for gainful employment. Panchayati Raj institutions should be given more power to solve village/local problems amicably.

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Economic Assessment of Smallhold Agroforestry Alternatives in Claveria, Misamis Oriental, Philippines

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The farms in Claveria, Philippines, with an average size of 1.7 hectares, can be classified based on elevation – the lower Claveria (300-600 masl), middle Claveria (600-800 masl) and upper Claveria (>800 masl). The farming systems adopted by farmers in these areas are influenced by their objectives and given natural, social and economic environment or resources. About 30% of farmers' plots are planted to annual crops usually to meet their food and cash requirements, and 68% to perennials to provide long-term benefits. Across different elevations, the practice is to combine fruit and timber trees among those planting perennials. While elevation does not influence species of trees planted, the farm size and slope seem to influence the spatial tree arrangements. In farms with limited spaces, farmers adopt less dense systems like border planting where trees mark farm boundaries and parkland systems where trees are scattered across the field. Trees are planted as hedgerows in steep slopes while in farms with more space, trees are planted as a block, a highly dense arrangement of trees. Other farmers practice combinations of these agroforestry systems. Given these conditions, the major issue that this paper addresses is whether tree-crop combinations in these farms are optimum. Are these the best-bet agroforestry choices? Would farmers who are presently annual cropping be better off with agroforestry systems given the existing economic and natural environment? This paper identifies the most important factors influencing farmers' decisions to adopt agroforestry systems and determines whether these provide the optimum economic returns to farmers.

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Scaling up of Leucaena/Eucalyptus Based Agroforestry Systems using GIS Techniques in Andhra Pradesh, India

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Many farmers in recent years are taking up *Leuceana* and Eucalyptus based agroforestry systems in the state of Andhra Pradesh because of the demand for pulpwood and low prices for conventional crops. There is a need to clearly identify potential areas suitable for these technologies to scale up the adoption. This will ensure maximum benefits from the technology avoiding long-term negative impacts, if any. The study has been accomplished by matching the agro-edaphic requirements of the eucalyptus (*Eucalyptus camaldulensis*) and leucaena (*Leucaena leucocephala*) species with the spatial databases of climate and soil resources in a GIS framework. Spatial databases for climatic parameters (annual rainfall and temperature) and soil databases (texture, depth, drainage characteristics and salinity) have been created with Arc/Info software. Soil resource maps of 1: 500,000 scale and long-term climatic data of different weather stations of Andhra Pradesh have been used. FAO guidelines were considered for agro-edaphic requirements of the trees. Proximity of paper industry was also considered as one of the factors. The sites were classified into most suitable, suitable, marginally suitable and non-suitable areas. The resultant spatially distributed maps are being used by the industry for identification of potential areas, and location of procurement depots and nurseries for production of planting material for quick distribution. These maps are also helping government agencies to devise suitable supportive measures for adoption of agroforestry systems in lands which otherwise are not fit for cultivation of conventional crops, thus helping small marginal farmers and benefiting the environment.

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A Shared Disciplinary Foundation for Agroforestry Seeds Spontaneous Adoption in Australia

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Without significant land use change it is predicted that 17 million hectares of agricultural land and 20,000 km of inland waterways in Australia will be affected by dryland salinity by 2050 (almost entirely attributed to land clearing for agriculture). In addition, the timber industry and government have targeted around 2 million hectares of high quality farmland for the expansion of the national timber plantation estate. Many people believe trees on farmland provide a means of solving problems related to land degradation, biodiversity, nutrient management, animal welfare, crop productivity and economic diversification. But, because they control the vast majority of this land, it is farmers who will ultimately decide whether trees are grown on their land and for what purpose. The need for trees underpins the need for publicly and privately funded agroforestry research, development and extension. However, the numbers of farmers that must be engaged, the multiple outcomes of tree growing, the diversity of stakeholder interests, and the long timeframes involved mean that agroforestry is inherently more complex than other types of agriculture development. This complexity may explain the lack of agreement over definitions, program goals, research purposes, education curriculum, extension methods and incentives. Whilst a diversity of opinion is healthy, the debate currently lacks a broadly understood and accepted disciplinary foundation. Based on selected Australian examples of public and privately funded projects that have been successful in facilitating the adoption of agroforestry without the use of financial handouts this paper seeks to define such a foundation.

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Distribution and Poverty Reduction Impact of the Participatory Agroforestry Program towards Sustainability of the Natural Forest in Bangladesh

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Bangladesh is a south Asian flood plain delta with 13.36% forest cover. Sal *(Shorea robusta)* is the only plain land forest that is economically and environmentally important to the country. High population and ever increasing poverty caused a mass destruction to the sal forest in last few decades. FAO estimated that only 10% of the forest remains at the present. To meet the adverse situation of the forest, Bangladesh Forest Department initiated a participatory forestry program by involving the encroachers and the rural poor. Agroforestry technology was used for reforestation activities. The study attempted to determine the distribution of net economic benefit generated by the program to the entities namely, consumers, participants and government. It also estimated the poverty reduction impact of the program. The sample size of the study was 118. Using benefit-cost analysis the distribution impact and poverty reduction impact was estimated. A real discount rate (5.6%) was used in the analysis. The consumers and the participants of the program were found more benefited than the government. The reorganization of economic system increased welfare of the society by enhancing distribution of net economic benefit positively. The participatory management option has positive impact on poverty. It is more feasible towards sustainability of the forest resources than the centralized management option. The findings of the study recommend further extension of the program to the other degraded and encroached forest lands of the country.

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Agroforestry Products Marketing in Haryana, India: Introspection, Issues and Challenges

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The success of agroforestry in Haryana and neighboring districts of Punjab, U.P and Uttranchal States of Northern region of India has led to evolution of an annual market of wood products worth more than US $ 210 million in Yamunanagar district of Haryana, India, benefiting not only farmers but has also generated employments of various kinds at different levels. A study has been conducted to analyze marketing pattern and facilities, price trends for agroforestry species. The declining trend of Poplar prices has been analyzed and corrective policy and administrative measures have been suggested to cope up with the abundant supply and for protecting the reasonable interests of the primary producers. Farmers should not sell the farm produce in distress and adequate price support mechanisms and Farmer's co-operatives should be developed to ensure reasonable returns, environmental sustainability and sustainable development and meeting National objectives. The role of State Forest Corporations and State Forest Departments should be redefined along with private stakeholders, including farmers, consumers and intermediaries. Efficient and diversified wood products utilization, development of high yielding and resistant varieties of Eucalyptus, Poplar and other suitable Agroforestry species, development of diversified uses of wood based finished products, appropriate incentives for setting new wood based industries, adequate market research methodologies and healthy buyer seller linkages should be ensured for sustained Agroforestry development.

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Agroforestry - A Key for Conflict Resolution in Different Land and Tree Tenure Systems in Sustainable Forest Management in The Gambia

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In order to combat the problems of forest degradation caused by increasing human population and annual bush fires, the Gambian Department of Forestry encourages the management of Community Forests by local communities and of Forest Parks by the Department of Forestry jointly with adjacent villages. In promoting community empowerment, the Gambian Forest Act and the Gambian Forest Management Concept foresee an ownership transfer of forestland from the state to communities in non-surveyed State Forests on basis of customary rights. In (surveyed) Forest Parks, villages basically take part at any level of decision making. Exclusive utilization rights, e.g., grazing privileges or firewood exploitation, are granted in both programmes on the basis of Forest Management Plans. *Community Forestry* (CF) and *Joint Forest Park Management* (JFPM) should motivate the forest-adjacent population including alternative users, especially herders and farmers, to protect and ensure the sustainable management of the forest. Since 1996, this participatory approach of the Forest Department has been supported in The Gambia's Central River Division by the German Federal Ministry for Economic Cooperation, through the *Central River Division Forestry Project*. Working with the *Department of Livestock Services* and the *International Trypanotolerance Centre*, the main goals of the Project are based on studies supporting CF and JFPM, with the aim of initialising development strategies which *integrate livestock and crop production with sustainable forestry*. In this context, controlled grazing strategies, fodder, firewood and timber substitutes, non-timber forest products and farmland tree planting are promoted, partly implemented and will be further developed.

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Economic Evaluation of an Agroforestry System of Mahogany (*Swietenia macrophylla* King) and Perse Lime (*Citrus aurantifolia*), Portuguesa State, Venezuela

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An agroforestry system of mahogany (*Swietenia macrophylla* King) and perse lime (*Citrus aurantifolia*) was evaluated in the Gato Negro area, Guanare municipality of Portuguesa state, on the flood plain of the Guanare River. The soils are loamy Typic Haplustepts. The climate is strongly seasonal. The population was defined by a plantation of mahogany and perse lime of one hectare and six years of age. Both species where fertilized with phosphated rock at moment of plantation and with 150 g/plant of 12-24-12 formula at the ages of six months, one year and five years. The plantation was irrigated every 15 days during the dry season. Weeds were controlled manually, mechanically, and with herbicides. *Hypsipyla grandella* was controlled with the insecticide Lagnate (Lambdacihalotrina) mixed with adherents. The mahogany plants were pruned at years 4 and 5 to correct the effects of the *H. grandella* attacks. The sample was based on 25% of the plants of both species and a systematic sampling with randomness at the starting point was applied, excluding the edge plants. Descriptive statistics were applied. The mahogany obtained the following average results: diameter at breast height 16.86 cm, total height 10.56 m, total volume 37.13 m^3/ha and commercial volume 17.09 m^3/ha. Commercial production of lime began at the third year, the production of year six was 13 894 kg/ha. The relation of benefit/cost at year six is US $ 19.25, therefore the association is profitable. At present no negative effects between the components of the system have been observed.

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Best Practices in Agroforestry: Lessons Generated from the Experiences of Upland Farmers in Northern Philippines

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There are many forms of agroforestry that exist in the country. As in most other regions in the Philippines, the typical upland farmers in Region 02 practice certain forms of agroforestry. Agroforestry serves as the most promising alternative in rehabilitating denuded forest lands and at the same time developing the countryside through the active participation and cooperation of the upland farmers. This paper identifies the best agroforestry practices adopted by farmers. The first part highlights the agroforestry practices initiated by the farmer in his own agroforestry farm. The socio-economic conditions of the farmers, sustainability, and the adoptability or replicability of the practice are the aspects to be explored. The second part discusses the best practice being implemented by a group or organization. The factors determining adoption highlights the land security, land productivity, people's participation, ecological and environmental management, socio-economic advancement, political will, and sustainable community organization. These factors serve as indicators of success and will determine how agroforestry practices in the region have affected the lives of the farmers. Factors determining the differences in practices such as type of agroforestry technology introduced, degree of agroforestry technology adoption, factors that influence success and failure of agroforestry, assistance extended to farmers, factors that contributed or influenced their decision, and courses of action and future expectation about agroforestry are examined in the interest of exploring its future directions. The best agroforestry practices in this region in effect manifest the capabilities of upland farmers in searching for livelihood options and in managing upland resources.

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Local Agroforestry Practices of Selected Cultural Groups in the Cagayan Valley, Philippines: Their Potential for Sustainable Land Use

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Even before the advent and popularization of agroforestry, rural upland communities in the Philippines had been practicing agroforestry fro decades, though the term has only been coined in recent years. These upland farmers have inherited these practices which may have their roots in the past but which have been constantly modified to adapt to the changing circumstances. They may have taken roots because of their good fit to the resource base of the people and to their skills, capabilities and traditions. This paper reports on the study conducted to document the local knowledge and practices of the different cultural groups in relation to agroforestry. These traditional or local practices are outstanding examples of efficient use and management of upland resources that are productive, protective to the environment, and socially acceptable. Areas were sought for differences in the origin of the upland farmers. Management practices highlights findings on the method of planting, planting materials used, site selection and preparation, watering/irrigation from creeks, fire prevention, post harvest practices, protection of natural regeneration, and soil conservation Likewise, this paper documents the differences in crops grown/species preference, cropping pattern, and socio-cultural practices of the upland farmers. These traditional practices if given enough attention and importance can be replicated and adopted by countries with similar setting and are also essential to consider in the quest for sustainable land use.

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Estimating Recreational Hunting Benefits of Silvopasture Practices: A Case Study from Florida

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Trees and other natural attributes of ranchlands provide habitat for various wildlife species. Ranchers in Florida are beginning to utilize these attributes to generate supplemental income in addition to their income from conventional ranching. Recreational hunting is a growing activity in Florida, wherein ranchers sign a lease with hunting clubs or other interested parties for recreational hunting uses of their ranchlands. Agroforestry literature suggests that silvopasture practices improve wildlife habitat, thus these practices are more likely to support recreational hunting. We analyzed the influence of the ranchland attributes such as tree cover, wetlands, parcel size, and proximity to urban center on hunting revenue. We estimated the impacts of these attributes using a hedonic price model. The results reveal that trees and vegetation cover on ranchlands have a positive impact on hunting revenues indicating opportunities for silvopasture practices. Furthermore, results suggest that larger parcel size reduces hunting revenue and higher distance to urban center increases it. A typical rancher in Florida, who maintains about 22% trees and other vegetation cover, receives $16.15 per acre per year from hunting leases, but doubling the cover would generate only an additional $3.20 per acre per year from such leases.

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Opportunities and Limitations of Agroforestry in South Asian Nations

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At the beginning of the new millennium the world has already surpassed six billion humans, which was barely 500 million in 1800 AD. The exponential population growth has increased consumption of forest products and hunger of land for agriculture, industries, settlements, roads, irrigation and many others. Per capita forests in the world have decreased from 1.2 ha in 1960 to 0.6 ha in 1995 and are projected to be 0.4 ha by 2025. Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, the South Asian nations, comprise more than 20% of the world's population, and are one of the most densely populated regions of the world. However, forest cover in this region is only 2.3% of the world's forest. Tree resources comprise more than 60% of energy and 50% of construction materials for living. More than 80% of forest is owned by states in South Asian nations. It is necessary to reverse the trend of reduction and depletion of forests and tree resources to create a better living environment. Based on the current forestry situation in the South Asian region, there is an urgent need for a strong institutional framework, which will help to launch extensive agroforestry practices in private and public sectors for long-term supply of wood resources, non-wood forest products and conservation of natural environment. In this paper, an attempt is made to describe the current forestry and agroforestry situation in the South Asian region as well as make recommendations for the future of agroforestry.

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Mechanization for Small Scale Agroforestry Systems

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There are abundant options for profitable agroforestry systems (AFS) for small-scale farm families in developing countries, especially in hilly terrain where 'conventional' agriculture can have disastrous consequences. Decades of abuse of the world's soil and water resources, coupled with increasing demographic pressure, has led to soil erosion, widespread land degradation, reduced productivity, poverty and famine. AFS options for small farmers cover a spectrum from slash and burn shifting agriculture through multiple variants to alley cropping with mixtures of trees and annual crops. AFS requires the application of agricultural engineering principles to produce profitable mechanization options. This paper details some practices which have proved to be attractive at the farm level. These include: establishment of contour lines and contour barriers of woody species for hillside stabilization; the application of draft animal power for reduced tillage on the forming terraces and for producing mini-terraces; conservation agriculture including direct planting; mechanical and chemical weed control; brush control and timber extraction.

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Underlying Patterns in Local Knowledge of Tree Biodiversity and their Implications for Policy Development

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Using knowledge-based systems methods, local ecological knowledge about trees in contrasting agricultural systems around the world has been found to be both detailed and explanatory. Detail relates to the proportion of the biota for which information is held, and explanation to the functional understanding of how species interact with each other and the environment, and can be manipulated to meet human needs. Cross-site comparisons reveal similarities in the way that people in different cultures understand nature. In general, local knowledge complements far more than it conflicts with conventional science, making combinations of the two systems vastly more powerful in resolving issues in natural resource management than either system alone. Agroforestry domains are characterised by multiple stakeholders, across a range of scales, requiring effective communication amongst different knowledge systems from local land users and scientists to policy makers and the public. Knowledge-based systems methods show promise in facilitating this communication by, on the one hand, rendering local knowledge understandable to scientists and policy makers, and, on the other, presenting new developments in science to rural people in terms that they can understand and, should they wish to, incorporate into their local knowledge and practice. Debates on local knowledge in agroforestry need to mature beyond the current focus on preserving indigenous knowledge to embrace empowerment and access to knowledge.

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Farm Forestry for the Market: Do Farmers Have a Choice?

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Farm forestry, as alternative land management system in rural areas, has been publicised and promoted as an additional source of income for farmers and supply of wood for commercial market in India. At present, this is true to a very limited extent and evidences suggest that over reliance on the informal market puts farmers at risks, which they find a major hindrance in adoption of farm forestry. Their vulnerability is aggravated when faced with 'buyer's market', notably in and around urban centres where there are complex networks of intermediaries. This article presents evidences from study of diverse systems of informal marketing arrangements of farm forestry produce and its influence on level of adoption by farmers in one of the India's largest state of Uttar Pradesh. The analysis suggests that informal arrangements are unable to ensure that farmers receive adequate return for their products. This is further related to experiences from other parts of the country. It argues that farm forestry has considerable potential for producing additional supplies of wood to meet commercial markets and for generating income for those able to participate. For instance, as per one study the public sector costs of growing trees of farm forestry are about a fifth of those of government forestry plantations. The main tasks of support programs, then is that of identifying viable opportunities for farmers to engage in tree growing for the market, supplying market information, technical advices in the initial stages and where necessary, providing access to credit and marketing services.

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Systematic Transfer of Agroforestry Technologies by Indian Council of Forestry Research & Education-An Enriching Experience

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With the launch of World Bank funded Forestry Research, Education and Extension Project (FREEP) in India in 1994-95, systematic effort was made to disseminate the forestry technologies developed to different end users which had direct bearing on agroforestry movement in India. Well designed modules were developed which can fit in to special circumstances as well as target groups. This effort has brought agroforestry revolution in several parts of India to the extent that in some of the cities 35% of the economy is controlled by agroforestry products. Also for reduction in rate of decrease in forest cover in last four years and subsequently substantive increase in forest cover as reported by Forest Survey of India (FSI 2003), some share of credits goes to adoption of agroforestry technologies by formers. This paper elaborates the methods used in selecting, designing, propagating, monitoring and evaluating the methods of transfer of technologies of agroforestry as well as those having direct positive impact on agroforestry in India which shares the credit of this success. It recommends the core issues, which can be handled in developing countries in dissemination of agroforestry technologies.

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Redynamisation of Cocoa Based Agroforestry Systems through Public-Private Partnership in the Humid Forest Zone of West and Central Africa

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Introduced in West and Central Africa in the 19th Century, cocoa (*Theobromo cacao*) is growing on land previously covered by forest and/or exists at the periphery of the forest. In the four main cocoa-producing countries (Côte d'Ivoire, Ghana, Nigeria and Cameroon) of the region, cocoa based agoforestry systems cover around 5 million ha. Previously, the cocoa sector had become an important economic driving force in rural areas of the region. But unfortunately, the cocoa sector went through tough economic crises in the early 1980s with a decline in prices in the international market and a liberalization of the economies in these cocoa producing countries. To *redynamise* the cocoa agroforestry practices of the region, a new program named the Sustainable Tree Crop Programme (STCP) was launced in May 2000 and is based at the International Institute of Tropical Agriculture (IITA). In this program, American and European chocolate manufacturers, bilateral donors, and international and national institutions are joining their efforts to improve the economic and social well-being of smallholders and the environmental sustainability of cocoa based agroforestry systems in West and Central Africa. Based on the experiences from Côte d'Ivoire, Ghana, Nigeria and Cameroon, this paper presents: (1) biophysical and socio-economic characteristics, (2) constraints in the management, and (3) new efforts in the *redynamisation* of cocoa based agroforestry systems of West and Central Africa.

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The Role of Local Knowledge in Determining Shade Composition of Multistratra Coffee Systems in Chiapas, Mexico

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There is potential for utilizing products and services from a wide range of shade tree species in multistrata systems to take advantage of new market niches, but changes in the management of these trees will also have impacts upon the coffee (*Coffea* spp). To realize this potential local knowledge is key information. The objective of this research was to identify farmers' knowledge about shade species and to relate this to the floristic composition of coffee farms in Chiapas, Mexico. Seventy four shade species were recorded in 24 multistrata coffee plantations surveyed in northern Chiapas. These trees and shrubs were classified by farmers into three groups depending upon their suitability as shade species for coffee. Major attributes of trees considered in this classification were leaf phenology, crown shape and the amount and timing of litter decomposition, as well as their overall impact on coffee yield and the value of products such as timber, fuelwood, fodder, fruits and medicines. Although a group of preferred species was identified, farmers retained all useful trees and shrubs in their plantations, taking into consideration not only commercial interests but also their contributions to ecosystem function. Farmers harness the forces of secondary succession by retaining pioneers as temporary shade, knowing that these plants will naturally be succeeded while at the same time promoting and tolerating other longer living native species that are more suitable as coffee shade. Managing diverse secondary succession instead of establishing a monospecific shade contributes to biodiversity and landscape conservation.

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Economic Analysis of a Joint Venture Agroforestry Project with Eucalyptus globulus Tree Belts from the Perspective of Land Owner and Investor - A Case Study on a Property in Western Australia

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The profitability of the Forest Products Commission's (FPC) commercial Tasmanian bluegum (*E. globulus*) package, currently offered to farmers in the medium rainfall areas of Western Australia, was examined. The tree belt layout consisted of two rows, spaced at 40 m centres. This layout allowed traditional agricultural practices to continue on the majority of the land (85%), whilst maximising sawlog production. The analysis used a discounted cash flow to compare the relative profitability of three 'within' tree belt densities (167, 283 and 400 trees/ha). The effect on profitably of stumpage price, tree growth rate, salinity, and variation in agricultural yield due to tree belts was examined. Establishment of tree belts was less profitable for the farmer than maintaining current agricultural practices, and this was due predominantly to the negative effects of tree belts on agricultural yield. If tree belts were established, low densities were most profitable for the farmer as agricultural yield reductions were minimised. Although high tree densities reduced downslope salinity to a greater extent, the resulting improvement in downslope agricultural productivity was not sufficient to offset the overall decline in productivity compared to lower density tree belts. Profits for FPC were maximised at higher tree densities, the profit margin was sufficient to potentially compensate the farmer completely for lost agricultural production while maintaining profitability for FPC. Therefore, an upfront payment to the farmer that ensures the profitability of tree belts will break-even with traditional agricultural practices may increase the adoption of the commercial tree belt package by farmers.

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Percentile Rank as an Approach to Evaluating Shade Tolerance of Ground Covers for Agroforestry

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Many agroforestry practices require vegetative ground covers that will tolerate shade. Results from several shade tolerance screening trials have been published; however, it is difficult to compare results across several trials. Often trials use different levels of shade, are conducted in different microenvironments, and have not used one species common to all trials. Our objective was to determine if species could be rated for shade tolerance across several independent trials by determining the percentile rank for each species. Percentile rank is determined from the percent change in yields for biomass harvested under moderate or dense shade compared to biomass harvested under full sunlight relative to all other species in the trial. Percentile rankings were calculated for forty-two species based on the results of five independent trials with multiple harvests or replications. All five trials evaluated plant growth in low (20 to 30 percent), medium (45 to 55 percent), and full sunlight. The average calculated percentile rankings tended to group warm-season grasses as the least shade tolerant, cool-season grasses and legumes as intermediate in shade tolerance, and native grasses and legumes adapted to savannas and open woodlands as being the most shade tolerant. There are, however, individual species that do not to fit into these groupings. Our results suggest that this technique can be used to rank species within large groups or cultivars within species.

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Agroforestry Practice, Economic Incentives, Household Economics: An Economic Analysis

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The current system of assessment of agroforestry practices adopted by farmers measures only the value of timber that they would get after certain number of years. Such a system underestimates the other productive contributions made by forests to the rural economy in terms of supply of green manure, fodder, fuelwood, fiber, wood for fencing, and agricultural implements. Further, no recording and assessment is done for protective functions like soil and water conservation, windbreaks, etc., that lead to an increase in economic welfare of the household. Though many other on-site and off-site benefits are generated that are external to the household, there is no mechanism to account for such contribution and to provide some compensation to people adopting such agroforestry practices that could be an incentive to farmers. The paper is an attempt to first enlist such benefits physically, estimate their monetary value and then see whether any such intra-village arrangements exist to compensate the farmers adopting agroforestry practices leading to ex-situ and in-situ benefits to other farmers using household economic approach.

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Agroforestry Practices in Marshall Islands: Challenges and Prospects

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Traditional agroforestry in the Marshall Islands is a complex, sustainable system of land use integrating forest trees with agriculture. It does not generally exhaust the soils, and thus continues to provide much food and other resources for the people in areas where it is still practiced. The early atoll populations depended entirely on foods gathered from the sea and grown on land. They were experts in growing plants that were vital for sustaining their nutrition requirements and providing materials for canoe construction, handicrafts, flowers and medicine. They knew which varieties of food plants grew well or poorly on their atolls, how to propagate them, and where on their atoll they grew best. Such information had been passed down through the generations although some of it has been lost in the last century. Nevertheless, although the traditional cropping system of agroforestry has significant value in its provision of nutrition, cultural preservation, and rural economic stability, this long-lasting local system is changing due to greater contacts with the outside world after World War II. And this has led to increasing desire for consumer goods and cash incomes, and increasing access to markets. Pressure to cultivate cash crops and to promote monoculture plantation agriculture and forestry has intensified thereby resulting in nature's imbalance. There is one practical way to overcome such a situation—revival of traditional agroforestry systems. And people of Marshall Islands have started re-establishing their traditional multi-spice agroforestry and land-use systems by growing food crops in-between forest trees.

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Non-timber Forest Products Gathering and Cultivating Practices in Forest, Swidden Field and Jungle Tea Garden: A Case Study from a Khmu Community in Nam Ha Village, Northern Lao PDR

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The northwestern part of Lao PDR is home to a rich diversity of endemic flora and fauna, including many varieties of non-timber forest products (NTFPs). It shares borders with China, Burma and Thailand. In 1993, this area was identified and designated to be one among 20 important National Biodiversity Conservation Areas (NBCA) of Lao PDR. It is called "Nam Ha National Biodiversity Conservation Area". It is located adjacent to the border with Xiang Yong Protected Area in Yunan, China. Within Nam Ha NBCA, there are 19 villages, inhabited by various ethnic groups, including Khmu, Akhar, Hmong, etc. The study village, namely "Nam Ha village" is one among them. This paper illustrates the distinctive characteristics of NTFP gathering and cultivating practices of a Khmu community. It provides insights on the transitional pattern of change in gathering of NTFPs from forest to cultivating in swidden farming system and jungle tea gardening. Furthermore, it also examines the external factors such as the adoption of land and forest allocation policies of the central government, which influence community ownership and access rights towards NTFP gathering and cultivation practices. One among many changes is the dramatic decrease in fallow period of swidden farming systems from an average of 38 years in 1950 to 5 years and even shorter in recent years.

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Where Gender Rights over Trees do not Constrain Agroforestry Adoption: The Case of Marsabit Mountain in the Arid Northern Kenya

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Household members would not be motivated to plant trees if they have no access to or control over on-farm tree products. In some of the communities in Africa, it is usually the women who are barred by men from planting or harvesting trees; yet it is women who are left at home managing the farm while men leave for urban centres in search of waged labour. This paper discusses the influence of household gender rights over trees on planting of trees in farmlands around Marsabit Mountain, in Northern Kenya. Rights of access included rights to plant and to use a tree and/or its products through harvesting the produce, and cutting all or part of the tree. Since household land decisions in the study area revolve around the adults, all the household tree rights considered were based on adults. There was no significant relationship between household gender rights over tree planting and planting of trees (X^2=1.02, p=0.715). Similarly, the association between household gender rights over use of tree resources and planting of trees was statistically insignificant (X^2= 3.857, p=0.114). Gender control rights over trees within the household had also no significant relationship with tree planting (X^2=1.073, p=0.623). Addressing women in agroforestry extension is important, for in addition to being majority farm managers in the study area (57%), they are not in any way inhibited from tree planting. Using female agroforestry extension officers and reaching women in groups are some important avenues for increasing adoption of agroforestry interventions in such environments.

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Managing Agroforestry Systems in the Presence of Carbon-sequestration Payments

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Planting trees with crops is argued by many to be the most appropriate way for landholders to meet both their financial and basic-food requirements while ensuring that the productivity of their land is maintained or enhanced in the medium to long term. Interactions between crops and trees, however, are extremely complex, and a positive (complementary) or negative (competitive) net outcome will depend on the site, climatic conditions and management of the system. Tree-management decisions impact on productivity and profitability through their effect on carbon (C) and nitrogen (N) levels in the system. C accumulation in biomass and soils represents a C sink that contributes to mitigation of global warming, and soil C may provide benefits such as better moisture retention and increased crop yields. Beyond these environmental benefits, both soil C and biomass C may have a direct market value since market-based mechanisms for C sinks are being developed both under and outside the Kyoto Protocol (e.g., various environmental-service payments in Australia). Through the use of bioeconomic modeling, this study investigates how landholder decisions that impact on N and C stocks will be affected by prices of outputs (wood, C, crops) and inputs (fertilizer, labour). A process model is used to simulate a *Gliricidia*-maize agroforestry system in Indonesia, under varying areas planted to trees and a range of fertilizer application rates and harvesting regimes. An economic model is developed to analyze these outputs and to determine optimal management scenarios from an individual landholder's perspective. Implications for policy are also discussed.

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Employment and Income Effects of Commercial Orange Production in the Hill Region of Nepal

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In marginal mountainous areas of the tropics, establishment of economically viable and ecologically sustainable farming systems is essential. Incorporation of high value tree crop production into subsistence food crop production is a promising agroforestry system which affords high income and food security without causing environmental degradation. Applying Gini decomposition analysis, this paper examines the employment and income effects of fruit tree incorporation into traditional farming systems in the hill region of Nepal. In the study village, the introduction of orange (*Citrus* spp.) production increased farm income substantially, while it was estimated to reduce employment opportunities in agriculture by 10% as a whole. The effect was most conspicuous for female labor (both family and hired) which decreased by 20%, while the use of hired male labor increased by 10%. It appears that the farm size was the major factor for the introduction of orange cultivation. Neither human resources (both quantity and quality) nor direct access to cash affected the dissemination of orange cultivation. Income from orange farming accounted for 44% of the total household income, while it contributes 56% of the total income inequality. Replacement of traditional upland crops by commercial orange may have worsened the income distribution, though absolute income increase might be significant. No villagers participated in marketing activities of orange, which has a large potential of employment and income generation. To further promote rural development focusing on the poor, use of labor for postharvest activities such as marketing and processing is recommended.

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Empowering Women through On-farm Production of Stakes for Climbing Beans in Rwanda

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Bean is an important crop in Rwanda, as both a staple and cash crop. Climbing beans hold much potential as they can yield 3 to 4 times greater than bush beans. However, the production of climbing beans requires stakes, which is a major constraint. Traditionally, farmers, particularly women and girls, had to walk long distances to fetch for stakes in natural forests. Stakes from agroforestry species planted in appropriate niches offer sustainable alternatives for on-farm stake production. A study was conducted to identify preferential niches and to assess stake production and its impact on empowering women in the rural areas of Rwanda. Results indicate that preferential niches were: rotational blocks, field boundaries, terrace edges, sidewalks, and live fences around homesteads. Stake production ranged from 1 to 2 per plant during the first harvest (six months after planting), 4 to 6 at second harvest (12 months after planting), and 7 to 8 at third and consecutive harvests. Average bean yield was increased 300 to 500% resulting into significant additional income for women. Among the impacts of this technique: (1) young girls were freed from the burden of fetching for wood which used to prevent them from attending school, (2) household nutrition was improved, (3) women were able to generate income and initiate other income-generating activities from that income, and (4) overall, women were empowered to plan and implement other agroforestry activities on family farms. This paper presents both technical, social, and equity aspects of this technology.

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Imitating Normal Forest to Manage Regional Shelterbelt Networks in Northern China

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Initiated in 1978 and regarded as the world's largest ecological project, the Three-North protective forest system in China covers 400 million hectares of areas in 13 provinces in the Northeast, North and Northwest China with harsh environmental conditions and fragile ecosystems. By the end of 2000, the shelterbelts, as one important component of the giant ecological project, established more than two million hectares. From this, 68% of total farmlands in the Three-North region are fully connected by shelterbelt networks, and more than twenty million hectares of farmlands have been effectively protected. In these areas, especially in northeastern China, large area networks link town after town, or even county after county. How to sustainably realize protection effects, however, has become a key problem for the management of regional shelterbelt networks. The spatio-temporal pattern of shelterbelt regeneration is an unsolved, but important issue which determines whether the shelterbelt network produces protective effects sustainably. This study developed a new method of imitating “normal forest” to manage shelterbelts. Based on an administrative village as an organized management unit, each shelterbelt in the organized management unit will be individually regenerated and regulated, until the number of the shelterbelts in each age-class from young to mature is equal, and the shelterbelts in each age-class will be spatially distributed uniformly in the shelterbelt networks of an organized management unit. Consequently, this method might ensure temporally sustainable and stable ecological services provided by the shelterbelts in an organized management unit.

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Macroeconomic Impacts of Policies Influencing Silvopasture Practices: A Case Study from Florida

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Cattle ranching is an important agricultural enterprise in Florida. Ranchlands cover over 2.4 million hectares, generate over $300 million each year with over 1.8 million cattle. However, this sector is raising environmental concern because of its contribution to phosphorus runoff and thus to water pollution. Implementing silvopasture may be a potential solution to this problem. Policies such as incentives or cost sharing payments, taxes on phosphorus runoff, or a combination of both can stimulate ranchers to adopt silvopasture. Economic impacts of these policies, however, will not be the same and may spill over to other sectors in the economy. Therefore, assessment of these policies by accounting for multiplier and trade-off impacts is of paramount importance for sound decision-making. This study addresses this issue by developing a multi-sectoral Florida Computational General Equilibrium Model (FLCGEM) and applying it to simulate economy-wide impacts of potential policies. We include trade, investment and saving, and dynamic features in the model. While IMPLAN data 2000 is used to calibrate benchmark equilibrium, population and technological growth are used to forecast the economy. We expect that output of cattle ranching sector would decrease and while the price would increase in response to a pollution tax. The impacts of pollution tax coupled with incentive payments for the adoption of silvopasture, however, is difficult to predict *a priori*. Furthermore, the effect of these policies on welfare, wages, employment, and income distribution will be analyzed. We hope that the results of this analysis would provide valuable insights for agroforestry policy-making.

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Commercial Agroforestry: IPHAE's Proposal for Community Development in the Northern Bolivian Amazon

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Poverty and forest degradation, which are the main problems of this region's extractivist communities of *campesinos* (local peasants), are being faced with a development strategy proposed by IPHAE. This strategy prioritizes management, use and conservation of natural resources through organizational strengthening and capacity-building processes for decision making, self-management and agreement with governmental and non-governmental organizations. It includes three programs: Sustainable Forest Management, Agroforestry, and Agro-industry. The Agroforestry program comprises a food security model and a commercial model. The first combines food cropping rotation with secondary forest enriched with fast growing *Leguminosae*. The second model associates commercial fruit species with woody species to finally obtain a more economically valuable forest. Fruit species, like *cupuazú* (*Theobroma grandiflorum*), predominate in the implantation of this phase. In the first six years of the program, most of the families in 10 percent of the communities adopted the program, thus increasing their income up to 50 percent. They also were involved in an Agroforestry Producers' Association which supplies a growing fruit pulp industry. Their current production of *cupuazú* pulp is about 20 tons per year and their prospective production is calculated to reach 200 tons per year after 2006. There is remarkable recognition and growing interest on the adoption of this program by other *campesinos* and institutions. Nevertheless, this process still needs the continuity of committed support from national and international cooperation until self-sufficiency and sustainability are achieved.

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V. Semiarid Regions, Soil Fertility and Agroforesty Education

Includes topics related to sessions on:

Agroforestry in Semiarid Regions,
Land Owners' Session,
Small Farm Soil Fertility Management Strategies,
and Agroforestry Education

Agroforestry Education in Africa, Vocational Training Approach: Experience with International NGO Collaborations in Nigeria

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Encouraged by the successes recorded from the initial four-year pilot collaborative efforts on the expanded agroforestry training curriculum of Leventis Foundation (Nigeria) Agricultural Training Schools at Ilesa, South West Nigeria, two international NGOs with the support of a foreign government have replicated this collaborative vocational agroforestry training in the remaining three schools located in the derived, guinea and sudan savannas agroecological zones of Nigeria.

Youth (men and women), aged between 18 and 30 years, with bias for making a career in agriculture, are trained yearly in agroforestry practices including animal and crop production as well as rural enterprise development. Within a calendar year, the trainees go through 20% classroom teaching of the subjects and 80% practical experience in various aspects of advanced agroforestry practices. The curriculum exposes them to agroforestry seedling production, including vegetative propagation of difficult materials, hedgerow intercropping, intensive feed garden/fodder bank, woodlot, modified farm-tree system and bee keeping. This training includes observation of agroforestry technology demonstration plots for on-station practices. Visits to practicing agroforestry farmers are conducted to encourage them in the practice of any of the technologies. Post-training evaluation and monitoring include a farmers' field day organised yearly to support ex-trainees and share their experiences with local farmers. It also includes promotion of establishment of village nurseries and provision of back stopping by Leventis Foundation Trainers to ex-trainees and interested farmers. The approach promises to be effective in the transfer of accumulated advanced knowledge in agroforestry science to the ultimate beneficiaries: the peasant farmers.

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Agroforestry and Soil Fertility Management Technologies in Southern Africa: Farmers Knowledge, Attitudes and Practices

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Based on a multi-stage stratified random sample of 302 households in five districts in Zambia and 300 households in five Extension Planning Areas in Malawi, a field survey was carried out to establish farmers' Knowledge, Attitudes and Perceptions (KAP) of agroforestry and several other soil fertility management options. The objectives of the survey were to (i) assess how farmers perceive AF in relation to other soil fertility management options, (ii) identify factors that systematically shape farmers' perceptions about different soil fertility management options over several years, and (iii) evaluate opportunities and constraints to the scaling up of AF based on current levels of farmers' KAP in southern Africa. Results showed that declining soil fertility, and non-availability or high cost of fertilizer, rank as the highest constraints facing agriculture in the two countries. Farmers' preferences for specific agroforestry species are based on various criteria: ease of establishment method; length of "waiting period" before obtaining benefits; ability to produce large quantity of marketable seeds within a short time; tolerance to livestock and fire; and compatibility with oxen-drawn ploughs during field operation. Although improved fallow species are primarily designed to improve soil fertility and increase farmers' income indirectly through improved yield, farmers clearly showed preference for plant species that both improve the fertility of their soil in the longer term and also increase cash income directly in the immediate term. For effective scaling up, the development of soil fertility management options should take into consideration the multiple objectives expressed by farmers.

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Variation in Growth and Nitrogen Fixing Abilities of *Acacia nilotica* ssp. *indica* and Its Use for Development of Agroforestry Systems in Semiarid India

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Acacia nilotica (L.) Del. ssp. *indica* (Benth) Brenan (locally known as 'babul') has been recognized as an important multipurpose tree in semiarid regions worldwide. It is found abundantly on farmlands on a wide range of soil types and agro-climatic conditions in India. Wide variation occurs among natural populations of *Acacia nilotica* ssp. *indica*. In the present study, an attempt has been made for selection of 50 plus trees from five states of central India and testing of progenies in the field at Hisar, northwestern India. The criteria for selection of trees were (i) straight tree bole, (ii) superior in height, (iii) conical shape of the canopy, and (iv) trees free from diseases. The height of 2 year old plants in the field ranged from 1.3 m of GJ-4 to 3.0 m of BH-4, the collar diameter from 11 mm of GJ-4 to 19 mm of HR-7, and the weight from 455 g/plant of GJ-4 to 988 g/plant of BH-4. In general, the progenies of Bihar were found to be superior in growth followed by those from Madhya Pradesh, with those from Gujarat being most inferior. Two progenies of Haryana state (i.e., HR-5 and HR-6) showed exceptionally superior growth both in the nursery and field. Number of nodules, their weights and nitrogen concentrations in plant parts varied significantly (P<0.05), and the values were the highest in progenies of Bihar state closely followed by that of Uttar Pradesh. The results are discussed in the context of improving soil fertility of agroforestry fields.

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The Role of Apiforestry (Bee-keeping) in Enhancing Food Security in Arid and Semiarid Areas: The Case of Kibwezi Division of Makueni District in Kenya

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This paper is based on a study conducted in the Kibwezi division of the Makueni district of Kenya between July 2000 and December 2001. The study concentrated on agro-ecological zone V (semiarid land) with three main objectives: to assess farmers' perceptions of apiforestry as a land use practice, to assess its actual and potential contribution to household welfare, and to address impediments to the optimal realization of benefits from apiforestry. Multistage sampling was used with four levels of sampling to select 60 sampling units. Data was collected using questionnaires, direct observation and oral interviews. Over 80% of households were directly involved in bee-keeping. Households had rich indigenous knowledge in the management of the practice. Honey was, however, valued for cultural practices and not for income generation. A poor honey marketing framework was identified as a major impediment to the growth of apiforestry. Farmer-managed cooperative societies were recommended for market improvement. An improvement of hive configuration was deemed necessary to enhance quality output. Apiforestry was thus seen as an area that has a great potential in enhancing food security in ASALs through improvement of household income. The practice is less affected by weather vagaries common in such regions. Research on production trends and marketing was recommended.

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A Web-based Agroforestry Distance Education Course for Undergraduates in the Southeastern U.S.

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In the Southeastern U.S., rural land ownership fragmentation, changes in the structure of forest industry, increasing importance of complex natural resource issues such as air and water quality and invasive exotic plant species, and the evolving interests of landowners and markets, present opportunities for the application of agroforestry practices. Students graduating with B.S. degrees in forestry and other natural resource fields will be employed by State and private agencies responsible for managing and regulating natural resources and for interacting with landowners. These students will need to know about the potential of agroforestry. This course, funded by a US Department of Agriculture Higher Education Challenge Grant to the University of Florida, is being developed in collaboration with Auburn University, the University of Georgia, and the USDA National Agroforestry Center. It will be offered for the first time as a University of Florida course in August 2004. The course objective is to increase the knowledge of region-specific agroforestry practices so the B.S.-level forestry and other natural resource students in the Southeastern U.S. will be better able to respond to the needs of their clients. The course will be web-based using WebCT software. Course material will be presented and examinations will be taken online. Several interviews with farmers practicing agroforestry and with researchers undertaking agroforestry studies will be provided to students on CD-ROM. Students will be required to complete one field exercise during the semester on the farm of a collaborating landowner.

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Using Multistory Farming Systems for Sustainable Upland Development in the Philippines: A D.A. CHARM Initiative in Showcasing

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In the highland municipalities of the Philippines where large areas have been denuded, forest covers suffer a steady state of decimation, resulting in unpredictable drought and flood conditions for both highlanders and lowlanders. The high rate of soil erosion, heavy siltation of rivers, and fast dwindling of forest covers, may potentially lead to environmental collapse, with negative repercussions for the uplands, lowlands and coastal areas, unless proper restorative measures are undertaken. Despite these bleak realities, there remains much hope for the Uplands due to its vast natural and human resources that remain untapped. Even those areas given up as hopeless can still be revived and made productive again, in light of the advent of technological breakthroughs and the will of the people to make a difference. After all, the Uplands are a promising resource that has so much in store which can contribute to a brighter future if wisely used. This paper includes practical suggestions on how multistory farming systems could be made to maximize their potential in meeting the needs and aspirations of the people without compromising the ability of future generations to meet theirs. A major focus of the study is ecosystem conservation in the Upland communities. Also discussed are possible directions that upland farmers, academe, NGO's and government agencies could make in multistory farming systems, so that these systems can contribute more meaningfully towards the search for the ideal upland development strategy in protecting fragile mountain environments.

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The Land Equivalent Ratio for Evaluating the Efficiency of Multi-strata Agroforestry Systems

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Much of the current analysis on the productivity of tropical multi-strata agroforestry systems considers individual evaluations of each component species. One reason for this is related to the difficulty of transforming the individual yield of species in a single measure. The main objective of this paper was to use the Land Equivalent Ratio (LER) to evaluate the land use efficiency of three 14-year tropical multi-strata agroforestry systems (AFS) in Rondônia State, in the western Brazilian Amazon. The species used were: banana (Musa sp.) - Ba, black pepper (Piper nigrum) - Pm, cupuaçu (Theobroma grandiflorum) - Cp, Brazil nut (Bertholletia excelsa) - Ca, freijó wood (Cordia alliodora) - Fr, and pupunha (Bactris gassipaes) - Pu. The AFS were: T1: Ca+Ba+Pm+Cp; T2: Fr+Ba+Pm+Cp and T3: Pu+Ba+Pm+Cp. The yield variables evaluated were: Ba and Pu: weight of cluster (kg); Pm: dry weight of grains (kg); Cp: weight of fruit (kg); Ca: wood volume (m3) and number of fruits (n); and Fr: wood volume (m3). Evaluations from 1988 to 2002 indicated that multi-strata AFS T1 and T2 were more efficient than the AFS where B. gassipaes was the perennial component. In the beginning years, land use efficiency was higher in monoculture systems, although AFS performance was, during a 10-year period, the most efficient land use system compared to monoculture. With three years of agroforestry production, the products harvested included three food crops. With 14 years the AFS still have potential to enhance diversity of food and to increase income through high-value wood and fruits.

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Technical Analysis of Multi-strata Agroforestry Systems in Rondônia State, Brazil

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Amazonian agriculture still needs key strategies to address the problems of shifting cultivation. In Rondônia, around 98% of agricultural production comes from small-scale farming areas, with high diversification of non-perennial / perennial crops and multi-strata agroforestry, among other systems. This implies a need to test and acquire suitable trees and crops for local conditions. In this paper, analysis on three multi-strata agroforestry system (AFS) production sets at the Experimental Area of Machadinho d'Oeste, in the western Brazilian Amazon, is presented. The experiment used a randomized block design with four replications and a split-plot scheme, in a clayey Oxisol. The species used were: banana (*Musa* sp.) - Ba, black pepper (*Piper nigrum*) - Pm, cupuaçu (*Theobroma grandiflorum*) - Cp, Brazil nut (*Bertholletia excelsa*) - Ca, freijó wood (*Cordia alliodora*) - Fr, and pupunha (*Bactris gassipaes*) - Pu. The multi-strata AFS tested were: T1: Ca+Ba+Pm+Cp; T2: Fr+Ba+Pm+Cp and T3: Pu+Ba+Pm+Cp. Banana and black pepper productions had better results in T1. Cupuaçu showed higher peaks of production in T1 until the tenth year, when lower values where found when grouped with long-cycle species in T2 and T3. Brazil nut and freijó wood showed low mortality rates in AFS. Brazil nut fruit production in AFS was compatible with that in monoculture. Pupunha, a species marked by increasing and decreasing intermissions in its production cycle, showed better results in T3. The tested species can be recommended for planting in multi-strata agroforestry systems, as they provide medium- and long-term income, and help to diversify farm production.

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Agroforestry in Semiarid Regions for Agricultural Lands having 200 mm Annual Complementary Irrigation

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Seasonal and yearly variations in rainfall make agroforestry practices complex in semiarid regions. When only silvopasture systems seem viable under rainfed conditions, the AF potentials become wider in irrigated areas. In Tunisia, summer is the driest and hottest season, experiencing more than half of annual Potential Evapotranspiration (PET). Hence, complementary irrigation during the rainy seasons is generally chosen instead of summer full irrigation. This choice results in a larger irrigable area, a higher number of beneficiaries and a more sustainable use of natural resources. Such is the nature of application in the Oued Rmel development program, an arid, windy area covering 5,000 ha of newly irrigated lands. The area has more than 1,000 farmers who have traditionally practiced rainfed agriculture with cultivation of fodder, cereals, olive trees, vineyards and pasture. A multidisciplinary team of researchers has developed a specific program of technology transfer over the past two years. The aim is to help farmers to improve and stabilize yearly yields and incomes by (i) adding to annual rainfall an amount of 200 mm of irrigation water, (ii) using technological packages and selected seeds, and (iii) promoting adapted AF systems. Results show that actual knowledge about windbreaks and fence hedges as AF sub-systems is sufficient to propose from the beginning an adapted extension program and further research is needed for alley cropping. The working framework used for on-station research/development is an integrated farming system aimed at increasing viability and sustainability. Field demonstrations are used as a support for the communication program.

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Agroforestry Education and Development in South Africa

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There is great concern today worldwide and in South Africa about the general decline of vegetation and the influence it has on the environment and the basic source of subsistence of all nations, namely soil, water and vegetation. In this regard, agroforestry is a promising land-use system for alleviating soil erosion and land degradation, while providing greater diversity, production sustainability, and many other benefits. However, for communities in South Africa to benefit from agroforestry, the nation needs a trained workforce of agroforestry professionals. To date, there is no higher learning institution in South Africa which provides formal undergraduate and graduate education in agroforestry. To respond to this need, the Faculty of Agriculture at the University of Fort Hare (UFH), in the Eastern Cape, has embarked on the introduction of an agroforestry education, research and outreach program as one of its training components. The main objective of this paper is to present an agroforestry education project developed through a collaborative project between Oregon State University, the University of Fort Hare and Fort Cox College of Agriculture and Forestry in the Eastern Cape, South Africa. The paper will identify the potential for agroforestry education in South Africa, and provides the needed education and training by developing agroforestry curricula, establishing research and demonstration plots and teaching material development at the University of Fort Hare and Fort Cox College. It will also address issues in agroforestry technology transfer and outreach by working with farmers through a participatory approach in the Eastern Cape, South Africa.

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Convergence for Agroforestry Capability Building: Lessons Learned and Insights Gained

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In the Philippines, promotion and implementation of agroforestry is done by government organizations, non-government organizations (NGOs) and other concerned agencies. Taking part also in the promotion of agroforestry is the Institute of Agroforestry (IAF) of UPLB through its education, research and extension functions. One of the strategies in the promotion and implementation of agroforestry is through IAF's training courses, whose properties are the following: 1) a multidisciplinary training team; 2) flexibility wherein training design is based on pre- and post-course evaluation; 3) partnership with other institutions, participation of both farmers and the NGO workers; 4) training follow-up activities; 5) development of new courses based on expressed needs of partners and which are now implemented on-site; 6) team work and respect for one another; and 7) consultation. During the conduct of the agroforestry training impact and needs assessment in 1999, 2000 and 2001, results showed that adoption of agroforestry is faster in areas where the farmer serves as the initiator of the technology in areas where it is the upland development workers who organizes the establishment of agroforestry in farmers' farms. The inclusion of farmers as participants in the training courses was prompted by the realization that the farmers are the key implementers of conservation farming practices. Assisting organizations including their project staff will soon turn-over the implementation of projects to farmers. As such, technical capability building in agroforestry is necessary for the farmers considering that they are the implementers of the technology.

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Replenishing Soil Fertility in Sub-Saharan Africa: Remaining Challenges

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There has been a wealth of development of both organic and inorganic technological approaches, e.g., agroforestry, green manures, grain legumes, to counteract soil degradation problems in Sub-Saharan Africa. However, despite some local success they have failed to make a major lasting impact. As a result, many poor households are now caught in a "maize-focused poverty trap": their first priority is to produce maize (*Zea mays* L.) for home consumption, yet yields are low and returns are insufficient to support investment in soil fertility enhancement technologies. To invest in their soils, most households need to diversify into higher value crops than maize. However, the combination of small land holdings and existing maize deficits mean that they will only plant other crops or improved fallows if they can simultaneously raise maize yields. They will only be able to do this if they can access a number of important support services. Firstly, households must have sufficient information about market opportunities. Secondly, they need technical knowledge, on best cultural practices for the new crops and, critically, on how to manage their natural resource base. Thirdly, they need good quality seeds of adapted crops. Most will also need access to credit, so as to be able to acquire inputs for more intensive maize production. Critically, all these services need to be in place before poor households can hope to shift from a staple food-only production system to one that delivers food and cash, whilst simultaneously enhancing soil fertility on which future production depends.

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Bachelor Programme in Agroforestry: A *Premiere* in Canada

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In 2004, the Université de Moncton (U de M) will receive the first students cohort in its new bachelor degree programme in applied agroforestry offered in French. It will be the first such undergraduate programme in Canada. In collaboration with a Community College (the Center for Excellence in Agricultural and Biotechnology Sciences), the Faculty of Forestry of U de M will form professionals in temperate agroforestry with a strong tropical accent. Located in Eastern Canada in an area where forestry and agriculture are the two main economic sectors, our new 5-year programme will contribute to promote agroforestry practices and research. The presentation will focus on the programme content and approach and also on the results of a previous market study which was done to identify the needs for formation.

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Mineral N Dynamics, Leaching and Nitrous Oxide Losses under Maize Following Two-Year Improved Fallows on a Sandy Loam Soil in Zimbabwe

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The fate of the added N on a sandy loam soil was determined in an improved fallow - maize sequence field experiment in Zimbabwe. Sequential soil augering was done at two-week intervals in plots that previously had 2-year fallows of *Acacia angustissima*, *Sesbania sesban* and unfertilized maize (*Zea mays* L.) to determine mineral N dynamics. Using the static chamber technique, N_2O fluxes were also determined in the same plots. There was a flush of NO_3-N in the *Sesbania* and *Acacia* plots with the first rains. Topsoil NO_3-N had increased to >29 kg N ha^{-1} by the time of establishing the maize crop, but decreased rapidly within three weeks of maize planting. Total NO_3-N leaching losses from the 0-40 cm layer ranged from 29 to 40 kg ha^{-1} for *Sesbania* and *Acacia* plots within two weeks when 104 mm rainfall was received in an already fully recharged soil profile. At one week after planting maize, N_2O fluxes of 12.3 g N_2O-N ha^{-1} day^{-1} from *Sesbania* plots were about twice as high as those from *Acacia*, and about seven times the 1.6 g N_2O-N ha^{-1} day^{-1} from maize monoculture. The unfertilized maize showed consistently low N_2O emissions, which never exceeded 2 g N_2O-N ha^{-1} day^{-1} for all the eight sampling dates. We conclude that, under high rainfall conditions, there is an inherent problem in managing mineral N originating from mineralization of organic materials as it accumulates at the onset of rains, and is susceptible to leaching before the crop root system develops.

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Propagation and Management of *Gliricidia Sepium* Planted Fallows in Sub-humid Eastern Zambia

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Gliricidia sepium, features prominently as a soil replenishment tree, in planted coppicing fallows in eastern Zambia. Its usual method of propagation through nursery seedlings is costly and may possibly hinder wider on-farm adoption. We compared fallows propagated by potted and those by bare root seedlings, directly seeding and stem cuttings in terms of, tree biomass production, soil inorganic N availability and post-fallow maize (*Zea mays* L.) yields under semiarid conditions at Msekera, Zambia. We hypothesized that cutting fallows initially in May (off season) would increase fallow tree biomass productivity as opposed to cutting them in November (at cropping). Tree survival and biomass order after two years was: potted = bare root > direct >cuttings (P<0.05). Post-fallow maize productivity sequence was: fertilized maize = potted = bare root > direct > cuttings = no-tree unfertilized controls, across seasons. However, farmers may prefer directly seeded fallows owing to their cost effectiveness. Soil inorganic N and maize yield was significantly higher in May cut than in November cut fallows (P<0.05). Preseason topsoil inorganic N and biomass N input correlated highly (P<0.001) to maize yields (r>0.70, n = 40). This implies that both parameters may be used to predict post-fallow crop yields.

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Soil Nitrogen Dynamics in Coppicing and Non-Coppicing Planted Tree Fallows in Zambia

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Soil degradation seriously threatens agriculture in southern Africa. Decline of soil fertility due to continuous cultivation without using fertilizers is a major cause of low crop yields in sub-Saharan Africa. Nitrogen (N) is cited as the most limiting nutrient to crop production in the region. We hypothesized that planted tree fallows can potentially improve soil properties and N availability, thus enhancing crop yields. Field studies were conducted at Msekera, Zambia, to determine the effect of contrasting fallows (natural fallow, non-coppicing and coppicing planted tree fallows) and no-tree no-fallow (maize with and without fertilizer) systems on soil fertility. Planted fallows increased topsoil N and maize (*Zea mays* L.) yields over the no-tree, unfertilized controls. Maize yields in planted fallows of *gliricidia* and *leucaena* were consistently high and comparable (P<0.01) to fertilized controls over 8 seasons. Maize productivity in non-coppicing *sesbania* fallows dwindled significantly after three post-fallow seasons indicating decreased soil fertility. Preseason topsoil N in planted fallows positively correlated (r=0.83) with maize grain yield. Nitrogen significantly accumulated in the subsoil under non-coppicing *sesbania* fallows (in post-fallow phase) giving a trend similar to continuously cropped controls. Topsoil N accumulation in the planted fallow systems was attributed to foliage biomass addition. Coppicing of *leucaena*, *gliricidia* and *gliricidia* + *sesbania* fallows, was more suited for long-term N amendment than sole *sesbania* fallows. Soil fertility replenishment in sub-Saharan Africa must go beyond just N amendments. Soil properties such as water storage, infiltration rate and compaction, combined with crop nutrients to significantly impact crop yields.

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Soil Water Dynamics and Changes in Soil Physical Properties under Agroforestry Systems in Eastern Zambia

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The major problems in sub-Saharan Africa are the prevalent droughts and soil deterioration due to continuous cropping. Agroforestry-based systems have the potential of reversing soil degradation. A series of field experiments were conducted at Chipata, Zambia from 1991 to 2003 to study the effect of improved fallows on soil water dynamics, soil physical properties and yield of rainfed maize (*Zea mays* L.). The treatments were: *Sesbania sesban*, *Tephrosia vogelii* (non-coppicing) and *Gliricidia sepium*, *Leucaena leucocephala* (coppicing) species and the controls of natural fallow, continuous fertilized and unfertilized maize. Total biomass at fallow clearance was significantly correlated with the first post-fallow maize grain yield. A polynomial regression model between cumulative rainfall during the tree phase accounted for 55% of variability in total biomass at fallow clearance. Improved fallows stored more soil water and had higher increased water infiltration rate than the continuous fertilized and unfertilized maize. Lower bulk densities and reduced soil resistance to penetration was recorded under improved fallows compared with continuously fertilized and unfertilized maize plots. Improved fallows had higher moisture content at field capacity and wilting point compared to the controls. Maize grain yield under improved fallows were significantly higher than unfertilized maize. Improved fallows are more effective in improving soil fertility and subsequent maize grain yields.

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In Situ Management of Sabiá (*Mimosa Caesalpiniifolia* Benth.) for Simultaneous Production of Wood and Forage in a Silvopastoral System in Northeastern Brazil

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A study was conducted on a silvopastoral system at Embrapa Caprinos in Sobral, Ceara, Brazil, from 1995 to 2002. The study aimed at the development of a sustainable forest management system for simultaneous production of Sabiá (*Mimosa caesalpiniifolia* Benth.) wood and forage and also a reduction of the time period for wood harvest. Trees were submitted to a uniformization cut at a 10 cm height and four treatments. The treatments were applied to 12 randomly selected group of plants as follows: 1) preservation of one stem with control of the sprouts; 2) preservation of two stems with control of the sprouts; 3) preservation of three stems with control of the sprouts; and 4) preservation of all the stems. Data were collected for total height, breast height diameter, production of fence post and firewood, and forage phytomass up to a height of 1.6 m. Treatments 1, 2, and 3 resulted in an increase of wood and forage production and significant reduction on the time period of fence post harvesting from 15 to 7 years. Treatment 2, preservation of two stems per plant, resulted in the greatest economic returns providing the highest additional income per hectare and year. It was observed that the preservation of all the stems was the worst treatment. Besides the increase on forage production, the mean annual increment rate of wood production was superior to those found in the semi-arid region of northeastern Brazil.

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Farmers Perceptions on Tree/Crop Competition in Dryland Agroforestry in Mali, Western Africa

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The most important parkland tree species in terms of socio-economic importance and soil fertility improvement have been investigated in two agroecological zones in Mali: a mesic area (Ségou) and arid one (Mopti). Tree species which bring income to farmers were ranked and traditional management strategies determined. Farmer's surveys were done in 15 villages, randomly chosen in each research area. Group and individual interviews have been done. Farmers' main activity in the two regions is agriculture. The number of tree species present in parklands in dry zone is 15 while it is 33 in mesic area. The two important species for their economic values are *Vitellaria paradoxa* and *Adansonia digitata* in Ségou. *Adansonia digitata* and *Acacia albida* are preferred in Mopti. Pruning and protection of mature individual trees are the main old management practices. Protection of the regeneration is more recently practiced. Most of the farmers (86% in mesic area and 100% in dry area) are aware about the reduction of tree numbers in parklands. Individual planting is done in all the villages. Farmers who do not plant trees have elucidated reasons: lack of seedling production techniques, draught or lack of interest. Farmers know the effects of trees on soil fertility and crop yield but they are not aware about the belowground competition for nutrients and water. Values of nontimber forest products from *V. paradoxa*, *A. digitata*, and *Tamarindus indica* could compensate for the loss of crop yield under tree canopy.

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An Improved Nursery Practice for Enhancing the Initial Growth Rates of *Garcinia gummigutta*

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This study is an attempt to standardize a nursery practice to optimize the seedling growth rate at nursery stage for *Garcinia gummigutta*, which is categorized as a threatened species endemic to the Western Ghats regions of India and Sri Lanka. A cost-effective method to raise seedlings under elevated CO_2 concentration was studied. CO_2 released by decomposing organic matter was trapped in a closed poly structure where seedlings were raised. Seedlings of 4 and 7 months age were exposed to elevated CO_2 concentration and supplemented with nutrients and hormones. A significant increase in plant height, stem diameter, leaf area, leaf number and dry matter production was noticed in both age groups in all the treatments. Maximum response was seen under elevated CO_2 concentrations supplemented with higher dose of nutrients. Response was better in four-month old seedlings than in seven-month plants. Increase in leaf area was due to both higher leaf expansion rates and increase in leaf number. Highest biomass accumulation was seen when plants were grown under elevated CO_2 concentration supplemented with nutrients in both the age groups. A concomitant increase in photosynthesizing surface area was seen in these treatments, indicating higher photosynthesis at elevated CO_2 concentration leading to higher biomass accumulation. This treatment combination also has influence on the morphogenic factors.

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The Role of Improved Fallows in the Satisfaction of Fuelwood Needs of a Senegalese Peanut Basin Semi-Urban Area

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High demographic pressure has led to soil and forest degradation in the 500-1100 mm rainfall zone of central Senegal. Soil fertility loss and fuelwood deficits are the main constraints. Does the use of improved fallows remove the fuelwood problem? To answer this question, three sites in the Peanut Basin (Sonkorong, Ndiaye Ndiaye and Ngane) were studied using a socio-economic enquiry and wood inventory. A 1-15 years natural fallow produced 2.5-25 t ha^{-1} of wood, while a *Racosperma holosericea* four-year old improved fallow produced 36-108 t ha^{-1}. A 13-member family used about 7.7 kg d^{-1}, or 2.7 t yr^{-1}, valued at US$25,000 to 469 families. Eighty percent of them bought for US$7,150 up to a yearly amount of 74.4 kg of charcoal. The last 20% collected locally 266 t of fuelwood valued at US$6,500. Differences between wood locally collected and bought made an 823 t deficit. Natural fallows are a wood deficit-maker while improved ones are an excess-maker, regardless of the stand duration. For a 1 ha-4 yr improved fallow, household wood excess ranged from 24.4 to 96.4 t, guaranteeing 8-35 years of wood autonomy or revenue of US$150-600 during four years. Seedlings and planting costs are about US$96 ha^{-1}. Economic investigation showed that a 1 ha improved fallow is a better income-supplier than 1 ha of 800 kg peanut yield or US$186. Thus, wood quantity bought by a 469 household village is cancelled with ten of the households each planting 1 ha yr^{-1} of improved fallows over a four-year period.

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The Southeastern Agroforestry Decision Support System (SEADSS): An On-Line Application for Tree and Shrub Selection and Agroforestry Decision Making

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Computers and the Internet are effective means of education and extension. An important initiative of the Center for Subtropical Agroforestry, University of Florida, is the development of an on-line GIS and database application to provide landowners and extension agents in the Southeast with information and decision-making tools for the adoption and management of agroforestry land-use systems. The Southeast Agroforestry Decision Support System (SEADSS) offers information on sub-subtropical tree and shrub species and county-level geographic site information. The basic agroforestry tenet of combining trees or shrubs with crops or livestock makes it essential in presenting information on the ecological, economic and management characteristics as well as site adaptability of potential trees and shrubs. Moreover, geographic information of specific sites or farms is also vital for landowners and extension agents to evaluate and plan agroforestry systems. Integrating Geographic Information Systems (GIS), the SEADSS provides on-line access to spatial data such as soil characteristics, hydrology, topography and land use. The SEADSS links the GIS with the subtropical tree/shrub database, allowing users to query biophysically suitable and/or economically and managerially desirable trees or shrubs in areas of interest, or conversely, spatially show potential sites for specific species being considered. The development of SEADSS has begun with pilot versions for several counties in Florida, mostly in the Panhandle region. Through a series of workshops, SEADSS is being validated and evaluated with the involvement of local extension agents and landowners, ensuring SEADSS becomes a powerful agroforestry planning and decision-making tool developed with and for intended end-users.

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Foliage of Locally Available Trees as Green Manure in the Northern Guinea Savannah of Nigeria

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The foliage of local tree species at Yamrat district in the northern Guinea savannah agroecological zone of Nigeria was evaluated for use as green manure. A survey was conducted to identify and categorize available tree and shrub species based on their utility within the farming systems. Twenty tree species were monitored to determine the leaf biomass production in the 2000 and 2001 cropping seasons. Tree population on farmers field was estimated while chemical analysis of the foliage was conducted. The plant residue quality index (PRQI) technique was used to deduce the individual tree foliage quality index. Twenty-eight tree species were identified, out of which 15 were selected as good candidates for green manure. Tree leaf biomass production ranged from 2.16 to 5.80 kg tree-1 on a dry matter basis four weeks after the inception of the rains. Recyclable plant nutrient found in the foliage of trees ranged from 1.23 to 2.39% N, 1.30 to 4.45% P, and 12.7 to 66.3% K. Other qualities ranged from 7.7 to 35% lignin, 3.32 to 6.67% polyphenols, and 12.8 to 38.4 C/N ratio. The PQRI ranged from 4 to 8. Organic carbon content of soil under tree canopy ranged from 8.8 to 42.4 g kg-1. There was a significant negative relationship between the percent nitrogen content of tree leaves and the soil organic carbon content under the tree canopy. Foliage of locally available tree species was found to possess characteristics good enough for their use as green manure for soil fertility maintenance.

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Fertilization of Agroforests- A Double-edged Sword?

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Forest and agriculture production both have increased through the use of inorganic fertilizers. Similarly, agroforests should produce higher yields of agronomic crops and wood fiber, but there is anecdotal evidence that fertilizing agroforests may result in greater susceptibility to insect infestation and damage. Our study of a loblolly pine (Pinus taeda L.)-hay agroforest in the western gulf coastal plain of southwest Arkansas experienced significant pine cone worm and tip moth damage following a fertilization regimen of 300 lbs (1 lb = 0.454 kg) of 17-17-17 each May and 100 lbs of 34-0-0 and 0-0-60 each July. Subsequent chemical analyses of both soil and foliage found foliar phosphorus concentrations were higher in fertilized areas. No difference in soil phosphorus concentrations was observed, but tests did indicate differences in concentration of calcium and sulfur. Based on the understanding of the role of calcium in cell wall development and the relative immobility of calcium within plants, we hypothesize that a calcium deficiency or an imbalance of soil calcium relative to other essential elements may predispose new cones and foliage on loblolly pine in fertilized agroforests to cone worm and tip moth infestation. Accordingly, gypsum was added to the fertilization regime at rates of 0, 500, and 1000 lbs/acre (1 acre = 0.4 ha) to assess if future rates of pine cone worm and tip moth damage are a function of soil fertility. If balancing soil amendments can decrease insect damage, then agroforest production can be improved without the use of costly chemical controls.

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Small-Farm Soil Fertility Management Strategies in Cameroon

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This paper attempts a study of the agrarian Nweh population of Cameroon and of the efforts they put forth in managing the fertility of the soil upon which they depend. The poorest of the poor, in the said area, often find themselves dependent on the soil, both those of the secondary forest and remnants of the montane forest. It is suggested that the causes of poor soil management by the land-based community need to be addressed before we are able to devise and develop more effective methods to protect and conserve soil fertility losses by small farms. In the case described, in the Nweh community, the adoption of 'slash and burn', fallowed and virgin land clear cutting, the introduction of exotic trees, and the natural effects of landslides, have led to poor soil fertility management in small farms. Community members are more traditional in soil fertility management by their attachment to the age-old land tenure system. It is concluded that to move towards an effective implementation of modern small-farm soil fertility management, it will require a reconciliation of the different perceptions (the land-based population and modern strategy managers) that will require not only further scientific research but also further efforts to ensure that research findings are better disseminated and linked to policy and land-use decision making.

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Management Effects on Holm Oak (*Quercus ilex*) Production, Regeneration and Biodiversity of Dehesa Agroforestry Systems in Spain: A Multi-level Approach for Assessing Ecological Sustainability

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Dehesa is a kind of agrosilvopastoral system which results from transformations of the original Mediterranean forests, including tree clearing and land plowing in order to keep open areas for livestock grazing. At present, dehesas cover 3.1 million hectares in western Spain and Portugal, and they are considered both ecologically valuable and threatened because of lack of tree regeneration. In this work we address the effect of different management combinations, namely rotational cereal cultivation (C), continuous grazing (G) and reduced grazing with invasion by matorral (M), on three components of sustainability. Through a whole reproductive cycle we estimated acorn production, flower-to-seedling probability of oak recruitment and number of plant species (an indicator of biodiversity) in three farms per each management type. Viable fruit production was higher in C plots, intermediate in G and lower in M. Acorn consumption by livestock and wildlife under oaks resulted in exhaustion of the crop irrespective of management, while acorn dispersed far from the trees survived better in C and were depleted in G. Cultivation also enhanced seedling emergence due to the exclusion of livestock, but mechanical harvesting and subsequent browsing resulted in lower long-term recruitment. Finally, plant diversity followed an opposite trend and was reduced both by cultivation and shrub encroachment. Overall, these results suggest a conflict between practices favoring biodiversity *versus* long-term persistence of trees and thus the sustainability of the whole system.

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Assessment of Subsoil Nitrogen Acquisition, N_2-fixation and N Cycling by Legumes in Mixed Stands in Tropical Farming Systems

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Mixed legume fallows planted in rotation with cereal crops are generating substantial interest among scientists and farmers in smallholder sub-Saharan farming systems, as they may enhance above- and belowground resource acquisition. Our study examined subsoil N uptake (15N deep placement method), N2-fixation (δ15N natural abundance method), and nitrogen productivity of four woody and herbaceous legumes, planted in mixtures and monoculture stands on a Kandiudalfic Eutrudox soil in western Kenya (0°06'N lat., 34°34'E long., 1330 masl). Legume species evaluated included: sesbania (Sesbania sesban), crotalaria (Crotalaria grahamiana), pigeonpea (Cajanus cajan), and siratro (Macroptilium atropurpureum). Sesbania emerged as a weak competitor for resource acquisition when mixed with crotalaria and pigeonpea potentially due to its poor initial establishment under relay cropping system. While sesbania recovered similar amounts of N from the topsoil (~15 cm) as crotalaria, the latter recovered more N in the subsoil (~200 cm). However, sesbania plants in monoculture recovered (~0.78%) more subsoil 15N than sesbania mixed with crotalaria and siratro. N derived from N2-fixation by sesbania was lowest when mixed with crotalaria (14%) and greatest when mixed with pigeonpea (44%). Despite poor performance of sesbania in mixtures, total N yield recorded from sesbania + crotalaria and sesbania + pigeonpea were similar to the monoculture stands of crotalaria, pigeonpea, and siratro. We conclude that the negative effects of interspecific competition between legumes planted in mixed stands can be surpassed by the compensatory biomass and nutrient yield gains from the stronger competing species as a result of reduced competition for available growth resources.

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Rainfed Agroforestry Systems for the Semiarid Subtropics of India

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Field studies were initiated at Indian Grassland and Fodder Research Institute, Jhansi (UP), India with four-month old tree saplings planted during the 1998 monsoon season on a sandy loam soil. Treatment combinations consisted of four tree species (Albizia lebbeck, Azadirachta indica, Dalbergia sissoo and Acacia nilotica) and three crops (no crop, barley and chickpea) raised as intercrops along with two control plots (barley and chickpea raised as sole crops) in a replicated randomized block design under rainfed conditions. The crops were introduced during the winter season of 1999 onwards. Results after three years indicated that, for the growth of trees, Acacia was the most ideal. In biomass production, Dalbergia maintained its superiority. Highest soil moisture content was on an average with Acacia and lowest in case of sole cropping of crops. Association of trees with crops accounted for the increase in soil fertility. Transmission of photosynthetic active radiation (PAR) was minimal under Acacia nilotica. For all tree species, the south sides received more PAR than the north sides. In addition, specific leaf weight (SLW) was lower in shaded areas. Interestingly, there was no significant variation in grain yield of crops as raised in association with trees or as sole cropping. The grain production was highest in the interspaces of Acacia closely followed with Dalbergia. Highest grain yield was registered in the 3rd and 4th row from the tree component. Overall performance was best with crop sown in association with Acacia nilotica closely followed by Dalbergia with intercrops under rainfed conditions.

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Studies on Mango-based Agrihorti-pastoral Systems under Rainfed Conditions for Overall Sustainability of the Production System (Andhra Pradesh, India)

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A field trial on Mango-based agrihorti-pastoral systems on three aged gardens viz. 1-2 years, 5-7 years and >10 years of mango orchards was laid out in red sandy loam soils of Andhra Pradesh, India at 4 locations each, comprising 12 farmers fields in different mandals of Rangareddy district during 2001 to study the effect of growing intercrops and pastures in between mango (Magnifera indica) trees for overall sustainability of the production system. The intercrops included horsegram (Dolichos biflorus), cowpea (Vigna sinensis), sorghum (Sorghum vulgare), and fodder crops Cenchrus ciliaris and Stylosanthes hamata. Mango yield in terms of fruit no. / tree, total soluble sugars (TSS °B) and yield (t/ha) and yield attributes like tree height (m) and crown spread (m) were studied at all four locations of 3 aged gardens and benefit-cost ratio was calculated to know profitability of the entire production system. Growing intercrops among mango orchards showed a beneficial effect in young and medium-aged orchards, but not in matured orchards. Among the intercrops grown, sorghum was not beneficial since it reduced the growth and yields of young mango. Horse gram was beneficial due to its nitrogen fixing ability, suppression of weeds and seed yield. Mango yield in 5-7 years (b) and >10 years (c) old orchards in terms of fruit number per tree (48.25, 264.25 in b and c respectively) and yield (0.74 t/ha, 9.63 t/ha in b and c respectively) were significantly higher when intercropped with cowpea. Other findings from the study are presented.

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Efficiency of Shelterbelts from Exotic Arboraceous Species on Dark-Kashtanea Soils of Prisivashya, Ukraine

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Observations of condition, longevity and growth of experimental forest shelterbelts in Prisivashya, Ukraine, allow recommendations for optimal composition of arboraceous species in zone of dark-kashtanea soils with high diversity of site conditions. The species of *Sophora japonica* L., *Juniperus virginiana* L., *Populus bolleana* Lauche., *Catalpa ovata* G. Don, *Populus pyramidalis* Rosier., *Robinia neomexicana* Gray., *Koelreuteria paniculata* Laxm., *Fraxinus lanceolata* Borkn., *Gymnocladus dioica* (L.) C. Koch., *Celtis occidentalis* L., *Gleditsia triacanthos* L. with disposition in determinate order were studied. In conditions of zone of dark-kashtanea soils there is an opportunity to plant long-term belts of various exotic tree species. The best results can be obtained by using *Gleditsia triacanthos* and *Celtis occidentalis*, *Sophora japonica*, *Gymnocladus dioica*. Widening of the positive experience of exotic tree species testing is rational in zone of dry steppe in forest melioration and green plantations. It is rational to continue the investigations of new tree and shrub exotic species from other continents in Prisivashya region.

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Habitat Utilization by Wild and Domestic Ungulates in Scrub Forests – A Case Study in Indian Desert Biome

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Due to overgrazing in grasslands, scrub forests and fallow lands in the Indian desert biome, we are facing challenges to manage these resources for better conservation on sustainable basis. We studied habitat utilization by wild (Blackbuck or the Indian antelope and the Indian gazelle) and domestic (sheep and goats) ungulates on the basis of feeding strategy, dietary overlap and ecology of water holes in a natural rangeland in the Indian desert biome to see how such resources can be used on sustainable basis without affecting conservation goals. Food preferences indicated that the Indian antelope and sheep are exclusively grazers and roughage feeders, while the Indian gazelle and goats are browsers and mainly concentrate feeders. There was not direct competition in resource partitioning during the year between browsers due to differences in dietary preferences. Except during summer, the Indian antelope, and sheep too, which utilizes the same niche, may not be in direct competition for the food resources of their habitat, which are usually sufficient to meet the needs of both. During summer, when the sheep flocks migrate to areas of better grass cover, the antelopes apparently find no serious difficulty to maintain themselves within the exiting resources of their range. The antelope augment their nutrient and moisture intake during summer by consuming pods shed by *Prosopis cineraria* trees. The ecology of two water holes utilized by the wild as well as the domestic ungulates of this biome, and an idealized exploitation of desert rangelands by these animals, has been discussed.

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Analysis of Agroforestry Parkland System in Eritrea

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Parkland agroforestry system, characterized by deliberately retained trees widely scattered on farms, combined with raising livestock, is part of the main indigenous land use system in the southern lowlands and midlands of Eritrea. Despite the agroforestry system is a long time-tested practice in the marginal lands of low-input farming, its socio-economic settings, management strategies, patterns of characteristic, and interactions of components and how the system functions in general are very little known. This paper attempts to describe the system and identifies the potential constraints that require researches. The system may optimize the ecological and economic aspects of the farm by obtaining higher, more diversified and sustainable total production than monocropping. Farmers could only benefit from the broader potentials of the system if the system is functioning effectively. For more improvement, it is so essential to understand the system's dynamics in spatial and temporal scales. More information on the system's production level could also lead to improved and greater benefits. Finally, it was noticed that in the long term tangible ecological benefit of the system could only be secured by current preservation efforts.

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Pest Management Research of Improved Fallow Technologies in Western Kenya

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Improved fallow—the planting of leguminous trees and shrubs for soil fertility replenishment purposes—is one of the predominant agroforestry technologies practiced in western Kenya. As scaling up took its momentum, more trees either indigenous or exotic are occupying the landscape. The change in the functional agro-biodiversity contributes to the dynamics and complexity of tree/crop/pest interactions. Trees and shrubs in the landscape might become susceptible to pest attack or act as an alternative food source to crop pests. On the contrary, they might also play a role as trap crops or deterrents to pests. The pest management research in the World Agroforestry Centre (ICRAF) is aiming on the development of a knowledge base about ranges of pests associated with agroforestry systems, evaluating their abundance and damage potential and developing integrated management options. The potential of introduced tree species to become weeds and harbour pests of agroforestry trees/shrubs and associated crops is also another dimension of research conducted to avoid risk. The findings clearly indicated the positive and negative traits of trees on farm. Through identifying emerging pest problems and reduction of the negative attributes using cultural and biological control methods, it is possible to scale-up the technologies in a more productive and sustainable manner.

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Northern India Agroforestry - A Unique Success Story

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Producing commercially fast growing poplar and cloned eucalyptus species, exclusively for the wood industry, on a harvest cycle of 6-10 years by small farmers is our unique success story. Twenty-three years ago another farmer and myself riskily ventured into poplar agroforestry. Today thousands of farmers grow poplars. Over 300 wood processing factories have been established nearby over the past 12-14 years producing plywood, wood board, flush doors, packaging, etc. to create a US $ 300,000 per year economy soon to be One Billion. Quality and quantity of wood produced varies considerably depending on the level of technology, management skill and investment. Like crops, most trees respond to irrigation, manuring and management. Hara Farms, being pioneers, took the challenge of producing trees both efficiently and economically. All five essentials of plant growth - 1) Irrigation/water, 2) Plant nutrition (NPK micronutrients, soil microbiology), 3) Sunlight maximizing photosynthesis, 4) Superior germplasm, and 5) Management, technology, investment - are blended to produce over 20 tons of timber per acre per year on 8-10 year harvest cycles. Agronomically compatible, shade tolerant, high value fruits, food and spice crops are intercropped for cash flow. This high input high output agroforestry, horticulture production is sustainable, agronomically compatible, environmentally beneficial, ecologically safe, reduces air and water pollution, is economically profitable, generates employment and substitutes imports. Visitors to Hara Farms leave convinced that the wood requirement of 21st Century would increasingly come from agroforestry. We come here in hope that our success is recognized and carried forward.

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Distribution and Resource Value of Tropical New World Prosopis Species

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Prosopis juliflora (Sw.) DC. and P. pallida (H. & B. ex. Willd.) H.B.K. are the only truly tropical American Prosopis species. They have been widely introduced and are now naturalised throughout the hot, dry, frost-free regions of the world. They are drought resistant, fast growing and nitrogen fixing species, provide a range of high quality resources, and form important components of agroforestry systems. In contrast, both species, but especially P. juliflora, have been declared noxious weeds in Australia, South Africa, Sudan and elsewhere. P. juliflora and P. pallida are difficult to distinguish and are frequently misidentified. In this study, herbarium specimens from within the native range and where introduced were examined. Additionally, seeds and/or mature leaves were obtained from over 25 countries worldwide. An analysis of leaf morphology showed that the two species could be identified using foliar characters and allowed development of simple identification keys. Analysis of seedlings by flow cytometry indicated that all P. pallida samples were diploid, whereas P. juliflora were tetraploid. Triploid hybrids between the two species were also found for the first time. The world distribution of the two species is shown, revealing major misidentification in several countries, including Brazil, Cape Verde and Senegal. The distribution is discussed in relation to resource value of Prosopis species in forestry and agroforestry, and to their potential weediness. The results have important implications for increasing production and protection through improved management and utilisation of existing trees, genetic improvement, and control of invasive stands by biological or other means.

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Effect of Three Year Fallow with Herbaceous Cover Legumes on Soil Fertility and Sweet Potato Production in Southeastern Nigeria

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The study, conducted between 1999 and 2003, investigated the effect of three year fallow (1999-2002) with green manure cover crop and NPK fertilizer on soil fertility and sweet potato production in the lowland humid forest zone of southeastern Nigeria. Treatments consisted of two sweet potato varieties (TIS87/0087 and TIS8164) and 13 manure treatments (Mucuna pruriens, Mucuna veracruz, Mucuna deeringiana, Centrosema pascuorum, Centrosema brasilianum, Crotalaria ochroleuca, Chamaecrista rotundifolia, Aeschynomene histrix, Lablab purpureus, Pueraria phaseoloides, Stylosanthes capitata, natural fallow and NPK fertilizer). Aboveground biomass at 3 months after planting was significantly higher in Mucuna veracruz than other cover crops except Mucuna deeringiana, Mucuna pruriens and natural cover. At 4 years after planting, however, Aeschynomene histrix produced significantly higher biomass than other persistent cover crops. Mean soil nitrogen was significantly higher with Centrosema pascuorum than with other legume cover crops and natural fallows except Aeschynomene histrix, Mucuna veracruz, Chamaecrista rotundifolia and Crotalaria ochroleuca. Soil potassium was not significantly affected by the cover crop fallows. Shoot dry matter, tuber weight and tuber yield in 2002 were significantly higher in sweet potato variety TIS87/0087 than TIS8164 by 37, 64, and 68% respectively. On average, tuber yields obtained from NPK fertilizer application were similar with those obtained from Mucuna veracruz, Centrosema pascuorum, Centrosema brasilianum, natural and Aeschynomene histrix fallows but significantly higher than the yields of other cover crop fallows. There were no significant interactions between sweet potato varieties and the NPK fertilizer or cover crop fallows on shoot dry matter and tuber yields.

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An Assessment of Indigenous Agroforestry Practices in the Limpopo Province of South Africa

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Although past governments in South Africa neglected agroforestry as a formal development program, indigenous people in South Africa practice it. Resource-poor farmers in the Limpopo province have integrated woody perennial trees and shrubs with annual crops, pasture and livestock. The current government of South Africa is now eager to develop and support agroforestry in the country. Surrounding countries in the region have active agroforestry programs from which South Africa can learn important lessons, especially given similar site conditions and development concerns. Prior to developing agroforestry projects it is important to assess current agroforestry activities. This paper provides a quantitative and qualitative assessment of indigenous agroforestry practice in the province. To characterize the different agroecological zones of the province the region was divided according to administrative district and by annual rainfall amounts. Rainfall in the province ranges from less than 300mm to over 1000mm per annum. Rainfall plays a significant role in the type and location of tree or shrub species used. Although the focus of government support has been on agricultural crops the study found that trees and shrub were retained on croplands and pastures for food, shade, fuelwood, windbreaks, building materials, and for demarcation. The main types of agroforestry systems include homegardens, fruit tree intercropping, and natural veld livestock production. The farmers have a strong interest in agroforestry but are constrained by limited land area per household, lack of extension assistance, inadequate water supplies, lack of credit, and concern for tree damage from vandalism and animals.

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Generalities vs. Depth: A Discussion of Teaching Agroforestry

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During the 2003 North American Agroforestry Conference (Corvallis, Oregon, USA) a discussion on teaching agroforestry was held. Fourteen syllabi on agroforestry from different universities were distributed and a discussion ensued about key topics and approaches to teaching a successful agrofrestry course. As expected there were a few key areas of consensus, but overall many topics were listed as important to cover in an agroforestry course. All participants in the session were eager to follow up with a more concentrated discussion on a specific topic on teaching agroforestry at the 1st World Agroforestry Congress. One of the pertinent topics for further discussion is, given that most universities only offer one course on agroforestry, how much depth or detail should be given to each topic in the course. At the World Agroforestry Congress we would like to have a discussion about whether a time-constrained one-semester course should provide students with a general overall background of agroforestry by addressing multiple topics briefly or to concentrate on a few key topics in depth. The discussion will provide educators with new ideas for topics and hopefully lead to improved agroforestry course syllabi.

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Coppicing Fallows: A New Innovation for Smallholder Soil Fertility Management in Sub-humid Africa

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Improved fallows, defined as the use of fast-growing leguminous trees in rotation with crops, is becoming popular among resource-poor farmers in the humid and sub-humid regions of Africa as a low-cost technology to improve soil productivity. Thousands of farmers are now using these fertilizer trees that have improved yields considerably especially when integrated with inorganic fertilizers such as phosphorus that the fallows cannot provide in adequate amounts. Many promising species have been identified but what appears most appealing to farmers are species such as *Gliricidia sepium* and *Calliandra calothyrsus* that coppice when cut back. These species are densely-planted in the crops and are cut back 1-2 times during the cropping season. A significant amount of nitrogen (100 to 150 kg ha^{-1}), much of which is biologically fixed from the atmosphere, is recycled by coppicing fallows (CF). Remarkable maize yield increases have been associated with CF, with increases of 1-2 tons ha^{-1} being typical over the 1.0 t ha^{-1} or less that is normally found under farmers' management conditions. Other factors contributing to the attractiveness of CF are savings in labor compared to the non-coppicing species such as sesbania as well as control of striga weeds. They also provide considerable amounts of fuelwood, with yields of 8-10 t ha^{-1} in 7-9 months duration being common. Given the great potential of this technology, a cross regional analysis from 3 regions of Africa is presented and highlights what is needed in the future to make the technology more profitable and acceptable to farmers.

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Forestry Education and Rural Livelihoods: Strategic Linkages for Sustainable Agroforestry Practices

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Forestry education in India has a long historical perspective from colonial rule to modern management practices. The successive paradigm shift in forest management with the importance of community participation in resource management has been a very important instrument in framing of the policy for extension of agroforestry for rural livelihoods. The social forestry program started in 5th Five-year plan has given a new thrust on agroforestry education, as one of the core subjects for forestry education. Presently the subject for agroforestry is taught in graduate programs as a part of forestry subjects at the university level besides in the institution for front line staff and the forest managers. The forest department, which is the key role player in the execution of forestry extension at rural level, has three tier forestry education system, for the frontline staff, the forest managers and for policy planners. The success of any extension program depends only when the linkage among the policy planners and the field situation is established. The extension education is only possible with the understanding of the approach for the field situations and strategic planning. This paper analyzes the present status of agroforestry education in India at various levels and establishing the links between the practices and the theoretical studies in the institutions. It also suggests the strategies for the agroforestry extension and education based on the survey of the various forestry educational institutes and their participants in study program, thereby suggesting a framework for strategic planning for agroforestry education.

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Soil Chemical Composition, Nutrient Budget and Biomass of Rubber (*Hevea brasilensis*) Trees in Kerala, India: A Comparison with Forest Ecosystem

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Rubber (*Hevea brasiliensis*) plantations in Kerala, India raised a century ago in freshly cleared forest where latex is commercially extracted. Trees are removed after the economic life span of 30-32 years. Nutrient store and export rates of twenty-year old trees was quantified based on estimates of biomass. Balance sheet of nutrients for a planting cycle was worked out, and comparisons drawn between rubber and forest ecosystems for soil nutrient reserve and/or depletion. Soil pH declined significantly from first to third cycle. Phosphorus in top soils under *Hevea* in third cycle was comparable with that of forest. Branches and trunk accounted for 80% and the roots comprised about 15% of the total dry matter on whole plant basis. Nitrogen concentration in leaf and bark exceeded those in the branches and trunk, while Ca in the bark was greater than those of the wood/leaf by factors ranging from five to forty times. Major portion of the nutrients were accumulated in branches and trunk, and was in the order of Ca>N>K>Mg>P. Nutrient losses by harvesting latex were: 300 kg N, 90 kg P, 180 kg K, 90 kg Ca and 90 kg Mg ha^{-1}. The depletion of K and Ca was significantly higher in rubber-cultivated soils as compared to forest soils. The 'R' factor (percent of cultivation within the total cycle of fallowing and cropping) was 12.5% under the cultivation situation in Kerala with intermediate input levels, and makes *Hevea* an agroforestry tree-crop.

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Participatory Development of Agroforestry Models for Improved Livelihoods in Semiarid India

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Population explosion has brought marginal and sub-marginal rainfed lands into cultivation, which is uneconomical and unsustainable. Grain farming in marginal and uneconomic holdings will not contribute to food and nutritional security of the people. In these regions, tree farming with crops or alone offers an efficient alternative towards satisfying varying needs of the poor. Many models have been developed on-station but most are confined there. Farmers do not adopt agroforestry models in the absence of some success stories and are unaware of intangible benefits of agroforestry. NGOs can demonstrate the practical feasibility and profitability of different models involving few progressive farmers. They also act as interface between researchers and farmers. Such successful examples could build confidence in the farming community and encourage them to adopt different models. Taking into consideration the above constraints in adoption of agroforestry models, CRIDA started an on-farm participatory development of agroforestry models in collaboration with six NGOs in Mahabubnagar and Nalgonda districts of Andhra Pradesh, India. After three years, the salient findings are: 1) Exposure visit cum training of farmers and NGO personnel on different aspects of AF models motivated the farmers and helped in better adoption of the models; 2) Participatory selection of species with farmer's choice based on soil type resulted in better survival of the species; 3) The growth and survival of the species was better when both wife and husband participated in its planting and care; and 4) Social fencing is very important for protection of the plants from stray cattle.

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Agroforestry Curriculum in African Universities and Colleges

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Agroforestry has been identified as having the potential to improve productivity and overcome some constraints to sustainable land use. Recognizing these benefits, many colleges and universities in Africa have incorporated agroforestry in their training programs. Given the large diversity of institutions and disciplines involved in teaching agroforestry, there has always been the question of knowing what an appropriate agroforestry curriculum should contain. This paper reports on the findings of a survey that was carried out in year 2001 in nineteen institutions in ten African countries. Using a structured questionnaire and interviews, data were gathered on agroforestry curriculum content, the way it is being delivered, and the institution capacity to teach agroforestry and the constraints and challenges facing agroforestry training. The survey revealed that in many colleges and universities in Africa, Agroforestry is taught as part and parcel of programs in agriculture, forestry and natural resource management sciences. At all levels of training, agroforestry is taught more in forestry as compared to agriculture-based institutions. In almost all forestry institutions, agroforestry is taught mainly as a separate subject as compared to agricultural based institutions where it is taught as a topic or a component of another subject. The survey revealed that some institutions have already started fully-fledged programs in agroforestry while others are seeking to do the same. Currently, there are already technical level and masters programs in agroforestry. It is noted that some important agroforestry topics are missing in many of the institutions' agroforestry curricula.

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Soil Organic Matter in Coconut-based Agroforestry Systems in Vanuatu: A Key to Sustainability?

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Traditional Melanesian farming systems include slash-and-burn, short cultivation and fallow periods. The extension of coconut plantations has modified these systems and led to a variety of complex agroforestry systems that combine annual, forage, and perennial crops such as cocoa or mango with coconuts. As there is no chemical input or tillage in any of these systems, soil organic matter (SOM) plays a crucial role in soil fertility conservation. Moreover, in these systems, agroecological functioning is closely linked with soil fertility dynamics to ensure sustainability. In recent years, the reduction in the economic viability of copra production due to the decline in world market copra prices, together with the high population growth in the Vanuatu Archipelago, raises questions about the sustainability of these cropping systems. What are the long-term impacts on soil fertility? A synchronic approach was adopted to analyse temporal SOM patterns in different coconut-based cropping systems. SOM contents were assessed by near infra-red spectrophotometry (NIRS). High SOM contents were measured (mean 13% in the top soil). SOM appeared to be preserved in smallholder coconut-based cropping systems. A slight SOM decrease was observed after 20 years of continuous cultivation, except in agropastoral systems. A comparison with coexisting industrial systems using tillage and fertilizers is currently under study. A comprehensive analysis of SOM patterns in Melanesian traditional and industrial coconut-based farming systems is proposed and the sustainability of the various options is discussed.

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The State of Agroforestry Education in the Philippines

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While agroforestry has been practiced in the Philippines for centuries as started by the forefathers who have cultivated the famous Banaue Rice Terraces, and were followed by the implementation of agroforestry projects by the government and non-government organizations, the science of agroforestry came in later. It started in 1976 when one state college in the northern part of the Philippines offered a four-year degree program leading to BS Agroforestry. Since then, a number of agroforestry schools have sprouted, reaching to 35 as of year 2003. Simultaneous with the proliferation of agroforestry schools is the growing number of agroforestry curricula/programs being offered at the formal level. Interest in agroforestry education has been increasing despite the issues and concerns confronting this field such as the lack of and/or outdated guiding principles and minimum standards, insufficient field and teaching facilities, lack of funds to implement research, extension and production programs that would support the overall education program. This paper discusses the current state of agroforestry education in the Philippines that will revolve around the basic considerations and processes in agroforestry curriculum development, institutional capacities to implement agroforestry education programs, and highlights of findings of the study on the demand and placement of agroforestry graduates in the Philippines. The paper likewise analyzes the strengths, weaknesses, and opportunities of agroforestry education in the Philippines. Finally, the paper presents recommendations as to how agroforestry schools can harness and make use of the strengths and opportunities in order to overcome the weaknesses and threats.

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Indigenous Soil Fertility Management Strategies in Smallholder Farms in the Cordillera Uplands of Northern Philippines

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Local farming communities in the uplands of the Cordilleras in Northern Philippines practice indigenous strategies to manage soil fertility. These farming communities manage combination of terraced paddy, permanently cultivated upland and shifting cultivation fields. All the three cropping fields provide the local people with their subsistence needs including cereals, vegetables and fruits. Documentation of indigenous farming systems in Bayyo and Ducligan was conducted using an array of Participatory Rural Appraisal (PRA) approaches including key informant interview, community resource mapping, transect line, time line, mind mapping, and focus group discussions. *Tithonia diversifolia* (sunflower) and *Chromolaena odorata* grow abundantly in the highlands of Bayyo (1000 masl) and in the drier areas of Ducligan (500 masl), respectively. These indigenous species are applied as organic fertilizer in the rice paddy fields in their respective areas, and each community has indigenous strategies of applying these fertilizers. In the permanently cultivated upland terraced fields where vegetables and corn are grown, weeds removed during weeding are placed in-between crops as mulch and organic fertilizer. Crop residues, like peanut and sweet potato, are also left in the field as organic fertilizer. Fallowing is widely practiced in the upland shifting cultivation fields to rejuvenate soil fertility after a few years of continuous cropping. During the fallow period, the field may rejuvenate back into a secondary forest. Fallowing also brings environmental and economic benefits to the local communities. These indigenous strategies indicate genuine innovativeness and resourcefulness of the local farming communities in the Cordillera uplands of Northern Philippines.

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Agroforestry Farmer School, Prachinburi, Thailand

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Agroforestry Farmer School, a small-scale privately-owned farm, was established in 2002 in the lowland area of Prachinburi, the eastern province of Thailand. The purpose of the agroforestry farmer school is to create experiential learning through farm-based agroforestry management and to facilitate the learning process for farmers, students and development workers. A land of 3 ha has been developed for experimentation on four agroforestry systems, that are: 1) integrated paddy field production system (comprised of paddy rice, fish, and ducks for household food consumption); 2) integrated pond production system (comprised of 5 fish species-- *Tilapia nilotica, Trichogaster pectoralis, Puntius gonionotus, Pangasius sutchi, Labeo rohita*, water plants and trees for production of fish and vegetables for consumption and for sale; 3) integrated fruit tree production system (comprised of more than 10 fruit trees-- durian, mango, longan, etc., with plantings mixed in 3 layers; and 4) integrated tree production system (comprised of various timber/pole tree species-- *Dipterocarpus alatus, Afzelia macrocarpa, Hopea* spp., as well as multiple-use trees for fruits, leaves, bark, resin, etc.). In each system, landscape was planned and an integrated management of tree, crop and animal has been applied. Basic practices with chemical-free techniques on soil improvement and integrated tree/crop/animal management such as natural-fed fish culture, rotational cropping, shelterbelt, living fence, nursing tree, multi-layered tree/crop planting have been experimented. Learning process between farmer and neighboring farmers and students has been initiated and will be further developed.

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Soil Quality under Agroforestry and Traditional Systems in Semiarid Tropical Andhra Pradesh, India

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There is a need to determine the long-term effects on soil quality of agroforestry systems that are currently being promoted for their sustained adoption in the state of Andhra Pradesh, India. The present investigation was undertaken to identify soil quality indicators and comprehensive soil quality index (SQI)-based physical, chemical and biological properties of soil from the data collected in long-term experimental plots set up in Alfisols at Hyderabad (Andhra Pradesh), India. The different land use systems evaluated were Leucaena (*L. leucocephala*) plantation, Leucaena–sorghum (*Sorghum bicolor*) alley cropping, sorghum–castor (*Ricinus communis*) rotation, *Cenchrus ciliaris* grassland, and an undisturbed bare soil as a benchmark. These land use systems were practiced since 1991. Multivariate statistical techniques using principal component analysis (PCA) were used to determine the smallest set of chemical, physical, and biological indicators of soil quality. Multiple regression was run to evaluate the efficacy of minimum data set (MDS) taking sustainable yield index (based on long-term yield data), soil water in 0–30 cm depth, runoff and net revenues as goal (r^2 = 0.64 –0.82). Total soil N, dehydrogenase activity, and saturated hydraulic conductivity, mean weight diameter of soil aggregates were found to be the most important indicators of soil quality. Leucaena plantation had the highest SQI, followed by grassland, alley cropping system, cultivated land with manure application, undisturbed bare soil and cultivated land without manure. The results of the study support the emphasis on planting of Leucaena-based agroforestry system in the state.

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Temperate Agroforestry Outreach Initiative for Small Landowners in North America

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Small landowners, who manage most of the private forest and farm land in North America, are seeking sustainable forestry and farming methods that are not only economically profitable but also environmentally responsible. Temperate agroforestry enterprises offer new opportunities for small landowners to diversify their farm and forest operations with products that are less subject than traditional commodities to the downward price pressures of global competition. Agroforestry practices are also biologically diverse systems that provide environmental services which society values, e.g., soil conservation, water quality protection and wildlife habitat. Although alley cropping, silvopasture, forest farming, riparian buffers and windbreaks are successfully used in many regions of North America, landowner adoption would likely increase if region-specific information on the management and economics of agroforestry were more widely available. The Agroforestry Outreach Initiative is a new collaboration between the Association for Temperate Agroforestry (AFTA) and the National Center for Appropriate Technology (NCAT). It serves to document the market opportunities, economic analyses, management practices and environmental values of region-specific agroforestry practices, and to disseminate this information to landowners, extension educators, and resource professionals in both the US and Canada. The anticipated outcome of this educational project is the wider adoption of agroforestry practices by small farm and woodland owners, thereby helping them progress toward the goal of sustainable land management. Both individuals and society will benefit as a result.

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Land Application of Wastewater for Wood Production: A Model for Small Communities

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Many small communities, especially in Latin America, lack adequate wastewater treatment facilities. However, these same communities often have adequate agriculture expertise that can be harnessed to manage land application systems for wastewater treatment. The objective of this project was to evaluate land application of municipal wastewater for the production of tree crops in a semi-arid climate. Municipal wastewater from Ojinaga, Chihuahua, Mexico was used to irrigate *Eucalyptus camaldulensis*, *Populus* hybrids and *Robinia pseudoacacia*. Growth, water consumption, and groundwater contamination was followed for seven growing seasons. In spite of freeze damage during the first growing season, the best *Eucalyptus* clones averaged 80% survival and over 16 m in height. The best hybrid poplar clone (367) averaged 70% survival and 12 m after 5 growing seasons. The top-producing *Eucalyptus* clone produced about 40 m^3/ha/yr. Applying over 3,000 mm of wastewater over a growing season resulted in neither nitrate-N nor fecal coliform contamination to the groundwater. However, salinity and chloride concentrations did increase. Economic implications for small communities are presented.

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Agroforestry Education in Bangladesh

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Agroforestry education in Bangladesh is very young though agroforestry practices have been playing commendable roles in rural livelihood systems for centuries. Attempts on agroforestry research and development undertaken by many Government and Non-government organizations have been impaired severely due to lack of technically qualified manpower. In view of producing qualified manpower to boost up research and education, a full graduate program leading to Master of Science (MS) in Agroforestry and Environment has been introduced for the first time in Bangladesh since 1996 at the Bangabandhu Sheikh Mujibur Rahman Agricultural University. Following this attempt, a fundamental course has been introduced to Bachelor of Science in Agriculture degree in all Agricultural Universities/Colleges, Bachelor as well as Master of Science in Forestry at Chittagong University and Bachelor of Science in Forestry and Wood Technology at Khulna University to provide fundamental knowledge to the graduates. Simultaneously a fundamental subject on agroforestry is taught in Diploma in Agriculture degree offered by Bangladesh Technical Education Board, Bachelor of Agricultural Education degree offered by Bangladesh Open University. Recently, Bangladesh Agricultural University has started MS program in Agroforestry. Presently, about 1100 students at BS level, 1200 students at Diploma level are getting fundamental knowledge on Agroforestry and 10-12 students are obtaining independent MS degree each year. As a young discipline, agroforestry education is expanding very rapidly but qualitative improvement could not be made particularly due to limitation in specialists, which could be overcome through joint program and support with the competent Universities and research organizations across the world.

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Alley Cropping: A Potential Option for Subsistence and Sustainable Farming through Fertilizer Saving and Soil Improvement in Plainland Ecosystem of Bangladesh

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Soils of Bangladesh containing an average 1.5 percent organic matter are under intensive cultivation with input-intensive technologies for nourishing her ever-growing population, resulting in quick degradation of soil and farm ecosystem. On the contrary, subsistence farmers representing the major farming community cannot co-opt with those input-intensive technologies because of economic hardship. For developing a sustainable and cost-effective production system, a long-term alley cropping research comprising four leguminous species (i.e., *Gliricidia sepium, Leucaena leucocephala, Cassia siamea* and *Cajanus cajan/Indigofera tysmanii*) assigned in main plots and five different nitrogenous fertilizer doses (i.e., 0, 25, 50, 75 and 100 percent) assigned in subplots has been carried out in plainland ecosystem of Bangladesh from 1998 to 2001. The common annual crops such as rice, wheat, maize, tomato, cabbage and eggplant were tested. During three years of experimentation, about 92, 72, 56 and 28 ton ha^{-1} pruned materials (green) were incorporated into the soil from *G. sepium, L. leucocephala, C. siamea* and *C. cajan/I. tysmanii* species, which added an estimated amount of 107, 97, 73 and 35 kg N ha^{-1} N, respectively. Three-year results revealed that although different crops responded differently, sustainable production system could be maintained by gradually improving soil health and consequently saving 40-50 percent nitrogenous fertilizer. Soil pH tended to neutral; and organic carbon, nitrogen, phosphorus, potassium, calcium, sulfur, and cation exchange capacity were increased by 23, 28, 22, 39, 30, 14, and 13 percent, respectively. Subsistence farmers may use the saving using less nitrogenous fertilizer in their other livelihood activities.

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Adoption of Leguminous Trees and Other Organic Resources for Soil Fertility Improvement in Meru South District, Kenya

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A study to assess acceptability and adoption process by farmers of leguminous trees and other organic resources for improving soil fertility was carried out from 2000 to 2002 in Chuka division, Meru South district, Kenya. In a collaborative project between Kenyatta University and Kenya Agricultural Research Institute on integrated soil fertility management, a follow-up was done on how farmers selected technologies for soil fertility improvement after field days held every growing season, and two surveys were also carried out to find out how farmers implemented and modified the technologies. Selection of technologies by farmers was variable. Farmers initially selected soil fertility improvement resources that combined both organic and inorganic resources, but majority of the farmers implemented tithonia and cattle manure. A good number were interested in leguminous trees but were initially discouraged by germplasm availability and the need to bulk the trees. The number of farmers adopting the technologies increased from about 20 farmers during short rains of 2000 to over 200 farmers by short rains of 2002. Farmers used the new technologies on relatively small plots of 0.02–0.05 acres citing reasons that they wanted to see the results first. Farmers who have adopted the technologies have benefited in terms of increased crop yields, but also indicated constraints in terms of inadequate biomass for incorporation into soil and lack of cash for farm inputs. The study has revealed the need to monitor how farmers adopt technologies as it facilitates in identification of issues and constraints that might hinder adoption.

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The Fermentation Characteristics and Nutritional Composition of Mixed Maize-Forage Tree Legume Silages in Zimbabwe

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Mixed legume silages in the sub-tropics can play an important role in providing good quality feed to livestock during the dry season. The objective of this study was to determine the fermentation characteristics and nutritional composition of conventional maize and maize-tree forage legume silages. The coppice growth of tree forage legumes (*Acacia boliviana* and *Leucaena leucocephala*) were enclosed, in a bunker and plastic bags, with maize (*Zea mays* L.) in a 50:50 ratio. The material was incubated for seven weeks pending laboratory analysis. The silages had similar dry matter content, 271–339 g/kg. The pH content of maize-leucaena, 4.8, was higher than that of bagged maize silage of 3.7, whilst maize-acacia and bunker maize silages had a pH of 4.5. The ammonia-nitrogen content of the silages was similar, 7.46 to 10.1%. The bagged maize silage had a higher lactic acid content, 73.3 g/kg DM, than the maize-legume, 29.0–33.3 g/kg DM, silages. The crude protein content, 176–209 g/kg DM, of the maize-legume silages was greater than that of maize silages, 65–71 g/kg DM. The silages had similar neutral detergent fiber content, 603–665 g/kg DM. The modified acid detergent fiber content of bunker maize, 354 g/kg DM, and maize-leucaena, 357 g/kg DM, silages were higher compared to that of bagged maize, 304 g/kg DM, and maize-acacia, 319 g/kg DM, silages. Maize-legume silages had lower digestibility compared to bagged maize silage. The study suggests that tree legume forage can be a beneficial protein addition to tropical maize silages.

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Modelling the Effects of Leafing Phenology on Water Use and Growth in Central Kenya

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Increasing population pressure in Kenya and consequent shortages of arable land has resulted in considerable migration from high potential areas to low potential semi-arid areas. This problem is particularly acute in Naro Moru, to the west of Mount Kenya, where immigration has led to rapid changes in land use and increased demand for water. Introduction of agroforestry trees such as Grevillea robusta has exacerbated the situation by increasing competition for water between trees and crops, leading to crop failures. It was anticipated that the introduction of deciduous or semi-deciduous trees into the cropping systems might reduce demands on the limited water supply. The potential of the WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems) model for evaluating the impact of tree leafing phenology on growth and water use in Central Kenya was therefore investigated. Three tree species, Grevillea robusta, Alnus acuminata and Paulownia fortunei, respectively representing evergreen, semi-deciduous and deciduous leafing phenologies, were intercropped with maize (Zea mays L.). It was hypothesised that the use of the deciduous A. acuminata and P. fortunei would reduce demand for available water. WaNuLCAS simulations demonstrated that altering leaf phenology from evergreen through semi-deciduous to deciduous decreased water uptake and interception losses by the trees, but increased crop water uptake, drainage and evaporation for all three tree species. The simulations imply that water use by P. fortunei would be lower, thereby increasing stream flow relative to G. robusta. Leafing phenology may therefore be one of the principal tree attributes affecting water use.

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Managing Decomposition and Mineralization of *Senna singueana* Manure to Improve N Use Efficiency and Maize Yield at a Study Site in Morogoro, Tanzania

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The carbon:nitrogen (C:N) and lignin:nitrogen (L:N) ratios of organic substances primarily determine the N mineralization and its availability to crop plants. Two field experiments were conducted at Kitete, Morogoro, Tanzania in 1998/99 to assess the effects of different C:N and L:N ratios of mixtures of Senna (Senna singueana (Del.) Lock) foliage and local straw materials on decomposition and N mineralization for optimum N-use efficiency of maize. Litterbags and the incubation methods were used for the studies. Residual mass, soil porosity, pH, SOM, available P, NO3-N and NH4-N, CEC, maize shoot height, N nutrient uptake and yield were measured. Senna leaves alone decomposed and released N faster than Senna foliages mixed with crop residues. But any increase in the proportions of straws in the Senna-straw mixtures resulted in reductions in mass loss % and levels of soil available mineral N. The medium quality Senna-straw mixtures (C:N ratio of 30:1 and L:N ratio range of 2.7:1 to 4.5:1) improved soil properties and optimally promoted maize root proliferation from 0.4 to 0.73 t ha-1, maize height growth from 160 to 248-cm and grain yield from 1.4 to 4.5 t ha-1. Critical period of high N demand by maize crop was between 4 and 8 weeks. It is concluded that foliage of Senna has high potential use for N management in annual crop production. For Senna-straw mixtures, the critical C:N ratio should not exceed 30:1 and L:N ratio in the range of 2.7:1 to 4.5:1 for maximizing maize grain yield.

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Some Aspects of Nutrient Cycling in a Silvopasture System with *Acacia mearnsii* De Wild. and *Panicum maximum* Jacq. in the South of Brazil

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The objective of this study was to quantify above- and below-ground biomass in a silvopasture system of black wattle (*Acacia mearnsii*) trees and *Panicum maximum* forage, as well as to determine the amount of nutrients in the arboreous and herbaceous biomass and from the soil. This work was carried out in a six-year old stand in the south of Brazil. After a forest inventory, 21 trees were cut, and were quantified according to biomass and the nutrients in the leaves, live and dead branches, bark, wood and roots; in addition, the above- and below-ground biomass from the *Panicum maximum* was also quantified. Forty samples of litter were collected for the nutrients and biomass quantification. The total amount of biomass production by *Acacia mearnsii* was 140.73 Mg ha^{-1}, allocated as 4.3% in the leaves, 4.5% in dead branches, 15.0% in live branches, 9.9% in bark, 79.1% in wood and 17.9% in roots. This biomass contained 571.0, 186.94, 412.56, 79.91 and 46.22 kg ha^{-1} of N, P, K, Ca, Mg and S, respectively. The litter over the soil was 9.1 Mg ha^{-1}, and the nutrients N, P, K, Ca, Mg and S were quantified as 141.96, 7.28, 25.48, 70.98, 7.28 and 12.74 kg ha^{-1}, respectively. The *Panicum maximum* biomass was 2.22 Mg ha^{-1} (1.63 Mg ha^{-1} above and 0.58 Mg ha^{-1} below ground). The amount of nutrients in the forage biomass was 41.54, 4.36, 25.28, 13.86, 7.65 and 4.63 kg ha^{-1} of N, P, K, Ca, Mg and S, respectively.

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Agroforestry for Integrated Natural Resource Management in Australia

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This poster will describe the broad picture of how agroforestry is used within the context of integrated natural resource management in Australia. It presents the framework of a new online university-level course developed under the aegis of the Cooperative Research Centre for Plant-Based Management of Dryland Salinity. The environmental functions served by agroforestry systems are in their ability, in varying degrees, to mimic natural ecosystems with balanced water use and biodiversity while protecting soil, crops and livestock and enhancing the amenity value of landscape. The productive functions of agroforestry systems are in their provision of sawlog, firewood, pulpwood, fodder and a uniquely Australian range of specialty tree products and integrated production systems. The implementation of agroforestry in Australia is supported by wide range of design and evaluation tools, and institutional arrangements to facilitate agroforestry adoption.

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Rotational Woodlot Technology in Western Tanzania: Effect of NPK Fertilization on Maize Yield after Tree Fallow in an Acid Soil of a Semiarid Regime

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Smallholder farmers in western Tanzania are establishing rotations of trees and crops in solving the problems of low soil fertility and fuel-wood shortage. The influence of maize yields by 5-year old agroforestry tree fallows (Acacia crassicarpa, A. julifera, Leucaena pallida and Senna siamea) were compared with the traditional bush fallow and continuous sole maize cropping systems, with or without NPK fertilizers. The analysis of results indicated that maize crop following tree fallows without fertilizer application gave significant greater yield than the crop after natural fallow and continuous sole maize. When fertilizers were applied, the tree fallows and N fertilizer applications had a strong influence on grain yield and yield components of maize, while P and K fertilization had less effect. Maize dry matter yields were significantly lower in tree fallows (2.7–3.1 Mg ha–1) and sole maize (2.9 Mg ha–1) than natural fallow (3.5 Mg ha–1). However, the maize harvest index in tree fallows (0.42 to 0.53) were higher than natural fallow and sole maize (0.37, respectively). With 50 kg ha–1 N, a significant response to P or K was shown by maize in all tree fallow types. The response curves for P and K showed that 20 kg ha–1 of P and K, respectively, were optimal, with mean grain yield responses ranging from 2.8 to 4.1 Mg ha–1. Incorporation of the fallow vegetation as a fire-free alternative should be supplemented with fertilizers in order to realize high maize yields in the short run.

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Residual Effects of Fallows on Infiltration Rates, Hydraulic Conductivities and Soil and Water Retention in a Kaolinitic Soil Subjected to Conventional Tillage (CT) and No Tillage (NT)

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The aim of this study was to quantify the residual effects of fallowing and tillage (conventional tillage (CT) and no tillage (NT)) on infiltration rates, hydraulic conductivity and soil water retention during the cropping phase. Treatments studied were fallows of Acacia angustissima, Sesbania sesban, NF and continuous maize. Infiltration rates were measured using a portable rainfall simulator and a double-ring infiltrometer, and hydraulic conductivity and pore sizes were measured using a tension infiltrometer. Water retention was measured using suction tables and pressure plates. Using the rainfall simulator, fallowing resulted in high infiltration rates, >24 mm h-1 relative to continuous maize which was 5 mm h–1 at fallow termination (October 2000). After two cropping seasons steady-state infiltration rates remained >14 mm h-1, in fallows and were unchanged in continuous maize. Steady-state infiltration rates using double ring infiltration method were significantly different and were 68, 67, 59 and 36 cm h-1 for NF, A. angustissima, S. sesban and continuous maize respectively. Hydraulic conductivity at 5 cm tension was significantly different and was 0.9, 0.7, 0.8 cm and 0.5 cm h-1 for A. angustissima, S. sesban, NF and continuous maize respectively. Water retention was the same in October 2000 and 2002 and was highest in fallows and was lowest in continuous maize. At suction >33 KPa, there were no differences across treatments. The results showed that fallows improved infiltration rates, hydraulic conductivity and water retention relative to continuous maize cropping.

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Strategies and Challenges in Developing Agroforestry Curriculum to meet Farmers' Needs: Experiences from Uganda

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Uganda's Plan for Modernisation of Agriculture (PMA) includes the development of agroforestry as part of the natural resources management strategy, increasing the productivity of land and eradicating poverty. At the same time, Uganda's extension service has undergone considerable changes in the last decade: first it was the responsibility of the line ministries, then it was decentralised to the districts and recently it was privatised and the service will be provided under the National Agricultural Advisory Services (NAADS). These changes have created the challenge of developing agroforestry curriculum that addresses farmers' needs in a broader perspective. The paper will highlight how agroforestry training in Uganda has developed over the years in response to changes in government policy and stakeholders' needs. The shortcomings and opportunities in the present curriculum are discussed as well as prospects for a more robust curriculum that will make graduates of agroforestry more versatile and competent to address agroforestry and natural resources management problems at local, national, regional and global scales.

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Consequences of Termite-Infestation on Agroforestry Practice in the Savanna Region of Nigeria

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Research needs to consider the effects of faunal components of various ecosystems especially those that could be detrimental to the success of potentially beneficial technology such as agroforestry. Low fertility status of tropical soils made soil improvement practices imperative and agroforestry is a good option. Presence of termites made establishment of woody perennials difficult and organic matter build-up impractical especially in savanna ecosystem, as termites attack and store-away cellulo-lignotic soil components. This research conducted survey on the termite species prevalent in Mokwa Local Government of Niger State, and their potential effect on soil productivity and rural livelihood. Cubitermes oculatus, Trinervitermes geminatus and Macrotermes bellicosus are the common termite species. All inhabitants of Mokwa are farmers. All the farmers interviewed have termites in their farms. Farmers also had these constraints: not ready to practice agroforestry for lack of adequate awareness, difficulties in establishment of woody perennials, initial investment that does not have immediate economic benefit, and unavailability of credit facilities. They reported low soil fertility and poor yields. In about 600 farms of sizes between 1-20 ha inspected, none had deliberately planted woody perennials. The woody perennials established by the forestry division, Ministry of Agriculture and Natural resources and those growing in the wild are under constant attack by termites especially during the dry season as they scavenge for moisture. Termite-control measures commonly practiced is bush burning. Agroforestry technology development and transfer should consider the peculiarity of recipient-ecology. Delivery of agroforestry package to savanna agrarian environments should consider compatible termite-control measures.

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Effect of One-year-old *Gmelina arborea* (Roxb.) on the Physico-chemical Properties of an Oxic Tropudalf in Southwestern Nigeria

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An investigation was carried-out on a one-year-old seedling plantation of Gmelina arborea (Roxb.) in Nigeria. Objectives of the investigations were to evaluate the effect of these seedlings on the soil physico-chemical properties of an Oxic Tropudalf and to quantify the effects of post-planting soil properties on the dry matter yield (DMY) of this tree on a 20 ha farmland. Prior to transplanting and after one year of cultivation, soil samples were collected and routinely analyzed. After one year of cultivation, 1000 recently matured leaves were randomly plucked, labelled, and oven-dried at 65°C and weighed. Soil physico-chemical factors that may significantly affect the DMY were estimated using proc stepwise (SMRA) of SAS at 0.01%. Results of the soil physico-chemical properties pre- and post-planting showed that statistically significant ($p<0.05$) differences could only be observed between the following chemical properties: total N, organic carbon, available P and the CEC within years. Soil available P, CEC, exchangeable Ca, organic carbon, and total N, increased by 23, 34, 58, 62 and 65% respectively. However, changes in soil contents of Na, Zn, K, Fe and Zn were observed to be negative. The result of SMRA showed that only total N content would significantly ($p<0.0001$) affect the DMY of G. arborea on this soil. The regression equation was DMY = -0.07 + 0.993 (N), R2 = 0.984. The study concludes that G. arborea seedlings might be able to increase the soil contents of total N, organic carbon, available P, exchangeable Ca and CEC.

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The Vulnerability of Traditional Agroforestry Systems: A Comparison of the Gum Arabic Livelihood Strategy prior to the 1984 Drought with That in Present-Day Kordofan, Sudan

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Agroforestry is a way to diversify the land use, which is crucial for rural households in semiarid regions. Agroforestry is widely implemented as a sustainable agricultural system in several developing countries where the external inputs are few. An example of a system well-integrated in society is that based on Acacia senegal, which is a tree that grows in most parts of the African Sahel. The resin of the tree is an important cash crop that is exported mainly to Europe and the USA. The gum has traditionally provided rural households with one of the most important sources of incomes in a large area of the Sudan; however, the national statistics show that the Sudanese production is decreasing. Semi-structured interviews were carried out in 2001 and 2002 in the semiarid areas of central Sudan to focus on the local scale. The study found that the distribution of gum production changed after 1984, triggered by the severe drought. The income from gum production has disappeared in some areas, whereas in others it is still as important. The study also concluded that there are many difficulties for a recovery in the villages where gum production no longer is important as the livelihoods have changed into a dominance of remittances. Furthermore, the study recommends that resources should be focused on improved market structures rather than reforestation projects at an initial stage.

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Effects of Intercropping Leucaena leucocephala with Gynandropsis gynandra in Kenya

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As a priority, food production should be intensified to generate surpluses for sale, improve crop varieties and accompanying necessary husbandry practices should be promoted, as the current use of fertilizers in this system is low. Some agroforestry interventions should address soil fertility and erosion problems persisting within the tropics of Eastern Africa. On-farm trials with Leucaena leucocephala and a variety of indigenous vegetables (local African spinaches) have shown considerable improvement in the yield. Intercropping with Leucaena species and timely pruning at about 15 cm, indigenous vegetable (Gynandropsis gynandra) has double yield compared to the control. This increase in cash income and production for extended period of time for the peasant farmers in poverty-stricken communities in Western Kenya is a positive intervention to improve the farmers' production and also increase farmers' income. Such practices also create suitable micro-climate which has net effect on the soil, thus reducing soil erosion and leaching of soil macro- and micronutrients. Leucaena seeds when fed to dairy goats results into increase in the amount of milk produced, also noted was increase in goat weight. The results indicate that L. leucocephala has a relative superiority compared to the other plant species tested. Pathak et al. (1985) also reported the relative superiority of the species over others like Albizia and Cassia sp. The study was carried out at Uhai field site, Kisumu, Kiboswa, under warm and cool climate with ample rainfall and average temperatures of 32°C and minimum 21°C, characterized by red soils.

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Establishment of Hybrid Poplar in Semi-arid Temperate Zones

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Hybrid poplar has become increasingly important for wood production in temperate North America because of its rapid growth and wide climatic adaptation, especially in humid and sub-humid regions. Recent research in eastern Oregon and western Colorado has demonstrated there also exists potential for poplar production in semi-arid zones. Northwest New Mexico and an extensive portion of the intermountain region of the western United States, has climatic and soil characteristics similar to those sites. These include a growing season of approximately 150-170 days, limited annual precipitation (200-300 mm), and alkaline soils with elevated pH. Native vegetation is xeric but productive agriculture is possible with irrigation. Ten hybrid clones of crosses between *Populus deltoides, P. maximowiczii, P. nigra,* and *P. trichocarpa* were obtained from nurseries in Oregon and Washington and planted in 2002 at the NMSU Agricultural Science Center at Farmington, New Mexico (36°41'N, 108°18'W). Pressure compensating, surface drip lines were installed with 2 lines per row of trees. The same ten clones plus an additional ten clones were planted in 2003 using a single line of pressure compensating drip tubing. Soil pH was high with an average of 8.2 and trees responded positively to foliar and drip-injected iron chelate. Based on two growing seasons, hybrid OP-367 showed the most promise for high pH soils typical of the area. OP-367 clearly exhibited the least chlorosis, greatest height, and diameter at ground level. Three other clones, 58-280, DN-34, and PC-06 also demonstrated acceptable adaptation potential.

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Rain and Runoff Effects on Soil Erosion in Coffee (*Coffea* spp.) Agroforestry Systems in Mexico

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There are few sources of information about the factors that control water-borne soil erosion in coffee (Coffea spp.) agroforestry systems. The documentation of this aspect is of interest to farmers in order to improve productivity and sustainability of their systems. In a tropical region of Mexico, runoff, soil loss, and nutrient loss were experimentally evaluated in small watersheds with different shaded coffee agroforestry systems, and they were related to different rainfall erosivity parameters for 2000 and 2001. It was found, of 178 annually-registered rainstorm events alone, between 26 and 32% were erosive and between 29 and 34% produced runoff, originating low runoff coefficients that oscillated between 0.8 and 14%. The soil loss in these systems varied between 0.28 and 4.56 t ha-1 year-1. The nitrate losses in such systems varied between 0.03 and 0.54 kg ha-1 year-1 and the potassium losses between 0.04 and 4.45 kg ha-1 year-1. At rainstorm level, the AIm erosivity index revealed high linear relationship with the precipitation and with runoff, greater than the relationship shown by EI30 and KE>25 index; the same thing happened with the soil loss in the second year of observation, since in the first one, the EI30 was better. Soil loss, and thus nutrient loss, showed high relationship with runoff.

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Agroforestry Education at Tertiary Level: The Nigerian Experience

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Agroforestry (AF) education was informally introduced to Nigeria with the establishment in 1951, of a Tectona grandis plantation at the University of Ibadan. In 1968 Dr. K.F.S. King, then a staff of the Department of Forestry of the University published his seminal bulletin “Agrisilviculture (the Taungya System)”. However there was no definite curriculum on AF, which was then taught as part of the forestry curriculum. By 1988 three specialized Universities (of Agriculture) were established in the country, all running programmes in forestry, but none specifically on AF. A survey funded by African network for Agroforestry Education, ANAFE, of seven Universities and one Vocational Centre during 2000/2001 showed that only three have Masters programmes, where aspects of AF is taught, two have Mhil and Ph.D programmes in forestry with option for specialization in AF. This is inadequate for a country of 120 million people. Support from ANAFE to three of the Universities through postgraduate fellowship awards, internet facilities, book support and upgrading of AF demonstration plots has rekindled interest in AF education. By 2001/2002 the Department of Forest Resources Management, University of Ibadan developed and obtained approval for curriculum on postgraduate programme in AF. Other Universities are in the process of it. This has brightened the prospects of increased student enrolment. Graduates of the programme will teach AF at lower educational levels and to farmers. Considering the ever-shrinking land: man ratio in the country, this has implications for employment generation, poverty reduction and sustainable landuse.

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Comparison of Four Tree Species and Artificial Shade on Understorey Pasture Yield, Species Composition and Soil Moisture Content: A Summary

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Agroforestry research in New Zealand has focused primarily on Pinus radiata and the impacts of this species on understorey pastures and soils. This paper draws together more recent work with three other tree species with a view to providing greater understanding of the interactions between tree species and the understorey components of agroforestry systems. Pasture understorey yield, pasture legume content, soil moisture content and light quantity measurements were measured at regular intervals under two tree species Acacia melanoxylon, Eucalyptus nitens and artificial shade. This was compared to other published work with Poplar spp. and with Pinus radiata. The trees were planted at a range of tree stockings providing a range of shading intensities. Each site was grazed by sheep and occasionally by cattle. Results clearly showed a decrease in understorey pasture yield with increasing tree stocking rate and shading, although responses differed by species and shade levels. Pasture yields under Poplar and Acacia were similar and greater than that for E. nitens, P. radiata and artificial shade at low shading. At high shading, pasture yields were greatest for artificial shade and least for P. radiata. Seasonal patterns of soil moisture content under trees and artificial shade equalled or exceeded that in open pasture for most of the year. Pasture legume content decreased sharply under all tree species and artificial shade. Overall, the main effect of trees on understorey pasture yield and species composition was shading. Appropriate tree management will help to reduce the competitive effects of shading on the understorey.

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Harvesting the Fruits of the Land: Agroforestry as Instrument in Local Governments' Tax Reforms to Abandoned and Denuded Lands

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This paper aims to present an innovative land-tax reform model as influenced by the agroforestry program in the Province of Guimaras, Philippines. It intends to present a mechanism to motivate private landowners to scale-up agroforestry dissemination in large and abandoned lands. Through successful lobbying with local government units, this model has influenced the passing of a province-level legislation granting tax incentives to landowners who adopt agroforestry technologies and giving higher tax obligation penalties to landowners who do not promote environmentally-sound agricultural practices. The small island-province of Guimaras in Central Philippines has a long history of environmental degradation due to complex land-tenure issues and absence of governmental support mechanisms essential to its development. For decades, few and elite landowners neglected their lands, which turned into barren grasslands with low assessed value. Summer fires were prevalent in these lands, which depleted biological life forms and had negative environmental effects to the communities. In recent years, some of these lands were subjected to agrarian reforms and social forestry programs, but with insignificant results because strategies for their development were not effective and the root causes of the problems were not addressed. The advent of the Agro-Environmental Productivity Programme, a five-year collaborative undertaking of the Dutch Government and Save the Children, made innovations on agro-silvo technologies and harvesting schemes that promoted a harmonious win-win relationship between landowners and farmer-cultivators. Years later, local governments increased their revenues through higher direct and indirect taxes derived from hundreds of hectares of agroforest farms.

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Cultivating Complexity: Local Soil Ecological Knowledge and the Management of Homegardens in Western Kenya

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The value of "local agro-ecological knowledge" is increasingly promoted by both international and national scientific "professionals" as a major contributor to natural resource management in East Africa. This increasing interest can be attributed to several factors, including the failure of technicist interventions to stimulate agricultural productivity, to reverse or even halt apparent continent-wide problems of soil fertility decline, and also the increasing use of multidisciplinary teams to address natural resource management. This paper looks at how local soil fertility management practices in western Kenya are informed by knowledge that has been generated and refined experientially. Such knowledge is responsible for the creation and maintenance of various "hot spots" within any given farmscape, most notably the "homegarden" for vegetables, medicinal plants, and other valued species. Specific examples will show how the management of these niches reflects dynamics of power and decision-making within the household, and also the broader framework of gender relations and communities' access to information and markets. The role of local soil ecological knowledge in managing homegardens serves as a useful entry point for examining the more general question of how households allocate capital (financial, human, and natural) to the maintenance of soil fertility on small-holder farms in Western Kenya. It is important to recognise that soil fertility managers and researchers alike must understand the strengths and limits of local knowledge before they can develop a "shared" knowledge base for soil fertility management concepts.

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Reorienting Agroforestry Education to Sustainable Forest Management

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This paper is about organizational re-engineering in support of Sustainable Forestry (SF) or Sustainable Forest Management (SFM). It focuses on the change strategies adopted by the University of the Philippines Los Baños (UPLB) College of Forestry and Natural Resources (CFNR) to re-orient its agroforestry academic programs to the needs and challenges of sustainable forest management. Sustainable forest management implies a new way of seeing, thinking and doing in relation to forests, natural resources, and the environment. As such, new policies, programs, and approaches as well as new institutional and individual capabilities (knowledge, attitudes, values and skills) in forestry are needed. To maintain its relevance, the UPLB College of Forestry and Natural Resources, as a leading tropical forestry institution of higher learning, has initiated changes in its academic programs so that it will be more responsive to sustainable forest management challenges. To achieve the desired changes, the College has adopted five institutional development and change strategies. The experience at UPLB CFNR could offer some insights to other forestry educational institutions who wish to maintain relevance in the face of the paradigm shift in forestry and natural resource management.

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Agri-horti-silvi Models for Sustainable Development in Semi Arid Tropical Regions of India – A Participatory Approach

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Farmers in the Semi Arid Tropical regions cultivate drought-hardy nutritious cereals. Poor yields coupled with low prices of these crops make dryland farming unprofitable. Hence, an alternate agri-horti-silvi model with participatory approach was attempted and developed for dryland farmers. Present study aimed at conserving soil fertility and thereby bringing about sustainability in four semiarid districts viz., Ranga Reddy and Mahaboobnagar of Andhra Pradesh and Beed and Sangli of Maharashtra in India on experimental basis. Mango (*Mangifera indica*) orchards of three different age groups viz., < 2 years, 5-7 years and >10 years old were selected. Erosion barriers like preparatory tillage, bunds across the slope, and semi-circular basins around trees were prepared. Teak (*Tectona grandis* L.) plantations were planted along the boundaries. Cowpea, horsegram, sorghum, *Stylo* and *Cenchrus* were selected as intercrops, grown in-between tree rows in different blocks with recommended doses of fertilizers (RDF), along with two other treatments viz., RDF alone or FYM without intercropping. Farmers' regular practices served as control. The estimated yields from the adopted technologies have 2- to 4-fold increase over control. Agri-horti-silvi systems provided higher net incomes to the rainfed farmers. The system also contributed for soil and water conservation in continuously degraded soils. Inclusion of fodder and livestock enhanced profitability to the system. Leguminous intercrops enrich the soil fertility. Teak plantations in the boundaries served as windbreaks and provided income through valuable wood. The adoption rate is very high with sustainable incomes and can be implemented in other semiarid regions of the world.

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The Effects of Root Pruning in an Alleycropping System in the Georgia Piedmont

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This experiment evaluated the effects of hedgerow roots on alley crop production and nutrient dynamics. It was hypothesized that competition for nutrients and water between hedgerow and alley crop could influence production. The experimental alleycropping system was established on an abandoned agricultural field in the Georgia Piedmont. Four blocks with three treatments were randomly placed using Albizia julibrissin, a legume, as the hedgerow species and a non-irrigated hybrid field corn within the alleys. To evaluate the effects of root interaction between hedgerow and crop, three treatments were utilized: a root prune with root barrier, a root prune without a barrier, and a control with neither a root prune nor a root barrier. Results from our first growing season showed marked differences in corn production between root pruned and non-root pruned treatments. Root pruned treatments had a substantial increase in production when compared to non root pruned treatments. These differences were attributed to competition for moisture, which were exacerbated by a five-year drought. No differences related to nutrient availability or soil organic matter content were found between treatments. Preliminary results for the present year were not influenced by water competition because of substantial rainfall. Results showed no differences between treatments regarding corn production. These results suggest that while there may be competition for water during drought years, during non-drought years competition for nutrients may not be important. Other studies have indicated that pruning of hedgerows results in root die-back, which could be a source of nutrients for the corn.

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Agroforestry Undergraduate Curriculum at the University of Melbourne

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Since 1989 The University of Melbourne has offered an elective in Agroforestry for final year degree students of Forest Science, Agriculture, Horticulture and Resource Management. The course is one of the most popular electives offered to this student group with more than 40 students enrolling each year. The subject focuses on the design, development and evaluation of multipurpose farm tree systems that meet the aspirations of farmers and the wider community. From the out-set, we adopted a human- and market-focused diagnosis and design approach which has resulted in quite a different structure to many courses in agroforestry around the world. For example, rather than teach about different agroforestry systems the lectures concentrate on the underlying needs and opportunities facing landowners and stakeholders and decision makers' performance measures. By working through the role of trees in satisfying these needs and the design principles for the integration of trees into their farming systems unique designs commonly arise that do not neatly fall into the traditional categories of agroforestry. This highlights to students the important of adopting a development approach to agroforestry research and extension rather than a technology transfer approach. Whilst strongly based on Australian experience the course involves international examples and research from South East Asia, the South Pacific Islands and Africa. Students are involved in real-life agroforestry design and evaluation projects with landowners.

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The Australian Master TreeGrower Program 1996-2004: Development, Delivery and Impact of a National Agroforestry Education Program

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With the financial support of the Myer Foundation, the RIRDC/LWRRDC/FWPRDC Joint Venture Agroforestry Program (JVAP), The Natural Heritage Trust and the National Farm Forestry Program forestry staff at the School of Resource Management developed the Australian Master TreeGrower Program (MTG). By 2003, 55 regional Master TreeGrower programs had been conducted involving over 1200 participants and more than 30 partner organisations making it the possibly the largest outreach program of its type in the world. The MTG Program is a comprehensive package that aims to ensure that the development of agroforestry is driven by the aspirations and opportunities of farmers and supported by the interests of industry, governments and community groups. International experience suggests that increasing farmer participation in forestry can have quite different social, economic and environmental impacts to that of industrial or government forestry. The results of the internal continuous monitoring and evaluation program and two national external reviews confirm that the program has had an impact on the perceptions, enthusiasm and activity of participants. The farmers believe they're making better farm forestry management decisions and are making a greater commitment to farm forestry on their own property as a result of their participation in the program. They are also making a greater contribution to farm forestry research, development and extension within their regions particularly through their participation in regional farm forestry networks supported by the program. There is now great interest in expanding the program into Africa and South East Asia.

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The Use of Indigenous and Exotic Fodder Shrubs for Reclaiming Degraded Arid Rangelands

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Over-utilization of plants in the semi-arid and arid rangelands of South Africa has resulted in degradation and desertification of the rangelands. In a number of areas this degradation is so severe that it has resulted in the development of large bare patches. This results in a reduction in the income and the destabilization of the rural communities within these areas. In such areas sufficient browse to provide fodder for the animals is important. The revegetation of the bare lands with fodder shrubs can improve the grazing capacity of these areas and thus prevent further overgrazing. A number of different fodder shrubs, both exotic and indigenous, are available for the revegetation and reclamation of rangeland. In the literature it is often stated that ideally the species used in the restoration should be with seed that was obtained in the area and which is locally adapted to the dry, hot conditions and uncertain rainfall found in arid areas. This trial includes three species, one exotic (*Cassia sturtii*) and two indigenous (*Sutherlandia microphylla* and *Tripteris sinuatum*). *Sutherlandia microphylla* and *Tripteris sinuatum* are both from the Northern Cape, South Africa, in an area known as the Karoo and are called “Karoo bossies” (“Karoo shrubs”). The objective of this trial was to make a comparison of production and quality, between the three species, over time. Data collection was completed by the end of January 2004, and the preliminary results, presented in this paper, provide a basis for species selection in reclamation programs.

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Chemical-nutritional Composition of the Fruit Flour from Three Tropical Native Leguminous Trees

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The objective was to evaluate the chemical-nutritional characteristics of the fruit flour from leguminous trees native to the dry tropics (*Acacia pennatula* (Ap), *Caesalpinia coriaria* (Cc) and *Senna atomaria* (Sa)) to develop food strategies in ruminants. We determined dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (H), cellulose (C), lignin (L) and *in situ* dry matter degradability (ISDMD) of the species. For the (ISDMD) test, a factorial-arranged completely randomized design 3x4x3 was used. The DM and CP results were (91.78, 89.84 and 92.28%) and (8.59, 6.03 and 11.99%); NDF and ADF results were (48.66, 43.87 and 51.15%) and (33.21, 11.03 and 29.15%) for Ap, Cc and Sa respectively; hemicellulose (15.45, 32.84 and 22.00%), cellulose (24.54, 5.46 and 17.63%) and lignin (8.02, 5.39 and 10.29%) for Ap, Cc and Sa. The degradability indicators of the soluble fraction (A) were for Ap (25.85%), Cc (70.59%) and Sa (23.90%), with difference between the Cc value and the other two. The degradable fraction (B) and fractional rate constant C (h^{-1}) were (33.44, 18.31 and 24.82%); (0.0396, 0.0139 and 0.0974), for Ap, Cc y Sa, with differences for all the flours in the (B) fraction and in C (h^{-1}), only different for (Sa). Finally, the (ISDMD) values (A+B) for Ap (59.30%), Cc (88.90%) and Sa (48.72%), with difference between the three flours. Given the fruit flour characteristics of the trees, we considered they provide nutritional fruit elements to be included in the alimentary ration of ruminants.

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Effect of Initial Height of *Leucaena leucocephala* (Lam) de Wit var. Peru on Grazing by Hair Sheep in a Protein Bank in a Dry Tropical Region of Mexico

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A study was conducted to determine the optimum height of Leucaena leucocephala var. Peru for grazing sheep. The information was analyzed using a complete randomized design on split-plot where the main plot corresponded to different initial heights for grazing and the small plot the grazing period. The treatments represented different initial heights (T1: 60 cm; T2: 80 cm; T3: 100 cm) with three replications per treatment. The experiment was conducted in the dry tropical climate of Colima, México, without irrigation or fertilization. The variables evaluated were production of dry matter (DM) (Kg/ha), crude protein (CP) (%), neutral detergent fiber (NDF) (%), percentage of plants that surpasses initial grazing height (H, %) and grazing recovery in days (D). The edible material was considered to be the forage made from leaves and stems less than 4 mm, not lignified. The study lasted 13 months during which seven grazing periods took place: four during the rainy season, one at the beginning and two during the dry season. The results showed an interactive effect of DM (974±144b, 1300±78a and 1193±166a kg/ha), for T1, T2 and T3, respectively. And H (64.90±8.23a, 67.81±7.67a and 48.81±7.87b %) for T1, T2 and T3 for treatments ($P<0.05$). Within the small plot, there was shown statistically significant differences for DM, CP, H, D and NDF ($P<0.05$). It can be concluded that the best height for grazing Leucaena leucocephala for sheep is between 60 and 80 cm, due to the architecture of plants, production and quality nutrition available for the animals.

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Cation Flux in Incubated Plant Residues and Its Effect on Plant Residue Alkalinity

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Seven plant residues, maize (*Zea mays* L.*),* sorghum (*S. bicolor*), groundnuts (*Arachis hypogaea),* soybeans (*Glycine max),* leucaena (*L. leucocephala),* gliricidia (*G. sepium)*, and sesbania (*S. sesban)* were characterized for base cations and alkalinity content. The residues were incubated for 100 and 14 d in an acidic Zambian Ferrasol. Each residue was partitioned into non-soluble and soluble factions. Cation flux was measured and its effects on plant residue alkalinity investigated. Base cation content ranged from 239-879 (Ca^{2+}), 188-458 (Mg^{2+}) and 298-477 $mmol_c\ kg^{-1}$ plant material (K^+). Of these, between 26-60, 62-92 and 76-96% in that order were water soluble. On incubation up to 70% Ca^{2+} and at least 80% Mg^{2+} and K^+ added in the residue were present at time zero increasing to 84 and 95% after 100 d respectively. Potential alkalinity ranged from 373 (maize) to 1336 (groundnuts) mmol kg^{-1}. A positive relation was obtained in the washed residue between total cations released and base deficits at the end of 14 d. This suggests that the alkalinity remaining after solubilizing a plant residue is associated with base cations locked in the structural make-up of the plant. Between 16-22% of base cations in soluble fraction were immobilized. A negative relation was obtained between immobilized cations and base from residue buffering suggesting production of acidity on cation immobilization. This study highlights the importance of both the soluble and solid fractions of plant residues in addressing soil acidity problems of the tropics.

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Survey of Agroforestry Research in Senegal

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The ecology of Senegal has changed under the influence of dramatic threats to the environment. Average annual rainfall is decreasing from North to South, agricultural production is also decreasing, livestock mortality is increasing, and forest resources are disappearing. To overcome these constraints, ISRA has been experimenting with new technologies within its agroforestry program these past 15 years. The objectives of the agroforestry research are to understand the interferences between trees, crops and animals in the parklands, and to solve identified constraints. Socio-economic and biophysical studies realised in the late 1980's were the basis of agroforestry research trials settled on station and farm since then. Complementary studies done in 1990 allowed to identify five Land Use Systems (LUS) in the semi-arid zone of Senegal. The main problems and constraints of agroforestry development were identified for each LUS, priority research highlighted, supported research proposed and agroforestry research themes to be deepening held. Based on a review of identified constraints, various types of technical alternatives were incorporated into an agroforestry system that gains these following results: (i) significant knowledge of the different LUS and constraints linked to their functioning; (ii) list of tree species usable for live fences, windbreaks, alley cropping, fodder bank, improved fallow; (iii) knowledge of live fence management and propagation techniques; (iv) knowledge of parklands functioning and their biological, socio-economic and cultural roles (Acacia albida, Cordyla pinnata and Sterculia setigera); (v) nutritional value of the main fodder species in Senegal; and (vi) advanced research in forest fruit trees domestication.

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Successful Agroforestry in Arid Zones: An Important Tool for Economic and Ecological Improvement in Degraded Regions

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Arid and semi-arid regions are characterized by hot climate during summer and very cold in winters, erratic rainfall, limited rainy days, poor soils (loamy sand to sandy) and contain high percentage of soluble salts and significant calcium carbonate percentage. Soils are very poor in organic carbon and poor in water holding capacity, which become detrimental to the growth and development of the vegetation cover. *Eucalyptus* spp. and *Populus deltoides* have been most common species under agroforestry systems in Northern region of India which brought substantial change in economic conditions of the farmers, but in arid regions economic conditions remained the same. Hence, there is need to have diversified multipurpose species suitable to arid and semi-arid regions, which should give good fodder, fuelwood, small timber, timber, fruit and herbal medicines. Such species should have short rotation and high economic return and also high nitrogen fixation for increasing soil fertility. A suitable agroforestry species should have most of these elements particularly for arid areas. Successful agroforestry in arid/semi-arid zones has huge potential in correcting the imbalance in socio-economic conditions of farmers, if suitable agroforestry species with proper cultivation techniques and appropriate support mechanisms for marketing are ensured. Agroforestry systems in arid zones should essentially encompass a mix of suitable diversified fuelwood, timber, fruit, fodder and grass species to ensure meeting up of economic needs of farmers and ecological needs of arid regions. The practices adopted should strengthen economic conditions of the farmers compared to the returns from previously adopted agricultural practices.

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Environmental Impact Assessment of Engineering Interventions on the Restoration of the Ecosystem of the Degraded Land through Agroforestry Practices

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Engineering interventions were taken up under the World Bank's Forestry Project for the restoration of the biodiversity of an area situated in the shadow of ecologically sensitive and geologically unstable Shivalik foothills, forming a part of the fragile Himalayan ecosystem. It establishes the linkages of hill denudation with environment and poverty in the area, where land degradation, because of over browsing and denudation had reached to the extent of almost no return. The area was also infested with the menace of forest fires, soil loss and change of soil properties. Commercially sensitive and economically exploitative attitudes of locals subjected this ecosystem to stress, leading to alteration and hampering of its functions and then lead to ultimate destruction. Engineering interventions in the catchments drastically reduced silt flow, improved groundwater recharge and moisture regime apart from providing food, forage, fuel, flood and social security to the locals. The optimum sustainable strategies also improved the soil environment –a crucial life support system! As a result there was integration of conservation and development – a 'win-win' situation. The paper apart from commenting on community based restoration and sustainable management of the fragile ecosystem and critically assessing the performance of engineering interventions, also focuses on the ecological principles that are real tangible parameters of sustainability of the ecosystem.

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Water Balance Modeling and Agroforestry Designing for Semiarid Regions of Tamil Nadu in South India

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Tamil Nadu is a coastal state in south India. The state is classified into seven agroclimatic zones with 64 per cent (833,997 km^2) of the total area under drought. The semiarid regions of the state are concentrated in northwest, west, south and some parts of northeast agroclimatic zones. The farmers depend upon dryland crops and trees for their subsistence in these regions. These regions need scientifically tailored agroforestry designs matching moisture availability, soil type and farmers requirements. Thus an attempt was made to design agroforestry system using water balance analysis and local knowledge for semiarid vertisols and alfisols of Tamil Nadu. The study was made in 5 typical semiarid blocks, 3 representing vertisols and 2 representing alfisols. A water balance model was developed with weekly rainfall, potential evapotranspiration and soil characteristics as input data. The long term data was collected from agricultural research centers of TNAU at the representative blocks. Based on the results of the water balance model and local knowledge, agroforestry systems are designed for different regions and soil types. The systems are designed with integration of various components like arable crops, long duration annuals, fruit trees, woody trees, fodder/green biomass, medicinal and aromatic plants, vegetables, etc., matching the moisture availability and farmers' interest. Crop management strategies like dry-bed sowing dates, water conservation, etc., for the designed agroforestry systems are also discussed using the water balance model.

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Agroforestry-An Experience with Bamboo in Tamil Nadu, India

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Bamboo is basically a household species and is the best friend of the farmers. The availability of bamboo resources has decreased and the sustained availability can be ensured only by raising bamboo plantations. In India, bamboo plantations are raised at an espacement of 6 x 6 m to meet the increasing demand of bamboo products. The first harvesting cycle begins at the age of 36 months of bamboo. So farmers cannot expect any revenue during these periods. In order to obtain good revenue between these periods, research has increased rapidly in recent years to cultivate agricultural crops in the espacement of bamboo plantations. Therefore there is a great need to identify suitable agricultural crops, which can grow well with the bamboo. In the present study, intercropping of agricultural crops (Pigeon pea, Soybean, Turmeric and Zinger) in the established bamboo plantations is attempted. On an average of three replicates, the per-plant yield of pure agricultural crops was found higher, when compared with intercropped stand. The land equivalent ratio (LER) of bamboo producing culms (dry weight) with agricultural crops showed 1.2 in the Bamboo / Pigeon pea, and Bamboo / Soybean model, however 1:1 in the Bamboo / Turmeric and Bamboo / Zinger model. This means that the productivity of one hectare under intercropping is equivalent to that of 1.2 hectares (o) 1.1 hectares under the sole systems. The results revealed that either Pigeon pea or Soybean can be recommended for intercropping of bamboo plantation for the benefit of farmers.

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A Synopsis of Alley Cropping Research in Haiti: 1991 - 2001

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Alley cropping practices were developed for low and mid elevations in Haiti. Research focused on choice of hedgerow species, hedgerow pruning management, and assessment of alley cropping from perspectives of soil fertility and conservation. The most productive hedgerow species at low elevation sites was leucaena (*Leucaena leucocephala*). *Gliricidia sepium* mulch decomposed faster than leucaena, but considering biomass yields, the two species had similar N release rates. Decomposing leucaena leaves released moderate K, but low P. In on-farm trials, more biomass was harvested from *Delonix regia* than leucaena, which was browsed by livestock. At mid elevations, *Acacia angustissima* gave highest biomass yield and was best source of N. Highest maize yields and N use efficiency were obtained by pruning three times at 30 day intervals during each maize cropping season and applying prunings to soil. There was no advantage for incorporation of prunings over mulch. Pruning at planting and 40 days later gave highest biomass, but lowest maize yield and N use efficiency. Fertilization with N, P and K further increased yield and N-use efficiency. Application of leucaena mulch increased maize yield over P and K alone. Except for the first two seasons, alley cropping sustained maize yields and soil organic C and N at higher levels than rock walls, contour canals, grass rows or no-barrier control over 17 seasons. Contour alley cropping reduced runoff and sediment loss on a 23-30 % slope. When properly managed, alley cropping is an effective system for soil conservation and sustainable production in hillside agriculture.

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Effect of Different Land Use Systems on Soil fertility and Soil Quality in Semiarid Tropical Alfisol

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A study was carried out at Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad (17°18' N latitude and 78°36' E longitude) in a semiarid tropical Alfisol representing typic Haplustalf, to monitor the effect of different land use systems on soil fertility, nutrient status and overall soil quality. Soil samples were collected from surface (0-15 cm) and subsurface (15-30 cm) layers from 36 sites under different land use systems. Among the systems, highest amount of soil organic carbon (0.94% at 0-15 cm and 0.84% at 15-30 cm) was recorded under silviculture system. However, soils under agriculture and fallow systems showed relatively lower organic carbon content. Silviculture system improved the available N, P and K content in soil over fallow land. Exchangeable Ca and Mg under silviculture and silvopastoral systems were higher compared to other systems. Agriculture and fallow land showed lower amount of secondary nutrients. Soils under agrihorticulture and silvopastoral systems showed higher amounts of DTPA extractable Cu and Zn respectively. Soil pH under silvopastoral system was highest followed by silviagriculture system. Highest soil EC was found in agrihorticulture system followed by silviagriculture. Conclusively, silviculture system showed higher organic carbon, available P, K, DTPA extractable Zn, soil pH and EC values in the surface layer. A relatively higher integrated soil quality index was recorded under silviculture and agrihorticulture systems compared to other systems. From the study, it was evident that the land use systems comprising tree component can improve soil fertility and quality in semiarid tropical Alfisols.

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Policies for Sustainable Management of Dryland Environments

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Degradation of dryland ecosystems is having profound negative consequences for one billion poor rural people whose livelihoods depend on the dryland resource base, most notably in Africa and Asia. There is urgent need for effective policies and actions to achieve social and ecological sustainability at regional scales. New concepts on integrated management of large-scale ecosystems recognize that drylands offer a range of ecosystem services: provisioning services (e.g., food, fresh water), regulating/supporting services (e.g., hydrological regulation, provision of habitat), and cultural services (e.g., aesthetic and spiritual values). The resilience of dryland ecosystems is being undermined by insufficient maintenance of regulating/supporting services which is negatively impacting on provisioning services, with harmful consequences for human well-being. Regional policies should seek to (1) restore and maintain the resilience of dryland land resource systems though adaptive management strategies, and (2) develop the adaptive capacity of dryland peoples by facilitating reliable social learning on sustainable ecosystem management. Implementing these principles requires that stakeholder groups at all levels better understand their links to ecosystem dynamics and responses; participate in consensus-building on use of ecosystem services; and accelerate learning and adaptive management through monitoring of policies and their effects. Agroforestry could play an important role in helping to maintain resilience in dryland ecosystems by enhancing regulating/supporting services while diversifying provisioning services. The United Nations Environment Programme (UNEP) is working to facilitate incorporation of adaptive ecosystem management concepts into regional and global environmental policy for sustainable dryland management. Examples including agroforestry are given from Africa and Asia.

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New Tools for Large Area Assessment of Soil Quality: Applications of Visible-Near-Infrared Reflectance Spectroscopy

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There is need for large area assessment and monitoring of soil properties to understand human impacts on the soil resource base and reliably guide sustainable development policy. However, the high cost of soil analysis currently makes such large studies infeasible. Diffuse light reflectance from soils in the visible-near-infrared wavelength range relates to most conventional properties used to assess soil quality. Unlike most laboratory methods, soil reflectance spectroscopy is rapid (500 samples can be routinely characterized in a day) and highly reproducible (repeatability of 0.99). We show results to demonstrate use of soil reflectance measurements in tropical watershed studies and soil management experiments to: (1) detect fundamental changes in soil properties due to soil management; (2) quantitatively assess effects of historic land use change on soil quality and soil erosion by calibration to stable- and radio-isotope concentrations; (3) predict soil fertility capability constraints with 80-95% accuracy using regional and global soil spectral/attribute libraries; (4) select diverse soils from farm soil fertility surveys for use in more detailed studies, such as field trials and laboratory bioassays; and (5) calibrate soil quality indicators to digital terrain and remote sensing information for soil-landscape modeling. Near-infrared spectroscopy is also being used for quality characterization of organic resource inputs. Soil and organic resource spectral libraries will likely form the basis for a new generation of expert systems for predicting soil properties and responses to soil management. These advances can help to increase the efficiency of agroforestry research and generate new insights into landscape processes.

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Agroforestry as an Interdisciplinary Subject Focus in Higher Education at the University of Wales, Bangor

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Although sometimes pigeonholed as a postgraduate specialism, broad interdisciplinary agroforestry curricula at BSc, Masters and Doctoral levels have been developed and implemented at the University of Wales, Bangor (UWB) since the 1980s, attracting hundreds of students from over 30 countries. Agroforestry education as a first degree subject was pioneered at the University of Wales, Bangor. This involved adopting a systems approach embracing social, economic and ecological aspects surrounding the role of trees in agricultural landscapes at a range of scales from that of the plot to the planet. Courses from a range of established disciplines were combined with novel systems methods for managing their integration. This marked out the specialist element of agroforestry as the development of skills in integration of disciplines around real word problems and issues in natural resource management. This focus has endured, spawned the development and teaching of interdisciplinary methods including participatory modelling and knowledge-based systems and been increasingly adopted in the research and development agenda of national and international institutions around the world. In 2000, the first joint doctoral degree programme in tropical agroforestry spanning Europe and Latin America was entered into by CATIE and UWB. This combines the tropical focus and facilities at CATIE with the broad systems focus and specific research skills available at Bangor. This has spawned changes in the practice of postgraduate education in both institutions and serves as a model for cross-cultural collaboration in higher education.

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Building Bridges: Center for Subtropical Agroforestry (CSTAF) Extension Efforts in the Southeastern United States

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CSTAF launched their agroforestry extension effort in 2001 with a needs assessment. Based on the survey results, in addition to findings from a white paper, CSTAF developed an extension program that incorporates landowner and educator participation in the design and testing of relevant educational tools. A series of two-day, in-service training workshops titled, “Tailoring Agroforestry Curricula to meet your Client Needs”, were held during Winter 2004. These workshops emphasized the integration of participatory learning methods, site visits, and the presentation of regional technological information. As a culminating event, participants presented plans for agroforestry integration in their local outreach programs. Extension agent responses to the in-service training illustrated a diversity of technology transfer approaches. Participants also had the opportunity to pilot test two new interactive website tools: SEADDS (Southeastern Agroforestry Decision Making Systems) and SANDS (Southeastern Agroforestry Network of Demonstration Sites). SANDS includes a detailed database of landowners in the region currently employing agroforestry, in addition to a SANDS listserv, which allows landowners to share their experiences and offer or seek advice on agroforestry-related topics. The first annual meeting of SANDS members was held in Spring 2004 to allow stakeholders to meet, set objectives for further in-services, and present information on outdoor education. Graduate student extension-based research is also serving to further the development of agroforestry awareness in the public and improve the relevance of CSTAF extension. Future CSTAF extension activities will diversify and expand according to the expressed needs of landowners and educators.

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Working Together for Sustainable Land-use Systems

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Approximately 1.3 billion people, or one fourth of the world’s population, live on about $1 a day. Poverty is a growing phenomenon, with the largest numbers of poor people in developing countries living in rural areas. While many people try to make a living on marginal lands (such as the drylands of the Sahel in Africa), the soil in many of these areas is generally degraded and vulnerable to erosion. In agroforestry in school, we will focus on ways that may help the soils and people of these marginal parts of the world. The main objectives of this project are to have students meet the following learning objectives: (i) identify ways agroforestry can help address farmers’ needs, (ii) recognize basic agroforestry practices, (iii) recognize tree characteristics that make them suitable agroforestry species, (iv) recognize and appreciate the rural population’s knowledge, and (v) explain to them the benefits and constraints of agroforestry practices. Agroforestry practices introduce to students some of different trees that may be grown on farms in order to improve soil fertility, protect soil from erosion and benefit people. Saving soil on slopes helps students take some practical steps to protect sloping farm land using trees. Essentially there will be three types of activities: classroom activities; activities that involve study of the local environment and/or community; and practical projects. Issues for discussion include: state of the place and local agroforestry systems; research of seeds and punting in place tree nurseries; training and institutional development; and vulgarization of appropriate technologies.

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Gum and Aromatic Resin Producing Trees and Shrubs for Agroforestry Based Development of Dry Lands in Africa

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Vast areas of land in Africa are semiarid and arid. These dry lands are often seen as resource poor and less attractive for development. Nevertheless, dry lands of Africa have numerous economic and ecological opportunities to offer. Several of the *Acacia*, *Commiphora* and *Boswellia* species native to these lands hold economically well recognized aromatic products such as frankincense, myrrh and gum arabic that are widely used locally and in several of today's commercial industries such as pharmacology. The potentials of these vegetation resources could be harnessed through appropriate agroforestry systems to ensure sustainable development of the dry lands that are otherwise marginal and fragile. In this regard, multiple actual and potential development possibilities are recognized: 1) the aromatic products and their vegetation resources provide considerable economic incentives at local, national and international levels. 2) Livestock husbandry, which is the dominant land use and principal capital of the pastoral families often inhabiting semiarid and arid lands, heavily depends on the same vegetation as source of fodder. 3) Some of the gum and resins from these plants are used by local people as emergency food during famine periods. 4) With increasing global desertification due to land degradation and global climatic changes, these economically valuable plant species adapted to extreme climatic conditions may provide genetic resources not only for combating desertification but also for sustainable economic use of dry land ecosystems. 5) They could also contribute to carbon sequestration in the vast semiarid and arid ecosystems of Africa and possibly of the world.

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Evaluation of Multipurpose Native Trees for Agroforestry in the Mexican Semiarid Plateau

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During the last decade, the desertification process has increased in central México where temperate forests, sub-humid tropical forests and semi-desert vegetation have been gradually replaced by agricultural and rangeland monoculture systems, characterized by extensive livestock management, intensive use of agrochemicals, conventional tillage, and overexploitation or removal of subtropical shrubs and spiny trees. As a consequence, native vegetation is disappearing despite the need for timber, forage, medicine and other derivatives from native shrubs, such as honey or colorants used in community industries and rural areas. Nursery technique studies and participative plantation designs with Multipurpose Native Trees (MNT) have been conducted since 2001 at the Bajio experimental station of INIFAP and at 40 farmers' field plots from different municipalities, as an alternative strategy of multicropping land use with agroforestry systems. A survey of the oldest inhabitants helped to identify 90 MNT from 33 botanical families, 50% of which were nitrogen-fixing trees (Fabaceae). The research at nursery level consists of seed pretreatment studies and production management that allows field plot plantations using agroforestry designs as alley cropping or improved fallows. The results revealed a high percentage of MNT survival in 2002; among the genera most tolerant to drought and low temperature were Acacia, Lysiloma, Condalia, Eysenhardtia, and Dodonea, while at the experiment station some species started to reduce yield of intercropped forage. Data collection and analysis from soil and trees will be evaluated as well as the social and environmental impact of these alternative systems for sustainable management of native vegetation and reforestation.

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A Practical Approach to the Incorporation of Local Knowledge in Agroforestry Research and Extension

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The approach we propose is compatible with, and required by, a growing consensus that agroforestry programmes are more successful where based on incremental changes of existing systems and practices than where based on extension of prefabricated technology packages that seek abrupt transformation. There is considerable evidence that although farmers may be interested in elements of technology packages (e.g., a tree species), they rarely adopt whole packages in the form in which they are disseminated (Buck 1990; Kerkhof 1990). Agroforestry researchers have not, in general, been able to design the practices which farmers adopt, which is perhaps not all that surprising given the complexities involved. This is reflected in the current shift in emphasis in the agroforestry activities in which concentration on the central development of one or two agroforestry practices (such as alley cropping, contour hedgerows or improved fallows) for widespread adaptation and dissemination is being suppressed by the facilitation of local development of tree resources at field, farm and landscape scales. This is the major shift in thinking which has led to redefinition of agroforestry as an incremental activity leading to increase in tree covers within farms and farming and landscapes over time (Lekey 1996). It implies support for local development initiatives that involves continuous integration of trees within farming systems, in various productive niches, over a considerable time period.

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Changing Scenario of Agroforestry Education in India

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Responsibility of forestry education and research in India had been with the Central and State Forest Services until 1985 when the ICAR stepped in to introduce undergraduate programs in forestry initially in six agricultural universities of the country. This was the transitional period when conventional forestry was going into the background and being replaced by new emerging concepts such as agroforestry, wasteland reclamation, and community forestry, etc. The basic aim of B.Sc. Forestry Program was to generate trained manpower to achieve the target of afforestation of 5 million ha of wastelands every year. This initiative of the ICAR was successful in creating trained manpower, and in further strengthening of forestry education through starting of M.Sc. and Ph.D. programmes in forestry in more than 20 agricultural universities. Agroforestry links different land-use components such as forestry, horticulture, crops and livestock. The clients, generally resource-poor families who needed fuelwood, fodder, small timber, and other minor tree products, were involved in retaining trees on farmlands, and they also developed commercial agroforestry systems with technical inputs from the universities. Although the advantages of the agroforestry approach in afforestation were known, however, scientific information was meager to tackle the big problem. Consequently, several co-coordinated research projects were planned in the country in the recent past, and education on agroforestry developed simultaneously. The various aspects of agroforestry education and the bottlenecks encountered have been discussed in the present paper.

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Perspective of Agroforestry Plantations to Control Waterlogging in Semiarid Regions

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Bio-drainage is a form of drainage technology that deals with a water excess problem by using the evapotranspirative capacity of trees. There are several examples where removal of native vegetation has played an adverse effect on rising underground water and salinity. Studies have been conducted on the capacity of trees to bring water from deeper layer to the surface soil for the use of agriculture crops. This phenomenon recently called as “hydraulic lift” has been proved in several tree species. Our studies proved that indigenous species have important characteristics, for example, Dalbergia sissoo makes maximum growth during summer, Acacia nilotica has four flushes of leaf during the year and Prosopis cineraria has deep root system. Ailanthus excelsa and Prosopis cineraria can tolerate arid conditions. Populus deltoides (poplar) can be successfully grown on semi-waterlogged areas where underground water is sweet. One of the clones of this species i.e. G48 has been found to be highly tolerant to waterlogged situations. Eucalyptus tereticornis, E. camaldulensis and Casuarina equisetifolia have also shown great success on waterlogged soil. In conclusion, agroforestry plantations may be encouraged to ameliorate the waterlogged fields.

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Evolving Suitable Agroforestry Systems for Southern Districts of Tamil Nadu, India

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In the present scenario of world agriculture, sustaining the productivity of all crops is essence one. In order to make it successful, management of land plays a significant role. Tamil Nadu, in south India, falls within a semiarid region often beset with erratic and uncertain rainfall over 10 years. In this context, suitable systems of Agroforestry have been identified based on rainfall analysis in which 31 years data were analyzed from the year 1971 to 2001. The rainfall analysis revealed that out of 31 years, 20 years are with normal rainfall and deficit during 1972. The initial probability analysis revealed that 697.5 mm rainfall is the 75% probability, whereas, the conditional probability of 63% for getting 25 mm rainfall recorded at 37th standard week. Under these circumstances, instead of raising the seasonal crops alone which is subjected to vagaries of monsoon, trees as major component and growing intercrops during rainy season is a best alternate land-use system for which the following systems are advocated. For alfisols, tree species like *Acacia senegal* (or) *Prosopis cineraria* in association with crops like sorghum + cowpea (grain) (or) sorghum + cowpea (fodder) as intercrops will be the most suited options. In vertisols, *Sesbania grandiflora* (or) *Leucaena leucocephala* intercropping with cotton + blackgram (or) sorghum + cowpea (grain) are best suited systems. For coastal saline soils, *Casuarina equisetifolia* (or) *Thespesia populnea* (or) *Unga dulce* + groundnut (or) ragi (or) chili will be more remunerative. In marshy lands, *Tecomella undulata* and *Unga dulce* can be grown.

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Call It Gray if We Must: Convergence for Agroforestry Development in the Philippines

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In natural resources management, agroforestry is frequently caught in a debate as to whether it is agriculture or forestry, as if the choice must be either of the two. However, today we are given another option, a mosaic of forms, a rainbow of colors – call it gray if we must – and in this shade lies the niche of Agroforestry. This paper discusses the historical experiences and implications of the move for institutionalizing Agroforestry in the Philippines, from fragmented and individual efforts of various organizations since the 1980s, to the widescale promotion of agroforestry through multisectoral partnerships. Among these developments include the adoption of Agroforestry as a land-use technology by various people-oriented forestry programs of government organizations and NGOs; establishment of the Upland NGO Assistance Committee (UNAC) and the Asia-Pacific Agroforestry Network (APAN) in 1992; Southeast Asian Network for Agroforestry Education (SEANAFE) in 1999; and, the formal organization of the Philippine Agroforestry Education and Research Network (PAFERN) in 2001. Since agroforestry is a concern of all sectors, a National Agroforestry Committee was convened by PAFERN in early 2003 to push for the institutionalization of Agroforestry. The National Agroforestry Development Program (covering education, research, extension, rural and enterprise development, and policy) will be presented in the National Agroforestry Congress in November 2003. Call it gray if we must, but the lessons and experiences in institutionalizing Agroforestry in the Philippines and Southeast Asia for the last two decades will fuel our search for the mythical pot at the end of the rainbow.

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Conserving Ecuadorian Dry Tropical Forests through Education: An Example from Ecuador

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The Ecuadorian Dry Forest is one of the World's most threatened ecoregions and at the same time an area of great biological importance with a high number of species and endemism (World Wildlife Fund, 2000). To counteract the loss of Ecuadorian dry forests, a concerted effort must be made to educate Ecuadorians on the importance of the dry forests for ecological services and production of non-timber forest products such as honey, *prosopis* (dietary supplement), and utilization of native fruits, through implementation of sustainable land-use practices focusing on agroforestry. To this end, *El Centro de Conservacion de Bosque Secos del Litoral* (Center for the Conservation of Dry Coastal Forests) was established in the Fundación Pro-Bosque's native tree nursery in 1999 and includes an exhibition room with exhibits on the dry forest as well as living examples of dry forest tree species, with information on uses, medicinal properties, etc., as well as a small agroforestry library, seed bank and herbarium. Through agreements with Ecuadorian universities, students carry out investigations, thesis projects, and work study programs both at the center as well as agroforestry demonstration parcels at the nearby integrated farm and forest restoration project within the adjacent 6,000 hectare Bosque Protector Cerro Blanco. The approximately 10,000 visitors a year to the Bosque Protector Cerro Blanco visit the Center as part of their tour and we hope come away with a greater appreciation for the endangered Ecuadorian Dry Forest, as well as learn practical ways of conserving these forests, through sustainable use practices.

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Changes in Physical and Chemical Properties of Soil under Pastorable Pastures in Rows of Thinned Loblolly Pine (*Pinus taeda*) Trees

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Managing pastures under thinned loblolly pine forest requires understanding of the soil physical and chemical properties to improve soil quality for grass and tree combinations. Shade from trees and hedgerows significantly modify the microclimate of the alleys and affect the quality of soil. This paper reports on the changes in the chemical and physical properties of soils following the establishment of bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon*) pastures in tree rows of loblolly pine. Prior to seeding tree rows with the pastures, soil samples were randomly taken at 6 inches depth (15 cm). Twenty soil samples per acre (1 acre = 0.4 ha) were collected from three separate blocks (2, 3 and 7) before and 28 weeks after planting (WAP). Soil particle size, pH, moisture, organic matter and nitrogen contents of the soils were evaluated. Pre-forage establishment results revealed that soil pH was 5.44 in block 2, 5.49 in block 3, and 4.63 in block 7 respectively; moisture content was 6.65%, 6.75% and 7.00% in blocks 2, 3, and 7; organic matter content was 2.9%, 2.9% and 2.4% in blocks 2, 3, and 7. Particle size for all three blocks ranges from 90 to 92% sand, 2 to 3% silt and 6 to 8% clay. Post-forage (28 WAP) results were higher than those shown above. The results indicated that management of this plantation would have to be block specific to reflect the utilization of soil nutrients among trees in different blocks.

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On-farm Conservation of Multipurpose Trees as a Strategy to Manage Soil Fertility in Smallholder Farming System of Western Oromia, Ethiopia

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A study on deliberately retained wadeessa (*Cordia africana* Lam.) trees in crop fields and grazing areas was conducted in western Oromia, Ethiopia. The objective was to evaluate the contribution of this multipurpose indigenous tree species to on-farm soil fertility management in rural landscape. Soil samples were taken under the tree canopy and in the adjacent open area, each at two depths (0-10 and 30-40 cm) from both cropland and rangeland ecosystems, and then soils from canopy zone versus open area and from cropland versus rangeland were compared with each other. Observation of soil properties under the two ecosystems indicated that cultivation significantly affected soil chemical properties as compared to that of uncultivated field, except for Ca, organic carbon and C/N. Soils were more acidic and contained less nutrients in cropland ecosystem than in rangeland; the difference was higher in 0-10 cm than in the 30-40 cm soil layer caused by organic matter and nutrient depletion through continuous cultivation. In addition, scattered *Cordia* trees substantially increased the availability of P by reducing the acidity and increasing organic carbon concentration of Bako soil, where P fixation is a problem. Therefore, on-farm management of *Cordia* trees is one of the strategies to cope with declining soil fertility, reducing household income (sale of wood products) and loss of agro-biodiversity (*in situ* conservation of indigenous trees on farms), and hence the integration of such valuable trees into the farming system has to be encouraged to enhance sustainable development.

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The Role of an Agroforestry Species in the Struggle against Poverty in Niger: Case Study of Doum Palm (*Hyphaene thebaica*) in the region of Maradi in Niger

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Like other tree species that are managed and protected over sahelian croplands, doum palm (Hyphaene thebaica) is an important component of the agroforestry parklands system in Niger, where it is spread over one million hectares. Investigations through population interviews and field surveys have been conducted in Mayahi, located in the region of Maradi (southern part of Niger), and crossed by the Goulbi Nkaba Valley, to assess the impact of agroforestry products derived from H. thebaica on the income-earning capacity of the rural population (97.5%) of the department. The population counts around 2 million people composed mainly of Haoussa, Touareg and Poular. Studies showed that doum palm agroforestry parklands play important agronomic and socio-economic functions. It was found that 7 to 10 different types of products such as ropes, mats, baskets, beds, etc. are generated from the different parts of the tree (palms, fruits, petioles, etc.). In addition, these products are subject to important commercial transactions throughout the region and even the country. Yearly income of CFA francs 1 352 000, corresponding to about USD $2,000, can be gained by a single wholesaler. Through taxes received from market-sold products, the government can collect a yearly amount of more than 4 million CFA. Aware of the important contribution of doum palm production in meeting family expenses for food, school fees, clothing, health and social events, farmers in Mayahi practice rejuvenation of the species in their croplands through protection of natural regeneration and planting of fruits.

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Quantitative Effects of Shifting Cultivation Fallow and Perennial Cocoa Agroforestry Systems on Soil Property Dynamics in the Rainforest of Southern Cameroon

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In southern Cameroon, small-scale farmers practice shifting cultivation and perennial cocoa (Theobroma cacao) plantations to ensure subsistence and a small cash income. In this practice, land which is no longer productive for food crops is either converted into cocoa plantation or abandoned for fallow of various durations. The objective of this study was to quantify the dynamics of soil properties along a chronosequence of fallows (four treatments) and cocoa agroforests (two treatments). A synchronic approach was used that analyzes the chronosequence at one time by finding sequence components (treatments) distributed in space. Three soil depths (0-0.1, 0.1-0.2, 0.3-0.5 m) were sampled. Factorial ANOVA and mean separation (Tukey's HSD) were used to evaluate changes in soil properties within each layer. Chronosequence components explained 20 to 35% of total variance of soil chemical properties and bulk density. Pair comparison of cropped soil with old fallow and old cocoa agroforest soils showed the highest significant differences ($p<0.001$). pH in water, exchangeable Ca, and available P increased with cropping under the influence of ash from burned biomass, while total acidity decreased. Bulk density increased under cropping and cocoa agroforest. Under long fallows and old agroforest perennials, these effects were reduced towards the situation found under virgin forest, except for the bulk density that remained significantly different ($p<0.05$) under agroforest perennials. These variations mainly affected the top 0.2 m of soil. The effects of old cocoa agroforests on soil chemical properties appeared to be comparable to that of long natural fallows and virgin forest systems.

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VI. Tree Domestication and Management

Includes topics related to sessions on:

Managing Genetic Diversity,
Short-rotation Woody Crops, Phytoremediation,
Tree and Component Management,
Tree Domestication,
and Trees in Fragmented Landscapes

Towards Developing the Miombo Indigenous Fruit Trees as Commercial Tree Crops in Southern Africa

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Many rural households rely on indigenous fruit trees (IFTs) as sources of cash and subsistence in Southern Africa. Despite deforestation threats and the waning resource stewardship of IFTs in the *commons*, there is little effort to cultivate or add value to wild fruit. The aim of this work is to develop top-priority indigenous fruit trees into commercial tree-crops for rural revenue generation. This paper puts ICRAF's R&D work on fruit trees in five SADC countries into perspective. A holistic approach was used involving grassroots in all stages of domestication, product development and commercialization. A recent *ex ante* impact analysis based on *real options theory*, indicates that wild fruit collection is economically attractive to producers, and a combination of technical change and decrease in resource abundance will create incentives for farmer-led investment in IFT cultivation. Priority-setting by diverse users showed varied country-specific priority species. Putative cultivars were captured from the large natural variation that exists in the wild and were vegetatively propagated. Clonal orchards are managed for selection of true-to-type cultivars for superior fruit loads, sweetness, fruit size and precocity. Preliminary results show promise to reduce the juvenile phase and increase fruit precocity. Prioritization of products by stakeholders based on technological, market, socio-economic and biological feasibilities showed varied preferences. Through strategic alliances with research and development partners, rural women's groups are being trained in product development involving fruit post-harvest, processing, packaging and enterprise development. Total quality management was identified as critical in the entire supply chain from production to the market.

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Integrating Cover Crops into Short-Rotation Woody Crops in Northern Climates

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Recommendations for the establishment of short-rotation woody crops (SRWC) in northern climates include mechanical and chemical weed control in the fall prior to planting. Because SRWCs do not fully occupy the site during the first growing season, there is a limited amount of cover on the soil from the time of site preparation until SRWCs occupy the site early in the second growing season. During this period, erosion becomes a significant threat to the long-term soil productivity of the system. Erosion will also damage the public perception about the sustainability of these systems. To address these issues, cover crops can be effectively integrated into the establishment of SRWCs. Competition for water, nutrients and light between SRWCs and cover crop, however, has resulted in reduced growth of the woody crops. In order to provide the benefits of soil cover without compromising biomass production, lessons from ground cover management systems developed for orchard and vine crops have been adopted. Recent studies with willow biomass crops have shown that biomass production is increased and weed competition decreased when a cover crop was established in the fall and killed before the SRWC was planted the following year. Also, a leguminous cover crop established in the spring and turned under as a green manure early in the growing season, was found to increase the foliar nitrogen concentration of SRWCs without reducing biomass. Research on other approaches and uses of some lessons are already being implemented in large scale planting in the northeastern United States.

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Biological and Genetic Diversity in Agroforestry: Lessons and Strategies in Conservation and Sustainable Use of Priority Tree Species

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Agroforestry has long been recognized as a system that is built on biological and genetic diversity. Traditional agroforestry systems are actually modelled around the complexity of forest ecosystems. This paper focuses on genetic diversity management and its implications for sustainable agroforestry systems. The paper analyzes the role that inter- and intra-specific diversity plays in agroforestry and stresses the importance of diversity management in the tree component in ensuring the sustainability and productivity of agroforestry systems. Through a review of current literature, the paper makes a comparative assessment of diversity within and between tree species in traditional agroforestry systems and modern agroforestry technologies, with a view to understanding the functional elements within them and assessing the role and place of diversity. A special emphasis in the paper is placed on the extent of diversity analysis in agroforestry research. The paper attempts to show that whereas agroforestry by definition, and by tradition, has been a genetic diversity and conservation system, research of agroforestry over time has de-emphasized the diversity element, and shifted increasingly towards simple “technologies” that only involve few tree species. Agroforestry research has tended to minimize the complexity that comes with diversity and has generally taken a reductionist approach in research on the system. The paper profiles a number of traditional agroforestry systems, and research-developed technologies, and makes a case for increased species and genetic diversity, at both inter- and intra-specific levels. Lessons learned from various projects and strategies for enhancing diversity in agroforestry research are discussed.

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Energetic and Economic Evaluation of a Poplar Plantation for Biomass Production in Italy

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The cultivation of crops for biomass production on high quality soils can serve to reduce surplus production of food crops and increase the sustainability of energy production, from the environmental point of view. Short rotation forestry (SRF), which is only at a preliminary level of study in Italy, is in working production in northern Europe. SRF is a very interesting technique developed in the Scandinavian countries that encompasses a high planting density (8,000-10,000 cuttings ha^{-1}) and a whole mechanization of plantation and biomass harvest. On the basis of this cultivation technique, we conducted an energetic and economic evaluation of a poplar (*Populus canadensis*) SRF in Northern Italy. Specifically, we studied poplar growth on a plantation for the production of two-year whips in the Western Po Valley, based on an SRF rotation of eight years and a biomass (20 t ha^{-1} DM) harvest every two years. The study operated on an assumed production regime where 12.5% of the surface would be replanted every year, with a spacing of 2.15 x 0.5 m (9,300 cutting per hectare) that allowed the use of conventional tractors. With these calculations we observed a ratio between output and input energy of 13 and a cost of 77.5 Euro t^{-1} of DM. In spite of the positive energetic balance, the economic sustainability of poplar SRF depends on the actual monopolistic energy management in Italy, political choices of chip price, and public subsidies to the producers.

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Transplanting of a Poplar Plantation for Biomass Production: Technical and Economic Evaluation of Some Implements

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In order to determine suitable machinery for planting cuttings in a Short Rotation Forestry (SRF) poplar plantation, a two-year experimentation with *Populus canadensis* 'I-214' was made in a typical poplar area located in the Western Po Valley of Italy. The trial compared different transplanting machines with regard to quality, work capacity and relative costs. Four different types of machines were tested: a Rotor semi-automatic transplanter, a Quick-wood forest planting machine, a Salix Maskiner step planter and a Berto planting machine. All the machines were set to operate with spacing of 180 × 70 cm, corresponding to a total establishment of 8,000 cuttings ha^{-1}. Twenty centimetres long cuttings, cut just above the first bud, were utilised for the Rotor, Quick-wood and Berto planting machines. The Salix Maskiner was fed with sets and was regulated to plant 20 cm cuttings. Rooting percentage at 90 days after planting was about 83% for the Rotor machine and always less than 60% with the other machines, likely due to adverse environmental conditions during the trial. The Salix Maskiner Step planter was able to plant over 6,300 cuttings in one hour, while the working capacity of the other machines was significantly lower (under 1,300 cuttings hr^{-1}). The experimentation pointed out the technical and economical validity of the Rotor semi-automatic planting machine, especially when used on smaller surfaces (up to 6 ha). The Salix Maskiner step planter is far more interesting as it is more convenient when used for planting poplar sets on larger surfaces (>6 ha).

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Provenance cum Progeny Testing for Assessment of Diversity in *Dalbergia Sissoo* in Northern India

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The vital importance of *Dalbergia sissoo* Roxb. in agroforestry plantations in India, its multiple uses and lack of information on provenance variation promoted the present study. Seedpods were collected from five random trees of *Dalbergia sissoo* from twenty diverse geographic regions of northern India during February-March 1990. Five-month-old seedlings of five progenies from each of twenty provenances were transplanted in field following randomized block design during August 1990. Data were recorded every year at the end of the growing season up to December 2001. Large variations were observed among provenances for total height, basal diameter, unforked height, clear bole height, stem straightness, pod production and survival. For the exploitation of total height, basal diameter, pod production and survival, provenance variation was found more important whereas for the improvement of unforked height, clear bole height and stem straightness, both provenance as well as individual tree variations were equally important. Specimens from Fatehabad, Muzzafarnagar, Kanpur and Haldwani provenances were found promising. Parent-offspring regression analysis found strong genetic control for the inheritance of stem straightness and unforked height. Seed production started during third year from the drier geographic sources while in many other sources it started from fourth year onwards. Different progenies of the same provenance source started seed production at the same age. Crown diameter:diameter ratio was found higher in the populations of low rainfall regions. Highly significant positive correlations were observed among early and later stages for total height and basal diameter.

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Status of Exotic Trees in Indian Agroforestry

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Agroforestry is being promoted and popularized in India by the government and wood-based industries so that the requirement of fuelwood, fodder and timber wood for industries is met from the field itself and the pressure on forests is reduced. Selection of trees for agroforestry is of paramount importance from the viewpoint of promoting tree cultivation on farmers' fields. Poplar (*Populus deltoides*), a native tree of the USA introduced in 1950, is widely grown in northern India as an agroforestry tree because of its fast growth, straight growing stem, short rotation, quality wood production and less adverse effect on agricultural crops. Poplar growers are seeing their green dreams wilt with the present throwaway prices in Indian rupees 125-200 per quintal as compared to Indian rupees 450-500 per quintal before 1996. *Eucalyptus*, another exotic tree having short rotation and broader utility of wood, is widely planted for windbreaks and rehabilitation of wasteland all over India. The vast genetic diversity of the genus *Eucalyptus* suggests a lot of potential for plantation forestry in India. Mesquite (*Prosopis juliflora*) has established on almost all the habitats and has become a major source of fuelwood and also a serious threat for the existence of indigenous trees and shrubs. *Leucaena*, a miracle fodder tree, has the problem of weed-like spreading habit. Desert-loving *Acacia tortilis* has undesirable wood quality. The introduction history of all exotic trees, their present status in comparison to indigenous trees, and future perspectives, are discussed.

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Agroforestry Scaled-up: Tree Pests and Diseases in the New Landscape, from an East African Perspective

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Widespread adoption of agroforestry technologies means more trees in the landscape and that facilitates spread of their pests. Complex threats can arise when previously isolated genotypes of pests are more easily brought together. This would allow for more gene diversity and a greater risk of the pest overcoming the trees' resistance. Both escalating and new pest problems have appeared recently in East Africa. Some examples are presented. Dieback of *Grevillea robusta* from a killing disease, probably *Botryosphaeria* sp., is escalating. Not only a problem for *Grevillea*, the indiscriminate spread of this apparent same disease to other exotics and to the indigenous *Melia volkensii* is a threat to their establishment on farms. In addition, termites are killing newly planted seedlings, and that is seriously hampering tree planting widely. This is an escalating problem as more trees are planted. Likewise, for sub-Saharan Africa, new insects attack shoots of different *Eucalyptus* species. Moreover, a gall-forming wasp (still not described) and a shoot psyllid *Blastopsylla occidentalis* were both found in 2003. Against these threats stand an increased biodiversity, which includes a host of natural enemies and antagonists to the pests, but the question remains—Is that enough?

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New Woody Crop Industries to Combat Agricultural Land Degradation in Southern Australia

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This paper presents early results of the 'Search' methodology for selecting woody perennial species and industries for large-scale crop development in the dryland agricultural areas of southern Australia. Some 70 million ha of land with 300-600 mm annual rainfall supports agriculture based on winter-growing crops and pastures. This agriculture produces $A12 billion/year in revenue mainly from grains, wool and meat but is afflicted with serious dryland salinity problems. Salinity reflects Australian agriculture's strong reliance on shallow-rooted annual crops and pastures that permit some leakage of rainfall to groundwater. This drives salinity and has the potential to impose costs, both on-farm and downstream, that exceed farm revenue. Salinity treatments being developed include greater incorporation of perennials into dryland agricultural systems to increase water use. A range of large-scale perennial crops and pastures will be required. Historic slowness in adoption of herbaceous perennials for grazing, and of agroforestry systems for conventional long-cycle products like sawn timber, indicated the need to investigate radical new short-cycle woody crops. Initial work has focused on domesticating native species, to take advantage of Australia's rich native flora, and to avoid the weed risk associated with introduced species. The native flora are being systematically screened to identify and test species with useful biological attributes for crop plants, as well as the potential to make products that have large markets. The promising results from initial work have motivated Australia's national agroforestry research body (Joint-Venture Agroforestry Program) to adopt development of new woody crops and industries as its top priority for research investment.

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Poplar, Eucalypt, and Willow Genotypes for PCE, TCE, Toluene, and Arsenic Dendroremediation Systems

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Fast growing eucalypt (Eucalyptus spp.), poplar (Populus spp.), and willow (Salix spp.) genotypes, commonly employed as short-rotation woody crops (SWRCs), have shown varying potentials to dendroremediate perchloroethylene (PCE), trichloroethylene (TCE), toluene, and/or arsenic contaminated soil and/or groundwater in studies at LaSalle, IL, St. Augustine, FL, and Archer, FL. At LaSalle, factors important to effective dendroremediation systems included unrooted vs. rooted cuttings, poplar and willow species and clones within those species, and environmental and cultural factors at and after planting in PCE-contaminated clay soil and above TCE contaminated groundwater. At St. Augustine, responses to toluene contaminated groundwater pumped on trees varied between P. deltoides (PD) and E. amplifolia (EA) species, among PD and EA genotypes, and between root-trained and unrestricted rooting cultures. In the chromated copper arsenate (CCA) contaminated site at Archer, growth and arsenic uptake were influenced by variation among PD, EA, and E. grandis species, among genotypes within species, across seasons, and among plant tissues. Overall, effective dendroremediation depends on tree-contaminant interactions and on tree growth as influenced by silvicultural, genetic, and environmental factors. Locally adapted trees, ideally genotypes derived from tree improvement programs, are essential for dendroremediation success. Certain poplars and willows appear promising for temperate regions, with eucalypts preeminent for semitropical and tropical regions.

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Oil-bearing Plant Resources in Nepal: An Alternative Energy to Fossil Fuel

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While the world continues to rely on non-renewable fossil fuels, the prospects for alternative sources of energy from oil-bearing plant resources have not been fully explored. The possibility of bio-fuel for the Least Developed Countries like Nepal is promising from both economic and environmental grounds, given its benefits over fossil fuels. It is a renewable energy produced from vegetable oil with characteristics similar to fossil fuel. Its proliferation creates employment and generates income for rural people, thus reducing the population pressure in urban areas. Research, development and conservation of oil-bearing plant resources can significantly uplift the economic conditions of rural farmers while contributing to the national economy. There is a good scope to improve the supply of plant oils and a number of steps can be suggested for the promotion of oil-bearing plant genetic resources as an alternative energy to fossil fuel in Nepal Himalayas. These steps include the following: (i) utilization of the more than 1,000 under-exploited, non-conventional oil-bearing plant species indigenous to Nepal, including oil-bearing fruits, nuts and seeds (e.g., *Jatropha curcas* seeds), (ii) substitution of suitable non-edible oils for edible oils that are used for industrial purposes such as paint, varnish and soap manufacturer, lubricants, dying, etc., (iii) introduction of these oil-bearing plants for cultivation in traditional agroforestry systems, and (iv) promotion of modern oil-extracting technologies, such as the Sundhara oil expeller, that are better suited to conditions found in the rural areas of Nepal.

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Agroforestry Production Systems Engage Landholders in the Management of Tree Vegetation for Multiple Benefits (Experiences from a Community Landcare Project in Northern Australia)

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Landholders in the beef and cropping industries of northern Australia are under increasing pressure to adopt “best management practices” for their enterprises. Native forests are a neglected resource that have not been adequately recognized and evaluated by most landholders. Agroforestry is an option for landholders looking for production systems that provide multiple (environmental, economic and social) benefits. However, interest in agroforestry production systems has been impeded by the long lead-time before such systems provide sufficient income from timber sales to enable the enterprise to be economically sustainable. Contributing to environmental services at a sub-catchment scale (reduced run-off with reduced sediments and nutrients, improved carbon cycle, improved hydrology and salt stabilization, etc.) via tree retention is a significant change in emphasis for many landholders. The conflict between providing enhanced environmental services and the long lead-time before extra income is acquired is a significant issue for many landholders. During a recent three-year community landcare project, 8 ha of native forest demonstration trials were established on four properties and another 20 ha of mixed species plantation trials were established on thirteen properties. These on-ground works provide an opportunity for industry, government, researchers, community and individuals to work with landholders to develop and demonstrate an economic framework to achieve simultaneous environmental, economic and social outcomes from implementing agroforestry. Some form of initial economic incentive will be required by landholders (from Government or Catchment Groups) until agroforestry production systems become self-funding. However, this investment contributes directly to the desired long-term outcomes for natural resource management.

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Fine-root Dynamics in Hybrid Poplar Plantations in Saskatchewan, Canada

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A two-year study was conducted on hybrid 'Walker' poplar (*Populus* sp.) trees in two newly-established short rotation plantations to determine the effects of tree stock type and applied fertilizer on seasonal fine-root (< 5 mm) dynamics and root biomass distribution. Root production, mortality and longevity were measured through monthly (July-October, 2002; April-October, 2003) minirhizotron (MR) image analysis, while root biomass was determined at the end of the second season by soil core (SC) method. Results indicated the superiority of rooted stock versus non-rooted stock. Rooted cuttings (RC) and rooted plugs (RP) showed substantially higher fine-root production than non-rooted cuttings (C), especially during the first year of establishment. Conversion of root length from MR image analysis to root length density in bulk soil indicated mean stock type values from 3800 (C) to 5700 (RC) m m^{-2} and 750 (C) to 1300 (RC) kg ha^{-1} in the upper 60 cm of soil. All stock types showed similar spatial and temporal patterns in root production, as approximately 80% of root production occurred during July and August, and between 10 and 40 cm depth. Root mortality ranged from 3 to 5 % of total roots produced at both sites; however, preliminary analysis of root cohorts suggested greater root longevity at the Cubbon site than the Culbert site. Discussion topics will also include the influence of fertilizer on root dynamics and an assessment of root data-gathering methodologies (MR and SC). Quantification of seasonal fine-root dynamics provides the necessary precision of data for belowground carbon accounting.

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An Alternative to Improve the Use of Woody Species in Animal Feeding (A Study from Tunisia)

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We studied the chemical composition of 13 woody species browsed by goats in northwest Tunisia and the effects of polyethylene glycol (PEG 4000) and feed blocks on nutritive value of this natural vegetation. Leaves and twigs (<4 mm) of shrubs were sampled monthly and analyzed for their ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content. Significant differences ($P<0.05$) between species and months of sampling for CP and fibre fractions were found. The ash content was very low (2.8-7.4%). The CP content ranged from 6.8% to 21%. Higher CP levels were found in young leaves compared to older leaves. All shrubs were rich in phenolic compounds. Effects of PEG and feed block supply were investigated on the mixture of 6 species *(Erica arborea* L.*, Phillyrea angustifolia* L.*, Pistacia lentiscus* L.*, Myrtus communis* L.*, Quercus suber* L. and *Viburnum tinus* L.) using a closed fermenter. Gas production, volatile fatty acid and organic matter fermented after 72 hr were increased ($P<0.05$) with PEG supply. The rate of increase was relatively low with feed block supply. In a field trial, 21 six-month-old local kids (~18.75 kg) were divided into 3 groups and allowed to browse in shrub-lands from July to December. Control group received no supplement whereas the two other groups received either PEG-free (B) or PEG-containing feed blocks (B-PEG). Feed blocks contained mainly wheat bran, molasses, urea and minerals. Overall, block supply improved ($P<0.05$) kid growth with highest values obtained with PEG-enriched blocks.

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Management Implications of Defoliation Patterns by Goats Browsing Mimosa (*Albizia julibrissin*)

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In recent years, demand for goat meat in the eastern United States has exceeded local production. Goats are typically browsers (as opposed to grazers) and are very susceptible to infection by internal parasites when forced to feed mainly by grazing, especially in warm, humid environments. However, very little research has been conducted in the Southeastern USA on plants that are suitable for browsing. Mimosa (*Albizia julibrissin*) is an introduced leguminous tree which is similar in appearance to *Leucaena leucocephala*. Preliminary research at Auburn University involving studies in which mimosa was defoliated by hand indicated that mimosa can provide high yields of good quality forage, and yields were higher following partial defoliation than following complete defoliation. However, the extent to which hand defoliation represented defoliation by animals was not clear. Therefore, the objective of this study was to determine defoliation patterns by goats browsing mimosa. Mimosa plants were marked prior to introduction of goats to the paddock in which they were growing, following which defoliation patterns were monitored by making daily observations of leaf disappearance. Goats tended to defoliate each mimosa limb completely before moving to the next limb, instead of defoliating all stems partially and uniformly over time. Consequently, results suggest that partial defoliation of all mimosa limbs prior to moving goats to the next subdivision in a rotational stocking system is not feasible, and therefore, will not result in higher forage production than complete defoliation.

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Interspecific Hybrids of *Leucaena* Species for Fodder and High-value Hardwood

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KX2 and K1000 are outstanding examples of interspecific hybrids in the genus *Leucaena* from the University of Hawaii. KX2 was derived from five cycles of recurrent selection in Hawaii from the hybrid of *L. leucocephala x L. pallida*. It was selected for fodder productivity and quality and for resistance to the leucaena psyllid, and is based on self-sterile trees and thus poorly seedy. It has shown a much wider climatic range of tolerance than K636, K8, K584 and other superior varieties of *L. leucocephala*, and has won forage yield trials in many countries. K1000 clones are fast-growing seedless triploids from the cross of *L. leucocephala* with *L. esculenta* that similarly perform well over a wide ecological range. They have led our yield trials for high-value hardwood. Twelve-year old trees of 20 m height and 40 cm dbh display high specific gravity (>0.6) and attractive red-brown color, and are easily crafted. Several other seedless hybrids are similarly attractive as hardwoods, e.g., *L. pulverulenta x L. diversifolia*, among >80 interspecific hybrids we've grown in Hawaii from crosses among the 22 *L.* species. Cloning technology has been refined for these hybrids, but we still seek to master tissue-culture methods that would facilitate international exchange of these fine hardwood clones. Colchicine-induced tetraploids now expand our options for new tetraploid (fodder) and triploid (hardwood) hybrids.

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Agroforestry Mushroom Cultivation Research at the University of Missouri

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The first field studies of outdoor cultivation of specialty mushrooms in Midwestern agroforestry at the University of Missouri Horticulture and Agroforestry Research Center in central Missouri began in 1999. We are currently studying natural log cultivation of shiitake (Lentinula edodes), reproductive biology of morels (Morchella sp.), and orchard production of the Perigord black truffle (Tuber melanosporum) and the Burgundy truffle (T. uncinatum). Studies of hen-of-the-woods (Grifola frondosa), oyster mushrooms (Pleurotus spp.), and wine-cap Stropharia (Stropharia rugoso-annulata) have been discontinued temporarily. Our experiences with each of these types of specialty mushroom are reported. Ongoing shiitake studies are evaluating effects on productivity of substrate wood species, fungal strain, inoculum form, season of inoculation, inoculation delay, temperature of water during force-fruiting, ambient precipitation and temperature, powder post beetle and slugs, and log orientation. Ongoing morel studies are focused on natural population biology and augmentation of natural fruiting. Questions addressed involve field-fruiting of lab-produced sclerotia, and longevity and spatial spread of individuals, as this will influence sowing density and frequency. Our truffle studies address the key features of compatible mycorrhizal systems: receptive hosts, competitive fungal strains, and appropriate environment. We are considering both Swedish (Gotland) and French strains of T. uncinatum, and French T. melanosporum. We are working with hybrid hazel (Corylus) with resistance to filbert blight, and with hybrid Q. robur x Q. bicolor selected for powdery mildew resistance and columnar growth habit. We are also experimenting with seedling production methods that may shorten the time to fruiting following outplanting.

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Shiitake Mushroom Cultivation in Midwestern Agroforestry

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Two outdoor shiitake (Lentinula edodes) mushroom cultivation experiments were established at the University of Missouri Horticulture and Agroforestry Research Center in central Missouri, in December 1999 and May 2000. The objective of these experiments was to evaluate the response of natural fruiting (precipitation was the sole source of water) to several initial treatment factors (i.e., season of inoculation, log species, shiitake strain, inoculum form, and post-felling inoculation delay). Fruiting began in August 2000. We compared two models for analysis of treatment effects. In the Harvested Weight (HW) model, weight (g) of mushrooms harvested from each log was the response variable, treatments were represented as categorical variables, and log characteristics were incorporated as covariates. This HW model provided insight into the results of analyses of Biological Efficiency (BE model). As of January 2003, the BE model detected that the wide range strain outperformed the cool and warm weather strains tested. Sugar maple (Acer saccharum) and white oak (Quercus alba) outperformed northern red oak (Quercus rubra). Sawdust spawn outperformed dowel spawn in the autumn-inoculated experiment and thimble spawn in the spring-inoculated experiment. Logs from trees felled mid-February outperformed logs from trees felled early-May (prior to bud swell). The HW model detected all but the log species effect. No difference was detected in HW among log species when non-discolored wood volume and bark thickness were included in the model, because these log characteristics functioned as significant covariates describing differences among log species. Results of fruiting through December 2003 (the fourth year) are presented.

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Government Policy as Determinant of Local Agroforestry Practices in the Philippines

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A number of Philippine national policies on forest management include agroforestry as one of the strategies for people-oriented forestry programs geared towards rehabilitating denuded forestlands while addressing the livelihood needs of forest occupants. Farmer and community participants with 25-year tenure over public forest lands are allowed to plant portions of their land with agricultural crops in tandem with forest and fruit tree crops. Several local agroforestry practices have since emerged in part as a result of the technology transfer by government forestry and community development workers to the participating farmers and communities, and in part, to the participants' compliance with the terms and conditions of their tenurial instrument. Adoption rates by participants are varied and have resulted in the emergence of various local agroforestry practices in different localities. This paper traces the evolution of Philippine national forestry policies on land tenure, area limitation, choice of species, silvicultural management, harvesting and utilization, among other things. Patterns of land use and emerging local agroforestry practices of participants in selected sites are described in relation to the development and implementation of the country's forestry and economic policies. The paper also outlines some of the lessons and issues on forestry policies as a factor in the development of local agroforestry practices for sustainable land use systems.

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Coconut-Based Agroforestry Farming Systems in Central Philippines

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The study aimed to (1) identify successful coconut-based agroforestry systems that could be extrapolated and adapted to other upland areas in the Philippines, and (2) identify weak components and "links" in coconut-based farming systems that could be improved through innovative strategies. Intercropping among coconuts started in the 1930s using corn, sweet potato, cassava and banana. Later, coffee (*Coffea* spp.), both native and improved, *L. leucocephala* and *L. diversifolia*, vegetables, pineapple, buri palm, taro, *Artocarpus heterophyllus*, S*andoricum koetjape,* mahogany and *gmelina* were introduced. Intercropping in coconuts increases income, and copra production was the main source of income. The cultivation of intercrops benefits the coconut trees. Intercropped trees adversely affect copra production. Soil erosion remains to be a serious problem on sloping lands planted solely to field crops. Intercropping systems could be improved with more strategic plant combinations, densities and planting patterns for the different life stages of the coconut trees. Effective erosion control on sloping fields requires the planting of a combination of tree and field crops and the application of organic farming practices. The planting of fast-growing and tall timber trees under coconut is not recommended (coconut is a C-4 plant and more than 30% shading adversely affects its growth). Only shallow-rooted and shade-tolerant intercrops should be planted within a 3-m radius around the coconut trees. More in-depth studies are required before potentially best-bet coconut-based agroforestry systems can be identified and extrapolated to other areas.

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Regrowing Forest-Confined Indigenous Timbers in Marginal Karst Areas of the Philippines

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Farming is a real challenge in Central Philippines and in similar *denuded karst regions* in the country and Asia. Deforested for decades, these areas are currently reduced to open, completely bald areas or scrublands. The precious timbers are now confined only in remnant patches of natural forests that hold the last threads of biodiversity and gene pool. The fragile karstic environment speeds up soil loss processes and renders the hydrology highly prone to pollution. The ecologically unsound use of exotic species in reforestation has been alarming in scale. Primary constraints to tree domestication are the lack of planting materials and the "*loss of confidence*" over the *capability of the degraded lands to support higher vegetation*. Within 1996-1998, three parcels of scrubland in Bohol Island, Philippines, were planted in a mixed manner, with more that *50 indigenous timber species including 8 dipterocarp species*. The area is 350 meters above sea level. Soils are very thin. The sites are about 12 km southwest of the world-renowned karstic Chocolate Hills. After 5-6 years of growth, the results are very rewarding. The tree farms showcase a successful domestication of the precious timbers believed to thrive only in natural forested areas. The dipterocarps, which even traditional foresters believe can grow only in a cool shaded environment, are performing well in these marginal lands.

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Smallholder Forest Nursery Operations in Southern Philippines – Evolving Mechanisms for Tree Domestication for Agroforestry

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The production and use of high quality planting stocks are critical activities in the improvement of agroforestry practices through tree domestication. Smallholder tree farmers' nurseries on Southern Philippines were surveyed to determine the forces that govern the production and distribution of seedlings in the study sites. Specifically, the reasons for going into forest nursery establishment, the choice of species to produce and the marketing of the planting stock were evaluated and their implications on tree domestication efforts in the country were assessed. Reasons for the establishment of small nurseries included the existence of a large demand for planting stocks, the desire to plant trees in their farms, the need for a livelihood opportunity to augment meager income, and the encouragement from government and nongovernment organizations involved in upland development. The choice of species was driven by the existing market demand, the availability of seeds and other propagules in the locality, the influence of organizations funding upland/agroforestry endeavors, and the previous experiences of the nursery operators. Interest in producing planting stocks of indigenous tree species is high but is constrained by lack of seeds, the distance of sources of such, the lack of seed and seedling production technologies and the poor awareness on the use and potentials of native species, specifically their niche in tree and agroforestry farms. The increasing interest on planting trees in agroforestry farms can indeed be very well complemented by the activities of these smallholder forest nurseries in the Philippines.

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Matching Demand and Supply for Farm Sourced Timber: Results of Business Census and Households Survey from Mount Kenya Region

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An important dimension in maintaining and improving the production of farm-sourced timber is through strengthened marketing system. Small holders often lack the necessary market information to sell their tree products or the market is just not there. Timber businesses around East of Mount Kenya were surveyed to characterize their market chains and their link with farms timber. Over 40 market chains were identified and characterized during this survey. Results show that timber business operates at different levels and operators are indeed engaged in diversified market linkages. The market chains demonstrate different operators' economic, technical and social adaptations at all levels. The household survey traces the intricacies of tree ownership and trade at the farm level. Two agro-ecological zones, the coffee zone and the cotton zone, were surveyed. *Grevillea robusta* is the most easily and widely traded species on farm. The cotton zone provides the highest and more diversified source of timber and fuel wood compared to the coffee zone. There is however more trees per unit area in the coffee zone as compared to the cotton zone. Predicted mean number of stems for 1-hectare farm in the combined cotton and coffee zone is 145 stems, providing a mean volume of 47m^3 of wood per hectare. Preferred farm timber includes *Grevillea robusta*, *Cordia africana*, *Vitex keniensis* and *Eucalyptus* sp. There seems to be a strong link with direct income element for every choice.

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Evaluation of Hedgerows of *Indigofera zollingeriana* Miq. on Degraded Hill Slopes in the Subhumid Tropics of India

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Indigofera zollingeriana Miq., a multipurpose tree with origin in tropical Southeast Asia and temperate Sino-Japan, was recently introduced in the Eastern ghats of India as a shade tree in coffee plantations. Its ability to bear early profuse seeding and better growth performance than the widely planted NFTs on degraded sites makes it an ideal choice for various forestry and agroforestry options in the hilly watersheds of this region. However, research works on this species are quite limited and no studies on its growth potential are reported from India so far. It also does not find mention in the Agroforestry database of the World Agroforestry Center. Considering its promising growth on acidic hill slopes rich in iron and aluminum and its growing social acceptance as a fuel and fodder tree, its performance has been evaluated as a hedgerow species for ecological and economic rehabilitation of degraded hill habitats and the poor tribal inhabitants in the Eastern ghats. Single row hedges formed by planting of this species at 1 m intra-row spacing and 6 m inter-row spacing across the hill slopes (12-15%) under a horti-silvo-pasture system are subjected to pruning at 1 m height. The biomass growth and yield, response of tree physiognomy to hedging, root growth behavior, moderation of soil properties and economics during the crucial first two years, are reported in the paper.

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How Can We Conserve Genetic Resources in a Participatory Domestication Program: The Case of Peach Palm (*Bactris gasipaes* Kunth)?

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Peach palm (*Bactris gasipaes* Kunth), originally domesticated by Native Americans, is cultivated in northwestern South America and southern Central America in two very different ways: (1) by small-scale farmers, mostly in agroforestry systems, to produce fruit for subsistence and local markets; and (2) by entrepreneurs in high-input monocultures to produce heart-of-palm, an expensive delicacy. There is considerable variation between and within recognized landraces for both uses. Patterns of molecular diversity support the landrace designation and suggest opportunities for peach palm improvement. There is concern, however, that further domestication will reduce genetic variation in peach palm, and may limit opportunities for future selection. This paper uses peach palm as a case study of indigenous fruit tree domestication, and addresses the following question: Can we balance the potentially conflicting goals of plant domestication and economic development for small-scale farmers with long-term conservation of genetic resources of species under domestication? Three topics are discussed: (1) conditions under which domestication of plant populations may be compatible or incompatible with conservation of genetic resources; (2) using peach palm as an example, the potential to manipulate the genotype and its environment, and match the genotype with the environment, and the consequences of these manipulations in terms of economic costs/benefits and genetic conservation; and (3) participatory domestication strategies for peach palm that may provide significant economic benefits for small-scale farmers while also minimizing the loss of useful genetic variation.

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Genetic Diversity and Population Structure of Peach Palm (*Bactris gasipaes* Kunth) in Agroforestry Systems of the Peruvian Amazon

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Peach palm (*Bactris gasipaes*) is an important component in Peruvian agroforestry systems, and is cultivated for its fruit and 'heart of palm'. Based upon observations of farming practices in the Peruvian Amazon, the genetic diversity of *Bactris gasipaes* appears to be vulnerable to erosion as a result of the way the palm has traditionally been cultivated. This study uses microsatellite molecular markers to assess the genetic diversity and population structure of *Bactris gasipaes* in the agroforestry systems of riverine communities in northeastern Peru. In addition, a sampling from a peach palm germplasm collection of diverse geographical origin is analyzed to provide relative levels of genetic variability for comparison. Farmers were surveyed pertaining to their cultivation practices for peach palm in swidden-fallow agroforestry systems. The genetic effects of farmer seed selection, germplasm exchange and aspects of fallow management are analyzed in the molecular record of the palms sampled. A meta-population approach is used to describe geneflow within and among these peach palm populations, implying an elastic structure which maintains relative levels of genetic variability in *Bactris gasipaes* over time by reducing or canceling any erosion taking place. The on-farm maintenance of genetic diversity in *Bactris gasipaes* will allow this domesticated palm to continue to evolve with cultural and environmental dynamics. This study offers important insight in developing strategies to sustain the evolutionary processes which actively create and preserve genetic diversity on-farm, focusing conservation above and beyond the preservation of genes and germplasm *per se*.

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Promotion of Cacao Agroforestry as a Conservation Strategy in the Buffer Zones of La Amistad Biosphere Reserve, Panama: Obstacles to Smallholder Adoption

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Agricultural expansion by smallholder producers has been identified by management agencies as one of the main threats to the ecological integrity of La Amistad Biosphere Reserve which crosses the border between Panama and Costa Rica. Intensifying and increasing the profitability of cacao agroforestry, one component of smallholder agricultural systems in the buffer zone of the eastern side of the reserve, has been proposed as a means to reduce the need for farmers to clear new land for cattle pasture or shifting agriculture within the reserve. While this may be one option, in order to realize this goal there is also a need to look beyond the small-scale agricultural practices that are the immediately apparent causes of ecological degradation and examine the larger cultural, economic and political forces that serve as drivers of these activities. The authors examine four of the main assumptions which motivate the proposal to develop smallholder cacao production in the buffer zone: 1) cacao agroforestry systems are entirely ecologically benign; 2) if cacao production is made to be more financially viable incentives for expansion of cattle production and shifting agriculture will be decreased; 3) migrants from other areas are primarily responsible for clearing of land for cattle pasture on the eastern side of the park; and 4) the most effective means to prevent agricultural expansion is direct intervention at the level of smallholder production. Recommendations for intervention strategies which incorporate this redefined analysis are then given.

** This study was an equal and joint effort by both authors. The order in which names appear is therefore irrelevant.*

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Managing Cattle and Timber for Profit: Silvopasture Systems in Minnesota

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Over 800,000 acres of forestland are being grazed in Minnesota. In many cases, the woods are unmanaged, resulting in low yield of both forage and timber. To address this topic, we are researching the use of crop tree management in currently grazed woods. We are not specifically encouraging new woods to be grazed, but instead working with management of existing grazed woodlands. This two-part study focuses on assessing forage response to crop tree management in the short-term and then the tree growth response in the long-term. We established three control plots and three crop-tree management plots. Each plot contained three fenced sub-plots for forage sampling. Year one post-harvest is showing nearly tripled forage yields under crop tree management with no change in protein or feed quality. Funding is provided by the Minnesota Department of Agriculture. Collaborations include the NRCS Grazing Specialist, the Cass County Soil and Water Conservation District, the University of Minnesota Extension Service and a Cow-Calf Operator.

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Can Genetic Improvement of Sissoo (*Dalbergia sissoo* Roxb.) Provide Economic Benefits to Tree Planting Farmers in Nepal?

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Sissoo (*Dalbergia sissoo* Roxb.) is a nitrogen-fixing multipurpose tree species grown mainly in South-Asia for its valuable timber (rosewood). Today, it is one of the most widely planted tree species in this region. Given the scarce resources available for support to domestication activities, it is therefore questionable if tree improvement programme for Sissoo is relevant for Nepal. The present paper compares potential economic benefits to agroforestry farmers with the cost of running Sissoo improvement programme. Use of improved seed is expected to add US$ 15,208/ha to the total value production of US$ 60,800 over a 30-year rotation. This value corresponds to a net present value (NPV) per ha at US$ 3,700 (at 5%), or US$ 6,500 (at 3%). Annual cost for successive generations of Sissoo tree breeding is approximately US$ 13,300/year in present prices. Investing in one-cycle of breeding activities for 10-year can be seen as a major investment worth US$ 22,000 (if inflated over 10-years with 5%), or US$ 19,700 (at 3%), but the aggregated NPV of only 100 ha (average 100,000 trees) planted by the farmers with the improved seed source would add US$ 648,000 (at 3%), or US$ 364,000 (at 5%). The increased future growth of only one-year of fairly small planting areas is estimated to cover the full cost of breeding. The economic gains exceed the costs to a degree that makes it a profitable investment; however, effective seed delivery systems should be in place to ensure that the seed reaches farmers for their agroforestry plantings.

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Biodiversity in Neem: The Potential Tree for Agroforestry

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The importance of neem (*Azadirachta indica* A. Juss) in the present day context is getting much attention as an economic tree because of the growing use of neem products at global levels in bio-pesticides, medicines, cosmetics and animal health care. Neem-based pesticides are eco-friendly, non-toxic and do not exert any residual effect on agricultural produce. Despite the high value of this tree species, very little efforts have been made to know the genetic variation within this species. With the objective of evaluation of biodiversity among the selected provenances of neem from different agroclimatic regions of India, biochemical and molecular markers were used. Oil and azadirachtin content showed a wide range of variation due to geographic locations. The seed samples from south Indian provenances exhibited a narrow range for all the fatty acids. A cluster analysis indicated that neem germplasm within India constitutes a considerable broad genetic base with the values of genetic similarity co-efficients ranging from 0.60 to 0.94.

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Implantation of Sylvan Systems with Timber-Yielding Species of Natural Regeneration in Venezuela

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For the purpose of evaluating the environmental impact of the implantation of sylvan systems with timber-yielding species of natural regeneration, an environmental diagnosis was carried out in a double-purpose unit at about 1 km from downtown Coloncito city in Táchira state, Venezuela. A cause-effect matrix was made in relation to the productive resources, use and environment. A sylvan model was created with timber-yielding species of natural regeneration chosen as a representative sample of homogeneous fields, which is fundamental for preventing, mitigating, and controlling the impacts caused by the current system. The owner, administrator and the workers were surveyed as for natural resources, including agricultural, ecological, social and economic aspects. The chosen species for the model was the Apamate tree (*Tabebuia rosea*), in milk circuits, because of its relatively fast growth, survival, and scarce appetizing attractiveness to the cattle. It was evidenced that these systems contribute to the protection of the soil and the incorporation of environmental services.

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Identification and Domestication of Selected Indigenous Fruits in South Africa

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The aim of the project is the identification of indigenous fruit species utilized in rural areas of Limpopo Province, South Africa and the development of these species to benefit rural communities by poverty alleviation, job creation and improved nutritional status. Participatory Research Appraisal (PRA) techniques were used in determining which fruit species are utilized and their importance to the local people. Data was synthesized and the species identified by most people and those used for income generation and not only as famine foods were ranked as highest priority. These highest-ranking species were selected for further study. From the initial survey, seven species were identified as being those with the most potential due to local popularity, nutritive value, processing potential or multi-purpose use, or a combination of these. Seeds of the following fruits were collected and planted at the nursery: *Syzygium guieense* (forest waterberry), *Parinari curatellifolia* (mobola plum), *Vangueria infausta* (mispel), *Ximenia caffra* (large sour plum), *Engelerophytum magalismontanum* (stem fruit), *Dovyalis caffra* (kei apple) and *Garcinia livingstonei* (African mangosteen). Propagation trials on these species indicate that *Parinari curatellifolia* is the only species which had poor germination. *Vangueria infausta* requires a long germination period if not treated, however, seed pre-treatment effectively shortened the germination period by 80%. *Dovyalis caffra* was successfully grafted. Superior selections of four species have been made in the wild. These trees are ideally suited to semiarid climatic zones, which make up a large part of South Africa. Their role in integrated farming systems in rural areas is discussed.

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Importance of Inoculated Beneficial Bacteria on Growth of Pine and Birch Seedlings

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Soil microorganisms are integral components of forest ecosystems, and many such microorganisms have the potential to influence plant growth significantly. Beneficial bacteria can facilitate the improvement of plant growth, plant nutrition, root growth pattern, and responses to external stress factors, including the production of growth-promoting chemical substances. The objectives of our study were to investigate the effects of plant-growth promoting bacteria on seedling growth of Scots Pine and Silver Birch in sandy clay soil. Soil was collected for the pot experiment from field site near Helsinki, Finland. Scots Pine (*Pinus sylvestris*) and Silver Birch (*Betula pendula*) were employed as the tree species in the inoculation experiments. Inoculation of tree seedlings with bacterial strains resulted in statistically significant seedling biomass increases after 12 weeks of tree growth. The bacterial strains *Bacillus megaterium* KMNL1A and *B. longisporus* KNOL6 significantly increased the shoot growth of pine and birch. Growth-promoting bacteria produced the phytohormone auxin, cellulase and pectinase enzymes. From the final results we concluded that plant growth-promoting bacteria can play an essential role in helping the plant establishment and growth of pine and birch.

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Ginseng Production in the Eastern USA Utilizing Natural Fungicides

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Ginseng (*Panax* sp.) can be a very profitable non-timber forest product. However, the harvesting of wild ginseng is regulated to prevent over-harvesting. As an alternative, ginseng is frequently grown in beds either in the forest or under shade-cloth. These ginseng beds are often planted as monocultures at a high planting density. One of the drawbacks to this approach is the increased incidence of fungal diseases that can result in large plant losses. The goal of this study, conducted under a SARE producer grant, was to determine the efficacy of possible alternatives to chemical fungicides for use on ginseng. The site for the replicated study consisted of thirty ginseng beds on a north-facing wooded slope. Nine hundred ginseng rootlets were planted in the Fall. The following April the leaf mulch was removed, a plant count taken (674 plants survived) and replants made. The plots were then sprayed with one of the following treatments: 1) goldenseal (*Hydrastis canadensis* L.) tea, 2) horsetail (*Equisetum* spp.) tea, 3) micronized compost tea, 4) Oxidate (commercial fungicide), or 5) water (as a control). Each application was scheduled to be sprayed on a weekly cycle. In mid-trial, the plots were vandalized and many of the roots were stolen; however, with only one year of data the results were still promising. The compost tea and commercial Oxidate kept the foliage alive a little longer than the goldenseal sprays, but were similar. The horsetail tea spray was only marginally more effective than the Oxidate and compost tea sprays.

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Evaluation of Cottonwood (*Populus deltoides*) intercropping with Watermelon (*Citrullus vulgaris*) and Colza (*Brassica napus* L.) Five Years after Establishment

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Agroforestry in Iran, despite its tremendous values and benefits, has not yet received the attention it deserves. The main purpose of this experiment was to demonstrate both to local foresters and farmers as well as to farmers in surrounding communities some of the potential socio-economic benefits of agroforestry. In this experiment, cottonwood (*Populus deltoides*) was intercropped with watermelon (*Citrullus vulgaris*) for four consecutive planting seasons followed by Colza intercropping in year five. Five years after the experiment, about 65% of the planted seedlings were still surviving. The average diameter of the trees was about 13 cm, while the average height of trees was about 11 m. Over 67% of the surviving trees attained a diameter of 12 cm or greater. In this experiment, the researcher tried to demonstrate that agroforestry could not only be beneficial for the farmers in producing more income compared to single-crop practice, but that it could also be useful for the local community in terms of creating more seasonal employment. As expected, the increasing competition of the seedlings at the later stages of growth, and thus their extending shade, reduced the yield of watermelon. However, the steady yearly increase in price of this product caused the total annual sale of the produce to rise rather than to decline. Although a complete economic assessment of this intercropping system is only possible after the final tree harvest, an attempt was made to estimate and quantify the economic value of such a practice based on the present variables.

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The Effect of Agroforestry Species on Rural Cropping Systems in South Africa: Part II. Soil Water

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An on-farm trial was conducted in South Africa to determine dry matter production of four fodder tree species and their effect on soil water and production of a maize (Zea mays L.) intercrop. Tree species were Acacia karroo (indigenous fodder tree), Leucaena leucocephala (nitrogen fixing), Morus alba (fodder and fruit), and Gleditsia triacanthos (fodder and fuel). Volumetric soil water was measured in the upper 0.3 m of soil in each row using time domain reflectometry. The Neutron probe technique was used for monitoring the water content deeper in the soil. Geostatistical methods were used to analyse treatment differences in the upper 0.3 m of soil. Soil water content did not differ significantly between the maize and tree rows indicating that competition for water in the upper horizon was not the reason for lower maize yields. However, at greater soil depths (75-125 cm) trees in the wide spacing used less water than those in narrow spacing. High soil water values recorded during summer indicated that in the current cycle of good rainfall the plants in the agroforestry trial were not stressed. Thus, the trees do not compete with the crops for soil moisture in good rainfall seasons. Light interception was an important factor in reducing maize yields in the row nearest to trees. However, this study would need further evaluation of water competition during low rainfall years. Since the trees have access to water at greater depths, they are likely to be more productive into the dry season than shallow-rooted crops.

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Agroforestry in a Temperate, Rural Cropping System in South Africa: Part I. Fodder Production

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In the Upper Thukela region of KwaZulu-Natal, South Africa, one of the main constraints to cattle production is a shortage of fodder in winter. In response to a request from a local farmers' association, a project was initiated in 1997 to examine the potential of an agroforestry system to increase fodder production. In the alley cropping system the most productive tree species throughout the three-year study was the indigenous species, *Acacia karroo* (1,600–3,000 kg ha^{-1}). Fodder yield in *Leucaena leucocephala* increased significantly from 1999 (500 kg ha^{-1}) to 2001 (3,800 kg ha^{-1}). The *Morus alba* tree had the highest fuelwood production (8,300 kg ha^{-1} in 2001) and was favoured by the farmer because of its fruit production. In 1999, the second year of tree establishment, average maize (*Zea mays* L.) yield in all the plots (5,014 kg ha^{-1}) was higher than the control (4,100 kg ha^{-1}). The maize yield in 2000 (3,700 kg ha^{-1}) was generally lower than the control (3,900 kg ha^{-1}). This decrease was greater in 2001 (450 kg ha^{-1}). Highest maize yields were recorded in *A. karroo* plots. In spite of decreased maize yields, this study showed that increased fodder and fuelwood production can result in considerable savings to the farmer. An *A. karroo*-maize intercrop could save the farmer \$650 ha^{-1} yr^{-2} on dry matter supplements, and a system with *M. alba* could save \$400 ha^{-1} yr^{-2} on fuelwood costs. Agroforestry thus provides financial benefits to the farmer and reduces pressure on grasslands and indigenous forests.

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Distribution Model of Dendrometrical Parameters of Dominant Species Stands in Natural Forest (A Study from Benin Republic)

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In the present article, we present an approach to modeling the distribution of dendrometrical parameters for dominant species stands in natural forest. Data have been collected from inventory of 314 sample plots with 15 m of radius on stands with dominance of *Isoberlinia* spp. in three natural forest areas (Monts Kouffé, Wari-Maro and Ouémé Supérieur) in Benin. For each plot, the parameters m, σ^2, β_1 and β_2, characteristics of distribution families are determined and used to establish models according to the dominance and diameter average. With the best models, the parameters of the theoretical crops are estimated. The results show that the type of distribution of the dendrometrical characteristics is the Type 1 according to the Pearson system. Distribution tables of stem numbers, basal area and volume were simulated according to the class of diameter and dominance.

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Cropping System and Its Relationship with Water Sources of Jammu & Kashmir State, India

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For the third consecutive year, world grain production has registered a fall, which compounded 35 million tons and 31 million tons in 2000 and 2001, respectively. India's production has declined from 196.13 million tons, which is short of the targeted 212 million tons for 2002 because of adverse weather conditions. Land and water are basic natural resources, which have a direct impact on agricultural production. Due to the introduction of high-yielding fertilizer-responsive varieties, the role of irrigation water has gained importance in development of agricultural economy. Shortage as well as over-exploitation of water resources has adversely affected soil productivity and the water table. Therefore, there is a great concern about sustainability of today's agricultural breakthroughs. An attempt has been made to quantify the utilization level of water resources in Jammu & Kashmir (J&K) state and to examine their impact on long-term sustainability. In J&K state, there was a decline of about thirty thousand hectares in the cropped area from 1990–91 to 2000–01. The net irrigated area of the state grew from 42.50 thousand hectares during 1980–81 to 1990–91, after which it declined by 1.83%; therefore, for the overall period 1980–81 to 2000–01 it declined by 2.26%, whereas the area under wheat-maize has increased significantly. In conclusion, soil of J&K state is facing deterioration due to exhaustive cropping patterns and erosion. To overcome these problems, there should be judicious use of irrigation facilities, and incorporation of pulses or leguminous crops in the crop rotation.

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Evaluation of Potential Tropical Multipurpose Trees for Silvopastoral Systems in Tabasco, Mexico

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The objective of this research was to know the uses and nutritional characteristics of three tropical multipurpose trees (*Albizia lebbeck*, *Erythrina americana* and *Morus alba*), species with potential use in the silvopastoral systems of the state of Tabasco, in southern Mexico. Field journeys, foliage collection and interviews with livestock and agricultural producers were carried out in the center and south of the state. Additionally, based on their importance in animal feeding, there were analyzed the chemical compositions and the presence of antinutritional factors in the foliages of the three species. It was found that *A. lebbeck* had different uses in the area, including as an ornamental and shade plant, a source of wood for firewood and charcoal, and for furnishing manufacture, besides the importance of its flowers for honey production. Several species of *Erythrina* are multipurpose trees widely distributed in the region, with great diversity of uses such as ornamental, living fences, human and animal food and principally as shade plants for cocoa (*Theobrama cacao*) and coffee (*Coffea* spp.) plantations. *M. alba* is a species recently introduced in the region, which actually is promoted principally for animal feeding. The foliages of the three species showed lower protein contents than those reported in other countries; nevertheless, protein levels in the foliage of evaluated species exceeded considerably those of the native and introduced grasses, which are the basis of ruminant feeding in Tabasco. Plant tissue analysis detected small amounts of tannins in the three foliages and absence of cianogenic glucosides and saponin.

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Importance of Fodder Trees in the Silvopastoral Systems of the Mountain Region of Tabasco, Mexico

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The mountain region of Tabasco, in southeast Mexico, is a zone with warm humid climate, total annual rainfall of 3,500 to 4,000 mm and annual mean temperature of 26°C. This area has diverse agroforestry systems, with silvopastoral systems (SS) standing out, particularly scattered trees on grassland and living fences. The SS of the mountain region of Tabasco comprise native or introduced grasses associated with multipurpose trees, principally for cattle (meat and milk) production and sheep fattening. The SS of mountain region include native or introduced trees as *Bursera simaruba*, *Cedrela odorata*, *Ceiba pentandra*, *Cordia alliodora*, *Crotalaria* sp., *Delonix regia, Dyphisa robinioides*, *Enterolobium cyclocarpum, Erythrina* spp., *Gliricidia sepium*, *Guazuma ulmifolia*, *Haematoxylum campechianum*, *Pachira aquatica*, *Pithecellobium saman*, *Salix chinensis*, *Spondias* sp., *Swietenia macrophylla*, *Tabebuia rosea*, *Tectona grandis* and *Brosimum alicastrum*. These species offer diverse products, uses and benefits by means of their uses as living fences, hedges, shade, human food (leaves, flowers and fruits), ornamental and medicinal uses, firewood, charcoal, housing construction materials, wood for furniture, tools and poles, and soil fertility conservation. Some species are fodder producers, a valuable resource that could contribute to improve animal diet and greater production and productivity, besides a better use of available resources and a more sustainable system.

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Genetic Diversity of Acid Tolerant Rhizobia of *Phaseolus vulgaris* L. from the Intensively Cropped Soils of La Trinidad, Benguet, Philippines

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The common bean or snapbean, *Phaseolus vulgaris* L. is a semi-temperate vegetable legume cultivated in the Philippines. It is a common source of protein in the Filipino diet and is planted in approximately 2,644 ha in areas with medium to high elevation. According to the Consultative Group on International Agriculture Research or CGIAR, it is considered to be the most important food legume in the world. The diversity of rhizobia associated with beans has been studied with emphasis on those of Mesoamerican origin. No studies have been done yet on the diversity of rhizobial strains in the Philippines particularly in La Trinidad, Benguet. Study of the diversity of *Phaseolus* rhizobia will go hand in hand with the selection of superior strains that can promote better nodulation and plant growth in acid soils. This study reports the genetic diversity of rhizobia symbiotic with *Phaseolus vulgaris* L. and the selection of a superior acid tolerant strain that performs very well in acid soils. Methods include isolation and authentication of rhizobial strains, phenotypic and genotypic characterization of rhizobial isolates, screening for acid tolerance, and testing the symbiotic performance of the most acid tolerant strains in comparison with a well studied acid tolerant reference strain in potted soil using *gus*-labelling.

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Participatory Design of Coffee Agroforestry Systems in Central America

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Agroforestry design research has concentrated on systems that include two or at most three species, but provide little indication of how to improve diverse agroforestry systems typical of small coffee farmers in Central America, or other traditional agroforestry systems across the world. A guide to the design of coffee agroforestry systems, tested with 50 coffee farmers in three agroecological regions of Nicaragua, consisted of the following steps: i) inventory of existing tree species, ii) qualitative evaluation of benefits of species as coffee shade, for household use, or for sale, iii) criteria to optimize benefits by adjusting numbers of each species. Evaluation of tree and coffee survival and health by farmers one year after planting, led to 44% planting more shade, 66% legume cover crops, and 66% more fruit trees. Over the first three years costs of maintenance of the plantations (US$150-300/ha/year) were recovered through production of bananas (US$150-250/ha/year), but not the costs of planting (US$1500/ha). These methods were taught to 140 coffee extension workers in Nicaragua who in turn taught 4500 farmers about inventories (45%), analysis of benefits of the trees (78%) and redesigning the shade (72%). Farmers responded by planting and/or removing fruit trees (44%, 23%), shade trees (41%, 23%) and timber trees (33%, 33%), respectively. On average participating farmers planted 1.3 new trees species while non participating farmers planted 0.6 new tree species. Quantitative observation linked to qualitative evaluation within a structured decision-making process can enable farmers to improve the design and benefits from complex agroforestry systems.

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Vegetative Propagation of Important Agroforestry Tree Species of Semiarid Tropics of India

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Present investigation was carried out to standardize vegetative propagation and to study biochemical changes during different stages of rooting in *Albizia amara, Albizia lebbeck, Azadirachta indica, Hardwickia binata, Melia dubia* and *Madhuca latifolia*, important tree species of semiarid tropics of India, extensively used in various agroforestry models. The cuttings taken from mature trees were treated with different concentrations of IBA and NAA and planted in polybags (20 cuttings per treatment, three replications). The data exhibited that *Albizia amara*, *Azadirachta indica* and *Melia dubia* easy to root, whereas, *Albizia lebbeck* moderately hard to root and *Madhuca latifolia* and *Hardwickia binata* are very hard to root species and rooted only when girdling was done on the branches from which cuttings were collected. All species exhibited supremacy of IBA over NAA for all the rooting related parameters. However, it was observed that exogenous application of auxins increased rooting percent significantly over control. It may be attributed to the fact that auxins play multifarious roles related to division and elongation of meristem, differentiation of cambial initials into root primordia and mobilisation of reserve food materials by enhancing the activity of hydrolysing enzymes. The biochemical changes occurring at different stages of rooting revealed that starch percentage, C/N ratio and peroxidase enzyme activity which were higher initially at the time of cutting plantation reduced during root initiation and further at the completion of rooting, whereas, sugar content increased at root initiation from initial value but reduced at completion of rooting as it was consumed during rooting.

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Ecological and Productive Roles of Live Fences in Tropical Agricultural Landscapes

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Although live fences are a conspicuous component of agricultural landscapes in the tropics, there is remarkably little information available on their composition, structure, management and functional roles. Here we present an overview of the ecological and productive importance of live fences, based on detailed inventories (at both the farm and landscape level), studies of local knowledge and management of live fences, socioeconomic surveys, and surveys of fauna in live fences in 4 landscapes in Costa Rica and Nicaragua. The density, composition and type of live fences often varies across different production systems, reflecting differences in farmer livelihood strategies- however most live fences have low local diversity (consisting of only 2-3 planted tree species) and are regularly pruned. Whereas the main productive role of live fences is to delineate pastures and serve as barriers for animal movement, they may also serve as important sources of fodder, fence posts and firewood, with the importance of these different products varying across regions. From an ecological perspective, live fences can play important roles by increasing the total on-farm tree cover, providing habitat and resources for animal species, and enhancing landscape connectivity- though their value for conservation will depend on their species composition, structural diversity and management. Both socioeconomic and cultural factors influence the way in which farmers plant and manage live fences, and ultimately these factors affect the value of live fences for both conservation and productive goals.

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The Role of Trees in Conserving Biodiversity in Contrasting Agricultural Landscapes in Central America

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In Central Amercia where large areas of land have been deforested and converted to cattle production, most landscapes now consist of mosaics of small forest patches interspersed within a matrix of pastures and crop fields. Within these agricultural landscapes, the remaining tree cover occurs as forest patches, live fences, dispersed trees, which may continue to provide habitats and resources for some plant and animal species - yet little is known about biodiversity that is conserved within these agricultural landscapes, or the role of on-farm tree cover for conserving biodiversity. In this study we present results of parallel studies conducted in Cañas, Costa Rica and Rivas, Nicaragua, of the biodiversity present in different types of on-farm tree cover including forest patches, riparian forests, regenerating secondary forest, live fences and pastures with dispersed trees, in landscapes dominated by pastures. Specifically, we compare patterns of species abundance, richness and diversity of birds, bats, dung beetles, and butterflies in different types of tree cover and evaluate the importance of each habitat for conservation. Conservation value of the different habitats varied across animal groups and across the two study sites. However, in general, the more forested habitats (forest patches, riparian forests and regenerating secondary forest) hosted a greater diversity of plant and animal biodiversity and are of greatest value for conservation. Silvopastoral systems are of lesser conservation value, but still retain a significant portion of the landscape's biodiversity and may aid in maintaining landscape connectivity. Implications of these results for sustainable landscape management are discussed.

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A Summary of Agricultural Effects over a 26 Year Rotation of *Pinus Radiata* Agroforestry in New Zealand

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A long term agroforestry trial was planted in 1973 at Tikitere, Rotorua, New Zealand and logged in 1999. The trial comprised a range of final crop tree stockings of *Pinus radiata*, planted into existing pasture. The trees were grown and managed for sawlog production and the understorey pastures grazed with sheep (and cattle) until canopy closure occurred. Agricultural measurements taken during the rotation included pasture production and composition, livestock performance, microclimate changes, soil pH, soil chemical and physical properties and soil fauna populations. Pasture growth declined with increasing tree stocking and age. Pasture botanical composition changed from high-producing temperate pasture species to low-fertility grasses and legumes, reducing feed quality. There was good potential for livestock farmers to graze their stock under trees until canopy closure, although stock performance declined over time. Microclimate changes in years 8-11 included substantial reductions in wind run, increases in grass minimum temperatures and reductions in soil temperatures as tree stocking increased. Soil pH declined with increasing tree age and at higher tree stockings. However, there were positive effects on soil nutrients with P, K, S and Mg increasing or remaining at adequate levels for subsequent pastoral use. Soil physical effects at time of logging indicated that open pasture had higher unsaturated infiltration rates, higher pore volume and more total porosity than forested sites. Earthworm and other soil fauna populations declined with increasing time and tree stocking rate. Overall, changes in soil chemistry and soil fauna populations reflected the change from fertilised pasture to coniferous forestry.

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Manokwari Betel Nut (*Areca* sp.): A New Commodity for Agroforestry in New Guinea

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Manokwari betel nut (*Areca* sp.) has been recently discovered in a jungle of Bird's Head peninsula of New Guinea. This palm is closely related to common betel nut palm (*Areca catechu* L.) but different in leaf shape and its fruits. The leaf has multiple-ranked leaflets similar to Australian fox tail palm (*Wodyetia bifurcata*). Fruits of this palm are bigger than common betel nut and are a very attractive colour of orange - golden yellow and also produce a specific odor. This betel nut has great potential economic value for horticulture and agroforestry. A few studies will be required to promote this palm as one of the main agroforestry commodities in New Guinea.

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Species Composition, Utilization and Silvicultural Practices in Homegardens of Chandanaish Upazila, Chittagong District, Bangladesh

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The study was carried out in Chandanaish Upazila of Chittagong district during April-June, 2003 with a view to find out the species composition, to identify the homestead utilization pattern, profitability of major fruit and timber tree species through investment analysis, to study silvicultural practices as well as constraints of homestead plantation. Data were collected from 80 households, 10 from each map unit and 16 from each farm categories. The sampled farmers were selected using purposive sampling technique. It was found that 32 different fruit and timber trees, 25 medicinal plants and 5 different types of non-timber forest products were grown in homegarden. The investment analysis revealed that longer-term investment on fruit and timber tree species is profitable. The analysis showed that benefit cost ratios was greater than one, net present values were positive and internal rate returns were more than 30%. The distribution of individuals of each species in different diameter classes showed that the maximum percentage of individuals (52.86%) belongs to diameter class less than 10 cm. The quantitative structure of different species showed maximum relative importance value of fruit tree. The relative importance of different uses of homestead trees revealed that most of the species are used for fruit, timber and fuel. Lack of technical knowledge of growing trees, unavailability of space and good quality seed/seedlings were the major constraints for homestead agroforestry production. Production of fruit and timber tree species is highly profitable if modern inputs and production technology can be made available to farmers in time.

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Study of Plant Species Diversity, Management Techniques in the Traditional Homegardens and Their Contribution in Rural Livelihood of a Forest-rich Area of Bangladesh

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An exploratory survey of the traditional homegardens of a selected village in Chittagong district, Bangladesh, was carried out from September-November 2002 to assess the species composition, management techniques and participation of women in different management activities, production and benefit from the system and the impacts of these on the socio-economic life of the villagers. A total of 66 tree species, 3 bamboo, 1 cane, 1 patipata and numerous species of herbs and shrubs were identified from the study area, which consisted of household surveys from five representative zones. Among the fruit and timber tree species *Areca catechu*, *Cocos nucifera*, *Mangifera indica*, *Artocarpus heterophyllus*, *Samanea saman*, *Swietenia macrophylla* and *Tectona grandis* were preferred by the villagers. Generally ornamental and fast-growing species were planted at boundaries of homegardens followed by fruit and valuable timber trees in the inner side and medicinal and flowering plants in spaces adjacent to homegardens. A wide variety of products came from homegardens during the year, with most of the production coming from agricultural crops followed by fuelwood, fish, timber, poultry, livestock, fruit, bamboo, cane and patipata, respectively. Due to changes in family perceptions, women have been participating more in different activities including decision making process. Although villagers practise different cultural operations, their homegardens were not managed scientifically. Most of the homegarden products were consumed by the villagers themselves although a small amount was sold if there remained any surplus. Besides consumption and sale, homegarden outputs are used in different social and cultural activities of the villagers.

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Modelling Farmer Decisions that Affect Tree Cover in Fragmented Landscapes in Costa Rica and Nicaragua

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Farm tree cover is important both for maintaining the productivity of cattle farms and regional biodiversity in pasture dominated landscapes in Central America. The amount of tree cover retained depends upon various decisions made by farmers, so understanding how these decisions are made is vital for developing appropriate policy to conserve desirable levels of tree cover. Here, we present models of farmers' decisions surrounding key actions such as cutting and pruning trees and live fences, weed control, burning and adjustments to cattle stocking density from contrasting landscapes characterized by their fragmentation in Costa Rica and Nicaragua. Farms were monitored and when actions affecting tree cover occurred the farmers were interviewed about the reasons for their decision. The causal explanations provided by farmers were used to construct decision trees that were grouped, generalized and then modeled using Bayesian belief networks. The implications of different decision making models used by farmers are explored with reference to policy drivers that may be manipulated to affect tree cover.

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Productive Roles of Trees in Agricultural Landscapes in Central America

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Agricultural landscapes often retain a conspicuous and abundant tree cover, in the form of small forest patches, riparian areas, live fences and dispersed trees in fields. This tree cover is spatially heterogeneous and varies as a function of farmer livelihood strategies. Here we present an overview of the types and patterns of tree cover present in landscapes dominated by cattle production, the factors that create these patterns and the importance of trees to farm productivity, using data from four contrasting landscapes in Costa Rica and Nicaragua, that are dominated by pastures and have a heterogeneous on-farm tree cover. We also explore some of the socioeconomic and biophysical factors that influence tree cover patterns at different scales and in different regions. Tree cover in all four landscapes consists of small forest patches, narrow riparian forests, small patches of regenerating secondary forest, live fences and large areas of pastures with dispersed trees but the patterns of abundance, density and spatial arrangement vary across landscapes. Factors that influence the patterns of tree cover in landscapes include the products derived from cattle, the level of farm intensification and the history of the landscape. Farmers manage trees for a variety of products and services, but the importance of these varies across landscapes, reflecting differences in livelihood strategies and socioeconomic contexts. Understanding current productive and service roles of these trees in relation to their size and spatial distribution is vital for developing strategies for their conservation as keystone landscape elements.

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Fodder Value of Farm Trees in Fragmented Landscapes in Chiapas, Mexico

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Smallholder farmers in southern Chiapas with commercial cattle integrated with subsistence cultivation of maize and beans, and, secondary forest plots of various ages, rely heavily upon tree fodder in the dry season. Twenty farmers in two sites were interviewed about their fodder tree utilisation and samples of fodder trees were collected, identified and analysed in a laboratory for their nutritive value. The production system was characterised and farmers' assessments of fodder value were compared with laboratory analyses. Thirteen species with long leaf retention were important for dry season cattle diets. Farmers preferred species that they considered had high palatability and high nutritive value which correlated well in some species with crude protein, dry matter digestibility and results from a controlled palatability trial in sheep. Local knowledge about *Acacia angustissima*, *A. pennatula*, *Leucaena brachycarpa* and *Pistacia mexicana* was complementary to scientific information on these species and critical for developing silvopastoral systems in fragmented landscapes in the region.

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Legal Mechanism for Protecting the Contribution of Small Scale Farmers and Communities to AFTP

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The success of AFTP domestication and commercialization will depend on the benefits remaining with the small-scale farmers and their local industries and markets. This will depend on finding ways to satisfactorily protect the intellectual property rights (IPR) of the farmers and communities investing in the process. As with all other plant species, trees became subject to new international regulations with the coming into force of the Convention on Biological Diversity. Moreover, over 50 countries have started to develop national legislation covering how to access to and benefit share from plant genetic resources should be handled. Yet, trees have not undergone the same level of scrutiny from advocacy groups or government watchdogs as commercial crop or medicinal plants, due in part to a lack of commercial interest from seed multinationals, and to the lack of harmonization of national laws on genetic resources of agricultural species and forest genetic resources. For example, although western methods of IPR may provide a useful starting point in developing mechanisms to share benefits and recognize famers' IPRs, actual experience of AFTP has also demonstrated their limitations. For example, even though using UPOV type PBRs seems the most appropriate type of IPR, there are significant problems and issues that limit its ability to benefit small farmers. This paper reviews existing trends for protecting farmer-domesticated germplasm (cultivars, improved varieties, etc.), considers the inadequacy of existing systems, explores options for protecting farmer-domesticated germplasm, and suggests possible steps to effect protection for third world farmers worldwide involved in participatory domestication.

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Alston trees (*Ailanthus triphysa* Dennst.) for Kerala Homesteads

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The State of Kerala, latitude 80°18' North; longitude between 740°52' and 770°24' East, situated on the southwest coast of the Indian Peninsula, is characterized by a farming system in the homesteads from time immemorial. These homesteads or small family farms cover the entire state except the plantation zones on the forested hills and lowland paddies on the coastal front. These homesteads are also endowed with a blend of diverse farming enterprises. Agroforestry components comprising tree perennials contribute a unique structural diversity characteristic to these places. A recent study by the Regional Agricultural Research Station, Kumarakom, on tree components of the homesteads of central Kerala covering Kottayam, Pathanamthitta, and Ernakulam districts revealed that Ailanthus triphysa (Fam: Simaroubaceae) is an important component among the woody perennials in these homesteads. The aesthetic and pleasing tree architecture, leaf characteristics, straight and tall bole, tolerance to pests and diseases, ability to thrive under low fertility and drought conditions, apart from its utility as soft wood timber for match-stick and plywood industry, make it a versatile agroforestry component in the homesteads of Kerala. This paper elucidates the potentials of Ailanthus as a candidate species for Kerala homesteads and for avenue planting along the State Highways in the context of its adaptation to the agro-ecology of Kerala homesteads.

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Allelopathic Effect of *Leucaena leucocephala* on Germination and Growth of Intercrops

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This paper addresses the allelopathic influence of aqueous extract of *Leucaena leucocephala* Lam de vit. under laboratory conditions and influence of soil beneath *L. leucocephala* plantation on seed germination and seedling growth of *Triticum aestivum* and *Glycine max.* The studies were conducted at National Research Centre for Agroforestry, Jhansi. The laboratory studies exhibited that aqueous extract of fresh leaf, flower and pod stimulated seed germination and seedling growth of *T. aestivum* and *G. max* at lower concentrations (up to a concentration of 40%), and inhibited significantly at higher concentrations (80-100%). The aqueous extract of decomposed leaves also followed the same trend. Mimosine concentration was estimated in fresh leaves, flower, pods and decomposed leaves. The maximum amount of mimosine was present in pods and minimum in decomposed leaves. The pattern of influence revealed that maximum inhibition was due to aqueous extract pod followed by flower, fresh leaves and decomposed leaves. The nursery studies revealed that treatment consisting of hundred percent soil beneath the *L. leucocephala* plantation inhibited the germination, growth and productivity of the intercrops and maximum values were recorded for treatment 1 : 3 (soil beneath *L. leucocephala* : normal field soil). In the present studies it was observed that the mimosine at lower concentrations enhanced the seed germination, seedling growth and productivity in *T. aestivum* and *G. max* and inhibited at higher concentrations. Thus, the productivity of intercrops can be enhanced by incorporating the mulch of *L. leucocephala* to get optimum growth and yield at lower concentrations of mimosine.

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Biomass Yield and Energy Value of Some Agroforestry Tree Species of North-east India

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The above-ground biomass yield of seven eight-year-old agroforestry tree species viz. Albizia moluccana, Bauhinia purpurea, Ficus auriculata, Michelia oblonga, Parkia javanica, Robinia pseudoacacia and Symingtonia populnea grown in an agroforestry plantation at Barapani, Meghalaya (India) were assessed. Various physico-chemical properties of wood such as moisture content, ash content, density, silica, nitrogen, and volatile matter were determined. The gross heat of combustion was determined in a bomb calorimeter. Fixed carbon content was calculated by subtraction. Fuel Value Index (FVI) of each of these species was calculated considering density and calorific value as positive character and ash content as negative character. Biomass production by each component of these tree species viz. stem, branch and foliage was determined and total biomass was calculated. There were significant differences in the above-ground biomass production of these tree species. P. javanica yielded the highest biomass followed by F. auriculata, A. moluccana and M. oblonga. FVI was found to be the highest in M. oblonga followed by A. moluccana and R. pseudoacacia.

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Diversification of Traditional Agricultural Crop Rotation through Poplar Based Agroforestry in Indian Punjab

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Punjab is a highly agrarian state, but its forests occupy only a small fraction (290,000 ha) of the state's 5.04 million ha of land area. Since it is not possible to divert the fertile agriculture land to forests in view of prevailing socio-economic and agro-climatic conditions favorable for agriculture, the only option to increase the area under tree cover is to integrate tree species with agricultural crops on farmlands. Poplar (*Populus deltoides*) has found a comfortable place for inclusion under agroforestry systems. Productivity of poplar is more than five times the productivity of forest plantations and seems to be a potentially viable land use system for maximum and sustainable productivity on farmers' fields. All the poplar adopters in the state cultivate agricultural crops including vegetable and flower crops, whereas, 8.33% farmers grow fruit plants, 15.74% rear honey bees in their poplar plantations and 37.96% follow pastoral component in poplar-based agroforestry system. With intensive management of poplar in agroforestry system, farmers are presently earning up to US$1700 to 2000 ha/year against approximately US$600 to 750 from rice-wheat rotation. In the near future, the area under poplar-based agricultural system in the state will increase. Presently, the majority of farmers are planting G48 clone, however, some other fast-growing clones (e.g., S_7C_8, S_7C_{15}, S_7C_{20}, WSL 22, WSL 39, 113324, Uday, etc.), have become popular among farmers. Present paper will deal with the diversification in crop rotation under poplar-based agroforestry systems and more specifically on wheat production under poplar-based agroforestry system.

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Fractal Patterns in Species Distributions of Some British Scarce Plants

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The spatial distribution and fractal structure of two British scarce plants, *Lobelia urens* (heath lobelia) and *Phyteuma orbiculare* (round-headed rampion), have been examined at several different scales. The two species have similar degrees of local patchiness at scale coarser than 50 km and have contrasting coarse-scale between 50 km and 1 km scales, but differed consistently in the slopes of their scale-occupancy curves distributions at scale finer than 1 km. The slope of the log-log plot of *L. urens* is not constant, but varies systematically with spatial scale, and from habitat to habitat at the same spatial scale. Abundance estimates suggest that the species *P. orbiculare* is found to be clumped at all scales, whereas *L. urens* is dispersed at intermediate scale. Fractal dimension analysis suggests that this changes through scale. The distribution varied in their pattern from highly clumped to randomly dispersed. Fairly predictions of *L. urens* can be made from 50 m and 200 m. Some issues affecting management of species abundance, as well as underlying mechanisms and conservation schemes, have been highlighted.

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Characterization of Coconut-based Agroforestry Systems in Melanesia, a Prerequisite for their Agroecological Evaluation

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The extension of coconut plantations in Melanesia, combined with the growing population, raises questions regarding the sustainability of traditional cropping systems. Mixed systems have been developed, associating a number of annual and perennial crops with coconut trees. A diagnosis of the performance and sustainability of these systems appears to be an essential step for their efficient management. This paper presents the methods and results used to characterise these systems. The study was undertaken on Malo (Vanuatu), an island that is representative of Melanesian copra production systems. Due to the high agrobiodiversity on smallholder coconut plantations, the notion of “cropping situation” was adopted for their analysis. This is defined as “a combination of a coconut development stage with a structural group” which refers to a type of vegetation’s structure on the plantation. We investigated the diversity of cropping situations at a given time in order to overcome the difficulty of studying such long-term perennial crops. Representative target areas for field work were first identified and located using the “zonal mapping” methodology. Secondly, a large sample of coconut plantations in the target locations were characterised in order to represent the broadest possible range of cropping diversification. Then the main cropping systems and their patterns were determined through an analysis of cropping situations and their development over time. An agropastoral and an agroforestry coconut-based system were identified, and both have transitional cropping situations that highlight their flexibility. These systems and their temporal patterns will be characterized for their functional evaluation.

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Agroforestry Practices for Restoration of Degraded Pasture and Water Conservation in the Atlantic Forest Biome of Brazil

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An on-farm research trial was set up in Itaperuna County, located in the Northwestern region of Rio de Janeiro State, Brazil. The trial comprises 4 ha and consists of already established braquiarão (*Brachiaria brizantha*) and jaragua (*Hyparrhenia rufa*) fodder grasses in steep slopes. A creek cuts the area at the midsection. A forested riparian buffer strip was installed beginning at the creekbank. The riparian buffer strip is 6 m wide and contains three rows of trees. The trees planted were laurel (*Cordia alliodora*) and angico vermelho (*Anadenanthera macrocarpa*), spaced 3 x 3 m. A hydro-sediment station was set up for monitoring the sediments and water quality. About 30 m above the riparian buffer strip a silvopastoral system was established with the following characteristics: trees were planted in six m wide strips, with three rows, prepared across the slope and separated by 20 m wide strips. Trees planted were *Acacia mangium*, laurel (*Cordia alliodora*), araribá (*Centrolobium tomentosum*), and ipê roxo (*Tabebuia avellanedae*), spaced 3 x 4 m. All trees were planted in January of 2002. The main objectives of this study are: to evaluate tree growth performance; and, to assess the impact of agroforestry systems on soil erosion control and water quality. Preliminary results showed that *Acacia mangium* had the highest growth performance reaching an average height of 2.43 m at 15 months of age. The budget necessary for the establishment of agroforestry systems was estimated at US $ 384.57/ha. All costs have been supported by PRODETAB Project number 106-02/99.

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Silvopastoral Systems for Recovery of Degraded Pasture on Rolling Topography of the Atlantic Forest Biome, Brazil

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The main objective of this study is to recover degraded pastureland with the introduction of fodder grasses associated with eucalyptus in a meat production system. This on-farm research trial was set up in Itaperuna County, located in the Northwestern region of Rio de Janeiro State, Brazil. The total experimental area comprises 6 ha, divided in three plots of 2 ha. Each plot was divided in three sections with electric fences. The forage grasses introduced in each plot were: braquiarão (Brachiaria brizantha), Tifton 85 (Cynodon spp.) and suazi (Digitaria swazilandensis), associated with trees of Eucalyptus torelliana. The trees and forage grasses were planted simultaneously from December of 2001 to January of 2002. Tree seedlings were planted in pits, spaced 20 x 20 m, total of 25 trees/ha, and fertilized at the following rates: 2 liters of farmyard manure; 150g of P2O5; and 200g of NPK 4-14-8 per pit. The herbaceous forages were planted in furrows spaced by 80 cm and fertilized with 100kg of P2O5 and 80kg of K2O/ha. Trees were protected with wire fences. Preliminary results showed that fodder grasses had provided significant growth rates to beef cattle, with initial body weight of 210 kg and high carrying capacity (500 g/animal/day and 3.5 UA/ha; 390 and 3.6; and 380 and 2.9 respectively, for Tifton 85, Braquiarão and Suázi). E. torelliana growth rates were satisfactory (1.7 and 2.8 m in average height, respectively at 9 and 15 months of age). These trials are being conducted under PRODETAB Project nº 106-02/99.

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Ground Cover Selection for Herbicides Remediation in Agroforestry Riparian Buffer

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Agroforestry-related research interests involve screening the best suitable ground cover species for tree-shrub-grass riparian buffer strip to sequester and degrade many herbicides in surface runoff and subsurface flow. In our research project, we investigate the effects of many forages on transport and transformation of the herbicides. Other studies involve evaluating sensitivity of the many shade tolerant forages to the diluted herbicide in the surface runoff, and the related detoxification mechanisms of these forages. To evaluate the bioremediation capacity of various ground cover treatments, in these studies, concentrations and distributions of the herbicides and their metabolites in the leachate, soil and plant tissues are determined by solid phase or liquid-liquid extraction followed by high performance liquid chromatography UV spectroscopy (HPLC-UV), HPLC mass spectrometry (HPLC-MS), HPLC tandem mass spectrometry (MS/MS), HPLC flow scintillation analyzer (HPLC-FSA) or gas chromatography tandem mass spectrometry (GC-MS/MS). Additionally, several microbial enzymatic activity, such as β-glucosidase and dehydrogenase activity, and fluorescein diacetate activity (FDA), were correlated with the herbicide degradation capacity in various forage treatments.

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The Role of Genetic Tools in Tree Domestication

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Genetic tools, both molecular and quantitative, can provide invaluable information on the extent and response of genetic resources during the early stages of tree domestication. Case studies are presented from tropical America and Africa to demonstrate how genetic tools can be used to develop best practice approaches to domestication. At the range-wide scale, genetic tools such as phylogeographic analysis and common garden provenance assessment, can identify regions within the natural range of a species which harbour high levels of genetic and adaptive variation, and highlight regions between which material should not be exchanged. At the landscape level, population genetic analysis, gene flow assessment and quantitative seedling assessment can help understand the dynamics of gene distribution within natural populations, advise on best source material for collection and establishment, and indicate how domesticated material may be genetically eroded by gene flow from locally adapted provenances. Such baseline studies are particularly informative for devising domestication strategies for semi-natural or low input systems.

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Influence of Training and Sources of Information on Adoption of Tree Conservation Practices among Upland Farmers in Southern Leyte, Philippines

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This study was conducted in a Community Based Forest Management sites in Southern Leyte from April to May 2000. Generally, it aimed to determine the effects of information sources and training-related factors on the adoption of tree conservation practices in the upland environment. A pre-tested semi-structured interview schedule was used in collecting the data from 60 randomly-selected program participants. Data were analyzed using descriptive statistical tools. Farmers adopt tree conservation practices through their own learning and experiences they had acquired from their forefathers. They protect a tree that grows from their respective farm lots from being illegally cut, they planted trees in their farm and even assist government technician in the dissemination of conservation practices to other farmers. Results show that conservation practices in the study sites were also learned from other sources including interpersonal communication with various sector representatives and from mass media. As to training, majority of the respondents had attended different kinds of training program being implemented by the Department of Environment and Natural Resources (DENR) and other organizations. They claimed that the trainings program had helped them increase their awareness about the importance of conservation, strengthened their indigenous tree conservation practices and gave them the motivation on the adoption of tree conservation and domestication technologies. Indeed, it is recommended that recent upland technologies be effectively provided to upland farmers through various sources especially interpersonal media to hasten farmers' acceptance and adoption.

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Modeling a Shelterbelt and Cropping System

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Estimation of the multiple benefits and costs of a shelterbelt, which vary substantially over its lifespan, is a complex task that is best done by a computer. Our research team is building a model, called the Shelterbelt Agroforestry Modeling System (SAMS), that simulates crop production on a field with a shelterbelt for the lifespan of the shelterbelt. SAMS is being developed as a web site (http://oriole.ae.iastate.edu/sams/) that will be a decision support tool for individuals interested in establishing shelterbelts. As farmers generally consider the impact of shelterbelts on crop yield to be the primary potential shelterbelt benefit, estimation of this benefit has been the focus of our research. Presently, SAMS uses the CERES and CROPGRO models to simulate crop yield. To use these crop models to simulate yield across a sheltered field requires estimates of microclimatic conditions across the field, which is done by equations developed from data collected for a variety of types of shelterbelts. Presently, SAMS uses estimates of crop production over the lifespan of the shelterbelt and user-supplied costs to estimate the net worth of shelterbelts in the Midwestern United States. Users enter their own costs, ranging from cost of establishing the shelterbelt through periodic maintenance costs. Additional benefits, such as carbon sequestration and reduced wind erosion, and additional crops will be added in the future.

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Proposal for Establishment of Agroforestry Systems in Agricultural Border Areas in the Brazilian Amazonian Region

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The deforestation of the Amazonian region during the last decade was of the order of 13.5 million ha. The state of Mato Grosso participated with 36.6% of that total. In the southern area of the Brazilian Amazonian region, the intense dynamics of human occupation and forest transformation in the form of expansion of pastures and cultivated areas, has produced a large zone characterized as an “agricultural border”. This border area composes the “Arch of the Deforestation” and burning zone, and includes about 188 municipal districts covering an area 600 km wide. The establishment of agroforestry systems in those areas can start from areas already opened and degraded or from primary or secondary forests. In opened areas the methods of establishment of agroforestry systems were already well-studied, however, for establishment in existing forests, the techniques were not still defined. In this regard, the objective of this work is to propose a technique for establishment of agroforestry systems, starting from forests, and operating from a forest inventory of trees with diameter at breast height (DBH) of 5 cm or greater. In that inventory would be surveyed relevant information about the form, size and health of the trees and their geographical location, making possible the application of silvicultural treatments of appropriate intensity to supply the ecological conditions favorable to the agriculture and/or animals species (farm production) to encourage its introduction, in agreement with the agroforestry system design. This system aims to reduce the biodiversity and genetic loss, by eliminating clear cutting.

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Assessing Agroforestry Systems in Large Areas

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For a sustainable management of any type of resource, it is imperative to know how much it is, where it is located and what the changes are. In this context, mapping and forest inventory activities play an important role in natural resources management. In forestry there are many references on this topic, but there are not many references on the assessment of agroforestry systems for large areas. This large area information is needed to generate a synoptic view of the general frequency and relevance of trees in agroforestry systems, and is among the elements required to define guidelines for the management of trees outside forests. Among the typical questions to be solved are the definition and classification of agroforestry systems for inventory purposes, the data sources to be used (remote sensing, field sampling), the definition of the variables to be observed, and the sampling and response (plot) design. In this paper some practical experiences in sampling and mapping approaches in large areas obtained in two different research projects in Central America are discussed, the main problems found are listed, and analysed.

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Evaluation of Four Propagation Methods in Field of *Trichanthera gigantea* and Establishment Costs for Protein Bank

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The yatago (*Trichantera gigantea*), a multipurpose tree, is a species with high potential for the production of forages and for the conservation of basins in Venezuela and other countries. However, its establishment is limited by high costs. In this sense, this investigation consisted on evaluating the effects of propagation methods in field of *T. gigantea*, with the purpose of analyzing characteristics for its propagation, establishment and costs. Different propagation methods were evaluated under a totally random design, with four treatments: T1: Nursery plants in plastic bags, T2: Stakes of naked root, T3: Direct propagation of a stake, and T4: Direct propagation of two stakes. Its variables were evaluated 120 days after, for % of survival, number of buds, fresh and dry weight of the forage, and % of dry matter for treatment. The establishment costs were analyzed, through the method of partial costs. The % of survival did not present differences among the treatments (p=0.933 K-W), while the variable number of buds, fresh weight, dry weight and % of MS presented differences (p=0.000). With these results an economic evaluation was carried out where it was determined that the method of direct propagation of a stake by point, reduces the costs in 22.3%.

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Four Methods of Vegetative Propagation of Mulberry (*Morus alba*) under Controlled Conditions

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Morus alba is a species traditionally used as a silkworm feed. It is broadly known and distributed in the planet. However, its use as livestock feed and the ways to propagate it are not well known. In this sense, the present work seeks to identify methods of vegetative reproduction and establishment of protein banks based on vegetative material. Two hundred stakes of Morera were divided into four treatments in a totally random design: T1: Control (straight cut), T2: Peeling (of cortex and phloem), T3: Diagonal cutting (in angle higher than 45°), and T4: Hormone treatment (Indolbutilic Acid 0.4%). The studied variables were: % of stakes with sprouted leaf buds, % of stakes with roots, and length of the roots (cm). For the variable % of stakes with sprouted leaf buds the results indicated that there were differences among the treatments (p=0.001). Peeling and diagonal cutting treatments presented highest values with 100% and 92% respectively, while the other treatments achieved 76% in Control and 82% in Hormone treatments. No significant differences were found between treatments for percentage of stakes with roots, (p=0.978), and length of roots (p=0.211). In conclusion, the treatment of vegetative materials did not increase the number of roots, but increased the number of leaf buds and therefore may contribute to the establishment of protein banks.

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Genetic Variation in an Endangered Afromontane Medicinal Tree Species, *Prunus africana*

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Most forest trees in tropical Africa are under threat of extinction due to deforestation for farming and human settlement, over-harvesting of timber and non-timber products and climate change among others. One such species is *Prunus africana,* whose bark extract is in high demand for the treatment of benign prostatic hyperplasia, a prostrate gland disorder. Destructive felling of the tree raises concerns on the long-term sustainability of harvesting and its conservation; *P. africana* is listed on Appendix II CITES. Incorporation of *P. africana* in agroforestry systems appears to be the best alternative of ensuring their survival and sustainability of bark harvesting. Such plantings will reduce the pressure exerted on natural forest stands and benefit the farmer from sale of bark. An understanding of the patterns of variation within and among species populations is essential for devising optimum genetic management strategies for its conservation and sustainable utilization. However, this knowledge is currently lacking for most tropical African tree species. Random amplified polymorphic DNA (RAPD) analysis has been used in three independent studies to partition variation within and among populations sampled from 5 countries across the geographical range of the species (Cameroon, Kenya, Uganda, Ethiopia and Madagascar). Ugandan material has been found to be most similar to the populations from Cameroon while the Malagash populations were most distinct. Kenyan and Ethiopian material was also found to be very similar. Significant differences exist among populations both within and among countries. The implication of these findings to appropriate approaches for conservation and cultivation are discussed.

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Why Domestication of Medicinal and Food Plants: A Case Study from Mt. Moroto Forest Reserve, Uganda

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The study was funded by UNDP/GEF Cross-border Biodiversity Project and implemented by myself for MUIENR. It aimed at designing a participatory biodiversity monitoring and evaluation framework for Moroto, Napak and Sango Bay Forest reserves. These reserves contain biodiversity of international importance in Uganda. This paper focused on biodiversity of medicinal and food plants in Moroto forest reserve found in Karamoja region of northeastern Uganda. The objectives of the study were: to identify indicator species, establish their abundances, trends and uses. Participatory Rural Appraisal (PRA) methods were used to identify and collect information on trends of the medicinal and food plants since 1950 to 2001. The respondents were elders, middle aged and the young who were gazetted inside the reserve. In Karamoja, elders are respected for their wisdom, and in this study, they specifically provided vital historical information. Data entry and analysis were done in Microsoft Excel, by descriptive analysis with graphical illustrations. I found both medicinal and food plants to have been significantly decreasing since 1950 to 2001, due to over-harvesting. The medicinal plants are very important for treatment of most diseases, while the food plants contribute a significant role in food security. With the increasing population in the forest reserve, these resources may be depleted; therefore, there is a need for domestication before they become extinct and to conserve biodiversity of Moroto forest reserve.

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Innovation of Farm Forestry Practices by Farmers: A Case Study from the Guraghe Highlands, Southern-Central Ethiopia

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Rural households of the Guraghe Highlands have been exposed to chronic wood product shortages and environmental deteriorations owing to excessive conversion of forestlands into low-yielding agriculture and pasture. Since the early 1980s, tree planting by villagers has been increasingly promoted as an alternative means of overcoming worsening environmental and economic problems. This approach was largely viewed as an effective means of rehabilitating fragmented landscapes and conserving the threatened biodiversity resources. A socio-economic survey and participatory observations were conducted in selected villages of three agro-ecological zones. Results indicate that farmers plant several tree/shrub species on their farms mainly to meet household wood needs and for cash generation. Ecological protection is only viewed as a subsidiary objective. Cash generation from eucalypt woodlots is largely confined to some mid-altitude households with readily accessible road networks. Highland households are also constrained by shortage of landholdings and lack of labor. Despite a history of poor support from governmental agencies, farmers are still planting eucalypts as a major on-farm tree species. Significant adoption of multipurpose tree/shrub species by farmers is restricted notably by lack of awareness and seedlings, weak marketing infrastructures and arrangements, and ecological limitations. Conventional top-down planning approach and high priority accorded to food-crop production further diminish the role of agroforestry in rural land management practices and undermine the success of government extension programs. The acknowledged merits of dispersed leguminous and other multipurpose tree/shrub species in the study area reveal a substantial potential of agroforestry in increasing the productivity of farmlands and distributing risks.

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Agroforestry Potential of Four Key Productive Non-timber Forest Species in a Shifting Cultivation System of Cameroon

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Coula edulis, *Dacryodes edulis*, *Irvingia gabonensis* and *Ricinodendron heudelotii* are indigenous forest trees, which are valued throughout the humid tropics because of their multiple uses by small-scale farmers. Although they have been recognised as key components to achieving sustainable tropical agriculture and forestry, there is little specific research that substantiates the potential of these trees as promising agroforestry species. More particularly, there is a lack of reliable quantitative information regarding their biology, ecology and fruit production in land use types other than forests. A study was undertaken to assess the density, population structure, phenology and fruit production of the target species in fallow lands of various ages in southern Cameroon. Results from this study will lead to recommendations as to how these species should be used in agroforestry systems that will improve the productivity and guarantee the sustainability of shortened fallows. The four study species were recorded at very low densities (< 10 individuals of more than 10 cm dbh), suggesting the need to develop preferential management of regeneration for these species. Apart for leaf flushing, flowering and fruiting phenology of these species were seasonal, with irregular flowering/fruiting observed for some *Dacryodes* and *Irvingia* individuals over the two years of monitoring. Fruiting was concentrated between July and October (and up to January for *Ricinodendron*), coinciding with the rainy season. Regression analyses showed that tree size parameters are correlated with fruit production for some species, but generally, do not explain an important part of the production data of the study species.

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Resolving Forest Fragmentation and Unsustainable Land Use Practices with *Landscape Agroforestry*: A Rural Development Proposal for the Pacific Slope Region of the Tilaran Mountain Range, Costa Rica

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Over the last half-century, Costa Rican forests have transformed from predominantly contiguous to highly fragmented ecosystems. In fact, during the 1980s Costa Rica experienced the world's greatest deforestation rate. This land use change was a result of conversion from primary and secondary forest to pasture and permanent agriculture. In the case of Costa Rica's largest private biological reserve, the Monteverde Cloud Forest, an adjacent agriculture matrix replete with cattle grazing and coffee production provides only modest habitat for endemic and migrating wildlife. Forest removal has also been associated with regional climate change and the disappearance of amphibians. Furthermore, local natural resources and alternative economic opportunities have diminished while farmers continue to depend upon unstable cattle and coffee markets. In response to deteriorating ecological and socioeconomic conditions, the Monteverde Institute is proposing a long-term *landscape agroforestry* development project. A regional transect methodology will serve as a tool to inventory and diagnose current land use and forest fragmentation patterns from the boundary of the Monteverde Cloud Forest near the Continental Divide to the Pacific Ocean. This data will represent a benchmark from which to monitor reforestation efforts based upon agroforestry interventions that are appropriate to environmental life zones and farmer needs. Moreover, life zone-specific nurseries, meteorological stations, and on-farm experimental plots will provide resource, research, and educational opportunities. The ultimate objective of this project is, therefore, to expand critical habitat patches and create habitat corridors along the altitudinal gradient while collaborating with farmers to develop sustainable land management practices and diversify production.

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The Cultural, Social and Economic Importance of the Marula Tree (*Sclerocarya birrea*) in South Africa

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The *Marula* tree *Sclerocarya birrea* is predominant as a scattered tree in farmlands in southern Africa. This paper analyzes the cultural, social and economic importance of the tree in South Africa. Results show that the tree is prolific in the production of fruits, which are high in Vitamin C. The fruit is the main ingredient used to manufacture the liquor Amarula Cream, regarded as one of South Africa's most successful exports. The Zulus use the seed oil as body massage and the Vendas use the same for meat preservation. The dioecious feature of the tree is extensively used in ethnomedical practices to increase pregnancy potency in women and to predetermine the sex of an unborn baby. It is claimed that a woman who takes infusion from a male tree would have a baby boy while infusion from a female tree would result in a girl. This gender-related discrimination further manifests in production and consumption of *Marula* products such that women undertake the processing while men engage in consumption especially the liquor. A very tasty alcoholic beverage known locally as "Manpoer" is believed to make adult men weep. Communities ascribe different names such as sacred tree, marriage tree, sex determinant, *sangoma* dice, fertility tree and elephant tree to *S. birrea*, which attest to its importance in the country. The paper concludes that these many attributes would upgrade the tree to wider uses in medicine, commerce and industry if proven and recommends well-ordered research interventions to verify the claims.

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Fruit Characteristics of *Irvingia gabonensis* in Production Zones of Central and Southern Cameroon

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Fruits and almonds of *Irvingia gabonensis* constitute the basis for its agroforestry importance. Yet, data are lacking on its fruit characteristics in production zones. A study was carried out in the framework of the project "Agroforesterie dans le bassin du Congo: séquestration du carbone" to assess morphological and quality traits of one thousand fruits collected in five localities from Central and Southern Cameroon. Ten productive trees were selected per site in a one kilometer radius. Fresh mass, width and length of each fruit were measured; color, shape, taste, fibrous and water contents were qualitatively assessed. Fruits of *I. gabonensis* were either bitter or sweet or both, juicy or not, with a variable fibrous content. They were round, oval or irregular shape. Mature fruits were green or yellow orange. Fruit fresh mass varied between 40 and 150 g; length varied between 39 to 67 cm and width from 36 to 60 cm. The biggest fruits were collected in Southern Cameroon and were juicier and less bitter. Fruits of *I. gabonensis* were collected in secondary forests in Southern Cameroon while they were collected in fallow lands and small cocoa plantations in Central Cameroon.

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Seed Germination Characteristics of *Irvingia gabonensis* in Cameroon

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Irvingia gabonensis (Aubry-Lecomte), a multipurpose tree species, is widely distributed and preserved in the humid forest of Cameroon. Bark is used in traditional medicine, fruits and oil-protein rich almonds are traded in local and urban markets and internationally in Central Africa and tree could offer high carbon sequestration potential. However, seed dormancy is long and natural germination erratic. Laboratory trials were carried out to assess the seed germination requirements of this species. After removing the mesocarp of seeds from various provenances, ten seeds per treatment were subjected to manual scarification, concentrated sulfuric acid, dry heat and hot water pretreatments at three temperatures (60°C, 80°C and 100°C) for 30, 45 and 60 sec each. Treated seeds were sown in sterilized sand and kept on greenhouse benches for germination. Fourteen days after treatment, 100% of manually scarified seeds had germinated against 60% from the control. Three weeks after treatment, 60%, 70% and 10% of seeds from dry heat, the control and hot water pretreatments had germinated respectively. With the dry heat pretreatment, germination rate was directly related with time of exposure. Seeds treated with sulfuric acid did not germinate.

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Comparative Tree Growth of Thinned Loblolly Pines for Use in an Agrosilvopastoral System in the Southern United States

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From 1979 to 1983 loblolly pine (*Pinus taeda*) trees were planted at spacing of 12' x 12' (1ft = 0.3m) as part of a natural resource conservation program to control soil erosion on a farm in Quincy, North Florida. At twenty to twenty-three years of age in November 2002 these trees were systematically thinned to a spacing of 12' x 42' in preparation for an agrosilvopastoral system using bahia grass and bermuda grass as pastorable pastures. Prior to establishing these pastures in March 2003, the diameter at breast height (DBH) of trees were measured in order to determine the effect of thinning and later the impact of pastorable pastures on tree growth and productivity. Diameter was determined by using a handheld caliper. Mean diameter for all trees was 7.64 ft, 8.21 ft and 8.92 ft at 4-5, 11 and 19 MAT respectively. The increased tree growth (20%) as represented by DBH, in just 20 months may be due to the wide spacing achieved from the thinning process allowing for more light penetration and reduced competition for other resources amongst the trees following thinning. Other observations included wind damage of existing trees and the rate of decay of tree stumps following thinning.

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Utilizing Meat Goats in Loblolly Pine Agroforestry Systems

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Sustainable land-use systems require the utilization of components in a farming operation that leads to long-term productive agriculture. Agroforestry systems are now widely recognized as systems for sustainable agricultural productivity. Agrosilvopastoral systems in the Southeastern United States, especially in the state of Florida, concerns cattle and planted pines. Thus, the need for agroforestry research using meat goats in relation to limited-resource farmers could not be overemphasized. It provides for an alternative agricultural system with possibilities for increased economic returns to limited-resource farmers in Northern Florida, Southern Georgia, and Southern Alabama. The project was undertaken to determine the stocking rates of meat goats in a 20-year-old loblolly pine (*Pinus taeda*) plantation that was thinned to a spacing of 12' x 42' (1ft = 0.3m). Two breeds of meat goats averaging 2-3 years old were obtained from Texas and bred after three months on the Quincy (FL) Research Center. The kids produced were then placed on the agroforestry plots containing bahia and Bermuda grass. Goats 30, 60 and 90 days old after weaning were introduced into three separate tree blocks fenced with electric fencing. Three stocking rates for each breed and age group were established (8, 12 and 16 goats per acre respectively). Live weights of the goats were taken weekly for three months while pasturable pastures were evaluated for their productivity. Results indicated that stocking rates for goats would be critical for their performance in an agrosilvopastoral system. Breed and age of goats were important in this production and land-management system.

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Indian Jujube Cultivars for Peri-urban Agriculture Diversification in Sub-Saharian Zone of Burkina Faso

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In the Sahel zone, there is an increasing interest of farmers in conserving and enriching tree diversity in their farms as source of food and incomes. Even though local variety of *Ziziphus mauritiana* Lam. was ranked as one of the most preferred species, its fruits are small whereas farmers are interested in varieties producing big and tasty fruits. A factorial experiment in a split-plot design was carried out to assess the performance of 3 introduced progenies of Indian jujube in a peri-urban garden in Ouagadougou, Burkina Faso. Investigated factors were irrigation (irrigated with 30 l week^{-1}, non-irrigated), rock phosphate containing 25% P_2O_5 (0 and 150 g P tree^{-1}) and variety (Gola, Umran, Seb and local as control). Twenty months after planting local variety (100%) had the highest survival rate followed by Gola (95%) and Umran (83%). The highest growth was obtained with Umran in treatment associating irrigation and rock phosphate with mean collar diameter and height of 7 cm and 3 m, respectively. Conversely, Seb gave the lowest growth when rock phosphate was applied whereas growth of local variety was not improved by application of irrigation, fertilization or their combination. Gola gave the highest fruit production (15.3 kg tree^{-1}) and the local the lowest (0.6 kg tree^{-1}) when applying irrigation and fertilization together. Therefore, Gola may be recommended in intensive systems like peri-urban gardens while Seb needs further investigation to improve its water and nutrient use efficiency through either better application timing of water and fertilizer or symbiotic association.

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Utilization Potentials of *Parkia biglobosa* Tree Species in South West Nigeria

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Parkia biglobosa is an important indigenous multipurpose tree species that has age-long association with traditional agriculture and of diverse usage in most Sub-Sahara African countries. It is popularly called the African locust bean tree. It has high nutritional, economical, industrial, medicinal, and social values in the livelihood of the communities in the low-income rural areas of Nigeria. The importance of this notable non-timber forest product (NTFP) in the provision of food, medicine, manure, fuel, fibre, and livestock feed, shade, bee food, and stabilization of degraded environment are highlighted. Some of the constraints discovered to impede the development of *P. biglobosa* were lack of adequate information, land tenurial problem, low-technology based processing methods, poor knowledge transfer and poor understanding of its numerous potentials. The need to promote *P. biglobosa* as a component of agroforestry system in Nigeria is emphasized.

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Syzygium cumini (L.) as an Agroforestry Plant in Sindh Region of Pakistan

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In the Sindh region of Pakistan, the share of forestry in value-added products of the agriculture sector was 1.10% for the year 1994-1995. In this regard, potential exists for exploitation of appropriate agroforestry plants. One promising agroforestry tree species is *Syzygium cumini* (L.), commonly called Jamon. Jamon belongs to the family Myrtaceae, which consists of 400-500 species but only a few providing edible fruit. At Panhwar Fruit Farm, we grow *S. cumini*, and produce a yield of 3 tons/acre. This species has many uses: Fruit is eaten fresh but is also processed into beverages, jelly, jam, squash, wine, vinegar and pickles. Seed powder is used for treating diabetics, dysentery, diarrhoea and other ailments. Twigs are used as firewood, leaves are used as fodder. Trees act as a wind break. Jambolan wood resembles Teak and is excellent for furniture making. Wood is used for beams, rafters, posts bridges, boat, masts, cart wheel and foundation frames as it resists action of water, insects and fungal attack. However, there is a large genetic diversity found in seedlings. Thus, we have to conserve germplasm for breeding. We have made selection for heavy fruit-bearing and dwarf trees. In the future, superior varieties gained by marcotting, inarching, grafting, budding and cleft grafting will become common. Budding can be done by patch or shield method. We have to consider Jamon as an Agroforestry Industry and conserve its germplasm for evolving better varieties suited to local conditions with good fruit post-harvest life, and better quality of wood production.

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The Domestication of Camu Camu (*Myrciaria dubia*) in Peru

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This study examines how small farmers in the Peruvian Amazon have adopted a tree crop that is being promoted as a new component in their swidden-fallow agroforestry systems. Camu camu (*Myrciaria dubia*) is a small tree native to wetlands of the Amazon basin. The high vitamin C content of the fruit has generated interest in camu camu as an export product. The government of Peru has actively promoted this new extractive industry, as well as the planting of camu camu in rural areas. In the last decade, non-governmental development organizations and private industry have started many camu camu planting projects and enterprises. However, many questions about the adoption of camu camu by farmers in their fields need to be answered in order to understand its role in the region's agroforestry systems. Findings indicate that households that adopted camu camu in their floodplain agroforestry systems farmed significantly more floodplain land than non-adopters, and were especially adept at experimenting with new innovations. Camu camu was found to be cultivated with a higher diversity of annual crops than is typically found in floodplain fields of the region. Lack of agricultural credit is major constraint to adoption of camu camu in Peru. Geographic isolation and location of processing facilities in relation to fruit harvests present major obstacles to economic viability of the new industry. This native fruit tree in the process of domestication could become an important species in agroforestry systems of the Peruvian Amazon if agricultural extension methods and marketing channels are improved.

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When Agroforestry Meets Productivity: The Necessary Evolution of Jungle Rubber in Indonesia

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Jungle rubber, a complex multi-strata rubber-based agroforestry system, is still the main source of income for most rubber smallholders in Indonesia. It has proved to be very adapted to poor farmers in pioneer areas. Several factors—large development projects based on clonal rubber since the 1980's, farmers' diversification strategies, availability of new crop opportunities (oil palm in particular), the economic crisis since 1997, and major social and political changes since 1998—have created a new socio-economic context for farmers that stimulates innovation processes. Improved rubber agroforests have been developed and tested through on-farm-trials leading to a recombination of knowledge: agroforestry practices (indigenous knowledge) and external technical innovations (clonal planting material, fertilizers, chemicals…). The positive externalities of agroforestry systems (maintenance of a certain level of biodiversity, soil fertility improvement…) and economic advantages of agroforestry practices (low labour and input requirements, limited risks, income diversification…) have been therefore integrated in cropping systems with a very high level of productivity (yield and return-to-labour). The paper presents the recent history of such evolution through the experience of the SRAP project in Indonesia (Smallholder Rubber Agroforestry Project CIRAD/ICRAF). Meanwhile, local farming systems have been modelled (using the software "Olympe", INRA/CIRAD) in order to enable study of different scenarios according to improved technology adoption, diversification strategies, commodity price volatility and climatic risks. This prospective analysis leads to identification of the "robustness" of technical choices by farmers as well as thresholds and potential situations according to hypothesis defined and tested with local communities using participatory approach.

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Dynamic of Cocksfoot Urine Patches in a Silvopastoral System in New Zealand

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Dry matter (DM) production and crude protein (CP) of sheep urine patches in a grazed cocksfoot (*Dactylis glomerata*) pasture (28-day rotation with 21±1 days regrowth) under 10-11 year-old radiata pine (200 stems/ha) were measured over time at the Lincoln University Silvopastoral Experiment (Canterbury, New Zealand). Cocksfoot interactions with environmental conditions were evaluated using a leaf photosynthesis model. The area of cocksfoot pasture covered by urine patches ranged from 25 to 32%. Mean rate of nitrogen (N) applied per hectare in an individual urine patch ranged from 221 kg N/ha in autumn to 445 kg N/ha in spring. Mean DM production of new, individual urine patches ranged between zero and three times more than for non-urine areas. This equated to 35% increase in DM production for the total area. Maximum difference between urine patches and controls was 1,562 kg DM/ha in spring. Smaller differences were measured in summer (220 kg DM/ha) and winter (265 kg DM/ha). Maximum difference in CP was also in spring with 28.5% for urine patches and 19.4% for controls. DM production differences were attributed to net leaf photosynthetic rate, which ranged from 22.5 to 4.6 μmol CO_2 m^{-2} s^{-1}. On most days, leaf photosynthetic rate was not limited by environmental factors, but in summer the rate was limited by low soil moisture and leaf N content (<3%N) compared with mainly low temperatures in winter (<9ºC). Duration of urine patch response was 133 days in winter compared with 105 days in spring and 77 days in summer.

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Morphological and Anatomical Adaptations of Cocksfoot Leaves Grown Under Different Fluctuating Light Regimes in New Zealand

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The effect of different fluctuating light regimes (24, 43, 58 and 100% transmissivity) on leaf morphology and anatomy adaptations of cocksfoot (*Dactylis glomerata* L.) was measured in the Lincoln University Silvopastoral experiment (New Zealand). Duration of alternating periods of full sunlight (1900 µmol m^{-2} s^{-1} PPFD at midday) to severe shade (130 µmol m^{-2} s^{-1} PPFD) ranged from 45 to 180 minutes. Length of the youngest fully-expanded leaf and pseudo-stem height increased by up to 33% and the leaf-width declined up to 22% with decreasing light intensity. This elongation was primarily related to enlargement of epidermal cell length as a response to reduced proportions of red (660 nm) to far-red (730 nm) wavelengths (R:FR) from 1.32 in full sunlight to 0.54 in severe shade. Cocksfoot leaves grown in fluctuating light regimes were thinner than full sunlight leaves due mainly to reduction in mesophyll cell size (bigger spongy and higher palisade cells) and bundle area and to a lesser extent in the number of cells. As a consequence of anatomical and morphological adaptations to different light regimes, cocksfoot plants increased the specific leaf area (SLA) from 27 to 38 m^2 kg^{-1} DM with decreasing light intensity. Mean canopy leaf angle decreased from 68º for plants grown in full sunlight to 59º under 24% transmissivity as a result of their longer and thinner leaves combined with a lower number and smaller size of bundles. The wide range of leaf morphology and anatomy dimensions emphasised the cocksfoot leaf plasticity under different light regimes.

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Responses of Net Photosynthetic Rate Related to Anatomical Adaptations of Cocksfoot Leaves Grown Under Different Fluctuating Light Regimes in New Zealand

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Net photosynthetic rate was measured from the youngest fully-expanded leaves of cocksfoot (*Dactylis glomerata* L.) grown under different fluctuating light regimes (24, 43, 58 and 100% transmissivity) in the field at the Lincoln University silvopastoral experiment (New Zealand). The light-saturated rate of net photosynthesis (Pmax), photosynthetic efficiency (α) and convexity (θ) of the light-response curve were derived from fitted non-rectangular hyperbola functions. The main features related to the effect of leaf adaptation to different light regimes on leaf photosynthesis were: (i) Pmax in full sun conditions was double that under severe shade; (ii) when re-exposed to full sunlight, plants previously grown under shade had lower Pmax and α values, showing they were photosynthetically less efficient than those grown in full sunlight; (iii) when plants were exposed to severe shade, leaves adapted to severe shade conditions (24% transmissivity) had the highest Pmax, α and θ, and saturated at a lower PPFD value compared with other shaded treatments. These changes were attributed to reduction in stomatal conductance (gs), the mesophyll-surface-area to leaf-surface-area ratio (A_{mes}/A) and maintenance respiration for shade-adapted plants. Reduction in gs was attributed to reduction in stomata density (total pore space) in the abaxial surface of leaves grown at low light intensity. Also, plants grown under shade invested leaf nitrogen (N) to total chlorophyll and decreased the chlorophyll a:b ratio which may improve light absorptance per unit N invested in light harvesting at low light levels. These results emphasise the physiological adaptation of cocksfoot leaves under different light regimes.

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Constraints to On-farm Tree Domestication among Upland Farmers in Southern Leyte, Philippines

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The study attempted to determine the different factors that contribute to farmers' reluctance in tree species domestication. A semi-structured interview schedule was used in data collection from a 180 randomly-selected farmer respondents. Descriptive statistics like frequency count, percentage, mean and rank were used to describe the respondents' characteristics and other study variables. Majority of them were male, married, had low level of education, old and had 4-6 members in the family. The annual income ranged from P23,250 to P33,879 and was mostly derived from their major source of livelihood, farming. The average farm area is less than 2 hectares, duration of farming experience ranged from 11 to 24 years, and farmers were affiliated to various organizations. Results show that there were only 26 different kinds of tree species being domesticated by the upland farmers. Of the total number of species, 13 are endemic, 5 are fruit trees and 8 comprise the exotic species group. The low rates of tree domestication among upland farmers in the province are mainly due to tenurial insecurity and smaller farm size. The lack of planting materials, poor marketing outlets, illegal cutting of planted trees, lack of technical expertise, delayed return from investment and accessibility were also considered as secondary reasons. Moreover, results of the study also emphasize that provision of important technological information and support, and the establishment of a model farm site, were considered as the best approach for increasing the adoption and conservation of the most valuable tree species in farmers' farms.

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Adoption and Impact of *Leucaena*-based Agroforestry Systems in Rainfed Semiarid Andhra Pradesh, India

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Agroforestry systems using *Leucaena leucocephala* are grown in the state of Andhra Pradesh, India in about 8,674 ha (by 2000) to meet the shortage of wood for pulp and paper industry. The present study was taken up to analyze factors influencing adoption of leucaena-based systems and their impact on farmers' livelihoods. The study was conducted in four villages in Prakasam district on a sample of 86 farmers through formal interviews. Low returns from traditional crops, high demand for *Leucaena* wood, technical support and buyback arrangement from paper mills, short rotation cycle and favourable government policies are encouraging farmers to take up the technology. Farmers plant *Leucaena* K8 or K 636 at a density of 5,600 to 23,000 trees/ha and grow two intercrops during the first year of the trees. More than 90% of the farmers harvest trees at the end of three years and generally take up one ratoon crop. About 60% of the farmers apply fertilizers to *Leucaena* at a rate of 58 kg N and 9 kg P/ha irrespective of the intercrops. Factors influencing the adoption of agroforestry include farmer's education, holding size, distance to the wood depot, non-agricultural income, and previous tree farming experience. Constraints identified by farmers for the technology include decline in productivity, tree mortality, excessive seed setting and theft of foliage. Majority of farmers claim soil improvement following leucaena system and 2 to 3 times greater net returns compared with traditional crops. The paper further discusses biophysical and socioeconomic implications of this technology.

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Mitigation of Energy Challenges through Domestication and Production of *Jatropha curcas*

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Energy is the single source which determines the human carrying capacity on this planet. The paper highlights new opportunities for biomass energy use in rural and urban neighbourhoods through domestication and commercialization of *Jatropha curcas*. The species is a large shrub native to the American tropics. It is commonly found throughout most of the tropical and subtropical regions of India as wild in degraded and abandoned lands. Recently, there has been increasing interest in the use of curcas oil as either a diesel fuel substitute or extender. Planning Commission, Government of India has recommended for use of curcas oil as an energy mix with diesel. *Given the demand for a continuous and uniform supply of oil and the accelerating depletion of oil reserves, studies are carried out to domesticate and cultivate J. curcas as a potential to yield biofuel.* The variability in oil content of the kernel in different geographical regions was undertaken. The oil content varied form 29 to 50%. Seed storage studies revealed that the oil content in the seeds decreased with time but the decrease is negligible (2%). Variability in seed oil content due to site revealed higher oil content in moist localities as compared to dry localities. Silvicultural and management practices to be followed for its commercial cultivation have also been worked out.

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Agroforestry for Conservation of Natural Forests: A Case Study of Kanneliya Proposed MAB Reserve in Sri Lanka

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Kanneliya forest, which is a proposed MAB reserve, is located in the Southwest of Sri Lanka. It is considered as one of the richest areas of floral diversity with exceptionally high level of endemism. It is surrounded by 16 villages, and is managed by the Forest Department. A study was conducted to identify dependency of community on forest reserve and role(s) of surrounding land use systems in conservation of the reserve. The major occupation of householders around Kanneliya is farming. All households sampled have access to paddy land and uplands. The average family income is US $ 126/month, of which more than 65% is derived from tea cultivation. Over 60% of population has visited the forest for collection of NTFP mainly for domestic use. Dependency of community on forest and their products is high at Kanneliya. Majority of people around Kanneliya have their own homegardens (average size is 0.4 ha/family). Over 65% of homegardens are in the well-matured category and provide many benefits to householders. However, compared to Kandyan homegardens, significant difference in homegardens in this area is lack of timber and fruit trees. This is mainly due to the existing legal status of the forest, and permit system for timber felling and transport in private lands. Over-promotion of tea has also caused problems to land use systems and natural forests. Implications of these findings on conservation and utilization of the forest, and formulation of policies on effective utilization of homegardens and natural forests are discussed.

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Tree Domestication as a Measure to Conserve Biodiversity in Kanneliya MAB Reserve in Sri Lanka

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Kanneliya forest is a proposed MAB reserve in the Southwest of Sri Lanka. It is considered as one of the richest areas of floral diversity with an exceptionally high level of endemism. It is surrounded by 16 villages and is managed by the Forest Department. A study was conducted to identify uses of forest tree species by villages and their impacts on biodiversity of the forest. The communities around Kanneliya have utilized the forest for ages for various reasons. They visited the forest and collect mainly NTFP and occasionally timber. The major tree species used by villagers are *Vateria copallifera, Cinnamomum capparu-coronde*, *Dipterocarpus glandulosus* and *Garcinia quaesita* and *G. zeylanica*. All these are endemic species. Extractions of products from *C. capparu-coronde* and *D. glandulosus* are destructive to trees. Individuals of such species have decreased during the last two decades. As a result, some of them were included in the Red data book as threatened species. Although such species are heavily used, they are not common in other land use systems, particularly in homegardens around Kanneliya. Even in tree planting programmes, these species received less priority. The present study expects to promote agricultural cultivation of *C. capparu-coronde, G. quaesita* and *G. zeylanica* and introduction of *V. copallifera* and *D. glandulosus* to streamlines and other common land use systems. Their genetic variation will be collected using local knowledge and multiplied by vegetative and seed propagation for domestication, which will be followed by genetic characterization of species for further domestication.

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Few Trees in the Landscape: Farmer-Developed Planning for Watershed Rehabilitation in the Ethiopian Highlands

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The USAID-financed AMAREW Project has as one of its objectives the rehabilitation of two pilot catchments in the Amhara Region of Ethiopia. The catchments are drought prone with poor soils, high human and livestock density, and little existing tree cover. The areas were historically covered with dry woodland. Tree planting is primarily seen as a practice of individuals engaged in market activity; that is, planting mainly eucalyptus in small plots for pole-size harvest and selling. A few native species are planted, but they are used on-farm for traditional uses such as implement handles. Cooking fuel is primarily a mix of crop residue and animal manure; deliberate fuelwood production is almost non-existent, and it is not a priority for the communities. Large trees are not desired around field edges because they harbor crop-eating birds. Farmers residing in the pilot catchments developed their own plans for watershed rehabilitation. Tree planting is only a minor part of the plans. Preferred rehabilitation options are small ponds to collect rain runoff, area closure to be managed as cut-and-carry for livestock feed, and bunding in agricultural fields for soil and/or water conservation. A common perception of outside experts is that the community is not doing enough to address problems with which the expert is most familiar. However, any extension approach should be based on Traditional Indigenous Knowledge (TIK) and preference of local communities. A two-way, long-term relationship between extension personnel and resident farmers will lead to mutual learning and sustainable catchment rehabilitation.

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A Growing Need for Woody Perennials in the Australian Landscape

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This paper considers the need to strategically increase the area of deep-rooted, woody perennials across broadacre agricultural land in Australia, in response to widespread degradation of natural resources in the landscape. Salinization of land and water resources, acidification of soils, and the decline in the health of terrestrial and riverine ecosystems affects large tracts of the major agricultural production regions of the country. The ecological, economic and social sustainability of traditional agricultural land uses and management practices are increasingly in question. Research confirms a need to (re-)introduce higher water using, woody perennials back into some parts of the landscape to address salinity, and native trees to expand and reconnect fragmented vegetation cover for biodiversity benefits, including the reestablishment of riparian buffers to protect water quality and streams. The future landscape vision for broadacre agricultural land is one of current farming systems, with higher adoption of current recommended practices, within a mosaic of agroforestry, industrial forestry and conservation plantings. These options are seen as the only viable alternatives, with new farming systems considered at least 5-25 years away, and transfer to and adoption by land managers more distant still. Government policy settings are endeavouring to use market and non-market based instruments to drive this large-scale landscape change, with an emphasis on capturing the value of ecosystem services with new trading mechanisms. This paper considers how research and development, with particular reference to the Joint Venture Agroforestry Program, has informed and led debate and policy direction on creating this future vision.

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Riparian-based Agroforestry to Achieve Conservation Benefits in the Australian Broadacre Agricultural Landscape

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Research consistently demonstrates that traditional broadacre agricultural enterprises in Australia are not sustainable across large tracts of land. With new farming systems at least 5-25 years away in terms of development, and longer still in terms of transfer and adoption, the available options are confined, in the near-term, to improving current farming systems and land use change to industrial forestry, agroforestry (an emerging industry) and nature conservation. This paper considers the scope for riparian-based agroforestry in the broadacre agricultural landscape, which has been highly modified in the 200 years since European settlement. The sheep-wheat belt suffers from land and water salinization, soil acidification and erosion, and the decline of in stream and terrestrial biodiversity. Current natural resource management policy emphasizes managing the highest value assets by combining market forces with new trading mechanisms for non-market goods and services, notably those for ecosystem-based services.

This paper considers riparian land management within this context, highlighting the potential role of riparian-based agroforestry in achieving broader catchment management objectives, especially conservation benefits. It further considers the extent to which existing research, development and extension supports sustainable harvesting of wood and non-wood products from riparian lands.

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Guatemala's Coffee Crisis: Socioeconomic, Environment and Opportunities

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This paper addresses three different aspects of the Guatemalan coffee crisis: socio-economic, environmental and existing opportunities. Currently, many small farmers are losing their farms because they have loans that are impossible to pay and they cannot afford needed cultural practices. In many areas, the cost to harvest is higher than market prices. As a result, farmers have abandoned many cultural practices and production has decreased 50% or more during the last three years. This has dramatically increased rural poverty, and has contributed to massive emigration from rural communities. Farmers are destroying their coffee plantations and replacing them with other crops. This is taking a high toll on the environment. Cutting coffee and associated shade trees results in increased erosion problems and decreased biodiversity. Often the new crops require higher levels of inorganic fertilizers and chemical pesticides, increasing the risk of ground water pollution and other environmental hazards. In addition, the unregulated cutting of commercial tree species in general and the lack of proper forestry management techniques are reducing Guatemala's forested areas. Over the last five years many organizations have been promoting other products and opportunities to local coffee farmers, including forestry products, bamboo plantations, macadamia nut trees, certified organic coffee, and gourmet coffee. Unfortunately, these efforts were too little and too late for many small farmers. On the other hand, the crisis is making some Guatemalans more creative and has increased the concern for our environment and biodiversity.

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Smallholder Farmer Seed Orchards: Producing Quality Tree Seed On-Farm

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The breadth and success of local tree planting activities are often limited by the availability of tree seed. Farmers and NGOs procure tree seed locally through collection, purchase and trade. Farmers, NGOs and local seed merchants have limited technical knowledge regarding suitable seed collection guidelines. They generally collect seed from a limited number of trees that are easy to access regardless of tree characteristics. The quality of this locally collected seed is dubious. Farmers and NGOs are aware of improved tree seed, but they have no access to it and it is of inadequate quantities and priced beyond their means. How to enhance the quantity and quality of tree seed received and used by farmers and NGOs is an important question facing the agroforestry research and development community. This paper discusses experience in Indonesia to: increase the technical tree seed management skills of farmers and NGOs; and develop farmer seed orchards from germplasm of superior genetic quality to greatly enhance the quality of tree seed available to local tree planters. Farmer seed orchards must be integrated into existing multi-species, multi-product, risk-adverse smallscale farming systems. The objective of these orchards is to produce tree seed of above-average genetic and physical quality, compared to other local tree seed, as one of multiple products from the system; not to produce seed of the best possible quality. Various models of farmer seed orchards, the conditions under which they are suitable, related support activities and lessons learned are shared.

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Rehabilitation of the Tropical Forest through Enrichment Planting: An Effective Technique for the Sustainable Regeneration of Logged-over Forest in Peninsular Malaysia

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In order to provide sufficient raw materials for the domestic wood based industries, the timber supply substantially depends on the availability of the Productive Permanent Reserved Forests (PRF) in Peninsular Malaysia. The supply of timber from these forests has decreased because of insufficient stock and diminishing production area. These logged-over forests need rehabilitation to meet the future demand for timber. Artificial and natural regeneration have been widely undertaken as rehabilitative measures for the poorly stocked logged-over forests. In natural regeneration, sufficient numbers of mother trees are left in the forest as residual stands for seed liberation. But this technique is not sufficient to regain the forest cover successfully in most cases. Artificial regeneration through enrichment planting activities seems to be the better rehabilitation measure to manage poorly stocked logged-over forests. Post-logging silvicultural management thus has potential to improve wood production under these conditions. Enrichment planting has been found as a potential option in comparison with other techniques. The study attempted to assess the enrichment planting option in rehabilitating poorly stocked logged-over forest in Peninsular Malaysia. It also focused on several key issues and suggestions for improving the enrichment planting towards sustainable forest management. In order to assess the financial viability of the technique, the study carried out a financial analysis. Based on the study's findings, it is recommended that, although enrichment planting is a potential option, more intensive research is necessary to incorporate some aspects like species site matching, biodiversity and planting techniques for further improvement.

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Gmelina arborea Promotion, Planting, Wood Processing and Product Marketing: Documentation of Best Agroforestry Management Practices among Smallholder Farmers in Mindanao, Philippines

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Gmelina arborea (*gmelina*) is being grown by small landholders in Mindanao, Philippines, as a result of an incentive program initiated by the Local Empowerment Foundation. Trees are provided to farmers for planting, and repayment is one mature tree out of 10 that are established. *Gmelina* is planted in agroforestry systems that include mahogany, bananas, pineapples and other crops. The annual crops provide short-term income to the farmers as the *gmelina* trees develop. Trees are ready to harvest by age 7 or 8 years using portable sawmills. The wood is used for a number of products, the most valuable of which are moldings. The paper describes the incentive programs initiated to convince farmers to practice agroforestry. Several lessons can be gleaned from these initiatives to promote small landholders to practice agroforestry using *gmelina*. Resource-poor farmers follow what they see and what they perceive as economically beneficial to them. Clear and practical examples must be given to the farmers to encourage them to practice agroforestry. *Gmelina* offers the most practical and economical alternative to other forest species for the housing, furniture and firewood industry in the Philippines. The traits that are most important are quick growth and early maturity, good wood quality and workability. The support of multiple stakeholders such as the government, donors and local leaders is a necessary ingredient for the success of any initiative. While this initiative is focused on individual farmers, it is also advantageous to target traditional groups for maximum impact.

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An Agroforestry System of Mahogany (*Swietenia macrophylla* King) and Papaya (*Carica papaya* L.) "Maradol", Portuguesa State, Venezuela

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An agroforestry system of mahogany (*Swietenia macrophylla* King) and papaya (*Carica papaya* L.) was established on loamy Haplustepts soils of the flood plain of the Guanare River in the Gato Negro area, Guanare municipality of Portuguesa state, in a climate strongly seasonal. The mahogany was planted at a distance of 6*6 m and the papaya in between at 2*2 m covering a surface of one hectare. Management of the system was followed during the first year. Growth and production were evaluated at one year of age, systematic sampling with randomness at the starting point was applied, excluding the edge plants, the sample consisted of 25% of the mahogany and 10% of the papaya plants. Both species were fertilized with 50 g/plant of complete formula 12-12-17-2 CP at the moment of plantation and 2 months later; 100 g/plant of the same formula were applied at ages 3, 5 and 7 months. Weeds were controlled manually every 3 months. Irrigation was applied every 28 days during the dry season (December to April). *Hypsipyla grandella* was controlled with the insecticides Corsario (Diazinon + Cipermetrin) and Dipel (*Bacillus thuringiensis,* Var. Kurstaki) applied on six occasions. The mahogany plants that presented attack of *H. grandella* were pruned at the moment of detection of the plague. The mahogany obtained the following average results: diameter at breast height 3.92 cm, total height 3.07 m, 60% were pruned due to plague attack. The average production of papaya was 18.85 kg/plant. Results are considered satisfactory.

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A Case for Domesticating Indigenous Fruit Trees as a Way out of Poverty

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This paper makes the case for a greater policy, research and extension effort to improve the contribution of indigenous fruit trees to poverty alleviation. A narrow international focus has led to the successful dissemination of 'exotics', like mango and citrus, around the world. But very little attention has been paid to indigenous fruit trees, many of which are so valuable to farmers that they have been shifted progressively from the forest to the farm. Often it is the timing rather than the absolute value of their products that is critical to families, and their sale and processing may specifically benefit women. Many also play an important role as companions to staple and commodity crops. While the safety-net function of indigenous fruit trees has long been recognised, this paper argues that they also have great potential to promote growth and help people move out of poverty. Research in Cameroon and Nigeria on *Dacryodes edulis* and *Irvingia gabonensis* highlights some of the factors necessary to realise this potential. Multidisciplinary extension support should build on farmers' existing achievements and cover all aspects from production to commercialisation in an integrated manner. National level recognition of the important contribution of these products should lead to the creation of a more favourable market environment including less restrictive transport and market regulations, and provision of micro-credits for indigenous fruit tree-based enterprises. At the same time, a greater and more participatory research focus is needed to improve management practices, and identify new value-adding and commercialisation opportunities.

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Allelopathic and Shade Effect of Mango and Citrus on Germination, Growth and Yield of Gobhi Sarson *(Brassica campestris)*

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Mango and citrus are important horticultural crops in subtropic zone of India, and Gobhi sarson is a common intercrop in orchards. The present studies were conducted to study the allelopathic and shade effect of mango (*Mangifera indica* Cv. Dashahari) and citrus (*Citrus reticulata*, Cv. Kinnow) on germination, growth and yield of Gobhi sarson (*Brassica campestris*) in a system in Himachal Pradesh, India. Mango and citrus plants of different height classes were grown in rows in an east-west orientation, with a Gobhi sarson intercrop grown in a north-south orientation. At time of Gobhi sarson maturity, data were recorded on plant growth and yield. Allelopathic effects of mango and citrus on germination and early growth of Gobhi sarson was studied in the laboratory using aqueous leaf extracts. Almost all the growth parameters studied and yield of Gobhi sarson were found to be affected significantly by mango tree height, direction and distance from mango and citrus trees. Yield was higher under smaller trees compared to tall trees in both the cases. This could be ascribed to shade effect that becomes more pronounced with increase in height and crown spread of trees. Higher yield in south direction may be due to longer photosynthetic activity of Gobhi sarson plants due to longer sun exposure. Germination of Ghobi sarson was enhanced by leaf leachate of mango whereas leachates of citrus had no effect. However, vigour index of Gobhi sarson seedlings was affected adversely by aqueous extracts of mango and citrus showing their alleopathic effect.

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Physico-chemical Characteristics of Wood of *Eucalyptus tereticornis* Smith and *Robinia pseudoacacia* Linn. Managed Under High Density Short Rotation System in India

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In India, about seventy eight per cent of population resides in rural areas and is dependent largely on biomass to meet the timber and energy requirements. Hence, to survive today people are forced to forsake their tomorrow and overuse their natural resources and environment. This has led to destruction of forests. To abridge the gap between demand and supply, the use of fast growing, high yielding and multipurpose tree species managed with intensive cultural operations in tree farming have opened up new vistas in wood biomass production. Thus, it was thought imperative to study the effect of HDSR *Eucalyptus* and *Robinia* plantations on wood properties for maximum benefits. For both species, twelve randomly selected trees, four each from three planting densities (0.60x0.60, 0.90x0.90 and 1.20x1.20m) were felled. Vertical stem analysis was completed on 5 cm long section cut from main stem at ground level, 30, 60 and 90 per cent of total tree height. The holocellulose content and pulp yield increased with the sampling height while fibre length, specific gravity, calorific value, extractives and lignin content of wood decreased from ground to top in both the species. The effect of spacing was found non-significant for wood density and calorific value. In *Robinia,* the extractives, holocellulose and pulp yield increased with increase in spacing. But on per hectare basis, pulp yield is more in 0.60x0.60m density due to more number of stems. The effect of planting density had been found non-significant for most of the parameters in *Eucalyptus tereticornis.*

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Population Structure of Juçara Palm (*Euterpe edulis* Mart.) in the Brazilian Atlantic Forest

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This study was carried out to derive a better understanding of the population structure of juçara palm (*Euterpe edulis* Mart.) in the Atlantic Forest, in Una Ecological Park, located in the municipality of Una, State of Bahia, Brazil. Based on its characteristics, juçara palm is a good alternative to several agroforestry system combinations. Data was gathered in June 2001, through evaluation of individuals in different stages of development in a single population, in three contiguous zones in the landscape (lowland, middle land, upper land). Soil samples were taken in each of three plots in order to understand the physical soil properties. Plants in the population were classified into one of six size classes: Plantlet, Young I, Young II, Immature I, Immature II, and Adult. For each size class, the following data were gathered: density and distributions of frequency, class of height at leaf insertion, number of leaves, diameter at breast height (DHB), and diameter at soil level (DLS). Comparisons were made among these values. Population revealed a demographic structure with a large number of immature individuals and few individuals in the largest size classes. Population density was found to be relatively low, leaving open the possibility that these populations should be treated as an ecotype different from others previously studied. For soil physical properties and soil organic carbon, the sandy fraction showed differences between the lowland and the upper land. Plantlets and Young I showed higher densities in the lowland and more mature size classes in middle and upper lands.

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Provenance Variation in Black Catechu (*Acacia catechu* Willd.): An Important Agroforestry Tree Species of Indian Western Himalaya

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Morphological and physiological attributes of mother trees of *Acacia catechu* Willd. were compared in field conditions at three different provenances in the state of Himachal Pradesh, India during 1998-2000. The early growth of selected provenances was also compared in the nursery trials to evaluate the seed sources at Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, India. Significant variation was observed in most of the morphological parameters of mother trees along with the growth parameters of their progeny. Wide range of genetic variability was observed for almost all the characters of mother trees and their progeny. High estimates of genetic parameters in this study are governed by the additive gene action and should be considered for selection. The observed variability was indicated to be an important biological variable which could be used to improve growth and yield in *A. catechu*. Out of three selected provenances, Subathu performed better as compared to others and is recommended for large-scale commercial plantation in suitable agroforestry systems in Himachal Pradesh, India.

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Supply of Wood / Timber in Jammu and Kashmir State of India

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In Jammu & Kashmir state of India, out of a total geographical area of 222,236 sq km, only 27.23% is under forests, out of which 75.58% of the forested area is concentrated in Leh, Anantag, Udhampur, Kupwara and Jammu districts. Forests, besides having bioaesthetic and ecological aspects, provide timber, fuel and other products. Afforestation is necessary to maintain ecological balance and to cater to the demand for traditional and commercial purposes. Revenue realization from forests has registered growth by about 98.92% in the last five decades. Total quantity of timber extracted from forests is 105 “000” cubic meters with the value around 9,615.44 lac rupees. Proper planning of farm sector with forestry in terms of current and advanced estimates of supply of forest products is equally important as that of its demand. Wood/timber will thus need to be generated from J&K state forests and from the farm sector. Thus, there is an urgent need to develop the coefficients for the wood supplied by different tree species in varied agroecosystems whereby good marketing information systems—specially for wood / timber, quality planting materials, and technical know-how to the farmers—must be provided by the Government for their good economic returns. This easy credit should be made available to the farmers for plantations.

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Management of Complex Cocoa Based Agroforestry Systems of the Humid Forest Zone Of Southern Cameroon: Typology and Conservation of Forest Resources

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In the humid forest zone of southern Cameroon some 300 to 400 000 ha of land are covered by cocoa agroforests. Cocoa (Theobromo cacao) is grown under the forest with non-cocoa plant species. The result of this combination of plants is a complex multi-strata system with the structure and functions similar to that of the forest. These agroforestry systems are then excellent models of association between non-domesticated forest species and cultivated species; between production of food, nuts and seeds, and other provision of environmental services in the forest ecology; and between sustainable management, flexibility and household food security. Despite this combination of plant species, research interest has been intensively focused on cocoa-trees and not on non-cocoa plant species. However, with the decline of cocoa prices, greater focus on ex situ and in situ conservation of forest species, and more desire to alleviate poverty in the forest area, efforts are now being put towards understanding all the components of the system. The structure and typology of this complex agroforestry system then needs to be understood to better target research and development interventions. Based on density of plants (cocoa and non-cocoa plant species), main function of plant species, age of plantation and cluster analysis, this study determined different types of cocoa agroforests and their importance. The apparent uniformity of cocoa agroforestry landscapes hid differences in composition and structure. Based on the findings, recommendations are made for future research and development interventions in cocoa agroforests of Southern Cameroon.

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Selection of Plus Trees of *Eucalyptus* for Agroforestry Systems

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With a view to improve the productivity and profitability of plantations and to make agroforestry an attractive land use option, the Company ITC ltd., initiated work on genetic improvement of planting stock of *Eucalyptus* species in 1989. The aim of the project is development of location-specific, high-yielding, fast-growing and disease-resistant clones of *Eucalyptus*, through applications of vegetative propagation and cloning techniques utilizing existing variation. 650 Candidate Plus Trees of *Eucalyptus* have been cloned since 1989. Replicated field trials for evaluation of comparative genetic superiority for selection of plus trees have been laid out. Since 1989, 150 Clonal test plots have been established covering 40 ha area at 15 locations. Several intra-specific and inter-specific hybrids have been developed through controlled pollination. This includes cloning of 315 hybrid clones and short-listing based on field performance of the 20 best hybrid clones. Based on the performance of individual clones in the field trials**,** 89 promising, fast-growing and disease-resistant clones have been identified, known as '*Bhadrachalam*' clones, with productivity ranging between 25 to 58 $m^3.ha^{-1}.yr^{-1}$ under rainfed conditions compared to 6 to 10 $m^3.ha^{-1}.yr^{-1}$ from seedling origin plantations. Plantations promoted by the company between 1992-2002 benefited more than 2,000 farmers who planted 10 million *Eucalyptus* saplings covering 5,000 ha. The popularity of the clonal plants can be gauged from the fact that production was increased from a mere 40,000 plants in 1990 to 65,00,000 plants during 2003. The paper discusses the performance of elite clones across different climates planted in agroforestry systems.

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Short Rotation Woody Crops, a Prospective Method for Phytoremediation of Degraded Agricultural Land in Southwestern Australia?

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There is broad recognition within Australia of the need to improve environmental sustainability of conventional agricultural systems. In southwestern Australia, salinisation affects an estimated 3.5 Mha of agricultural land, soil acidification, waterlogging, soil structure decline and subsoil compaction affect 9.4 Mha, 1.8 Mha, 1.75 Mha and 8.5 Mha, respectively. Growing short rotation woody crops in rotation with conventional agriculture is a prospective method of diversifying farm income and ameliorating degraded soils. The Joint Venture Agroforestry Program is funding new research investigating crop and pasture productivity, changes in soil chemical, physical and biophysical properties and changes in soil water content and ground water recharge over five years following harvesting of tree crops at two sites in Western Australia. One year after harvesting the tree crops, the principle benefit appears to be reduced soil water storage and hence groundwater recharge. Rooting depth of trees growing on a site with dense clay subsoils was 4-6 m; this resulted in a reduction of stored soil water of 230-300 mm compared to adjacent agricultural land. At the other site where tree roots penetrated in excess of 10 m, soil water depletion was 830-1040 mm. There is also evidence of trees accessing nutrients from deeper in the soil than annual crops and pasture. Offsetting these benefits were reduced crop and pasture growth due to nutrient deficiencies (despite the application of additional fertiliser) and dry subsoils. These preliminary findings highlight the importance of understanding site conditions and how soil water content and fertility change during the rotation.

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Eco-friendly Preservative Treatment of Heartwood of Australian River Red Gum (*Eucalyptus camaldulensis*)

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Eucalyptus camaldulensis Delnh, a native of Australia, known as River red gum, is grown mainly for the purpose of fuelwood, pulpwood and to certain extent for small furniture. This species is widely grown in dry tracts in India due to its high drought tolerance nature, fast growth, pest and diseases free nature and adaptability. The heartwood of this species has got very low durability when compared to other woods. Hence there exists a prime need to improve the durability and the quality of the timber after harvest. Though more reports are available on the use of chemical preservative treatment of this wood, a study was designed to find out the influence of Linseed oil, an eco-friendly product, extracted from the seeds of *Linum usitatissimum* L., an oil seed crop in India, on the wood quality in the heartwoods of River red gum by diffusion. This study was taken up at University of Melbourne, School of Forestry Creswick, and Victoria, Australia. The chemicals like Boric acid, Furfural alcohol resin along with a water soaking treatment were included in the study to obtain comparison. The method of treatment was diffusion. The influences of the various chemicals and linseed oil on wood parameters like Modulus of rupture, Modulus of elasticity, Janka indentation strength (hardness) were investigated. The strength test was performed using a Hounds field strength-testing machine. The study clearly demonstrated that heartwood of red gum could be treated with linseed oil for 2 hours to impart durability and strength to the wood.

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Long-term Sustainability of Taungya Teak Plantations in Bago Yoma, Myanmar

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In Myanmar, taungya teak plantations have been in successful operation for more than one century, and have been considered an exceptional successful case of the plantations in the tropics. But this does not guarantee that the taungya system has future long-term sustainability. According to Jordan (1992), there are two phases when the taungya system is particularly susceptible to nutrient loss, i.e., during the intercropping period and during the harvest of the trees at the end of the rotation. Thus, the quantitative data on nutrient loss during these phases, which has not been closely studied, is required. In this study, in examining long-term sustainability of the taungya teak plantations in Myanmar, nutrient dynamics during the intercropping period was examined by repeated sampling method, while that during the teak tending period by chronosequence method. During the intercropping period, no significant change was observed in content of soil carbon nor in exchangeable cations, with the exception of significant increase (P<0.05) in exchangeable K. During the teak tending period (stand age: 4~96 years), soil organic matter did not accumulate with time and carbon content in surface soil fluctuated between 6.8~11.3 t ha^{-1}, which was lower than that observed during the intercropping period. It can be assumed that frequent forest fires prevent the accretion of soil carbon by combustion of the litter, which is a main source of soil carbon. The results indicate that fire control during the teak tending period is crucial for the long-term sustainability of taungya teak plantations.

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Integrating Short-Rotation Woody Crops into Farming Systems for Profit and Sustainable Land Management

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Across temperate southern Australia approximately three million hectares of farmland are under threat from dryland salinity and the prognosis is for this to increase markedly in the next 50 years. In Western Australia the currently saline area of 1.8m ha may treble. Tree planting has been advocated to address the problem but where salinity is a major problem, rainfall is generally low and profitable tree crop options are limited. An opportunity exists for the integration of short rotation coppicing species into farming systems. The most promising of these are a group of eucalyptus species known as oil mallees because of the high essential oil content of their leaves. Economically viable industries could be based on the three products generated from oil mallee biomass, i.e., the essential oil, activated carbon and electricity. The degree to which oil mallees can control recharge to groundwater is untested and impacts on crop/pasture productivity remain unquantified. This 5-year project aims to evaluate the hydrological impacts and productivity interactions of integrated oil mallee farming systems at three representative sites in Western Australia and to undertake economic analyses using the model “Imagine”. Hydrogeological and geophysical surveys have been carried out to characterise the regolith and aquifers and piezometers installed to monitor impacts on water tables. Productivity measurements of tree and crop/pasture growth have commenced. Expected outcomes of the work will be improved design and management of integrated oil mallee-agriculture systems and an ability to predict their landscape-scale impacts in terms of productivity and salinity control.

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Putting Participatory Domestication into Practice in West and Central Africa

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The World Agroforestry Centre (ICRAF) had been working in the African Humid Tropics (AHT) since 1987. Despite the region’s natural wealth, small-scale farmers here are among the poorest people in the world and have relied on extractive harvesting of forest products and traditional shifting cultivation for their food and other needs. After severe deforestation, alternatives have to be found as land pressure has increased, commodity prices of cash crops have declined, and the national economies have weakened, creating uncertainties in farmer-level income-generating strategies. Moreover, macro-economic policies including structural adjustment and currency devaluation have not achieved the economic growth desired. The Participatory Domestication of indigenous fruit and medicinal trees is seen as one way of empowering rural households to improve their own situation. Many of the products of indigenous trees have potential niche markets in local, regional and international commerce. In participatory domestication, villagers are helped to develop local nurseries, taught skills of cultivar development and assisted with the technical implementation of selecting superior trees that meet specific market-oriented ‘ideotypes’. Currently, at least 2,500 farmers from 35 villages in southern and western Cameroon are practicing tree domestication techniques while more than 1,000 farmers in eight villages in southeast Nigeria use vegetative propagation techniques to multiply their high-value tree species. The present paper describes the steps in implementing a participatory approach to tree domestication, the perceived advantages and disadvantages as well as the constraints and opportunities. The marketing importance of processing for improved storage and for *value adding* is also discussed.

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Paper Mulberry (*Broussonetia kazinoki*) as an Alternative Crop of Agroforestry System in Thailand

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Paper mulberry is a raw material for special and high quality paper in Thailand. At present, the annual demand for paper mulberry inner bark could be as high as 68,000 Mg, but the amount of transaction in markets is only 5,000 Mg/yr. To promote local supply of paper mulberry, cultivation by private sectors should be encouraged. Since there are some ecological risks of monoculture as well as shortage of land, agroforestry system of paper mulberry is an alternative. In this study, teak (*Tectona grandis*), eucalypt (*Eucalyptus camaldulensis*) and banana (*Musa* sp.) were selected as the main trees with an intercrop of paper mulberry (*B. kazinoki*) considering the soil environmental quality of planting sites and traditional practices of farmers. Paper mulberry and teak, eucalypt or banana were planted at spacing of 4x6 m in superposed rectangular method. Paper mulberry combined with eucalypt or teak had better growth and development (regeneration and biomass) than that in banana plot. Natural regeneration of paper mulberry in terms of the number of shoots originating from root suckers showed a progressive development. New shoots in eucalypt plot were two times higher than those in teak plot. With regard to the biomass of paper mulberry, the highest amount of inner bark and total biomass were recorded in teak plot (112 g/stump and 2,066 g/stump) followed by those in eucalypt plot (85 g/stump and 1,640 g/stump), and least in banana plot (58 g/stump and 1,118 g/stump).

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Tree Growth and Nutrient Dynamics in Wheat-Poplar Agroforestry System under Various Management Options

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Poplar (*Populus deltoides*) based agroforestry systems have emerged as sustainable land-use systems in Indo-Gangetic plains of India. A long-term experiment was initiated to evaluate the independent and interactive effects of irrigation and N levels with and without wheat as intercrop on growth of poplar trees. The experiment consisted of two levels of irrigation (designated as I_1 and I_2 based on IW/PAN-E = 0.5 and 1.0), three levels of N (N_0, N_1 and N_2) and two levels of wheat intercropping (cropped and uncropped). Perusal of the data revealed that girth at breast height (GBH) was higher under uncropped conditions and the magnitude of this increase was greater at I_1 than I_2. At the end of six years of growth, tree volume increased by 35% with increase in irrigation level and 76% with both irrigation and N up to N_1. Quantity of leaf litter in various treatment combinations varied from 3.16 to 7.51 t/ha during fourth year of growth which was positively linearly correlated with increase in tree volume (r = 0.86). Results regarding mean nutrient return through leaf litter, irrespective of treatments, revealed that 136 kg/ha of calcium were returned to soil. The quantity for nitrogen, potassium, magnesium, sulphur and phosphorus was 56, 48, 27, 22 and 8 kg/ha, respectively. Nitrogen content in leaves without application of N was significantly higher at higher level of irrigation and under cropped conditions. The application of N and intercropping of wheat resulted in a significant increase in fine root biomass and its N content.

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Nutrient Dynamics in Poplar Agroforestry Systems in India

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Intensive studies on nutrient dynamics have been carried out in tropical forests in India. There are, however, only a few comprehensive studies made on commercial agroforestry systems, where the whole crop or a part of it, is removed after a period of 4-10 years, upsetting recycling processes and depleting soil fertility. To maintain an optimum level of productivity and soil fertility, nutrients need to be replaced through external inputs. The strategies of trees such as pumping of nutrients from deeper layers to the upper root zone and storage of nutrients into perennial woody components, help to restore the nutrient balance to a great extent. Nutrient cycling in different age plantations of *Populus deltoides* on deep alluvial soils of north-western India, have been discussed in the present paper. Input of nutrients through litterfall of poplar (5 t ha^{-1} yr^{-1}) alone contributes 28 kg N, 9 kg P, 76 kg K, 103 kg Ca and 16 kg Mg @per ha in a 7-year old plantation in eastern parts of Haryana; as a result, the input of nutrients from inorganic fertilizers decreases substantially as compared to younger plantations (1-3 years old). The loss of nutrients through agricultural crops and timber was maximum for potassium, which would have long-term effects on soil fertility, and the same has been discussed in the present paper.

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Classification of Traditional Agroforestry Practices in West Mediterranean Region of Turkey

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Agroforestry – while still a new concept in Turkey at the academic and institutional level – has been practiced in traditional forms for many years by villagers in nearly every part of the country. This study therefore undertook to observe and document traditional agroforestry practices in Turkey. The West Mediterranean region was selected for this purpose. Diagnosis and Design Methodology (D&D) was applied for examination of the traditional agroforestry practices. Each agroforestry practice was determined and classified in the agroforestry systems. According to this study, the nature of agroforestry systems and the purpose of the productions in the region are similar to other applications in the world. Many of the agroforestry production patterns are seen as traditional to the entire region. Results showed that agroforestry applications in the region can be placed in the following major categories: (i) *agricultural systems* (e.g., alley cropping, multilayer tree gardens, multipurpose trees on crop lands, plantation crop combinations, homegardens, trees in soil conservation and reclamation, shelterbelts and windbreaks); (ii) *silvopastoral systems* (e.g., trees on range land or pastures, protein banks, plantation crop with animals; and (iii) *agrosilvopastoral systems* (e.g., homegardens involving animals, multipurpose woody hedgerows, apiculture with trees, aquaforestry, multipurpose woodlots). These practices are also suitable agroforestry patterns for solving problems related to deterioration of family farms, increased soil erosion, surface and ground water pollution in West Mediterranean Region of Turkey. As agroforestry practices, *shifting cultivation* and *taungya* were also determined in the region; however, both practices are not applicable, as they lead to forest degradation.

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Temperate Bamboos: A Non-timber Forest Product of Great Value

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In many tropical areas Bamboos have a long tradition of use in agroforestry type applications and that use has become more or less pan-tropical. Temperate Bamboos, despite being well valued and utilized in their lands of origin, have been much less investigated or even seriously considered for applications in other similar or compatible climatic zones. The traditional uses of cut Bamboo products have been enumerated often (and are currently at over 1,000). The ecological services of Bamboos are known (if obscure). The "high-tech" potentials are only now being explored. The senior author, an ethnobotanist with 24 years of Bamboo investigation experience, will seek to make a case for the prominent inclusion of temperate Bamboos in Agroforestry scenarios for USDA climatic zones 6-9. Essentially the salient fact is that Bamboos can be used in any manner that tree wood can plus a number of applications requiring its unique structure. It can do this while performing needed ecological services and with an annual yield (after establishment) on a short-rotation cycle. From fuel to food to fiber, from re-bar to dimension lumber (composite) to houses, Bamboo can save forests and farms. It can shrink our footprint and raise the water table while rebuilding the soil. Certainly, it is worth considering, as the authors will show.

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Improved Natural Regeneration-based Fallows in Lower Floodplains of the River Aguaytía, Peruvian Amazon

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The felling of Amazonian floodplain forest during slash-and-burn agriculture practiced by 'ribereño' farmers in the Peruvian Amazon is often followed by abundant natural regeneration of *Guazuma crinita* (Martius) (bolaina blanca), a medium-density timber tree with heavy local demand. This 'natural *taungya*' can be managed as an improved fallow which represents a productive option of growing local importance. Like unimproved secondary forest, the improved system offers stabilization of erosion-prone riverbanks and trapping of fertile sediments. However, it also provides additional benefits to the farmers, i.e., higher yield and conscious integration of the secondary forest in the farm economy. As the system is based on natural regeneration, establishment costs are lower than other improved fallows, thus partially removing one barrier to adoption. Regeneration should be 'respaced' after harvest of the agricultural crops (typically crops of maize and rice in successive seasons), with silvicultural thinning in the third year. Maximum mean annual increments can reach 20 $m^3 ha^{-1} yr^{-2}$. *G. crinita* timber from alluvial forests provides the raw material base for an important micro-industry, supplying cities such as Huanuco and Lima as well as Pucallpa itself with a versatile sawnwood. Successful management of the improved system appears to depend on four main factors: possession of sufficient land of adequate quality to permit a fallow rotation of 6-7 years; sufficient seed rain at the end of the dry season; correct farmer identification of tree crop density commensurate with acceptable financial return; and sufficient capital, labour and technological capacity to execute tending and harvesting.

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Cultural Practices for Establishing Hybrid Poplar Plantations in Saskatchewan, Canada

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The Provincial Government in Saskatchewan has a goal to increase forestry activity by linking new forestry developments to wood supplies from private land, and the need for economic diversification for farmers experiencing a decade of poor harvests has lead to the push for afforestation/agroforestry systems on marginal farmland in Saskatchewan, Canada. Two short-rotation plantations of hybrid poplar (Walker) were established two years ago on an alfalfa field and pasture site to understand the cultural practices needed to successfully establish and grow these plantations. Treatments included stock trials (cuttings, rooted cuttings, rooted plugs), fertilizer (yr 2) and pruning (yr 2). Sites were instrumented for collecting soil temperature and moisture and climatic data. Planting the first year occurred in a drought period and saw survival and growth dramatically reduced. Cutting survival ranged from 30 to 50% while rooted cuttings and plugs had survival ranging from 85 to 95%. Height growth ranged from 20 cm for cuttings to 50-60 cm for rooted cuttings and plugs. Nitrogen fertilizer applied in yr 1 with labeled ^{15}N showed that rooted plugs had higher nutrient use efficiencies than rooted cuttings and cuttings for both sites. The alfalfa field also had higher soil nitrogen levels resulting in lower fertilizer nitrogen uptake than that for the pasture field which had lower soil N levels. The use of fast-growing hybrid poplars in Saskatchewan appears to be a viable alternative for increasing fiber for forest industry, diversifying farm income and addressing Canada's commitment to reducing GHG emissions.

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Incorporating Short-Rotation Woody Crops into Agroforestry Systems in North America

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A number of issues are developing simultaneously, creating a unique opportunity for agroforestry and short-rotation woody crops (SRWC) to be more widely adopted in North America. The growing concern about non-point source pollution is being translated into new agricultural policies and regulations. Results from years of research are being used to deploy SRWC and agroforestry systems across the landscape. Policy makers are beginning to value the multiple environmental and rural development benefits associated with these systems. Potential markets are developing for woody biomass, including small and large-scale energy production, feedstocks for bioproducts and specialty markets. The convergence of these issues has created a synergistic opportunity where the two fields overlap to combine the benefits of SRWC and agroforestry, especially for riparian buffers, windbreaks and living snowfences. The increase in above- and below-ground diversity, due to the inclusion of SRWC, improves the ability of riparian buffers to remove sediment and nutrients before they enter streams. Incorporating SRWC into windbreaks and living snowfences will reduce the time until these systems are functional to as little as two years. The high yields and short rotations for SRWC enhances both the productive and protective functions of these systems simultaneously. It is essential for both functions to operate effectively if agroforestry and SRWC systems are to be adopted and maintained across the landscape. Capitalizing on the development of both of these fields will require interdisciplinary research, support from policy makers, commitment from end product users, and the active participation of individual landowners and communities.

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Changes in Physical and Chemical Properties of Soil under Pastorable Pastures in Rows of Thinned Loblolly Pine (*Pinus taeda*) Trees

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Managing pastures under thinned loblolly pine forest requires understanding of the soil physical and chemical properties to improve soil quality for grass and tree combinations. Shade from trees and hedgerows significantly modify the microclimate of the alleys and affect the quality of soil. This paper reports on the changes in the chemical and physical properties of soils following the establishment of bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon*) pastures in tree rows of loblolly pine. Prior to seeding tree rows with the pastures, soil samples were randomly taken at 6 inches depth (15 cm). Twenty soil samples per acre (1 acre = 0.4 ha) were collected from three separate blocks (2, 3 and 7) before and 28 weeks after planting (WAP). Soil particle size, pH, moisture, organic matter and nitrogen contents of the soils were evaluated. Pre-forage establishment results revealed that soil pH was 5.44 in block 2, 5.49 in block 3, and 4.63 in block 7 respectively; moisture content was 6.65%, 6.75% and 7.00% in blocks 2, 3, and 7; organic matter content was 2.9%, 2.9% and 2.4% in blocks 2, 3, and 7. Particle size for all three blocks ranges from 90 to 92% sand, 2 to 3% silt and 6 to 8% clay. Post-forage (28 WAP) results were higher than those shown above. The results indicated that management of this plantation would have to be block specific to reflect the utilization of soil nutrients among trees in different blocks.

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Tree-crop Diversity and Farmer Preferences on St. Croix, Virgin Islands

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The number and size of farms in the US Virgin Islands have steadily declined since 1965. Only 6% of the islands remain covered with natural forest or woodland. Agroforestry designs that combine annual and perennial crops can be employed to enhance food production and rehabilitate previously forested lands of the USVI. A participatory inventory of farms and homegardens with 204 farmers was made to characterize species composition and geographic distribution on St. Croix during 2003. Two objectives of the on-going project are to foster conservation of trees on farmland and promote enterprise development with nontimber forest products in collaboration with local institutions, producers, and landowners. Semi-structured interviews and resource transects across each site with producers showed 64 total tree species with mango, papaya, banana, sugar apple and soursop as the most abundant species cultivated on 40 to 50% of farms. When asked what tree species they would plant, 95% wanted something to eat or sell. The species most preferred for planting, besides mango and avocado, were mamee (18%), coconut (11%), lime (8%), breadnut and mespel (7% each). Top-ranked production practices were fertilizer use (69% organic, 31% inorganic), irrigation (36%), mulch (34%), and pasture or crop rotation (13%). Of producers interviewed, 56% want to begin or expand a business. Based on survey results and GIS data on soils, vegetation and land use, further analyses to determine locations and viable planting sites for native tree species will support strategies to collect germplasm, enhance biodiversity and realize agroforestry activities with local partners.

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Effects of Different Nursery Potting Media on Growth and Survival of Containerized Tree Seedlings in Oromia, Ethiopia

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A study on containerized seedlings of Grevillea robusta, Melia azedarach, Eucalyptus camaldulensis, Calliandra calothyrsus, Leucaena pallida, and Acacia mearnsii raised under different growing media was conducted at Bako tree nursery in Oromia, Ethiopia. The objective of the study was to investigate the response of different tree seedlings to the different nursery potting substrates and recommend suitable substrate for production of quality planting stock. The growing media consisted of local soil, sand, forest soil and farmyard manure in different proportions. Seedling growth, survival, and dry weights were assessed. Results showed that seedlings responded considerably to variation in growing media. Addition of farmyard manure to the potting substrates significantly improved seedling growth and dry weights, particularly for Eucalyptus. But differential response of the different species to difference in potting substrate was noticed for seedling survival; that is, the survival of Calliandra and Leucaena seedlings was significantly affected, whereas those of Eucalyptus and Grevillea were not affected. Increasing the forest soil increased seedling survival, whereas increasing the farmyard manure significantly decreased the survival, especially for the legume species. But change in sand content influenced neither seedling survival nor its growth. The growth of seedlings in poor substrates was relatively better for the legumes than for the non-legumes due to their capacity to compensate for N through biological nitrogen fixation as an adaptation strategy. Therefore, nursery growing media without farmyard manure are suitable and recommended for leguminous species, whereas those containing farmyard manure are suited for non-leguminous tree species in containerized seedling production.

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On the Planting Arrangements and Spatial Patterns of Shelterbelts in Farmland (Liaoning Province, China)

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The planting arrangements and species composition of trees and shrubs in a shelterbelt determine the internal structure and external characteristics of this type of agroforestry system. The temporal-spatial patterns of shelterbelts determine the effectiveness and sustainability of shelterbelts on a landscape scale. For maximizing and sustaining the benefits of these systems, the planting arrangements, species composition and temporal-spatial patterns require appropriate technical design. Investigating on the field shelterbelts established in 1992 in Changtu County, Liaoning Province, China and reviewing the experiences and practices of shelterbelt management, we studied the spatial patterns of shelterbelts, the arrangement of trees, and mixture of tree species forming the shelterbelts. The spatial pattern of shelterbelts here is described by the directions of a shelterbelt and shelterbelt-networks, and the interval between shelterbelts. We conclude: 1) the directions of a single shelterbelt and shelterbelt-networks should be perpendicular to the prevailing/problem winds, 2) the triangle planting arrangements of trees in a shelterbelt is favorable to the shelterbelt structure associated with the effectiveness, 3) the tree species growing more slowly with ages should be planted in outside rows and those growing faster should be planted in the inner rows for the mixed shelterbelts, reconciling the edge effect. Furthermore, the optimal distance between two adjacent shelterbelts is predicted using the structural descriptor of a shelterbelt (optical porosity), desired wind reduction and tree growth model determining initial protective maturity age. The shelterbelts in a landscape scale should be evaluated and spatially arranged using the principles of landscape ecology.

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