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Towards Optimizing the Benefits of Clonal Forestry to Small-scale Farmers in East Africa

Edited by

Catherine Ngamau, Benson Kanyi, James Epila-Otara, Patrick Mwangingo and Samuel Wakhusama

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Workshop Report
26–27 January 2004
The Windsor Golf and Country Club
Nairobi, Kenya

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About ISAAA

The International Service for the Acquisition of Agri-biotech Applications (ISAAA), a not-for-profit international organization cosponsored by public and private institutions, facilitates the transfer of agri-biotechnology applications – particularly private sector proprietary technology – from industrial to developing countries. ISAAA's mission is to contribute to poverty alleviation through increased crop productivity and income generation, particularly for resource-poor farmers, and to bring about both a safer environment and long-term sustainable agricultural development.

ACKNOWLEDGEMENTS

The Tree Biotechnology Project (TBP) in East Africa and the International Service for the Acquisition of Agri-biotech Applications (ISAAA *Afri*Center) are sincerely grateful to their respective staff members for their contribution to the workshop's success and publication of these proceedings. We wish to thank the speakers, session chairs, rapporteurs, and workshop participants for their productive contribution to the workshop. Their inputs ensured a high level of discourse and helped achieve the established objectives.

Much appreciation is also extended to the small-scale farmers in Githunguri, Kiambu who clearly demonstrated both the energy and willingness of accepting new technologies; to the Parliament of the East African Community (EAC) for sending its Honorable Member Kate Kamba as their workshop representative; and to the Government of Kenya for its high-level participation at the workshop.

The TBP's implementation in East Africa owes its success from the support of various institutions, namely; the Gatsby Charitable Foundation (GCF) – UK, Mondi Forests – South Africa, Forestry Department – Kenya, Kenya Forestry Research Institute (KEFRI), Forestry Resources Research Institute (FORRI) – Uganda, Tanzania Forestry Research Institute (TAFORI), Genetics Technologies Ltd – Kenya, Forestry and Agricultural Biotechnology Institute (FABI) – South Africa, Agro-Genetic Technologies Ltd – Uganda, Kenya Gatsby Trust (KGT) and Tanzania Gatsby Trust (TGT).

Finally, we are especially grateful to the Gatsby Charitable Foundation (GCF) for funding the project, workshop and publication of this document.

Editors
Catherine Ngamau, Benson Kanyi, James Epila-Otara, Patrick Mwangingo and Samuel Wakhusama

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FOREWORD

The Tree Biotechnology Project (TBP), spearheaded by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) with financial support from the UK's Gatsby Charitable Foundation, began in Kenya in 1997 as a collaborative effort to help increase the country's forest area and the supply of forest products and services. It was extended to Uganda in 2000 and Tanzania in 2003.

In the past, the region's tree-planting efforts were severely constrained by a lack of quality seed supply and inefficient traditional propagation methods. Using proprietary technology – donated to TBP by South Africa's Mondi Forests – scientists from East Africa's Forest Departments can now propagate *Eucalyptus* to help meet the region's wood and fuel-wood demand, currently at an average annual shortfall of 30 million cubic metres. In Kenya and Uganda, the project is now generating data which matches tree species to specific sites. Kenya's TBP has successfully reached its third phase of implementation, providing encouragement to its sister partners in Uganda and Tanzania to fully embrace the technology.

The TBP Workshop, held in January 2004 in Nairobi, Kenya, marked the culmination of integrating the project in the East Africa region. With participants from Ethiopia, Kenya, South Africa, Tanzania, Uganda and the United Kingdom, the workshop brought together scientists involved in *Eucalyptus* research, forest nursery management, seedlings marketing and related tree improvement programmes.

We are pleased to disseminate the information presented at the workshop to a larger audience and hope that the collaborative structure of the project and information found herein may serve as a model for similar South–South partnerships in technology transfer. ISAAA will continue to foster the partnerships developed through this work to ensure the long-term sustainability of the project's realised benefits for the greatest number of beneficiaries. We look forward to the continued collaboration and extension of similar benefits to other countries with comparable challenges.

Samuel Wakhusama
Director
ISAAA *Afri*Center, Nairobi, Kenya

GATSBY CHARITABLE FOUNDATION'S INVOLVEMENT IN THE TREE BIOTECHNOLOGY PROJECT

Gatsby Charitable Foundation (GCF) is a private foundation funded by Sainsbury's supermarket chain, UK. Its overall objectives include: supporting science education; supporting the application of science (generation of science to technology); and supporting small-scale enterprises through micro-credits.

In developing countries, the aim is to promote environmentally sustainable development and poverty alleviation through programmes that support basic agriculture and other micro-credit enterprises.

The African Programme, which receives about 10% of grant payments from the Foundation's trustees, has three strands:

1. Supporting small-scale enterprises through micro-finance managed locally by local trustees
2. Promoting science education to ensure improved economic growth
3. Encouraging technology transfer where effort is made to transfer identified technologies to poor rural farmers.

For the third strand, in which the Tree Biotechnology Project (TBP) falls, GCF works in collaboration with centres of the Consultative Group on International Agricultural Research (CGIAR), local research institutions, such as the Kenya Agricultural Research Institute (KARI) and Uganda's National Agricultural Research Organisation (NARO), and other relevant national organizations.

GCF is proud to have supported the TBP through ISAAA's expertise and pleased with the experience and outcomes. The Foundation hopes that the conclusions of this workshop will address and make recommendations on how the TBP and its scientific implications can fit more broadly in future forest sector planning.

Laurence Cockcroft
Advisor on African Programmes
Gatsby Charitable Foundation

SESSION I OPENING THE WORKSHOP

1. Keynote address

Honourable Dr Newton Kulundu, *Minister for Environment, Natural Resources and Wildlife, Government of Kenya*

This conference, the first of its kind in East Africa, brings together individuals and institutions with a shared vision on the region's future in forestry development. The forum will help each of you to assess how much 'value-addition' your experiences have provided – or could potentially provide – to the ongoing Tree Biotechnology Projects in East African countries.

Historical evidence reveals that, through practices such as coppicing and rotational harvests, people all over the world have used forests as a source for various wood and non-wood products for at least 6,000 years. Forestry as a science, however, emerged during the early years of the industrial revolution in response to the clearing of forests for agriculture, fuel-wood and timber for burgeoning industries. More recently, centralized forest management – mainly characterized by state control – has promoted the emergence of an established bureaucratic forestry system that has both overseen and sustained the over harvesting of forests and misallocation of forest lands. This trend must be stopped and can be achieved through stakeholder involvement, partnerships and regional collaboration. As forests continue to provide the basic needs of a growing population, communities cannot be prevented from using the forest resources on which their livelihoods depend. Adoption of novel technologies, however, will encourage regeneration and help stem rapid forest deterioration.

Kenyans are primarily based in rural areas where they rely on the available natural resources for survival. These same natural resources also form the foundation of Kenya's main productive sectors, including agriculture and tourism. Over the last 20 years, it is estimated that some 19,000 hectares of forest cover have been lost or converted each year. Total forest cover in Kenya now stands at below 2% of the total land area. With over 80% of the population depending on biomass as their main source of fuel, this is bound to have serious implications for the remaining forests. Such complex and multi-faceted challenges call for working in partnership to achieve success.

I am delighted that a number of local and international stakeholders have come forward to work with the Government to find solutions. I wish to thank The Gatsby Charitable Foundation, Mondi Forest and ISAAA for the commitment they have demonstrated in partnering with the government and local institutions, not only in Kenya, but throughout the East Africa region. This partnership must ensure that a wide range of stakeholders are actively engaged in the implementation of the Tree Biotechnology Project in order to favour positive and sustainable outcomes. Partnerships are critical for scaling up lessons learned from country to country and to spur success in the practice of forestry into a momentum for change both in the region and beyond.

We must put forward a framework for action that will satisfy regional, national and local needs whilst also meeting wider international obligations, thus putting our countries at par with global trends in forestry development. This can be done through wide consultations with interested and affected parties, addressing aspects of forest policy and legislation to match present needs and through the gradual devolution of forest management to grassroots communities. One key principle shall always remain: forests and forest resources are national assets that must be protected and conserved for both present and future generations.

The Government of Kenya recognises the important contribution of forests to national development. Forestry development has been included in the economic planning blueprint entitled *Economic Recovery Strategy for Wealth and Employment Creation: 2003 to 2007*. However, the contribution of forests to national development cannot be realized without addressing the current challenges facing the sector. These include: increasing population pressure and encroachment on residual forests, over-exploitation leading to deforestation and reduced vegetation capital stock, and the limited capacity of the government in management and enforcement. As these challenges persist, they diminish our forests' potential contributions to the goals of economic growth, food security and export competitiveness. The search for solutions is therefore a means for us to improve our forest resource base productivity, accessibility and sustainability for national and regional development both now and in the future.

I would like to thank The Gatsby Charitable Foundation, UK, for its generous financial support of this conference and ISAAA-*Afri*Centre for facilitating the forum. I wish to extend a very warm welcome to delegates coming from outside Kenya and wish you all fruitful deliberations. I look forward to receiving your recommendations, which we will consider very seriously in the government's strategic planning.

2. The Tree Biotechnology Project in East Africa: An overview

Samuel Wakhusama, *Director, ISAAA*-Afri*Center*

The East African Clonal Tree Project first started in Kenya in 1997. Initiated by ISAAA through technology brokerage with Mondi Forest and funded by The Gatsby Charitable Foundation (GCF), the project aimed to increase forest area and fuel-wood supply where land clearance for agriculture and an increasing demand for wood were causing widespread deforestation and environmental degradation. Following successful trials, work expanded into Uganda in 2000 and Tanzania in 2003.

East Africa's wood crisis is caused by the overwhelming need for firewood in rural communities: 80–90% of the population depend on it for 96% of their energy needs. The problem is further exacerbated by the nonavailability of fast growing seedlings to meet this demand – Kenya alone requires 60 million seedlings per year. Current tree planting efforts are severely constrained by a lack of quality seeds and slow, inefficient traditional propagation methods.

Access to convenient and sustainable sources of fuel-wood can help alleviate poverty in both rural and urban areas. Fuel-wood and timber 'cash crops' provide a reliable source of income for small-scale farmers and feed wider economic growth. And both commercial forestry and the timber trade benefit through increased employment opportunities in tree production and timber processing.

The project has brought together many partners with complimentary strengths with the objective of improving resource-poor rural livelihoods through the integration of improved and proven forestry biotechnologies into traditional propagation systems. Partners include: Mondi Forests of South Africa, GCF, ISAAA, the Kenya Forestry Research Institute (KEFRI), Forest Department of Kenya's Ministry of Environment and Natural Resources, Forestry Resources Research Institute (FORRI) of Uganda's National Agricultural Research Organisation (NARO), Tanzania Forestry Research Institute (TAFORI), Kenya Gatsby Trust (KGT), and Tanzania Gatsby Trust (TGT).

The two-day workshop was held to promote the sharing of project experiences. Specific objectives included:

- Facilitating experience sharing and broad discussion on the current means by which farmers are planting *Eucalyptus*
- Encouraging private-sector involvement and identifying new opportunities
- Discussing how clonal forestry – with questions on species and multiplication systems – fits into broader national programmes
- Assessing the merits of clonal production and distribution approaches in relation to enhanced village-based systems
- Discussing current marketing and distribution realities in each of the 3 countries – government versus private nurseries – as well as seed distribution and cuttings
- Defining the way forward for the sub-region's tree biotechnology projects.

SESSION II SHARING EXPERIENCES IN CLONAL FORESTRY IN EAST AFRICA

1. Tree Biotechnology Project: Kenya's experience

Benson Kanyi, *Tree Biotechnology Project (TBP)*

Abstract

Kenya's Tree Biotechnology Project (TBP) has achieved great impact over 7 years through partnership and collaboration in clonal forestry adoption by way of capacity building, infrastructure development, agro-ecological trials, and delivery networks. The increase in demand for both clones and improved seedlings bears testimony to these high acceptance levels (TBP 2000–2002). This section summarizes lessons learned in terms of technology transfer through partnership, downstream adoption and dissemination, relations with stakeholders, project challenges, and the way forward.

Introduction

The TBP began in Kenya in 1997 to mitigate the country's declining supply of wood products caused for the most part by the shortage or unavailability of desirable tree seedlings due to poor seed sources and inappropriate propagation methods (Wakhusama *et al.*, 2002). Most common indigenous species are slow growing, resulting in declining forest cover from over-exploitation and poor natural regeneration.

Clonal forestry technology offers great potential for propagating selected trees with desirable traits (Duncan, 2001). The project aimed to help resource challenged small-scale farmers by providing superior planting stocks of multi-purpose tree species for distribution. Integrating improved forestry biotechnologies into traditional propagation systems would, in turn, improve living standards through enhanced forest productivity. With technological support and expertise from South Africa's Mondi Forests, a private firm, the project established trials and a clonal propagation nursery using selected *Eucalyptus* hybrids and seed lots (Wakhusama *et al.*, 2002).

Clonal forestry technology transfer

Kenya's population is primarily based in rural areas where communities depend on the environment and natural resources for their livelihoods. With poverty levels estimated at 56%, 80–90% of the population depend on wood as a source of energy for cooking. Poverty is directly linked to environmental degradation, though other causes include drought, crop failure, and disease outbreak among others. As associated costs to mitigating environmental degradation continues to rise, the need to find affordable solutions in these areas becomes increasingly urgent.

One such solution – clonal forestry – has been successfully exploited in South Africa for over 20 years by Mondi Forests. Through a sustained broad genetic base, continued field testing of clonal rooted cuttings prior to deployment, and high-level nursery management, their *Eucalyptus* breeding programme has produced considerable species variation and generation of breeding (Duncan, 2001). Though *Eucalyptus* trees have grown in Kenya for over 100 years and most farmers are familiar with its management, little research had previously been devoted to the species. With the available species diversity and hybrids through the project, *Eucalyptus* can now be grown in diverse sites and their growing performance assessed to provide both basic wood and non-wood products to farmers.

Project partners

The project brought together public, private and non-governmental organizations (NGOs) with a shared vision to enable the transfer of clonal forestry technology from South Africa to Kenya. The partnership promoted participatory involvement and expertise using complimentary institutional strengths (Table 1).

Project objectives

Kenya's TBP has three primary objectives:

1. Promote sustainable forestry through the distribution of affordable improved tree varieties

Table 1 Tree Biotechnology Project partners and their contributions

Objective	Institutions	Main output
Technology sourcing	Mondi Forests, ISAAA	Technology donor, technical backstopping
Strategic/adaptive research	Kenya's Forestry Department (FD), farmers	Scientific knowledge of trial plot handling, field extension support, and data collection for comparative studies
Field monitoring and disease/pests surveillance	Kenya Forestry Research Institute (KEFRI), ISAAA, FD	Technology dissemination to small-scale farmers through social-economic studies
Clonal and seedling production	FD, Genetics Technologies Limited (GTL)	Maintenance of clonal hedges, clonal multiplication, and management of clonal nurseries
Distribution and marketing	FD, Farmer cooperatives, Government nurseries, NGOs, schools, small-scale and large-scale entrepreneurs	Seedlings sales, establishment of distribution nurseries and demonstration plots
Financial support	Gatsby Charitable Foundation (UK)	Project funding
Financial management	Kenya Gatsby Trust	Project financial management
Facilitation	ISAAA	Maintaining project focus, communication and networking, coordination, reporting, identification of appropriate partners, contractual issues and soliciting donor support

2. Contribute to environmental conservation by increasing forest cover
3. Reduce poverty by improving access to affordable wood products and creating wealth at the household level.

Activities

To reach these objectives, the following activities have been implemented:

1. Capacity building and training of Kenyan scientists in clonal forestry propagation and commercial plantations. Scientists were trained by visiting Mondi Forests facilities in South Africa and through training sessions by Mondi staff in Kenya.
2. Seventeen clonal screening and adaptability trials were established countrywide. These cover each of the country's agro-ecological zones in order to identify particular clonal germplasm for specific sites (Table 2). Preliminary trial results are summarized in Table 4 (see also Session IV 1. Deploying clonal forestry technology into Kenya's National Forestry Programme, p. 53).
3. A clonal forestry nursery was established at Karura Forest Department Headquarters. To date, it has produced over 4.7 million improved seedlings and clones and has an annual production capacity of 3.5 million (Figure 1 and Table 3).
4. A nationwide distribution and delivery network for seedlings and clones to target groups is now operational through collaboration with public extension agents, non-government organizations (NGOs), the private sector, learning institutions and direct delivery to individual growers.

Table 2 Agro-ecological zones and number of trials carried out in Kenya

Province	Geographical location	Agroclimatic zones (annual rainfall (mm), temperature range (°C))	Number of trials
Coast	Malindi (Gede)	IV, 1 (600–1100, 24–30)	1
	Kwale (Msabweni)	III, 1 (800–1400, 24–30)	1
	Kilifi (Sokoke)	III, 1 (800–1400, 24–30)	1
Eastern	Embu	III, 3 (800–1400, 20–22)	1
	Makueni	V, 2 (450–900, 22–24)	1
	Kitui	III, 3 (800–1400, 20–22)	1
	Kibwezi	V, 2 (450–900, 22–24)	1
Central	Hombe	II, 6 (1000–1600, 14–16)	1
	Muguga	II, 6 (1000–1600, 14–16)	1
	Kabage	III, 4 (800–1400, 18–20)	1
Rift Valley	Laikipia	III, 6 (800-1400, 14–16)	1
	Marigat	V, 2 (450–900, 22–24)	1
	Naivasha	V, 5 (450–900, 16–18)	1
	Timboroa	I, 7 (1100–1700, 12–14)	1
Western	Kakamega	I, 4 (1100–1700, 18–20)	1
Nyanza	Yala	I, 3 (1100–1700, 20–22)	1
Nairobi	Karura	IV, 4 (600–1100, 18–20)	1

Figure 1 Seedling and clone production at the Karura clonal forestry nursery, Kenya, 2000–2003

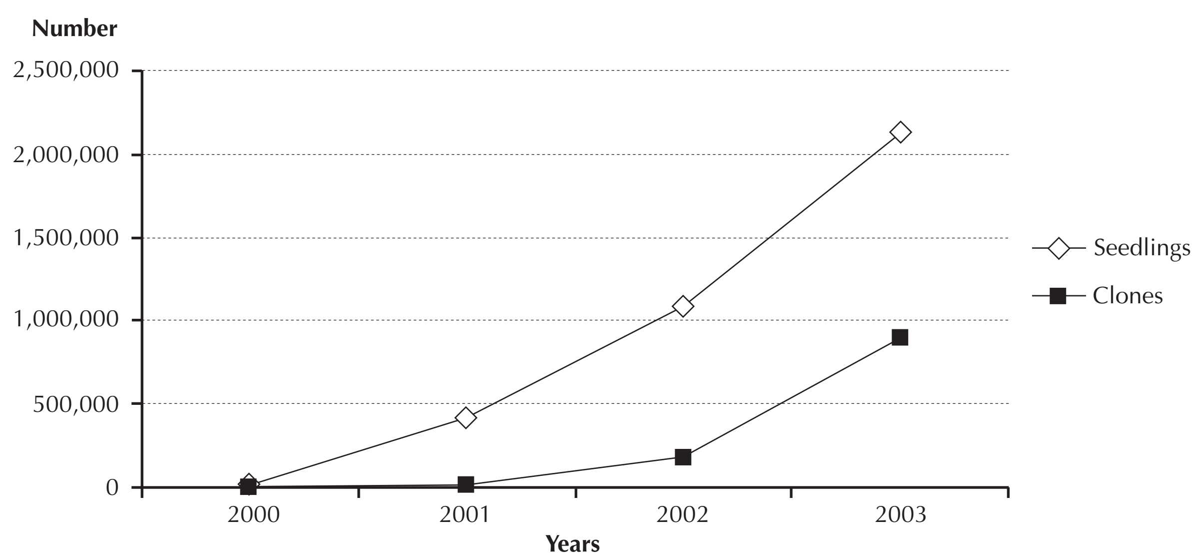

Table 3 Seedling and clone production at the Karura clonal forestry nursery, Kenya, 2000–2003

Year	Seedlings	Cuttings	Total
2000	13,000	102	13,102
2001	412,870	14,110	426,980
2002	1,088,962	185,062	1,274,024
2003	2,131,931	897,200	3,029,131
Total	3,646,763	1,096,474	4,743,237

Table 4 Matching *Eucalyptus* species to sites

Species	Altitude (metres above sea level)	Average annual rainfall (mm)
E.grandis	1,200–2,000	Not < 900
E.saligna	1,200–2,000	Not < 900
E.camaldulensis	0–1,200	450–900
E.tereticornis	0–1,200	450–900
E.urophylla	0–1,800	Not < 900
E.nitens	1,500–2,200	Not < 900
E.dunii	1,000–2000	Not < 700
EGC (Hybrid)	0–1,600	Not < 600

Project impacts

Project activities to date have had three notable achievements:

1. Species identification

Suitable *Eucalyptus* species were identified for growing in Kenya's different agro-ecological zones (Table 4).

2. Land preparation and harvesting methods for commercial woodlots

Land preparation and harvesting methods for *Eucalyptus* were identified to promote the establishment of commercial woodlots under current agricultural practices. These methods include:

- *Cropping:* intercropping is recommended for the first 2 years using common annual agricultural crops, particularly legumes.
- *Spacing:* 2.25 m x 2.25 m (2000 seedlings/ha) is recommended for growing fuel-wood and poles; whereas seedlings for transmission poles, fencing posts, timber and pulp can be planted at 2.5 m x 2.5 m (1600 seedlings/ha).
- *Pit preparation:* the hole should be 30 cm deep and 30 cm wide.
- *Planting:* the polythene tube should be carefully removed to avoid damaging the young plant. The hole is first half-filled (15 cm) with top soil before the seedling is placed in the hole, the seedling is then covered with 15 cm of remaining top soil.
- *Optional additions:* Fertilizer – 17:17:0 diammonium phosphate (DAP) at planting (30 g/hole); Termiticide – regent 3G at 33.0 g/hole for termite-prone areas; Hydrogels – mix one teaspoonful in one litre of water then apply 0.5 litre of the mixture per tree.

Eucalyptus will coppice after harvesting. To promote vigorous coppicing, fell trees with a saw, not an axe.

3. Employment creation

Eighty (80) individuals currently work full-time on the project, with a further 50–60 casual labourers periodically employed. The 4.7 million seedlings/clones distributed to date represents approximately 2,400 ha of additional forest cover, translating into an additional 7,200 jobs (at an average of 3 jobs per ha annually).

Challenges/opportunities

TBP's remaining challenges and opportunities include:

- Decentralizing the distribution system to enhance downstream clone and seedling dissemination
- Integrating a breeding and selection programme into the project to sustain clonal propagation
- Initiating a clonal propagation programme for indigenous species
- Reducing nursery production costs to meet pricing expectations of poor rural farmers
- Initiating an appropriate micro-credit scheme for smallholder farmers to enable them access to planting materials in larger numbers
- Meeting the high demand for clones and seedlings as compared to current production.

Future strategies

Future activities should largely focus on increasing production, promoting extension and marketing activities, and breeding more materials for trials. These require more private sector involvement and an enhanced budget to secure technology adoption and long-term impacts.

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2. Tree Biotechnology Project: Uganda's experience

James Epila-Otala, *Tree Biotechnology Project, Forestry Resourses Research Institute*

Abstract

Firewood and charcoal are extracted from Uganda's natural forests and woodlands at an alarming rate for cooking and heating in poor urban and rural areas. To mitigate the associated problems of environmental degradation, the Tree Biotechnology Project (TBP) in Uganda was set up to provide immediate and long-term solutions to the imminent national wood scarcity. This paper discusses experiences in implementing two of the project's objectives: demonstrating superior performance of *Eucalyptus* clones; and the creation of a mini-clonal nursery with the private sector for scaling up clonal production.

Overview

Eucalyptus clonal performance demonstrations were to be implemented in three phases over twenty sites. Phase I began on five sites in April 2002 and Phase II planting occurred on nine sites in May 2003. The remainder will be planted in 2004.

After 15 months of growth, the diameter and height of Phase I trees showed that local seedlings and clones were more or less alike. Similarly, both seedling and clonal trees attained marketable pole sizes (> 7 cm) within the same period. Seedling trees, however, showed variations in height and diameter and were poor in stem form compared to most clones. Phase II clones are showing similar trends in growth performance.

The uniformity and good stem form of the clones indicate that the productivity per unit land area will be higher than with the seedlings. The project is currently in the process of involving the private sector in mass production of suitable clonal planting materials.

Based on the Kenyan example, the construction of a mini-clonal nursery was also carried out in phases: nursery housing construction, followed by irrigation system instalment and the planting of a clonal hedge. Housing construction was completed on time, but the irrigation system is incomplete due to technical complications. Clonal hedges have performed well to date, though ramets have been attacked by an unknown clone-specific disease.

Background

Status of forests in Uganda

Uganda has some 5 million hectares of forests covering roughly 24% of its land surface area. 80% of these forests are woodlands, 19% tropical high forests, and less than 1% is forest plantations. There are substantial forest resources on farms (70%) in the form of tropical rain forests, scattered trees, woodlands and agroforestry crops. These resources collectively form the source of wood and non-wood forest products and environmental services of the national economy.

Utilization and limitation

An estimated 800,000 cubic metres (m^3) of wood are used annually for construction, furniture and other manufactured products. A further 875,000 m^3 are harvested for building poles, while estimates put national fuel-wood consumption at 18 million tons per year. Half a million tons are used for charcoal production. Though Uganda's tropical forests are incapable of producing a sustainable annual yield of wood, utilization levels are bound to increase. The ever-increasing demand for agricultural expansion, rural settlement and urbanization will exacerbate the situation. Conservative estimates suggest that forested areas have been shrinking at the annual rate of 3% since 1890. Private forests have shrunk more rapidly than government-managed forests.

Remedial measures

In the 1940s, plantation forestry was recommended to increase the slow productivity rates of natural forests (Dawkins, 1954). Suitable plantation species first needed to be identified. The most sought after indigenous species (mahogany, *Milicia excelsa* and *Maesopsis eminii*) proved unsuitable in experiments due to their slow growth rates and susceptibility to disease and pests (Osmaston, 1958). Attention shifted to exotic species: large numbers of pines and *Eucalyptus* were tested for possible introduction (Anon, 1963). Of the 52 *Eucalyptus* species tested, only four were recommended for plantation forestry: *Eucalyptus grandis*, *E. saligna*, *E. cameldulensis* and *E. tereticornis*. The first two were assigned to the moist southern regions and the more drought-tolerant *E. cameldulensis* and *E. tereticornis* were earmarked for the dry northern zones. To date, plantation forestry has barely succeeded in redressing national wood production, primarily due to production constraints.

Production constraints

Unlike agriculture, forestry in Uganda has rarely attracted funding from the private sector. Instead, tree planting and growing has largely been undertaken by the government, albeit under donor-driven schemes. Reliance on donor funds proved disastrous in the face of the country's troubled political history. Donors abandoned Uganda in the middle of the planned tree planting programmes of the 1970s. A 30-year gap has thus been created in Uganda's tree growing programme. Its implications are alarming given that the end-use envisaged and the selected tree species compound rotation age. The gap for fuel-wood production using *Eucalyptus*, for example, now ranges from 32–35 years; for building poles (35–37), transmission poles (37–40) and sawlogs (40–60) years.

Other production constraints include poor planting materials, scarce planting materials, lack of tree planting awareness, misinformation peddled by non-professionals, and pests and diseases associated with the length of time taken for trees to mature.

Enabling environment

Nevertheless, Uganda has favourable conditions for forest production. These conditions, combined with the country's economic liberalization policies, have motivated individuals to grow trees. There now exists a core of profit-motivated tree planters who are actively patronizing tree growing programmes. To make an impact, the aforementioned production constraints must be addressed. Doing so would help small-scale farmers grow trees as an alternative rural enterprise for poverty reduction. Four 'catalytic forces' are needed to encourage such activities:

1. An experienced and perceived scarcity of wood energy in urban slums, rural areas and the tea industry.
2. An embedded enabling environment in strategic government policies and interventions.
3. Fear of increasing desertification.
4. Emerging market outlets for wood, triggered by the boom in housing construction (brick making and timber), rural electrification, industrial charcoal production and an upsurge in demand for non-wood forest products.

Health and environmental consequences

Demand for wood energy ranks highest amongst forest wood needs. If no programme is implemented to restore the imminent scarcity of wood energy, most rural consumers will need to change their dietary habits or destroy the remaining forests and woodlands. Both scenarios have social, economic and environmental consequences. Forest degradation would lead to irretrievable loss of biodiversity and gene pools critical to agriculture, medicine and the environment. Dietary manipulation to overcome lack of wood energy could induce a number of direct and indirect health problems. This would, in turn, lead to weakened economic and social sectors.

Timely intervention

Uganda's 30–60 year gap in her tree-growing programme leaves very little forest resources for the present generation. Wood scarcity in many regions has forced even the most misinformed advocates of food security to recognize the critical role of wood for national food security. Now is the time to make strategic interventions in order to sustainably meet the future demands that will be placed on forest resources.

Project conception

The Tree Biotechnology Project in Uganda (TBP-U) was conceived to alleviate imminent wood scarcity associated with the national wood production gap, now estimated at 10 Mm^3/annum. The speed with which TBP-U is to deliver desired outputs is pivotal to the project's design, implementation and documentation. The project aims to introduce, test, and demonstrate clonal forestry and produce suitable clones for public consumption. Activities are defined by four objectives to:

1. Transfer and utilize clonal forestry biotechnology
2. Build capacity in clonal forestry technology
3. Recruit valuable indigenous trees to clonal forestry
4. Involve the private sector in mass clonal production.

TBP-U initiated activities to varying degrees for three of these objectives. Twelve proprietary *Eucalyptus* clones from Mondi Forests in South Africa were imported. These are being evaluated and used to demonstrate their potential in 14 sites. A mini-clonal nursery was constructed at Kifu, Mukono district for clonal forestry backstopping. With assistance from Forestry Resources Research Institute (FORRI) scientists, stakeholders are being progressively introduced to *Eucalyptus* clonal forestry.

Technology transfer

TBP-U imported 12 clones on two separate occasions (2002 and 2003). Plants were packed differently each time: in 2002, they were dislodged from their plastic inserts, wrapped in plastic bags and packed in cardboard cartons. In 2003, the plants were packaged as before but left intact in the inserts. The plants experienced varying degrees of stress; with more extensive stress occurring in 2002 as the root plugs for GU 607 and GU 609 disintegrated in transit and had to be re-constituted using a mixture of original medium (vermiculite and perlite) and local forest soil. The 2003 plants withstood the transit stress much better. The 2002 plants were acclimatized for one month before planting; the 2003 consignments were planted one week later.

Experimental design

TBP-U trials randomised clones in four complete blocks (Table 5) along the contours with experimental plots of 4 x 4 trees spaced at 2.5 m x 2.5 m, control plots of the same size contained eucalyptus clones. Each trial site's perimeter is guarded by 2–3 lines of local seedlings.

Site preparation and planting

Active termite mounds were poisoned prior to clonal planting with termiticide regent 3G. Existing trees/shrubs were uprooted and the site either ploughed or cultivated twice. This would protect clones against termites and give them an up-start over the local vegetation. TBP-U has established fourteen clonal trials in the districts of Mukono, Mayuge,

Table 5 Layout for clonal trials at various sites in Uganda

Block 1	TAG 5	GU 7	GU 8	CN	GC 540	GC 514	GU 21	GC 550	GC 796	GU 607	GC 578	GC 784	GU 609
Block 2	GU 607	GC 550	GU 7	GC 874	GU 8	TAG 5	CN	GU 21	GC 578	GC 540	GC 796	GU 609	GC 514
Block 3	GU 609	CN	GC 578	GC 514	GC 796	GU 21	GU 607	GC 540	GC 784	GU 7	GC 550	TAG 5	GU 8
Block 4	GC 540	GU 8	GC 514	GU 21	GU 7	GC 784	GC 578	GC 796	GC 550	GU 609	GU 607	CN	TAG 5

CN=control plots

Kumi, Soroti, Katakwi, Lira, Masindi, Kabarole, Bushenyi, Ntungamo and Kabale over the last two planting seasons (April–May 2002; 2003). Planting was done with the help of local populations following the demonstrations for three critical precautionary measures: how to remove clones out of inserts, how to incorporate granules of termiticide into the soil refill without poisoning oneself, and the appropriate planting depth for clones. This strategy enabled the establishment of 2–4 trials in a row within a short time using relatively vigorous clones. All trials were fenced with barbed wire to keep livestock out.

Managing trials

Trial management has been influenced by land ownership. For the 2002 trials located on National Agricultural Research Organisation (NARO) land at Kifu, Ikulwe, Serere, Ngetta and Abi, responsibility for weeding, pest and disease monitoring, protecting trials from fire, etc. is done from FORRI headquarters. Second generation trials located on private land in Kabale, Ntungamo, Bushenyi, Masindi, Lira, Kumi and Katakwi are jointly managed by participating farmers and the project personnel at FORRI. The Kabarole trial site on government land at Kyembogo is managed directly from FORRI headquarters. Both management strategies have cost and efficiency implications. Direct management has been costly and inefficient compared to joint management, with the notable exception at Kifu. Under joint management, participating farmers view the trials as their own projects and are keen to maintain them properly.

Results

Clonal performance and site-specificity

Clonal growth and health under trials was regularly monitored. 2002 clones exhibited variable temporal responses to sites. GCs (*Eucalyptus* hybrid *E. grandis* x *E. camaldulensis*) grew faster than GUs (*Eucalyptus* hybrid *E. grandis* x *E. urophylla*) when young, however, results were mixed as trees aged. Although the best basal diameters (BD) in Ngetta, for example, were registered by GCs, in Ikulwe and Kifu both GCs and GUs faired equally well. Stress in transit did not influence survival or performance. An important characteristic was observed among the clones: compared to the location-specific seedling trees, all but GU 21 clonal trees produced small, self-pruning branches. GU 21 in Kifu also responded strangely: in block 4 all GU 21 plants died and yet performed very well in the other three plots. Similarly, marked stunted growth was observed among the GU 7 of block 3, yet it was doing well elsewhere. In contrast, whereas the majority of the tallest trees in Ikulwe were GCs, in Ngetta and Kifu height superiority was exhibited by both groups of clonal hybrids (Table 6).

New scenarios emerged when data for BD, height and stem form (SF) were rounded to the nearest whole number and the clones grouped for quality. At Ikulwe 48% of clones reached heights above 8 m, followed by Ngetta with 39%. Only 13% of the Kifu clones grew beyond 8 m (Table 6).

Table 6 Summary from Ngetta, Ikulwe and Kifu trial sites, Uganda, of average base diameter (BD), diameter at breast height (DBH), height (HT) and stem form (SF) of 16 trees per clone

Site	Ngetta				Ikulwe				Kifu			
Parameters	BD (cm)	DBH (cm)	HT (m)	SF	BD (cm)	DBH (cm)	HT (m)	SF	D (cm)	DBH (cm)	HT (m)	SF
GC 796	10.8	7.1	7.7	4.4	9.1	6.6	7.9	4.5	9.6	7.0	7.7	4.5
GC 550	10.3	7.7	8.5	4.2	9.9	7.6	8.5	4.2	9.7	7.2	7.7	4.5
GC 578	10.0	7.1	7.8	4.4	9.7	7.0	7.9	4.0	9.1	6.6	7.4	4.0
GC 540	10.0	7.0	8.0	4.1	9.2	6.7	8.2	3.4	8.8	6.1	7.1	4.0
GC 784	9.8	7.0	7.7	3.9	10.2	7.1	7.6	4.2	8.3	5.7	7.3	4.5
GC 514	9.9	7.0	7.7	4.3	10.0	7.0	8.7	4.0	8.3	6.1	6.9	4.0
GU 7	10.5	7.6	7.7	4.3	10.0	7.2	7.6	5.0	8.8	6.0	6.5	5.0
GU 8	9.6	8.0	7.4	4.3	10.1	7.4	7.6	5.0	9.0	6.1	6.3	5.0
GU 21	9.6	6.9	7.6	4.3	9.1	6.6	7.4	3.4	8.7	6.3	7.2	3.7
GU 607	9.5	7.4	7.7	4.7	8.3	6.4	7.6	4.8	8.0	6.0	7.0	4.7
GU 609	9.2	6.0	6.8	4.3	8.4	6.0	7.8	4.6	9.0	6.2	7.0	4.8
TAG 5	9.0	6.5	7.1	4.5	7.4	5.5	7.5	4.5	8.5	6.6	8.1	5.0
Control	9.0	6.1	7.0	3.0	8.5	6.3	7.2	4.0	8.9	6.4	7.0	3.0

Stem form: 1 = poor, 2 = average, 3 = good, 4 = very good and 5 = excellent

In Ngetta 56% of clonal trees registered BD growth beyond 10 cm, compared to 33% for Ikulwe and and 11% for Kifu. The trend in SF was reversed: 50% of the Kifu clones had a perfect score of 5, with Ikulwe following at 38% and Ngetta only 12%.

Rounding the data for BD also brings out a variable element of environmental dependency amongst the clones of this age. Only GC 550, for example, showed similar growth patterns at all three sites, while plasticity was exhibited between Ngetta and Ikulwe by GC 578, GC 514, GU 7, GU 8, GU 609 and TAG 5. Environmental plasticity was evident for GC 796 in Ngetta and Kifu. Economically, BD statistics are very interesting in that they indicate that all the clones and location-specific seedling trees attained the status of marketable class one poles (> 7 cm) within 15 months or less.

Trends are similar for the 2003 clones. To date, the GCs are sprinting faster than the GUs as they did in the 2002 trials. Site-specificity, however, has emerged: clones at Masindi have performed the best with an average growth of 4 m, followed by good growth rates at Apala, Akol and Bushenyi where both GCs and GUs have attained growths from 2–3 m at 6 months. The GUs suffered the highest mortality in Kabarole. Ntungamo and Kabarole clones were not properly weeded and suffered from stunted growth. Ngetta, Masindi, Apala and Bushenyi trials were intercropped with groundnuts, though it is difficult to ascertain whether this intercropping helped the trees in anyway.

Matching clones to sites
Testing the 12 clones using the same experimental design and location-specific control seedlings has yielded valuable information. The strategy revealed, for example, that clonal *Eucalyptus* hybrids can grow anywhere in the country, barring changes which may come with aging. Only the TAG 5 clone did not do well within the Lake Victoria agro-ecological zone. Results also show that, as trees aged, earlier differences between clonal groups either balanced out or reversed in growth trends. Noteworthy reverses were observed at Ikulwe and Kifu where *E. urophylla* hybrids out-performed *cameldulensis* in both girth and height. Specific clonal environmental plasticity in Ikulwe vs. Ngetta and Kifu vs. Ngetta was another important discovery. Implicitly, clones showing uniform widespread adaptive responses can be produced in large quantities for extensive planting at much lower costs.

Goods and services
Perhaps most importantly, *Eucalyptus* clones have already produced two critical goods: firewood and poles for scaffolding and rural house construction. Similarly, the canopy closure at the early age of six months demonstrates the potential for reclaiming degraded or exposed sites. Provisions of these goods and services, in part, address the project's goal of immediately providing goods needed by the rural population.

Pests and diseases
Joint work with Kenya Forestry Research Institute (KEFRI) scientists found a *Chalcid* attack – small parasitic wasps – on a single tree of GC 540 at the Ntungamo trial. Otherwise no incidence of this virulent new pest was found on the test clones. An *Analeptes* beetle attack on GC 540 at Serere proved parochial and did little damage.

Nursery construction

Design and citing
Cited on an old agroforestry experimental plot (35 x 125 m) in which banana and 5 species of *Ficus* were intercropped, the mini-clonal nursery was constructed and developed in three phases. Except for the water reservoir, the Uganda nursery was modelled after the Karura nursery of Kenya. Houses for the pump, standby generator and control panels, cutting production, security guard and toilet together with perimeter fencing were constructed first. The planting of the clonal hedge followed in May 2002. The last on-going phase of nursery construction is the irrigation system which includes a reservoir whose water is distributed through a pumphouse for four main uses: the cutting house, clonal hedge, rooting section and grow-out section.

Construction strategy
Nursery construction was contracted out through selective bidding. Civil work was awarded to a local firm and completed within the stipulated time. Initially, a special stakeholder meeting directed that the irrigation should be contracted to the same Kenyan firm that constructed the Karura one. The Kenyan firm proved to be expensive and was replaced by a local firm: Balton (Uganda) Limited. The installation work has been fraught with complex technical difficulties and omissions that are being sorted out.

Clonal production
Clonal production is a very exacting task. Water pH must be about 5.5, high humidity must be maintained, precise watering regimes are needed for different ages of the cuttings, sterile rooting mediums and a high level of hygiene also need to be observed. As irrigation is partially complete, the first three requirements have not yet been realized. Nevertheless, TBP-U has manipulated the watering regime to enable the production of clones to begin at the Kifu nursery. In order of decreasing rate of successful rooting, the following clones are now being produced: GC 578, GC 796, GU 609, GU 8, GU 7, GU 607, GC 784, GC 540, GC 550, GU 21, GC 514 and TAG 21. Production will improve when the basic requirements are in place.

A pathogenic problem cropped up in the nursery: a severe attack on the clonal hedge by a GC-specific disease. The symptom of this disease was not noticed but the attention was drawn to the dying ramets in August 2003. Speculations have since been made about the cause and hence its potential damage and possible control measures. TBP-U has engaged pathologists from

Namulonge Agricultural and Animal Research Institute of the National Agricultural Research Organization (NAARI–NARO). The project is also in contact with the Tree Pathology Co-operative Programme (TPCP) of the University of Pretoria. NAARI scientists suspect the pathogen is bacterial but results are not yet back from the laboratory. TPCP will examine specimens of this disease in their laboratory at the end of January 2004.

General remarks

Collaboration

TBP-U partnership has worked extremely well during the implementation process of the aforementioned activities. The Gatsby Charitable Foundation (GCF) provided timely the funds to finance the activities. Mondi Forests Limited donated and supplied the clones. Similarly, ISAAA has done a commendable job of coordinating and informing the stakeholders on all aspects of TBP-U. Both the steering and technical committees kept the project on course, and farmer cooperation has been exceptional.

Pending activities

The project failed to conduct a socio-economic study and initiate tree improvement programmes as planned. The socio-economic study failed because the FORRI socio-economist assigned to the task was transferred to a distant NARO institute. The tree improvement programme was never initiated because the preparatory work and skilled manpower needed to launch it was underestimated while concurrently implementing other critical project.

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3. Proposed Tree Biotechnology Project in Tanzania

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Abstract

The Tree Biotechnology Project (TBP) was introduced to Tanzania in 2003 to help increase the amount of wood resources in the country. This paper provides highlights on forest resource utilization in Tanzania, why the country opted for the technology, implementation progress and future plans.

Introduction

In Tanzania, fuel-wood accounts for 92% of primary energy uses. 91,300 ha of forest land are degraded yearly due to fuel-wood cutting and such land uses as clearings for agriculture, settlements, overgrazing, wildfires and charcoal burning (MNRT, 2002). Wood is also used for construction and furniture. By 2020, it is estimated that fuel-wood shortages will be as high as 65% (Lundgren, 1985)

Forest ecosystem degradation also contributes to the depletion of plant and animal diversity and reduces land productivity, negatively impacting returns from forest investment. Finding efficient methods to raise tree species to meet demand needs and mitigate negative impacts has become essential.

Tanzania and tree improvement efforts

Reforestation and afforestation programmes have been ongoing for some years to provide the population with additional and alternative wood sources, increase forest cover and conserve valuable biodiversity. Currently, there are 19 government forest plantations with a total coverage of 89,000 ha. Main species include *Pinus patula* (56%), *Cupressus lusitanica* (13%), *Eucalyptus* spp. (4.3%) and *Tectona grandis* (3.3%). Others include *P. caribaea*, *P. elliottii*, *Grevillea robusta*, *Juniperus procera*, *Sena siamea*, *Terminalia spp.*, *Cedrella spp.* and *Ocotea usambarensis*;

Since 1967, there have also been efforts to establish village or community woodlots and farm forests (Kaale, 1981; Mnzava, 1979; Kaale, 1984). Yet, the wood supply from these sources has been too low to meet increasing demand. Most of the wood requirements for home use are still being met from natural forests, putting more pressure on in-situ conserved forest genetic resources.

Through the Tanzania Forestry Research Institute (TAFORI), a number of improvement programmes have been implemented aimed at providing wood biomass for an array of end uses. Other goals include soil erosion control, soil enrichment, beautification and providing non-timber forest products. Arrays of species have been tested over 65 sites, including *Pinus* (the most commonly tested species), *Eucalyptus* and *Cupressus*. Some 12 progeny trials have been carried out involving *Pinus* and *Cupressus* genera. The five available seed stands are primarily pines and teak, while the three existing tree banks contain pines and cypress. Due to the long time required for effective progeny testing to reach advanced-generation seed orchards, this research method appears unrealistic. Other options should be explored.

Tree biotechnology in Tanzania: Project conception

The TBP in Tanzania was conceived in an effort to find more effective and efficient means of raising forests and making it a productive venture to interest the private sector and various other stakeholders in tree planting.

Though Tanzania has, to some extent, begun matching various species and provenances to sites, the country is far behind in terms of maximizing growth and productivity rates. The growth rate of most species remains low and the uniformity to a particular user need is yet to be achieved. Annual plantation yields for pines and cypress are at 25 to 35 m^3/ha. Similarly, the annual yield of *Eucalyptus* is only at 30 m^3/ha and of teak is 10 m^3/ha (Nshubemuki, 2003).

It is hoped that the acquisition and development of tree biotechnology will contribute toward minimising constraints that have hindered the smooth development of forest production, such as the use of unimproved seeds/planting stock with low growth rates and poor access to desired germplasm. Clonal forestry will also help to:

- supplement the limited supply and use of improved seeds, seedlings, wildings, scions, etc.
- mass produce plant material at a relatively low cost
- provide fast growing plant material to cut down the time involved in raising
- establish uniform crops for specific purposes
- supply plant material that is pest and disease resistant.

The project aims to develop large-scale production and distribution of superior clonal plants of several tree species, starting with *Eucalyptus* clones. By increasing trees planted on farms and woodlots, the project is expected to provide more timber, building and transmission poles, charcoal, and sawn timber thus removing pressure from the few remaining natural forests.

The project partners are GCF (UK), TAFORI, Tanzania Gatsby Trust (TGT), Mondi Forests of South Africa and ISAAA. Their roles are the same as those respectively described in Table 1 (page 6).

Project vision and objectives

The project aims to 'open up' and revitalize commercial private seedling distributors and establish a self-sustaining system. Given the central role that fuel-wood plays for the poor communities in Eastern Africa, this will perform a major role in poverty alleviation and environmental conservation.

The overall objective is to improve the living standards of rural communities, particularly of the resource-poor population segment, by enhancing forestry production. This will be achieved through the transfer and application of proven tissue culture and clonal technology for large-scale multiplication using proprietary *Eucalyptus* clones as an entry point. The project will later include local biodiversity. Specific objectives are to:

1. Transfer and apply clonal forestry biotechnology and tissue culture techniques using superior *Eucalyptus* clones for field evaluation trials and demonstrations while monitoring performance, environmental adoption and sustainability.
2. Establish a clonal plant production facility through private sector involvement based on successful

commercialization and risk management experience from South Africa, Kenya and Uganda. The TAFORI-owned nursery – with a capacity of a million seedlings per year – would be used to demonstrate the process and interest private investors to venture into commercial clonal production and distribution.

3. Promote environmental restoration and the creation of niche product markets through clonal tree technology – based on the *Eucalyptus* model – by selecting and utilizing indigenous trees with economic value. High in priority are *Grevillea robusta*, *Melia volkensii* and *Acacia* hybrid (*Acacia mangium* x *Acacia auriculiformis*).
4. Apply and adapt clonal forestry for income generation through the sale of wood products by involving resource-disadvantaged communities, NGOs and the private sector. Providing alternative sources for wood energy and timber will mitigate environmental degradation.
5. Create job opportunities and encourage entrepreneurship in both rural and urban environments by building capacity in both tissue culture and clonal forestry technology and management.

Implementation strategies

Project implementation will begin with screening and demonstration trials in Tanzania's five ecological zones. In each 'eco-zone', at least two trial sites will be established to cater for inter-zone variation. Eight sites will be planted in 2004 and are in various stages of preparation. Four sites are anticipated to be established in 2005 and four more in 2006.

A relatively small clonal nursery will be established for demonstration and sensitization. To help bring new partners on board, both the public and private sectors will be shown the superior performance of the clones, the production process and the need for the technology. Publicity campaigns and information dissemination will be done through mass media and such materials as videos, brochures and newsletters. Visits to Kenya, Uganda and Mondi Forests sites are also planned. Following these activities, it is expected that one or two private entrepreneurs will establish a fully operational clonal production nursery.

Local scientists and technicians will be trained in clonal nursery technology and tissue culture management in South Africa and Kenya to assist the private sector which currently has insufficient training resources.

Progress achieved

Visits have been completed to select planting sites for demonstration trials in coastal regions (Kibaha, Dodoma, Kwamarukanga), lowland regions (Mombo), highland regions (Lushoto and Sao Hill) and Arusha. Data on site soil characteristics and water quality are being analysed to determine the possible location of the clonal nursery. Site preparation for planting is in progress in Kibaha, Kwamarukanga, Mombo, Sao Hill and Dodoma. Provisional clonal testing sites have been laid out at Lushoto and Mombo to assist in establishing the location of the clonal nursery. Three *Eucalyptus* landraces (*E.grandis* and *E.camaldulensis*) have been sown for testing with clonal material. Screening and demonstration trial sites have been established in the different ecological zones, including clonal hedges, and an office built at Kwamarukanga.

Future work

The establishment of all screening and demonstration trials for the first phase will be concluded by May 2004. Efforts will then turn toward setting up a clonal nursery and training staff to handle it.

Though the project aims to increase the productivity of forest resources, the main focus is to improve the general income of the rural poor by providing fast-growing, quality planting material, that provides a reasonable return. An awareness-raising and marketing strategy should be implemented to ensure and encourage further production. The project will also provide hands-on training in clonal bank management, nursery management (including cuttings), and field disease monitoring. Training of a few scientists on tree breeding, tissue culture and micro-propagation at the Master and PhD level is also essential as there is a current lack of specialized personnel. In turn, trained staff can eventually provide services to private entrepreneurs who may not be able to afford to train their personnel outside of the country.

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4. The Ethiopian experience in growing *Eucalyptus*

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Ethiopia has a population of 65 million people of which 85% is rural. With an overall forest cover of 4%, annual deforestation is measured at 0.8%, indicating a widening demand-supply gap for forest products and services.

Eucalyptus is the most widely planted genus in the country and was first introduced in 1895. There are some 55 species in the country, found mainly in the Highlands where there is mean annual rainfall of over 400 mm. The common genuses are: *E. globules*, *E. camaldulensis*, *E. citrodora*, *E. saligna*, and *E. treticornis*.

Though some claim that *Eucalyptus* dries up soil, reduces biodiversity and suppresses plant growth in the vicinity, it is very popular with farmers for such products as fuel-wood, construction poles, and farm implements. It also provides financial security for rural farmers as it can be quickly sold for cash in times of need. Rural households commonly plant the trees in homesteads, boundary areas, and woodlots. They prefer *Eucalyptus* for its fast growth, resistance to browsing and its relatively better market value. By relieving pressure from natural forests, *Eucalyptus* also impacts positively on the environment.

The constraints experienced in propagating *Eucalyptus* trees and seedlings are similar to the constraints within the forestry sector in general. These range from poor or absent policy, legislation and institutions to such site-level factors as germplasm availability, poor extension services, low access to markets, land and tree tenure and small-sized holdings. In addition, the private sector is weak and faces problems including old technology, high transaction costs, competition with open access products and low tariff imports as well as an export ban.

Opportunities do exist, however. Research has been completed to establish *Eucalyptus* wood properties, economic viability, interaction with other plants, its yield of essential oils, and provenance trials. Results are ready to be scaled up. In 1998, the Ethiopian Agricultural Research Organization began agricultural biotechnology research – including forest biotechnology – with a mandate to coordinate national forest research to improve results and impacts. For more information on these activities and preliminary results, contact:

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5. Discussion

Participants discussed the need for information dissemination strategies, including mass media (electronic and print), information brochures and pamphlets, and farmer demonstration visits to build farmers' and stakeholders' awareness on the advantages of *Eucalyptus* and the benefits of growing clonal trees. This should be made some-what easier as results from the biotechnology programme are already being rolled out to farmers in Kenya. Some organizations, such as the Kenya Biotechnology Information Centre (KBIC) and African Biotechnology Stakeholders Forum (ABSF), are purely involved in biotechnology awareness creation and ideally suited to disseminate information on *Eucalyptus*.

One of the recognized advantages of the TBP in the region is its potential to establish commercial woodlots to supply fuel-wood and other products. Commercial woodlots would go a long way to supporting regional policy efforts to reduce poverty and create wealth and employment. Participants recognized that growth for commercial purposes had a potential to assist largely in sustaining rural energy needs. The Kenya Tea Development Agency (KTDA), for example, is being encouraged to grow and use fuel-wood in its tea drying operations instead of industrial oil, thus creating a major saving.

The workshop recognized that markets are already available for clonal tree products, re-organization is what is now needed. As the capacity of existing nurseries is limited, the private sector is being encouraged to fund the research or pick up the technology to begin commercial production of clones so as to meet demand. However, it was noted that the private sector may initially find the nursery component of clonal forestry to be expensive as prices at which clones are sold are low compared to production costs. Though the project does not intend to subsidize the price of clones, production costs should decrease in future through economies of scale achieved by increased demand. Clonal production is sustainable as demand for wood products continues to outstrip supply. The large number of clones grown and the long-term impacts that these trees will provide, in terms of human and environmental welfare, should also offset this disparity.

Participants further recognized that a successful on-going sustainable clonal programme must be based on a broad genetic base and be subjected to new genetic material after each generation of breeding. The number of clones cannot be limited and new clones should be regularly introduced into the breeding programme. This should be done using well adapted local material and new genes from external sources. Though *Eucalyptus* is known to be of low caloric value, the breeding programme can produce varieties that have higher caloric values in areas where fuel-wood is the desired end product.

6. Field visits

Field visits were made to the Central Clonal Nursery at Karura and Kamuchege sub-location in Githunguri, Kiambu District. At the nursery, participants were shown the facilities and briefed on the clonal tree production process ethics and protocols.

At Kamuchege, participants were shown a community initiative for clonal tree farming. Small-scale farmers in the area (2–4 acres) have been re-evaluating their traditional farming practices due to the decline in cost of most farm products, lower farm productivity, fuel-wood shortages and overall environmental degradation. This has helped make farmers more likely to place monetary value into the trees growing on their farms and to grow them as crops. Through this initiative, 32 farmers and one primary school are actively growing improved *Eucalyptus* trees on their land. Approximately 7,500 *Eucalyptus* trees have been grown so far, and there are continuing requests for more seedlings.

Participants visited five farms and held discussions with farmers. Three farmers grew clonal *Eucalyptus* trees, another *Eucalyptus* from improved seeds, while the last farmer had relied on tree sales for income, proving that economic opportunities existed in small-scale tree growing. General observations included:

- Farmers had great interest in growing clonal *Eucalyptus* trees despite existing limitations
- Limiting factors to the growing of clonal *Eucalyptus* trees included land shortage and accessing funds to purchase seedlings
- Most farmers believed that clonal *Eucalyptus* was a better strategic crop than coffee
- Tree nurseries/clonal supplies should be located closer to farmers
- Farmers were the main decision makers in planning what and where to plant on their farms.

Farmer experience indicated that:

- Early management of young seedlings is critical
- Use of manure during planting and intercropping improved tree growth performance
- Moles and termites were the main pests of young trees
- Replacement of dead plantings should be done early before the surrounding trees develop full canopies
- Farmers growing trees felt more financially secure than farmers growing other crops.

SESSION III DELIVERY OF FORESTRY TECHNOLOGIES TO FARMERS

1. East Africa's regional forestry needs: Wood requirements and the dimensions of deforestation

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Abstract

The demand for wood and wood products in East Africa – approximately 117 million m^3 – far outstrips the sustainable supply in Kenya, Uganda and, to a lesser extent, Tanzania. In Kenya, although significant quantities of wood are harvested from private farms, current demand is creating an annual deficit of about 12.2 million m^3. Localized shortfalls throughout the region lead to unsustainable utilization and deforestation with significant negative implications on rural livelihoods, water levels and quality, and climate change mitigation through carbon sinks.

This paper looks at the sustainability of the region's supply of forest goods and services by examining the extent of the existing forest resource base, regional and local utilization levels and their impacts on the environment, and the socio-economic status of the people. Where significant forest ecosystem degradation is occurring, options for controlling it in order to help sustainably meet demand are discussed. These include: (i) enhanced regional cooperation for free trade; (ii) intensified management of gazetted closed forests to increase achievable yields; and (iii) intensification and promotion of short rotation forestry using improved fast growing and high yielding tree species and clones on private farms.

Introduction

Forestry is a multi-benefit land-use system with a wide range of benefits appropriate for sustainable development. These include

- Sustainable production of raw materials (timber) for industries
- Local employment and rural development
- Habitat creation and biodiversity
- Environmental protection
- Recreation and amenity
- Landscape enhancement
- Carbon sequestration to mitigate greenhouse gas emissions.

But how should these forests be managed in order to maximize these benefits without reducing their capacity for future generations? Discussions are needed on the role of forestry in economic development and whether East Africa's forests are effectively meeting regional challenges and needs. Some important questions include: What is the extent of East Africa's forest cover? How much wood is found in these forests and what is their current annual increment (CAI)? Can East African forests sustainably meet the growing demand for forest and wood products and services? Is harvesting taking place? Where and for what purpose? What are the socio-economic, forestry and environmental implications of harvesting? What options do we have for forestry development and for mitigating deforestation impacts? What is the capacity of existing agencies to meet forest resource management requirements?

Forest resources

The climate in East Africa ranges significantly from montane climates with high rainfall and low temperatures, to humid coastal areas with high temperatures and a short dry season, to large areas with arid and semi-arid climates. These conditions have a considerable impact on vegetation ecosystems and forest biomass coverage. They greatly determine the degree to which wood is used. And they influence settlement trends for the increasing population and its need for forest resources to sustain urban and rural lives.

Forests in East Africa cover an area of 41.4 million hectares, representing 1% of the worlds forests (Table 7). Forested land is divided into four categories: 1. natural forests (tropical high forests); 2. woodlands; 3. plantation (man-made) forests; and 4. trees on farms.

Table 7 Forest resources in East Africa

Country	Total land area (000 ha)	Population, 1999 (000)	Forest land (000 ha)		Other wooded land (000 ha)	Forest land (%)	Per capita forest land (ha)	Per capita GDP, 1997 (US $)
			Total	Plantation				
Kenya	56,969	29,549	1,305	160	15,511	2.3	0.04	330
Uganda	19,955	21,143	6366	20	9,657	31.9	0.30	326
Tanzania	88,604	32,793	33,709	154	34,788	39.0	1.03	183
Total	**165,528**	**83,485**	**41,380**	**334**	**59,956**	**25.0**	**0.5**	

Sources: FAO (2003); MNRT (1998); RoU (2001); KFMP (1994).

Natural forests cover approximately 41 million hectares while plantation forests under effective management cover only 0.33 million hectares.

Though localized differences exist on a national level, an estimated 25% of the region's total land area is forested. Differences in national forest endowments, shown in Table 7, have significant impacts on the local availability, accessibility and utilization of forest resources.

Forests and woodlands in Tanzania cover some 33.7 million hectares – an estimated 39% of the total land area and a per capita forest land area of 1 ha. Thirteen million hectares are gazetted forest reserves, of which 1.6 million hectares are managed as water catchments, while an estimated 0.15 million hectares are *Pinus patula* and *Cupressus lusitanica* plantations. About 6% of the forest area is within National Parks.

Uganda has approximately 6.4 million hectares of forests, of which 80% is woodland, 19% moist high forest and 1% is under commercial plantation (RoU, 2001).

Kenya has lowest forest cover among the three countries with total closed canopy forest covering 1.3 million hectares (or 2.3% of the total land area). Woodlands cover 2.1 million hectares, wooded grasslands cover about 11.8 million hectares and 0.16 million hectares are plantations. Farmlands with highly variable wood productivity make up 10 million hectares.

Growing stock

Forests are typically defined as land with a 20% minimum crown cover, thus excluding areas such as open woodlands and scrublands (Table 7). Such a definition is inadequate as it does not indicate available harvestable volumes and their capacity to support wood-related industries. Further, some forests are valuable water catchments or national parks – areas where commercial exploitation may be restricted. It would be more helpful, therefore, to define the land's growing stock.

The growing stock indicates the actual wood resources available in forested areas and provides an indication as to their maturity. Only the forest increment (or 'interest') should be harvested, while the growing stock (or 'capital') should remain untouched. Unfortunately, such data is either rare or outdated as national forest inventories in East Africa were last completed 20 years ago.

Total forest wood stocks are estimated at 2.7 billion m^3, with Tanzania holding the bulk (2.19), followed by Uganda (0.414) and Kenya (0.085) (Table 8). Large volumes of wood are found in both woodlands and bushlands, despite their lower stocking densities (20 to 100 m^3/ha) compared to gazetted forest lands. The forests of Kilimanjaro and Tanzania's Southern Highlands have some of the highest stocking densities in the region

(200–400 m^3/ha) compared to the average stocking in Kenyan forests of 65 m^3/ha.

The annual increment of harvestable volume in Tanzanian woodlands is estimated at 70 million cubic metres (Mm^3), while the annual extraction of wood is 30 Mm^3.

In Kenya, the total potential volume from closed forests (with an average annual productivity of 3 m^3/ha) is approximately 1.6 Mm^3. Woodlands have an average annual productivity of 0.64 m^3/ha, yielding a total of 1.3 Mm^3. Bush and grasslands contribute 13.5 Mm^3 annually. Estimated farmland annual yields average 1.44 m^3/ha and supply approximately 14.4 Mm^3 of wood (Holmgren *et al.*, 1994), whereas plantations have an average annual productivity of 19.9 m^3/ha and contribute 2.7 Mm^3. Thus, total wood volume available for sustainable harvesting is approximately 33.5 Mm^3 annually. Data for other forest types, especially for Uganda, is lacking.

Forest/wood harvesting

Annual increments in woody biomass should dictate the amount of allowable forest extractions. As forest resource utilization varies by region and climactic conditions, total quantities of wood from all sources – gazetted forests, woodlands and private farmlands – should be considered. An estimated 128.5 Mm^3 of roundwood is harvested annually, a *per capita* wood harvest of 1.29–1.45 m^3, against huge disparities in endowments among the three countries (growing stock *per capita*, Table 8).

Though comparing total forest fellings as a percentage of net annual increment would provide an important indicator of wood harvesting levels, there is insufficient data to do so at this time, particularly in Uganda. Calculated values of 1.28 for Kenya and 0.67 for Tanzania indicate that, while Kenya is over-harvesting its wood, Tanzania could still be exploiting within its sustainable potential.

Low mean annual increments in closed forests (less than the total roundwood removals) are an indication of the importance of woody materials outside gazetted forests. Both woodlands in arid and semi-arid zones and farm forestry provide important sources of commercial and subsistence supplies of wood products, estimated to be about 29.2 Mm^3 of Kenya's annual requirements.

Wood consumption by sector

Approximately 80–90% of the wood harvested in East Africa is used for fuel-wood (Table 8) due to: (i) the high rural population base dependent on biomass for energy (68–86% of the population) and (ii) the high and rising levels of poverty (*per capita* GDP of US $183–$330). The bulk of the fuel-wood is converted and used in low efficiency appliances, such as earthen kilns for charcoal production and three-stone open fires. Higher consumption levels in Kenya may be due to the higher *per capita* GDP. A stronger GDP implies higher consumption of wood products and services, particularly of pulp and paper and charcoal among urban communities. However, the higher rural populations in the other two

Table 8 Wood resource base in East Africa (1995)

Country	Forest area (000 ha)	Exploitable forest area (000 ha)	Forest growing stock (Mm^3)	Roundwood removals (Mm^3) Total	Roundwood removals (Mm^3) Industrial	*Per capita* biomass stock (Mm^3)	*Per capita* removals (Mm^3)
Kenya	1,305	1,187	85	45.7	1.96	2.8	1.45
Uganda	6,366	6,346	414	35.7	2.35	12.0	1.29
Tanzania	33,709	33,555	2,191	47.2	2.2	65.8	1.44
Total	**41,380**	**41,088**	**2,690**	**128.5**	**6.52**	**29.9**	**1.41**

Source: FAO (2003b)

countries rely heavily on fuel-wood, leading to high overall wood consumption.

Harvested industrial roundwood is dominated by sawlogs. The regional wood industry is poorly developed, characterized by low efficiency technologies, such as pit and power sawing, only two integrated pulp and paper mills, and a few reconstituted wood panel mills.

Forests are often not within reach of the population and are inaccessible to many communities. On-farm wood resources, in contrast, can provide nearly 90% of their needs. Only 35% of plantation wood is available for rural household energy use. The significantly higher consumption in the subsistence sector points to important entry points for intervention measures to control utilization or enhance supply. Forest Department activities should extend beyond gazetted forest boundaries by adopting a broader land classification that includes all growing woody biomass and should provide technical assistance to encourage private tree growing.

Supply and demand gaps

Supply and demand projections for wood products (timber, pulpwood, poles and fuel-wood) indicate that the increase in total wood supply is not keeping pace with the increases in demand. According to the Kenya Forest Master Plan (KFMP, 1994), supply in Kenya was at approximately 28 Mm^3 while demand stood at 26 Mm^3. By the year 2000, however, the estimated demand of 45 Mm^3 could no longer be met from the sustainable supply of only 22.1 Mm^3 (a 22.9 Mm^3 deficit met through stock depletion). Annual demand in Uganda is estimated at 35.7 Mm^3, whereas in 1993, fuel-wood consumption in Tanzania was estimated at 45 Mm^3 per annum, most of which was used in rural areas. In all three countries, demand is increasing.

Wood demand in Kenya is projected to exceed 45 Mm^3 by the year 2020 while the supply will be roughly 38 Mm^3. The deficit, used mostly to meet fuel-wood needs, will lead to further deforestation and environmental degradation.

Although the region has the potential to be self-sufficient in industrial wood use, current harvesting policies are not geared towards sustainable supply. Presently, immature crops in more accessible areas are over-harvested. Large, felled areas have not been replanted. The future supply of industrial wood from large-scale plantations is uncertain. Urgent measures ought to be taken to improve plantation management and develop alternative sources, such as supplying industrial wood through farmlands.

Changes in forest area and cover 1990–2000

East Africa is one of the least forested sub-Saharan areas. Continued deforestation only exacerbates the situation. Between 1990 and 1995, East Africa lost 1.9 million hectares of forest land (Table 9), with most forest loss occurring in Tanzania, followed by Uganda. Kenya's lower deforestation rate may be due to its more developed plantation and farm forestry base.

By correlating harvesting rates with the mean annual increments and the growing stock in Kenya (85 Mm^3 over a forest area of 1.3 million hectares), current stock depletion of 12.2 Mm^3 translates into clearing 0.2 million hectares of forest/wooded land annually. Deforestation figures (Table 9) are merely best estimates for planning purposes as the analysis does not take into consideration the adaptive measures taken by residents in the wake of resource scarcity.

The demand for wood products continues to increase despite the reduction in forested areas. Recent projections by the United Nations Food and Agriculture Organization (FAO, 2000) estimate that consumption will rise in Africa by 5% by 2010 where at least 90% of the population depend on firewood and other biomass for their energy needs. Regrettably, the increasing demand will not be balanced by commensurate tree planting.

Although significant plantation areas were established in the 1970s and 1980s, these areas declined in the 1990s, as did management standards. Future expansion of forestry and wood resources will need to raise standards of management, restock forest lands and include areas traditionally not considered in the forestry domains – private farmlands.

Table 9 Changes in East African forest cover (1990–95)

Country	Forest area, 1995 (000 ha)	Total change, 1990–95 (000 ha)	Annual change (000 ha)	Annual rate of change (%)	*Per capita* forest land (ha)
Kenya	1,305	–17	–3	–0.3	Ns
Uganda	6,366	–296	–59	–0.9	0.3
Tanzania	33,709	–1,613	–323	–1.0	1.1
Total	**41,380**	**–1,926**			

Source: FAO (2003)

Causes of deforestation

Forests in the region have continued to decline (Obare and Wangwe, 2000**)** due to:

- Clearing natural forests for plantations using exotic species
- Licensed logging for industrial applications
- Conversion of natural forests into agricultural land
- Human settlement
- Forest excisions
- Inadequate forest management capacities by relevant agencies
- Outdated and conflicting forest policies and legislation
- Fires.

Each of these factors should be analysed in relation to future regional forestry needs and development.

Deforestation impacts

The environmental consequences of deforestation and land degradation include loss of biodiversity, ecological instability, loss of livelihoods for forest dependent social and commercial activities, reduced pace of rural industrialization, loss of agricultural production, desertification, and climate change. The impacts of biodiversity loss include species loss, habitat loss, declines in the variety of genes within a species, and overall decline in the number of species. In turn, this affects the potential production of pharmaceuticals and medicines, biotechnology research, and food security.

Deforestation can also be associated with the extreme water level fluctuations that have recently been experienced, that adversely affects other sectors.

Finally, deforestation makes it more difficult and time consuming for rural women to collect fuel-wood and other forest products. Women are forced to travel longer distances to collect the bare minimum of wood needed for survival at the expense of other socio-economic activities, such as schooling and child rearing. If fuel-wood is not available, women switch to alternative fuel sources, such as animal dung or crop residue. These fuels not only take longer to burn, but they also produce hazardous fumes. The use of manure and residues also deprives the soil of nutrients needed for agricultural production. Fuel-wood shortages thus produce a chain reaction affecting the nature of rural society, its agricultural base and the stability of its environment. Productivity loss due to land degradation also means that women have to work harder to increase their crop yields.

The way forward

Centralized plantations are an ineffective solution to fuel-wood and industrial wood deficits, given the dispersed nature of the region's population. Similarly, existing forestry management and utilization practices are unable to sustainably meet wood needs. New ways and means of ensuring sustainable forest production, utilization and management must be explored. In addition to forestry issues, the underlying socio-economic factors that contribute to deforestation, particularly poverty, should be addressed through a consortium of governmental and natural resource development agencies. Two approaches could be simultaneously considered: (i) minimize demand through efficiency measures; and (ii) enhance the resource base by strengthening and improving existing forestry management practices while seeking alternative wood production technologies.

Specific measures that could be considered include:

- Enhancing cross border trade flows and regional free trade cooperation by planning a common customs union and clear regulations on imports – especially phytosanitary measures with respect to biotechnology. This will help tap into the rich Central and West African forest resources.
- Increasing achievable yields by enhancing the capacity to intensify management of closed gazetted forests.
- Promoting short rotation forestry (SRF) activities, emphasizing intensive culture techniques and using proven high yielding superior species and clones to supply fuel-wood, pit sawing, posts and pulpwood requirements.

In the shortterm, measures must be taken to minimize deficits by reducing the demand for forest goods and services. This entails improving adoption rates of improved species, processing and use of new technologies. Industrial processing will require investing in more-efficient processing equipment. National governments should consider offering incentives, including tax beaks, to encourage this.

Forest resource sustainability can be achieved through long-term measures to improve production and enhance the natural resource base so as to supply forest goods and services to the ever-increasing population.

Both policy and technical level initiatives should be carried out to meet projected wood demand and cover localized deficits. Most of the harvested wood is used for subsistence, either as fuel-wood, poles or posts. In Kenya, such wood is primarily obtained from non-gazetted forested lands (private farms and woodlands). Thus, increased tree planting by farmers for both commercial and subsistence use, especially in SRF that incorporates fast-growing, high-yielding species and cloned material, would significantly reduce the imbalance. Encouraging the use and adoption of fuel-efficient charcoal and fire-wood appliances would further reduce *per capita* consumption.

Studies show that, if appropriate polices and management systems are put in place, existing plantation forest lands are capable of meeting the region's industrial roundwood needs (White, 1997; Odwori and Ogweno, 2001; Osoro and Ogweno, 2004). There is need to: (i) enhance investment in processing and conservation technologies to stem the poor recovery rates; (ii) move to higher value added reconstituted wood products requiring less prime material; and (iii) raise payable wood royalties to realistic levels to discourage waste and promote commercial tree planting on farms. Policies and forest resource use regulations should also be revised and streamlined. *Ad-hoc* bans on timber harvesting, for example, discourage tree planting, as does the lack of legislation governing non gazetted forests and woodlands – often regarded as free access goods.

Short rotation forestry (SRF)

The concept of SRF entails planting fast growing trees at higher stocking densities (>3000 stems/ha), harvesting the trees at relatively short intervals (1–10 years), and either replanting or allowing the trees to coppice (resprout) into a new crop (Senelwa, 1997). High stocking densities achieve rapid canopy closure and high productivity (Senelwa and Sims, 1997). In turn, this facilitates the transition to more efficient land use systems and ensures better resource management while enhancing the quality of life for women. For maximum regional impact, SRF products should be integrated and incorporated with improved fuel-wood appliances and the intensified use of agro-based industrial wastes, such as sawdust, as a medium-term solution.

Optimum configurations for maximum biomass yields have been studied using various species, rotations, stocking densities and other silvicultural combinations (Senelwa, 1997; Senelwa and Sims, 1999a; Senelwa and

Sims, 1999b; Sims *et al.*, 1999a; Sims *et al.*, 1999b). Results indicate that *Eucalyptus* spp., planted at stockings of about 3,500 stems/ha, managed in coppice regimes and harvested at rotations of 4–8 years produce higher annual yields than other species (up to 40 m^3/ha).

Clonal technology promises to revolutionize wood production by increasing yields, especially in small land holdings where the bulk of the demand is located. Unfortunately, policy and legal instruments required for proper on-farm forestry development incorporating biotechnology are currently inadequate. Future work should emphasize farm forestry research to regionalize SRF concepts for local application, accelerate the current pace of tree planting, improve the management of on-farm trees and stimulate income generation from tree products.

Kenya's supply gap could be met using SRF schemes under intensive management with enhanced Mean Annual Increment (MAI) of 40 m^3/ha, requiring under 0.3 million hectares of additional land, only harvesting the annual increment. Total adoption of higher efficiency appliances, such as the 'Kuni Mbili' stoves (15% efficiency), higher efficiency kilns (30%), and the Kenya Ceramic Stove (KCJ, 25%), would reduce consumption by about 40%. These viable options would also minimize soil nutrient loss and improve crop yield. Finally, the availability of sustainable wood resources closer to communities would free up the time of women and children for other socio-economic activities, including child rearing and schooling.

Conclusion

There are localized differences in forest endowments throughout the region, though *per capita* resource use and consumption is largely comparable among the three countries. Thus, the rate of forest destruction varies. The extraction of woody biomass currently outstrips the sustainable supply and surplus demand is being met from stock depletion. Yet, existing gazetted forests, together with other woodlands, could sufficiently provide for a variety of products and needs as long as they remain well stocked and managed. In the immediate to long term, SRF on private farms could provide the much-needed breakthrough in bridging the supply and demand gap.

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2. Biodiversity and clonal forestry: Is there a conflict?

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Abstract

Today, there are only a few examples of active clonal plantations around the world. New technologies, however, are already being developed in countries such as Australia, Brazil and South Africa. Cutting-edge activities are taking place in Queensland, Australia where research is being carried out on 'designer trees' – trees that grow uniformly in size and shape. Tree genes are being probed and cryopreservation is being used to keep tested individual clones artificially young.

In planning future plantations and growth areas, forest management practitioners will need to consider the advantages of clonal forestry, including designer trees and the promise of continued gains in growth rates for trees that are ready for early harvesting. Practitioners will also need to consult the timber industry about the characteristics they most desire in the wood products they purchase and process. Other factors such as disease and pest control, timber quality, rates of return, geographical suitability and market needs will also have to be considered.

This paper discusses the synergies and differences between clonal forestry and biodiversity. It brings out the important relationship that forests have with biodiversity and explores the advantages and disadvantages of clonal forestry to biodiversity. A synopsis of biodiversity species that can benefit from clonal forestry and those that are at risk is also included.

Introduction

Though the total area of plantation forest (187 million ha) represents only 5% of global forest cover (FAO, 2001), their importance is rapidly increasing as countries move to establish sustainable sources to meet the increasing wood and pulp demand. Plantations typically consist of intensively managed, similarly-aged and regularly-spaced stands of a single tree species (indigenous or exotic), often genetically improved, and are characterised by relatively short rotations when compared with natural forests. Non-industrial plantations, established for fuel-wood, soil and water conservation, and wind protection, account for 26% of the world's plantation forests. An additional 26% are established for other, unspecified purposes (FAO, 2001).

Over the past decade, global forest plantation area has increased in tropical and non-tropical regions by an estimated 32 million hectares while natural forests have declined by 126 million hectares. In both tropical (+20 million hectares) and non-tropical (+12 million hectares) regions, the conversion of natural forests and reforestation of non-forest areas have contributed in roughly similar proportions to these increases (FAO, 2001). Between 1990–2000, the conversion rate for natural to plantation forests in tropical regions was equal to the increase in natural forest resulting from natural reestablishment of non-forest areas. Only 7% of natural forest area converted to non-forest land uses. In non-tropical areas, the net increase in natural forest was more than three times the rate of conversion of natural to plantation forests.

China, India, the Russian Federation and the United States account for approximately 60% of the world's plantation forests. Though the most commonly used species used in plantations are *Pinus* and *Eucalyptus* genera (30%), the overall diversity of planted tree species is increasing (FAO, 2001).

What is biodiversity?

Biodiversity is defined as 'the variability among living organisms from all sources [including] diversity within species, between species and of ecosystems' [Convention on Biological Diversity (CBD): United Nations, 1992]. Forest ecosystems shelter a major part of the world's biodiversity – an estimated 80% of all terrestrial species. Approximately 12% of the world's forests are in protected areas (FAO, 2001).

The importance of maintaining biodiversity in forest ecosystems has been emphasised both politically, through international conventions and agreements promoting sustainable forest management (SFM), such as the Montreal Convention on Biological Diversity (CBD, 2002), and commercially as part of forest certification schemes. Biodiversity is therefore an issue of increasing relevance to plantation forests and their long-term sustainability. As a criterion for SFM, maintaining biological diversity has direct implications for plantation forests and their management.

Biodiversity in a forest ecosystem is determined and influenced by climatic and soil conditions, evolution, changes in species' geographical ranges, population and community processes, and natural or human-related disturbances. Ecological processes and biodiversity change over time as ecosystems recover from natural or human-caused disturbances. Such disturbances, depending on the scales and measures of biodiversity, can either increase or decrease biological diversity. The highest biodiversity levels are often found in forests that have been subjected to intermediate frequencies and scales of disturbance (Kimmins, 2000).

Four biodiversity components are particularly relevant to discussions on plantations and their environmental impacts, of which 1 and 2 are discussed in detail:

1. *Genetic diversity:* the genetic variation within a population or a species.
2. *Species diversity:* the number of species in a particular area or community (species richness) or the relative abundance of the species therein (species evenness).
3. *Structural diversity:* how forest plant communities are structured both horizontally and vertically. This changes continuously as stand development proceeds and is particularly significant in plantation forests. Structural diversity can be as important as diversity of plant species for animal species diversity.
4. *Functional diversity:* variation in functional characteristics of trees and other plant species (evergreen *vs.* deciduous, shade-tolerant *vs.* light-demanding, deep-rooted *vs.* shallow-rooted, etc.).

These defined measures can be applied at various spatial scales – local ecosystem, stand level, landscape level, regional and beyond. They are dynamic and changing over time. Though discussions about biodiversity have mostly focused on the local ecosystem level, biodiversity measures at this level exhibit the greatest temporal variation.

This paper considers key issues related to intraspecific diversity, focusing on genetic diversity within tree plantations, as well as the influence of plantations on interspecific diversity both within them and in surrounding landscapes. Further, we consider the role of biodiversity in plantations and the strategies for managing them to conserve or enhance species diversity at various spatial scales.

Genetic diversity

Characterization of genetic diversity in tree plantations

As a fundamental component of global biodiversity, genetic diversity includes the intraspecific variations between individual trees, both within and between populations (races, ecotypes and provenances). This genetic diversity largely controls adaptability and resistance to abiotic and biotic disturbances. The rapid development of tools such as molecular markers for analysing the genetic variability of forest trees (Petit *et al*., 1997) has enabled scientists to better characterize and assess pollen fluxes between individuals and populations, spatial distributions within stands of genetic diversity, and better understand the effects of silvicultural practices on the long-term evolution of genetic diversity. The molecular characterisation of plantation populations and improved varieties also enable us to better manage and control the movements of forest reproductive materials (FRM).

Modification of genetic pools

Many questions remain in assessing the possible impact of plantations on intraspecific genetic diversity, despite the increasing body of available scientific information. Plantation impact is influenced by the type of forest reproductive material (FRM) used, the quality of available FRM genetic information, and the feasibility of the control applied to it. Their impact on genetic diversity depends on the FRM's level of genetic variability and on the possible gene exchanges between planted FRMs and surrounding tree gene pools. At the regional level of forest tree diversity, impact also depends on the total area afforested with this FRM and for how long. A very real challenge for sustainable forest management is to consider what would happen if highly selected FRM (hybrid, clonal or GM varieties), initially planned to be clear-felled and re-planted, were to regenerate naturally from lack of control over time and spread outside plantation areas.

The introduction of genetically improved exotic species increases productivity and carbon-fixation efficiency, but also interspecific diversity on landscape and regional scales. In France, for example, 30 introduced tree species are commonly used in plantation forestry, compared to 70 natural species, and help to increase the local interspecific genetic diversity of forests (Le Tacon *et al.*, 2000; 2001). In Europe, forest flora was very diverse at the end of the tertiary geological era and numerous species disappeared during the successive glacial periods. The introduction of new species has partly restored species richness.

Introduction of exotic species, while popular in the past, has been limited more recently because of their associated risks. Establishing long-term adaptation to local soil and climate conditions for the use of exotic species in extensive plantation programmes is necessary to avoid severe damage. This includes summer drought and winter frost resistance, tolerance to hydromorphic soil condition, and resistance to insects and diseases. Also, fast-growing exotic species can replace native forest tree species because of their natural invasive potential.

Impact of genetically improved FRM use

FRM collected from registered seed stands results in plantation forests with a level of genetic diversity similar to the wild population from which it originates. Main genetic impacts depend on the adaptation level of introduced populations and the possible gene transfers to the surrounding native population. Possible undesirable impacts of long-distance seed transfer require special consideration.

With the development of selection programmes, the level of genetic diversity of planted material has been progressively restricted, as it has with single or controlled mixtures of full-sib families, clonal varieties, or genetically modified (GM) trees. Consequently, such FRM could be expected to have a lower adaptability and an increased ecological risk over the same rotation time (Gadgil and Bain, 1999; Evans, 1999; Wingfield, 1999). On the other hand, the genetic information is considerably greater, allowing the forest owner to better weigh the expected economic gains and ecological risks. There are, also, relevant breeding and gene conservation strategies able to maintain the genetic variability of the plantation species over several generations.

Clonal varieties

A major concern with respect to clonal plantation forestry is the safeguarding of stand adaptability, *i.e.* the ability to face a catastrophic biotic or abiotic perturbation. Does increased use of clonal planting stock contribute to a decrease in stand viability? Such questions were theoretically explored by considering simplified situations in which susceptibility to the unknown hazard is controlled by one single diallelic locus. Results varied according to: (i) the frequency of susceptible genotypes, and (ii) the level of acceptable stand mortality.

If the former is higher than the latter, increasing the number of clones will result in greater susceptibility in the multiclonal variety. If the former is low, increasing clone numbers boosts the probability of success, usually up to 10 genotypes. To cover a wide range of situations, Bishir and Roberds (1999) recommend clonal mixtures of 30 to 40 genotypes.

Genetically modified (GM) trees in commercial varieties

Gene transfer is currently being tested in most forest species undergoing intensive breeding activities (Radiata pine, Scots pine, Maritime pine, Sitka spruce, Norway Spruce, *Eucalyptus*, poplars). In conjunction with other biotechniques, such as somatic embryogenesis, important genetic gains can be transferred to forestry. Transgenesis, for example, is considered an attractive tool for genetically improving trees for pest and insect resistance, wood properties and lignin content. Expected benefits include increased ecological and economic wood production efficiency, increased adaptability and resistance to biotic and abiotic stresses, and reduced use of insecticides and pesticides. There are currently 117 experimental plantations with GM trees for 24 tree species around the world, but no commercial plantation has been reported.

Principle risks for biodiversity are related to the dissemination of GM material which might result in introgression with related tree species (Matthews and Campbell, 2000) and in the spread, through natural regeneration, of GM trees that are potentially better adapted to site conditions. The potential use of transgenic trees in forestry has raised concerns among the public, foresters, and scientists. In some cases, the controversy has led to vandalism and other criminal acts, highlighting need for an in-depth debate on the benefits and risks associated with transgenic technology in forestry.

Species diversity

Species diversity in plantation forests versus other habitats

Plantations are widely believed to be a less favourable habitat for a wide range of taxa, particularly in the case of similarly aged, single-species stands of exotic species. Bird fauna of single-species plantation forests, for example, are reported to be less diverse than those of natural or semi-natural forests. In Ireland and the UK, vegetation in conifer plantations was less diverse than semi-natural woodlands (Fahy and Gormally, 1998; Humphrey *et al.*, 2002). And beetles were not so abundant in plantations as they were in natural or semi-natural forests in Ireland, Hungary and South Africa (Samways *et al.*, 1996).

General conclusions, however, cannot be made. In New Zealand, for example, species richness of indigenous birds was only slightly lower in pine plantation forests (Clout and Gaze, 1984) and in some cases bird counts in these plantations exceeded those of most natural forests (Brockie, 1992). The diversity of bird species in a *Lophostemon* plantation was similar to that in secondary forest (Kwok and Corlett, 2000). In the UK, the fungal and invertebrate communities in conifer plantations were found to be similar to those in natural woodlands (Humphrey *et al.*, 1999; 2000; 2002).

Importantly, an analysis based simply on comparisons with natural forests in the same area is not always appropriate. While converting old-growth forests, native grasslands or other natural ecosystems to plantation forests is not desirable, planted forests often replace other land uses. When established on abandoned pastures or degraded land, they improve biodiversity. In New Zealand, for example, pastureland dominated by exotic species is considered a poor habitat for indigenous species growth, whereas the undergrowth in pine plantations often includes indigenous plant species (Brockerhoff *et al.*, 2001).

Studies have also shown that plantations can accelerate natural forest regeneration on degraded sites where persistent ecological barriers would otherwise preclude recolonization by native forest species. They fulfil this role due to their influence on understorey microclimatic conditions, structural complexity of the vegetation and development of litter and humus layers during the early years of plantation growth. In the Mediterranean region, artificial forests created for watershed protection and subsequent harvesting naturally reverted to mixed conifer–broadleaved forests similar to those that existed prior to degradation. Additional case studies of their 'catalytic effect' on degraded landscapes (Parrotta and Turnbull, 1997; Parrotta, 2002) have been completed in Australia, Brazil, China, Congo, Costa Rica, India, Indonesia, Malawi, Puerto Rico, South Africa and Uganda. The differences in species diversity between plantations and natural forests can be due to a number of factors, including land use history. All such factors should be considered when evaluating species richness in plantation forests.

The use of exotic tree species has implications for indigenous forest species, which may have certain requirements that are not met by the exotic species or the habitat they create. For example, exotic trees in Britain are attacked by fewer insects than those in indigenous forests (Kennedy and Southwood, 1984). By contrast, vascular plant species can colonise plantation forests regardless of the canopy species, provided the physical characteristics of the habitat are appropriate – some plantations have a surprisingly diverse understorey of indigenous species (Allen *et al.*, 1995; Keenan *et al.*, 1997; Oberhauser, 1997; Viisteensaari *et al.*, 2000; Yirdaw, 2001).

There can be considerable variation in the richness and abundance of understorey plants on plantations, due in part to the amount of available light (Cannell, 1999). Particularly dense stands of spruce and Douglas fir can cast so much shade that they appear to literally 'shade out' the understorey vegetation (Humphrey *et al.*, 2002). Likewise, single-species plantations of *Rhizophora* may prevent site colonization of other, non-planted mangrove species (Walters, 2000). Clear-felling harvesting significantly constrains species richness as it dramatically changes the composition of understorey plants (Allen *et al.* 1995), although subsequent runs often restore the pre-cleared understorey vegetation (Brockerhoff *et al.*, 2001).

Site management practices also have direct impacts on plantation biodiversity. Fertilizer use, especially if the site was degraded prior to reforestation, can limit populations of native plant species, yet increase the populations of others. It may also induce increased microbial diversity by accelerating turnover of organic matter (Nys, 1999). Information on the effects of planted forests on the diversity of soil biota is limited, though it has been demonstrated in the southern United States of America that longer rotations foster soil biodiversity for loblolly pine plantations (Johnston and Crossley, 2002). Short rotation plantations have also had positive effects on biological soil fertility in the Congolese savannah (Bernhard-Reversat, 2001).

Herbicide or insecticide applications often associated with plantation forest management can also result in a temporary decrease in plant, fungi and insect biodiversity (Dreyfus, 1984). Short rotation management can reduce the quantity of deadwood beneficial to saproxylic insect species (Jukes *et al.*, 2002) or bryophyte species (Ferris *et al.*, 2000) and may decrease the opportunities for colonization by poorly dispersed native plant species (Keenan *et al.*, 1997). And short rotations will limit the extent to which structurally complex understorey development will occur.

Which species benefit most from planted forests?

Plantation forests, due to their more intensive management, are characterized by their constraints to other species. Clear felling and comparatively short rotations, for example, favour the occurrence of ruderal plant species. Harvesting disturbance may also enable invasive exotic plants to invade plantation forests (Allen *et al.*, 1995).

Older stands, though, can provide habitat for indigenous shade-tolerant species that are typical of natural forest understories. Similar patterns have been observed for common bird species (Clout and Gaze, 1984). Plantations can also accommodate edge-specialist species (Davis *et al.*, 2000) and generalist forest species that would benefit from any forest type (Christian *et al.*, 1998; Ratsirarson *et al.*, 2002). In the event that plantation forests have replaced less suitable habitat, all species benefit from the additional habitat.

Planting 'tree monocultures' has been suggested as a restoration strategy for forest vegetation on degraded land by providing a sheltered environment for the colonisation of forest tree species (Lugo, 1997). Rare and threatened bird and animal species are not often reported from plantation forests, nor has there been significant study in this area, with a notable exception: large populations of threatened kiwi – flightless, endemic birds – currently inhabit some pine plantations in New Zealand (Kleinpaste, 1990). Findings such as these are significant as conservation issues, but also because they can have implications for plantation management strategies (Brockerhoff *et al.*, 2001).

Spatial considerations

Biodiversity benefits of plantation forests on a regional scale depend on their location within the landscape. They can potentially negatively affect adjacent communities due to the invasive natural regeneration of planted trees (Engelmark, 2001) or alter the soil's hydrological properties. In contrast, they can make an important contribution at the landscape level by adding structural complexity to otherwise simple grasslands or agricultural landscapes and foster the dispersal of species across these areas. They can also increase bird diversity on both landscape and regional scales despite lower biodiversity levels than natural forests.

In tropical regions, wildlife species (especially bats and birds) are of fundamental importance as dispersers of seeds and soil micro-organisms. Their effectiveness in facilitating plantation-catalysed biodiversity development on degraded sites depends on the distances they must travel between seed sources (remnant forests) and plantations, the ability of plantations to provide habitat and food, and the condition of the forests from which they are transporting seeds (Wunderle, 1997). Plantation forests adjacent to exposed remnants of indigenous forest can therefore provide beneficial shelter, enlarge species habitat, and increase connectivity between forest fragments (Norton, 1998). Much, however, remains unknown on how such outcomes might be achieved.

Suggestions for managing planted forests to enhance biodiversity

Genetic resources

Suggestions for preserving and enhancing genetic diversity in plantation forestry can be provided by combining scientific knowledge on forestry and tree genetics with common-sense forest management. These include:

- *Monitoring and improving genetic diversity in breeding populations* – Main concerns about improved forest reproductive material (FRM) use are whether genetic gain and diversity can be simultaneously maintained at reasonable levels over successive generations during the whole selection programme. As many operational tree-breeding programmes conducted on fast growing species are entering their third or even more advanced generations, these questions have raised theoretical and experimental approaches. These approaches should provide guidelines to geneticists for maintaining genetic diversity. Furthermore, at any moment conservation strategies can enrich the genetic base and should be used as a complement to the breeding process.

- *Controlling the quality of forest reproductive material (FRM)* – FRM quality is directly related to the quality of available genetic information, allowing its final user to optimally balance expected gains and possible risks. Reliable information can be found on: (i) geographic origin of the parent gene pool (natural population or selected genotypes); (ii) identities, number, and genetic characteristics of the parents as well as the crossing scheme used to obtain the commercial variety; and (iii) selection procedures (description of the mono- or multi-site experimental design, selected traits and levels of genetic superiority assessed). This information can be used to control quality and to favour FRM resulting from long-term breeding schemes combining recurrent selection and gene resource conservation.

- *Diversifying genetic resources at stand or landscape levels* – through the parallel development of genetically improved varieties and limited use of a given variety to prevent genetic 'uniformization'. Associated risks with improved FRM and decreased genetic diversity can be minimized by: (i) using multi-clonal mosaic schemes, where genetic diversity at a given time within a stand is replaced by genetic diversity between stands at the landscape level, and (ii) limiting the monoclonal plantation area on a regional scale as well as the time during which a clonal variety is permitted for use.

- *Evaluating genetic risks* – Develop risk simulation methods and secured long-term trials to monitor the impacts of GM tree introductions in forest plantations. This should be done prior to any commercial deployment or use. Economic and biological constraints limit the number of GM trees created, imposing the need to deploy them through clonal varieties. Recommendations for their use include: (i) male sterility, preventing pollen contamination of the surrounding forest, and (ii) testing not only in typical clonal tests (comparing one clone with a limited number of standard other clones in controlled conditions), but also in long-term experimental field trials to evaluate environmental risks.

Stand management

Enhancing biodiversity in plantations can generally be achieved by increasing variability when plantations are established or tended. Past emphasis has been on reducing variability to improve predictive capabilities and effectiveness of establishment, tending, and harvesting operations. As a result, there is little experience with enhancing variability in plantation management settings. Future plantation owners, however, especially those operating on a small scale, will be seeking more than just timber production and may be willing to trade off efficiency and predictability for the sake of ecological services.

Increased variability can be achieved in several ways, including the use of multi-species plantations rather than monocultures. Random species assemblages are unlikely to be successful and care is needed to design mixtures that are both stable and productive (FAO, 1992). The choice of species and the number to use will also be affected by economic considerations. A potential advantage of diversity is that it provides insurance against future changes in market values. All potential species, however, must have broadly similar values. Otherwise, the opportunity cost of reducing high value species stocking for lower value species may be too high.

Various planting arrangements have been tested but alternate row plantings seem to be the most common. Plantations with more than one species planted in alternate rows may increase yields and facilitate removal of slower growing species in an intermediate thinning. They may also provide higher wood quality through mutual shading of lower limbs.

Even plantation monocultures have considerable scope for enhanced variability, including less uniform site preparation treatments and variations in tree spacing and thinning treatments. Structural complexity is an important determinant of subsequent biodiversity enrichment due to the importance of habitat heterogeneity for attracting seed-dispersing wildlife and microclimatic heterogeneity required for seed germination. This suggests that broadleaved species yield generally better results than conifers and that mixed-species plantings are preferable to monocultures, due in part to their increased structural complexity.

Two-aged stands may also be a viable alternative where clear-cutting is unpopular. Extending the rotation length could also benefit biodiversity, particularly favouring soil biota and species associated with dead wood or leaf litter. Maintaining snags, logs and other woody debris on site can also enhance habitat values for a range of species, from fungi to cavity-nesting birds. Management practices that increase soil organic matter content (spot cultivation, use of amendments, retention of harvest residues) and decrease soil disturbance are desirable for maintaining the inherent biological capacity of soils and diversity of soil living organisms essential for nutrient conservation and cycling.

Landscape level

Forest management should consider plantations from a landscape perspective. They comprise a spatial array of different elements that can be arranged in different ways depending on management goals. Key elements within a plantation are individual stands of different age and species composition, remnants of native ecosystems (including riparian strips), and amenity plantings.

Managing plantation densities and creating irregularities within the spatial structures – favouring the proportion of borders and clearings and preserving natural plant communities along rivers and swamps – should increase the level of plant and animal biodiversity. Retention of broad-leaved species or native remnants among coniferous plantations has also been proposed as a biodiversity enhancing management tool. Humphrey *et al.* (2000) suggested locating plantations near existing semi-natural woodland fragments. In North America, spatial modelling tools have been used to optimise timber harvesting in native forests (Bettinger *et al.*, 1997).

Similar modelling could be used to optimize the arrangement of different-aged plantation compartments and species to maximize timber production, biodiversity conservation, and ecosystem stability. This approach considers biodiversity conservation on a landscape scale rather than on a stand scale, removing the direct conflict between conservation and timber production at any individual site. The major challenge is that land ownership patterns and management decisions are often made on a local rather than a landscape scale. Ways must be found to ensure both social and ecological outcomes at the landscape level.

In his analysis of the role of industrial plantations in large-scale restoration of degraded tropical forest lands, Lamb (1998) suggests a number of management approaches by which forest productivity (and profitability) and biodiversity objectives may be harmonized. These include: increased use of native rather than exotic species, creation of species mosaics by matching species to particular sites, embedding plantation monocultures in a matrix of intact or restored vegetation, using species mixtures rather than monocultures, or modifying silvicultural management practices to encourage the development of diverse understories beneath plantation canopies.

What is the way forward then?

There is no simple answer. Plantations can have positive or negative biodiversity impacts at the stand or landscape level depending on the ecological context in which they are found. Objective assessments of the potential or actual impacts on inter-specific biodiversity on different spatial scales require appropriate reference points. In this regard, it is important to consider the biodiversity status of the site and surrounding landscape prior to plantation establishment, and the likely alternative land-use options for the site. Could a site be managed for biodiversity conservation or converted to agriculture or other non-forest uses?

The establishment of an industrial pine plantation on a particular site, for example, will clearly have a more negative impact on stand-level biodiversity if it replaces a healthy, diverse, old-growth native forest ecosystem than if it replaces a degraded abandoned pasture system. The ecological context of planted forest development, as well as the social and economic context shaping land-use change, must be considered when evaluating biodiversity impacts (Romm, 1989; Walters, 1997; Rudel, 1998; Clapp, 2001; Rudel *et al.*, 2002).

Observational, experimental, and theoretical studies all indicate that biodiversity can improve ecosystem functioning, providing a strong argument to pay more attention to biodiversity issues in plantation design and management. Many plantations are being established for their potential contribution to overcoming ecological degradation (soil salinity, erosion) and improving the sustainability of land uses such as agriculture.

Faced with unpredictable environmental changes, enhancing species diversity improves the adaptability of all managed forest ecosystems. Though the primary management objective of plantations will continue to be optimising timber production, it will not necessarily be the case for small-scale plantations owned by farmers or other groups. For them, management objectives may place greater weight on the provision of non-timber products and ecological services. This will require developing a new range of silvicultural tools to establish and manage them.

Invariably, difficulties arise when making the necessary trade-offs in order to produce both goods and ecological services. These trade-offs operate at all levels of biodiversity. In the case of genetic diversity, for example, a balance must be struck between the need to identify the most productive FRM to plant and the desire to re-establish original genotypes. Should one use highly productive planting material with a narrow genetic base developed from an intensive selection programme or clonal material? Or should one rely instead on natural seed sources with a wider genetic diversity as these will confer greater resilience to the plantation? Judicious use of relevant, well-known tree breeding strategies and gene conservation strategies can greatly facilitate efforts to maintain genetic variability over several generations, thus achieving better economic and environmental balance.

Likewise, should managers at the species level establish monocultures or emphasise to multi-species plantations? Too much depends on the fertility of the soils – are they able to support the native species and the soil biota required for maintaining soil fertility and nutrient cycling processes – and on the objectives of the landowner to provide a simple answer. Usually a compromise is made. How to combine biodiversity maintenance and wood production on various spatial scales (stand, forest, landscape) is a crucial consideration for the future. A balance can be achieved through improved practices at the stand level or alternative silvicultural regimes – species mixture on different scales from individual trees to compartments of different sizes, age, and clone mosaic – combined with biodiversity management at landscape level.

This would include, for example, modifying extensive clear-felling practices to reduce coup sizes (*i.e.* plan for smaller compartments of same-aged stands that are dispersed within the plantation landscape). It may thus be possible to achieve a degree of biodiversity at the landscape scale to create mosaics of different plantations and natural vegetation habitats, even if each individual plantation stand is established as a monoculture. This will require a change of current practices in many parts of the world and, in particular, a shift from stand-level to forest- or landscape-level approaches of plantation management.

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3. *Eucalyptus* clonal forestry – a time and a place: Availability of genetically improved material to small-scale farmers

Flic Blakeway, *Mondi Forests*

Tree improvement and propagation strategies

Genetic improvement of forestry species has successfully contributed to significant improvements in plantation forest growth, yields and fibre quality (Vergara and Griffin, 1997; Carson *et al.*, 1999; Cotterill and Brindbergs, 1997; Li *et al.*, 1999). 'Genetic gains', or desired changes in traits, have been brought about through tree improvement efforts – the selection of parents that produce fast growing, high-yielding trees is a direct outcome of efficient test design and measurements.

To capture the highest level of genetic gain in plantations and growing areas, breeding and propagation strategies must be aligned (Bayley and Blakeway, 2002). Both are dependent on the biology of the species, the sites to which the material is deployed, the maturity of the breeding programme, and whether the value of the crop at rotation justifies the propagation strategy investment. The complexity of breeding and propagation strategies is determined by species and final product value.

Forestry clonal programmes

Tree breeding is defined as the study of hereditary variation and the capture and use of this genetic variation to produce superior trees. Clonal forestry is considered as one of the most effective methods of capturing and commercially deploying the benefits of genetic variation. It offers the quickest means of capturing genetic gains, particularly from young breeding programmes (MacRae and Cotterill, 1997; Griffin, 2001).

While seed production areas, seed orchards and clonal seed orchards deliver between 0 and 10% genetic gain, clonal forestry can deliver up to 25%. Clonal forestry programmes have developed due to the need to afforest diverse and marginal sites with appropriate planting stock, including hybrid species, and to meet the demand for quality wood fibre (Denison, 1998). Benefits include the ability to propagate hybrids, increased growth and yield rates with appropriate clone-site matching, disease and drought tolerance, and wood quality improvement. Economic benefits associated with crop uniformity are also considerable, as well as being able to screen for traits of economic importance.

In a 5–7 year rotation of clonal *Eucalyptus*, increased yield, disease resistance and specific fibre quality improvements are key objectives (Denison, 1998; Wright, 2003). Appropriate clone-site matching is critical to optimising gains from clonal selections. Rigorous clonal testing programmes are key to the success of the practice.

Yet, clonal forestry does have some associated disadvantages, including intensive and costly testing requirements and the dependence on the species' rooting ability. Clonal forestry is also very site-specific and clones are at greater environmental and disease risk than seedlings. And the higher technical and management input required in clonal propagation operations results in higher propagation costs (Burdon, 1989; Bayley and Blakeway, 2002).

Importantly, clonal forestry is not a breeding method representing the ultimate refinement in tree breeding. Rather, it is a component of the total genetic management system (Burdon, 1989). A clonal system should result in continued genetic gains over successive generations, but must allow breeders to meet changes in selection criteria. It is, therefore, dependent on maintaining a breeding programme.

Key issues in clonal forestry application

Questions that should be answered in considering the application of clonal forestry and clone use include:

1. Biological safety against biotic, climatic and other environmental effects (Burdon, 1989). What numbers of clones are needed to manage risks in clonal forestry (Bishir and Roberds, 1999)?
   - Establishing the numbers of clones needed to protect against catastrophic failure is critically important.
   - Achieving a maximum risk level changes with parameters such as loss acceptability, severity of disease and pest attacks, and level of clonal resistance to attack (Bishir and Roberds, 1999).
   - Multiplicity of clones also depends on the scale on which the species or hybrid will be grown, the investment available for the area to be planted, and rotation age.
   - The use of clones as individual blocks, or in mosaics and mixtures depends on the individual circumstances (Burdon, 1989).
2. In clonal testing, what are the steps required for cost-effective clonal forestry?
   - Species, provenance and progeny trials are required as part of the underpinning tree improvement strategy to maintain a broad genetic base and ensure that the availability of improved clones is sustainable.
   - Clonal trials are required on multiple sites to identify disease resistance and clonal response to site factors such as soils, water availability, nutrients, altitude, latitude and temperature.
   - Improvement in specific desired clonal properties (fibre quality, higher wood density, etc.) must be considered as part of the breeding and clonal selection strategies.
3. What management strategies need to be in place to practice clonal forestry?
   - Nursery management – clonal hedge/garden management is critical. Co-ordination of clone demand by site and year requires careful planning. Large-scale propagation should be attainable, and is frequently precluded by inherently poor rootability and maturation decline in rooting and growth rate (Burdon, 1989). The failure to propagate selected clones can seriously compromise genetic gains, especially when the clonal base is limited.
   - Silviculture – appropriate clone-site matching and rigorous weeding and management of sites is essential. Site preparation is important and soil conditions (nutrient availability and physical characteristics) must be monitored.
   - Tree improvement – continuous investment in tree improvement is required to ensure that clonal gains are continuous and sustainable
   - Growth and yield – monitoring clonal performance for improved growth and yield is crucial to

realizing the benefits offered by the technology.
- Disease and insect monitoring and control – the selection of clones that are tolerant/resistant to pests and diseases for the region is also key.
- Fibre quality and wood properties – the selection of clones with desired properties (high density, high calorific value, etc.) determines the value of having homogeneous populations with greater intensities of the particular characteristic.

Harnessing the value of clonal *Eucalyptus* for small-scale farmers

In optimizing the benefits of clonal *Eucalyptus* forestry for small-scale farmers, the key issues critical to any clonal programme (as outlined above) are necessarily addressed linearly. They are combined or run in parallel in an effort to maximize benefits for as many small-scale farmers in as short a time as possible.

While elsewhere, the focus of clonal programmes has been on improving fibre type for large-scale industrial end-use processors (such as pulp and paper mills), in the East African Tree Biotechnology initiatives Mondi has directed its efforts to benefiting small-scale farmers. The project has aimed to provide improved genetic resources and clonal and propagation technology to small-scale farmers to improve their access to faster-growing, higher-yielding, disease-resistant clones with appropriate density for the production of poles (fencing, building and transmission), charcoal, and fuel-wood.

The sustained success of clonal forestry is dependent on long-term, clearly defined breeding strategies that ensure that the resource of a broad genetic base is maintained. The essence of clonal forestry is the large-scale use of a finite number of selected clones from a robust breeding programme. In ensuring a sustainable supply of genetically improved material (*Eucalyptus* clones) to small-scale farmers, two key components need always be considered: the production and selection of clones from the breeding programme, and the ability to cost-effectively deploy clones to plantation areas. Both of these will determine the success of the clonal strategy application in any region, country, forestry company or situation.

In many traditional *Eucalyptus* clonal programmes, a breeding programme precedes a clonal programme. Eventually, it culminates in the deployment of clones through vegetative propagation (cuttings) programmes. In the East Africa Tree Biotechnology Projects, access to Mondi clones and required expertise made it possible for the clonal testing, breeding programmes and deployment strategies to be simultaneously planned and implemented in the region.

Mondi Forests focused on three major aspects:
1. Assessing growth, yield and disease resistance characteristics in the clones being tested in Kenya, Uganda and Tanzania.
2. Selecting high-performing Mondi clones, as well as local landraces, to begin local (in-country or in-region) breeding programmes using these superior selections so as to be self-sufficient and independent with time.
3. The introduction of nursery and tissue culture technology, specifically for the multiplication of superior clones, to enable the production of these clones for distribution to small-scale farmers. Initially, these will be tested Mondi clones and eventually include clones from local clonal testing programmes.

Mondi adopted this strategy by considering the uniqueness of the East African situation, the immediate critical fuel-wood shortage, and the need for these countries to become independent of Mondi's genetic resources. The transfer of *Eucalyptus* breeding, clonal and nursery technology within Africa also strengthens its position as a continent with advanced short-rotation hardwood breeding and propagation technology.

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4. Assessing the merits of community level seedling production and distribution

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Abstract

One of the challenges facing projects that promote on-farm tree planting or forest plantations is how to provide seeds and seedlings at reasonable cost to planting sites. This can be overcome if planting is done on forest block sites through the forestry department's central nursery. Earlier attempts to promote community tree planting based on central nurseries operated by extension agents or non-governmental organizations (NGOs) proved both costly and ineffective. To reduce costs, there are continued efforts to decentralise seedling production and distribution to community levels through groups or central nurseries organized in schools, camps belonging to community chiefs and privately managed nurseries.

In the past, group nurseries often did not survive past the group formation or project support stage. Central nurseries, also, were sometimes abandoned when funding priorities changed. Yet, there are success stories and many farmers continue to be effectively reached through such nurseries. Certain group nurseries, for instance, were left under the management of a single individual yet continue to supply seedlings to the community. Privately owned nurseries, in contrast, have been able to survive for longer periods, albeit with little support from developmental organizations. Depending on the operating scenario, all three types (group, central and private) are feasible seedling supply alternatives and can evolve along with the awareness and tree planting culture of the community.

Introduction

The 1970s saw, amid major concerns on deforestation in the tropics, the creation of many afforestation projects to alleviate both rural and urban fuel-wood needs through government and donor organization forest extension services. The concept of agroforestry – trees on farms – was also born in this era due to an International Development

Research Centre (IDRC) report on the advantages of mixed farming systems in the tropics that incorporate trees, crops and animals. The World Agroforestry Centre, formerly the International Centre for Research on Agroforestry (ICRAF), with its headquarters in Kenya, was established to push the agenda further (Bene *et al.*, undated). Today, trees on farmlands occupy twice the forestland area in Africa. With two and a half decades of agroforestry research and development, tree products and services – apart from fuelwood – have been identified.

A key requirement to both afforestation and agroforestry is seedling supply. Foresters who led the agenda initially employed the operations of centralized seedling production centres. Centralized nurseries were established at forest stations, administrative area centres, such as camps belonging to community chiefs or schools, and areas designated as forest extension nurseries or project offices. Farmers would be asked to collect seedlings from nurseries at the beginning of the planting season. Alternatively, project staff would transport seedlings to collection areas closer to farms. In the 1980s, as the implications of seedling distribution began to seriously impact project costs, a shift took place from centralized production to decentralized community nurseries (Guggenberger *et al.*, 1989; Shanks and Carter, 1994).

Many such nurseries were organized by farmer groups that had been established for other purposes. Change agents found them appropriate to initiate training on tree planting. Support was provided through material inputs such as seeds, polytubes, watering cans and more. Soft inputs, such as technical advice and seedling acquisition were also occasionally provided.

A lot of group nurseries did not survive beyond the project support phase, while individually operated nurseries spontaneously sprang up for their own seedling needs and distribution to neighbours. Surprisingly, there was little initial project interest in these private nurseries, though some projects eventually supported them as they were more popular with farmers (Guggenberger *et al.*, 1989). Other community nurseries were organized by schools, churches and other groups who used them as a forum for agroforestry training. Such nurseries today are found throughout the tropics and their level of success depends on the tree-planting scenario of target communities. The applicability, merits and demerits of each category are discussed below.

Central nurseries

Central nurseries are run by research and development projects, schools, institutions, forest stations, or private companies. They are normally led by appointed managers and staff and often specialize in species that are relevant to the organization. Their main advantage is that staff can be directly employed to run them or can be redeployed from other activities within the organization. This enables a seedling production system to be set up very quickly. Production costs drop as more seedlings are produced as necessary inputs can be obtained in bulk and operations streamlined to meet growing demand. Direct project supervision ensures high seedling quality and protection, which wins market trust. Central nurseries are necessary to produce species that are difficult to propagate (or need special inputs) and those that require longer periods in the nursery, such as rootstocks and clones. They are also useful in areas where water is scarce.

The main disadvantage of central nurseries is that long distances hamper seedling distribution. One project, for example, found that farmers were unwilling to walk more than 2 km to collect seedlings (Kerkhof, 1989). Distribution levels drop even more for distances where farmers are required to pay for seedling transportation. In many areas, the average distance between farmers and the central nursery is 20 km – a strong disincentive for collecting seedlings. Nursery staff can transport seedlings to villages, schools and other collection points if they have available vehicles during the planting season, though rural roads are often impassable at that time. This leads to seedling wastage and transportation damages.

Other drawbacks include the centralization of benefits – as locals are not involved in any benefit sharing from nursery proceeds, and they require large amounts of land which could otherwise be used by the community. If funds are delayed or project priorities are changed, seedling production can be seriously hampered or stopped

(Shanks and Carter, 1994; Holding and Omondi, 1998). If staff is temporarily redeployed to other activities, this can lead to poor supervision and impact the quality of the seedlings.

Group nurseries

Farmers occasionally form groups to meet certain perceived needs. This can be focussed on a dairy cattle project, a credit scheme, or tree planting. In the case of the latter, this leads to the launch of a group-managed tree nursery for sharing seedlings or to generate income through seedling sales. Some nurseries are established for both: any seedlings that are not sold are shared among members. Group nurseries can operate under different management schemes. In Arusha, Tanzania, for example, a chairperson leads the activity, but each member has their own small nursery. Other groups either have a central production area to which all members contribute labour, or a few strategically located and managed satellite nurseries.

Early project attempts to decentralize seedling production at the village level were done through group nurseries which are often smaller in size and use simpler techniques than standard forestry nurseries. Support was primarily provided through the distribution of plastic bags, tools, seeds, and technical advice.

Group nurseries are very useful when tree planting, nursery production or agroforestry technology is new to a community. They are an effective forum for training and information dissemination if the species used are primarily for personal use. Groups are simple to organize, particularly in a small, cohesive community, and can be easily mobilized if they have successfully passed the following: the first stage when a group comes together to discuss an issue of similar interest (*e.g.* soil fertility), the second when a group through a series of discussions and break-out subgroups, actually redefines the issues and identifies the real priorities, the next stages are maturing (beginning implementation) and funding.

Their primary disadvantage is that their success depends on the group's cohesion. For this reason they require strong extension organization and an interest among the local people in tree growing. Nurseries turn to neglect if groups disintegrate, though the nursery may be taken up by one of the members and turned into an individual enterprise. Group nurseries rarely reach out beyond their locality and many project leaders have expressed dissatisfaction with the results of the groups they supported (Kerkhof, 1989). It is difficult to establish beforehand whether group nurseries are formed due to the kind of input support they are given by a project, or if they are motivated by the accruing benefits from tree planting and nursery establishment.

Privately operated nurseries

Individual nurseries range from small farm nurseries for personal use or sales to large establishments that supply to a broad clientele. They usually spontaneously start operations and rarely with any project support. Projects do, though, later identify and support them with both inputs and technical advice. They tend to use simple technologies for quality seedling production which may not always be technically sound. They are more sustainable than group nurseries, though when project support comes in through financial or material inputs, questions arise about their sustainability as entrepreneurs tend to be donor dependent for personal gains outside of nursery operations.

The advantage of these nurseries lies in the fact that owners are enterprising and geared to demand-driven production to raise their income and support their family. In certain areas of Kenya and Tanzania, they contain a wider range of species than group nurseries (Muriuki and Jaenicke, 2001; Guggenberger *et al.*, 1989). Other areas may differ depending on local circumstances. In Kenya's Muranga district, for example, group nurseries were found to be more species rich than private nurseries (Niewenhuis and O'Connor, 2000). Each operator can also adopt their own strategy for seedling production and distribution without having to grapple with group problems, though many prefer working with groups (Guggenberger *et al.*, 1989). And private nurseries are often located closer to clients.

Unfortunately, such nursery operators rarely adopt advice on seedling improvement, especially if it implies additional labour or capital investment. The quality of the seedlings, therefore, is compromised. Their sources of seeds are also normally of low genetic quality, leading to questionable future tree performance (Muriuki, unpublished MSc data).

The case for nursery associations

Surveys and interviews with nursery operators indicate that seedling demand is not being met and varies from site to site (Basweti *et al.*, 2001; Muriuki unpublished MSc data). Operators only collaborate to a small degree in order to meet demand. Nursery associations are envisaged as a mechanism to improve communication between nursery operators and increase market knowledge and transparency. They encourage knowledge transfer and sharing from within the network and promote linkages with seed dealers. And they can help in demand forecasting, bulk orders, providing information on new species, and sharing financial and market information. This relatively new idea needs to be promoted based on other local small-scale associations. Once operators establish recognized associations, they should be able to better market their products and apply for loans from micro-finance institutions.

ICRAF has promoted the creation of associations in Kenya by bringing together nursery operators in workshops and meetings. The Tree Nursery Operators Self-help Group, for example, was initiated by nursery operators from Nairobi and its peri-urban fringe and operates successfully with little intervention from ICRAF.

Tree planting scenarios

One should consider the scenarios that influence tree planting practices in target areas to determine which seedling production and distribution approach to use. The environment, individuals, groups, and communities will all play roles of various importance. Table 10 below provides simplified scenarios derived from real examples where a variety of nursery development strategies have been suggested. Major factors that determine strategies include: the extent to which the local population is used to planting and managing trees (tree planting culture); the level of existing trees and species diversity on farms; average farm size (room for more or new species); existing technical knowledge and market information; the role of the community within the society (whether individual development is encouraged); the extent to which the tree seed and seedling sector is commercialized; and the extent of political decentralization.

Projects must assess the situation in each target area, taking into consideration project objectives before determining which approach in devolving seedling production and distribution is best. Though some of the suggestions provided in Table 10 may suffice, situations vary and a careful study of the community is necessary before embarking on any strategy.

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Table 10 Tree planting scenarios, main constraints and possible interventions

Scenario	The situation	The constraints	Strategy elements
A	• Well developed tree planting culture • Existing tree diversity dominated by exotic species • Existing basic technical knowledge • Community supports private entrepreneurs • Tree seed sector is commercialized • Political system moving toward decentralization	• Insufficient information exchange between producers and buyers • Nursery operators hesitant to raise new species • Nursery operators have insufficient access to quality seeds	• Training in germplasm handling • Develop market information delivery systems • Strengthen the seed sector • Focus on developing individual nurseries
B	• Underdeveloped tree planting culture • Space for additional trees on farms • Existing tree diversity is low • Technical knowledge is poor • Close-knit community • Commercial tree seed sector non-existent • Political system favours grass-roots decision making	• Lack of interest in tree planting • Lack of technical knowledge	• Involve many stakeholders in raising easy species • Promote group training activities • Develop seed stands with communities • Support existing group nurseries
C	• A tree planting culture is developing through contacts with projects • Large but infertile farms • Community supports private entrepreneurs • Commercial tree seed sector poorly developed • Political system favours centralized decision making	• Insufficient nurseries to satisfy demand for high-value species • Low quality planting material	• Training and selection of key nursery operators • Develop a monitoring body for clonal horticulture • Develop market information delivery systems • Focus on developing individual nurseries
D	• Tree planting culture exists primarily for commercial cash crop species • Existing diversity dominated by forest trees retained on farms • Existing technical knowledge very basic • Close-knit community • Commercial tree seed sector poorly developed • Political system favours centralized decision making	• Insufficient nurseries to satisfy demand • Individuals lack technical knowledge	• Focus on improving and developing group and central nurseries • Strengthen central nurseries through training • Improve access to germplasm

Table 10 Tree planting scenarios, main constraints and possible interventions *(continued)*

Scenario	The situation	The constraints	Strategy elements
E	• No tree planting culture due to missing land tenure rights • Large tracts of land completely deforested • Scarce technical knowledge • Community supports private entrepreneurs • Commercial tree seed sector non-existent • Political system has central control over land and tree rights	• Insecure land tenure • Political climate not conducive to tree planting by individuals • Insufficient access to quality germplasm	• Strengthen government nurseries through improved germplasm and technical training • Engage in political dialogue to increase awareness of the importance of trees within agricultural systems • Focus on improving central nurseries
F	• Well developed tree planting culture • Poor tree diversity • Existing basic technical knowledge • Highly segregated community, private entrepreneurs encouraged • Highly commercialized tree seed sector • Political systems vary	• Land tenure insecurity for nursery operators • Insufficient information exchange between producers and buyers • Low quality seeds	• Improve seed dealer network • Provide technical training to seed dealers • Establish seed orchards • Develop market information delivery systems • Focus on improving and developing individual nurseries • Support the creation of associations

Adapted from Jaenicke (2001)

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5. Seedlings and clones: Kenya's marketing and distribution experience

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Abstract

In 2001, Kenya began its distribution process for biotechnology trees. Marketing strategies that were adopted included placing grass-root staff in different regions of the country to create market awareness. Information packages, such as flyers, brochures, and posters were distributed to farmers by technical staff both in the field and office. Advertisements were placed with local and national media outlets. And marketing agents were recruited to help in seedling marketing and distribution.

By 2002, awareness had spread significantly and farmers were convinced of the seedlings' superiority, leading to an increase in sales. Over one million seedlings were distributed. By 2003, demand and sales again increased by 29%. Since marketing began, over three million seedlings – roughly translating to over 2100 hectares (5400 acres) of land under new forest cover – have been distributed to various parts of the country.

The major marketing challenge is the ability to continue to reach farmers at the grass-roots level. The project therefore will hold more workshops for extension agents, open nurseries in different parts of the country, intensify awareness creation through field day participation in rural areas, and distribute additional information packages. Though there is a will to grow these trees, seedling costs for small-scale rural farmers remain prohibitive. A micro-credit facility is a possible solution.

Introduction

Marketing is the process of identifying consumer needs and wants, translating them into products and services and making it possible for more people to enjoy them. In 2001, marketing began of clonal hybrids and improved seedlings produced through the Tree Biotechnology Project. When introduced, the need for wood products from fast growing trees was clear to both producers and consumers. However, no data were available as to farmers' preferred species of *Eucalyptus*. Different strategies were therefore adopted to ensure that information on clonal hybrids reached the resource challenged rural farmers (*i.e.* the target group) and to help them identify their needs.

Why market?

Technologies are only as good as their appropriateness to local ecological and social conditions. Marketing results can, therefore, only be achieved by moving beyond on-station technology development. 'Extending' technologies means stretching them to fit multiple conditions in such a way that communication networks and feedback loops are established between technicians, innovators, extension agents and end-users.

Marketing objectives for this project included:

- Enhancing awareness and technology adoption at the grass-roots level
- Ensuring that the product meets the customers needs and wants
- Building a sustainable distribution network.

Marketing strategies adopted to reach these objectives were:

- Awareness creation
- Enhanced technology dissemination
- Networking
- Monitoring and evaluation.

Distribution channels adopted

Distribution was done through both short and intermediary channels. Short channels included direct purchase by farmers from the nursery, distribution by field officers, and project deliveries. Intermediary channels included purchases by marketing agents and extension service providers, private nursery operators, NGOs, and community-based organizations (CBOs). Table 11 shows the distribution channels used and the marketed number of seedlings and clonal hybrids.

Project milestones

Awareness creation

At least eight marketing channels were used to create market awareness for rural-based farmers, including:

1. Publishing and distributing information packages containing posters, brochures, leaflets and pamphlets (see Table 12)
2. Organizing group and individual visits by farmers and stakeholders to the Karura nursery and field trial sites

Table 11 Project distribution channels and marketed number of seedlings and clonal hybrids (2001–2003)

Distribution channel	Number of seedling and clonal hybrids
Marketing agent	220,589
Direct deliveries	779,917
Direct purchase	2,482,733
Total	**3,483,239**

Table 12 Publications released to farmers during marketing

Publication	Number
Posters	4,000
Brochures	6,200
Newsletters	2,000
Technical bulletins	11,500
Contact leaflets	2,000

3. Providing on-farm training and demonstrations on clone management
4. Deploying grass-roots staff to various 'hot spot' regions to help with information dissemination
5. Participating in field days to market clones and high quality seedlings
6. Advertising through mass media (radio and newspapers) to market the products
7. Participating in the Nairobi International Trade Fair
8. Recruiting marketing agents to enhance technology diffusion through information dissemination and seedling distribution.

Project staff participation in field days proved to significantly improve awareness and disseminate the technology at the grass-roots level.

Enhanced technology diffusion

The project deliberately tried to target resource-challenged, small-scale farmers in its marketing of improved seedlings and clones. A certain measure of success is established by estimating the increased total area under trees on small-scale farms. Table 13 highlights the effectiveness of the targeted marketing strategy.

A small-scale farm located in Mwea Division of Kirinyaga district with an annual rainfall of 700 mm.

Networking and linkages

Networks and linkages were created through collaborative efforts with NGOs, CBOs, and other extension agents. The project has actively collaborated with the Rural Energy Technology Assistance Programme (RETAP),

Table 13 Number of seedlings/clones purchased by different farmer categories and approximate land area planted

Category	Number of seedlings/ clonal hybrids	% of total	Approximate total area under trees (acres)
Small-scale farmers	2,086,477	60	3,260
Large-scale farmers	550,000	15.8	859
Organized groups	394,591	11.2	617
Corporate	452,171	13	706
Total	**3,483,239**	**100 %**	**5,442**

Note: Seedlings purchased by organized groups also end up in the hands of small-scale farmers. Therefore, 71.2 % are being grown by small-scale farmers.

which, as part of the United Nations Development Programme/Global Environment Facility (UNDP/GEF) Eco-Schools Programme, targets boarding schools in the Mt. Kenya region to establish woodlots for conserving the Mt. Kenya Forest.

The following pictures show examples of schools establishing woodlots on their premises to address local fuel-wood deficiency.

Monitoring and evaluation

Data sheets were introduced to key farmers in various parts of the country and extension agents were trained at the community level to create an effective information channel for dissemination and feedback between the farmers and project. The objective was to secure orders for seedling and clonal hybrid production. An example of some pending orders from farmers for the year 2004 is provided in Table 14.

Table 14 Orders for seedling and clonal hybrids by Kenyan farmers (2004)

Province	Number of seedlings and clonal hybrids
Rift Valley	514,300
Coast	650,000
Western	30,000
Central	400,000
Nyanza	10,000
Nairobi	15,000
Eastern	250,000
North Eastern	1,000
Total	**1,870,300**

Future strategies

The project will adopt the following steps for its future strategy:

- Intensify extension and marketing at the grass-roots level
- Decentralize distribution and delivery channels
- Enhance networking and linkages through collaboration
- Build market research and information systems.

Constraints to marketing and distribution

Some of the main marketing constraints experienced were:

Lack of micro-credit for small-scale farmers

Most small scale-farmers in Kenya live below the poverty line (US $1/day). Although most farmers are willing to grow improved seedlings and clones, current costs remain prohibitively high. A micro-credit scheme for these farmers would help their purchasing power.

Distribution and technology adoption at the grass-roots level

Distribution of tree plantlets and seedlings to small-scale farmers is a big problem since farms are widely scattered and access is difficult due to poor road networks. Regional distribution nurseries and demonstration plots can act as outlets for seedlings and clones, as well as a source of information and training for farmers and rural communities.

Other factors include:

- Erratic rainfall – rainfall over the last 2 years has been inadequate due to climate change.
- Land availability – most small-scale farmers own very small pieces of land (ranging from a quarter of an acre to five acres) of which most is under agricultural cultivation.

6. Discussion

Participants discussed whether the Kenya Tree Biotechnology Project should concentrate on its core activity of producing clonal tree seedlings and should outsource distribution needs. Though there is a need to involve the private sector in distribution, and this remains a key component of future strategies, the entire production and distribution system must be workable and sustainable. Clonal propagation facilities run successfully as a result of attention to detail and by remaining an overseeable size with realistic production targets. If clonal plant demand increases, additional clonal nurseries should be established so as not to put unrealistic demands on the existing nursery. Private sector partnerships in the future should not focus solely on distribution but on the production of clonal *Eucalyptus* as well. Nursery operators should also consider partnerships to enhance distribution. To ensure system sustainability, training in clonal propagation technology needs to be extended beyond the personnel at Kenya's Karura nursery.

Additional thought and planning is needed prior to involving the private sector in the planting of clonal trees. Many industries do not own the land on which they would plant the trees and, in the past, certain overseas investors have misused forest reserve lands that were allocated to them. In this respect it is easier to involve farmers or private landowners in planting activities.

Based on Kenya's experience, people in densely populated areas are actively planting trees as private individuals. At this point, most wood is required for subsistence purposes and this is where efforts should be concentrated. To sustain livelihoods through adequate wood supply it is necessary to identify both individuals and enterprises involved in tree farming. There is a need to influence and improve the way these stakeholders produce trees.

Nursery operators' involvement in clonal production is possible once mechanisms to share the technology with them are put in place. When nurseries work together as an association, this facilitates information sharing and quality control and also supports pooling resources for investment. As they grow, nurseries can partner in both production and distribution aspects.

Enticing the private sector to become a partner is a lengthy process which should begin as early as possible. The challenges are that the technology is still relatively new, impacts need to be better and more widely demonstrated, and private sector foundations, which are donor dependent, may not prioritise clonal tree forestry. To attract partners, Uganda's new Forest Authority recently began a US $23 million Plantation Fund, which is expected to raise confidence in tree planting.

Participants also discussed awareness program strategies to target decision makers and demonstrate the advantages of *Eucalyptus* clones in terms of biodiversity. A key to success is the sharing of awareness programs and materials amongst the three countries. Importantly, decision-makers need to understand that 'there is nothing magic about cloning'. To be sustainable, the technology must be scientifically rigorous using a broad-based genetic programme that matches clonal features to both site specificity and required products.

It remains impractical at present to expect sufficient clonal material to meet Kenya's national strategy goal of 80 million trees as the Forest Department does not have the required capacity. It will be possible, however, through farmer participation on private farms.

SESSION IV INTEGRATING CLONAL FORESTRY INTO NATIONAL PROGRAMMES

1. Deploying clonal forestry technology into Kenya's National Forestry Programme

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Introduction

Kenya today has limited land under forest cover, a growing population, an increasing wood deficit, and mounting pressure on remaining natural forests as wood supply from unsustainable sources leads to accelerated environmental degradation.

The country desperately needs to simultaneously increase forest cover and wood productivity on available land. Clonal forestry technology was included in Kenya's National Forest Programmes' strategy in an effort to meet this need. Existing forest programmes include: Farm Forestry (trees on farms); Drylands Forestry; Industrial Forest Plantations; Natural Forests in the highlands; Forest Industry; Forestry Research; and Education and Training.

Clonal forestry in Kenya

Kenya has used clonal forestry technology since 1966 to establish pine and cypress seed orchards. Other clonal activities have included pilot plantations of *Pinus radiata* and, more recently, *Eucalyptus* clones. *Eucalyptus* trials were established at different ecological zones in the country. Results are summarized below.

Summary of trial area results

Coastal areas (e.g., Sokoke, Gedi, Msambweni)
Grandis x Camaldulensis (GC) hybrids have shown exceptionally good growth in areas with about 900 mm of rainfall (7 m in height in the first year at Sokoke). Local *E. camaldulensis* and *E. urophylla* have also shown potential for improvement.

Semi-arid areas (e.g., Kitui, Marigat, Machakos)
GC has shown promise in areas up to 1400 m in altitude with 500–900 mm of rainfall though it is still too early for conclusions. *E. camaldulensis* from Zimbabwe performed remarkably well. However, certain indigenous species seem to do better in some of the drier sites. Termites have been a major problem for clones.

GC hybrid growth has been encouraging in regions with less than 500 mm of rain, though hybrids are unlikely to survive severe drought and termite attacks.

Highland areas (e.g., Hombe, Embu, Muguga)
At 1500–1700 m elevation with rainfall above 900 mm, GC clones have been generally growing well though there has been variable growth due to poor tending on certain sites. Pure, improved *E. grandis* have demonstrated a similar growth rate on wetter sites.

At an elevation of 1800–2200 m with 1200–2000 mm of rainfall, in contrast, improved local *E. grandis* has shown the best growth rate – up to 5 m per year. GC hybrids have not grown so quickly and tend to have poor stem form.

At 2300–3000 m with rainfall above 900 mm, both GC clones and pure improved *E. grandis* have not performed well due to low temperatures.

Integration of clonal forestry into national programmes

Farm forestry
It is estimated that 9.5 million hectares of total farmland area is suitable for tree planting. Though tree planting is traditionally done by small-scale landholders, current yields remain low, hence the need for clonal forestry. Forestry policy now prioritizes farm forestry. New commercial tree growers are also on the increase.

Integrating clonal forestry onto farm forestry still has challenges, including:

- High farmer expectations of good returns
- Appropriate clonal site matching

- Availability of planting material
- Developing affordable methods to produce planting material (cuttings) at the farm level
- Farmer seed collection from clones
- Poor site preparation and tending
- Poorly developed market for wood products.

Industrial forest plantations
The total area under industrial forest plantations declined from 170,000 ha in the mid-1980s to 80,000 ha in the late 1990s. This is exacerbated by the low rate of reforestation. It is planned that large-scale planting activities will rely heavily on the locally improved *E. grandis* in order to quickly provide wood and fuel-wood.

Drylands forestry
In semi-arid areas, land tenure, harsh climatic conditions, high consumer transport costs and termite attacks make tree planting on a large scale more difficult to achieve. More time is required to monitor the performance of promising clones.

Forestry research programme
The Kenya Forestry Research Institute (KEFRI) has established both on-farm and on-station demonstration plots as well as over 100 ha of improved *E. grandis* for seed production. The programme organizes short refresher courses for Forest Officers. Clonal forestry is included as part of the curriculum.

The programme has already initiated a breeding programme for landraces of *E. grandis*, *E. camaldulensis*, and *E. urophylla*. It will soon carry out a breeding programme for high altitude species (above 2300 m) and indigenous plantation species such as *Melia volkensii* and *Vitex keniensis*. Developing cheap clonal propagation methods remains the challenge.

Education and training programmes
These programmes involve:
- Public awareness creation on clonal site matching
- Organizing short clonal forestry courses for practicing foresters
- Introducing clonal forestry at both the technical and professional levels
- Promoting private sector development of wood-based industries.

2. Farm forestry as a livelihood option for small-scale farmers: Neem case study

Constantine Kandie and **Mary Onyango**, *Kenya Gatsby Trust (KGT)*

Abstract
Kenya requires a new culture of responsibility both towards conservation and the way business is done in order to effectively exploit available resources, eradicate poverty and include a high proportion of Kenyans in the fruits of development. Farm forestry, as a natural resource management strategy, is one of the keys to the sustainable supply of raw materials required for economic and livelihood activities. It improves wood quality and quantity while ensuring market competitiveness of products. Many rural communities have engaged in the production and marketing of forest products for some time, including timber, charcoal, handcrafts, gums and resins, herbal medicines, and honey. The Neem tree, in particular, offers new income and market opportunities for small-scale farmers in Kenya.

Neem products and services include:
- Food and animal fodder
- Oil, valued roughly at US $700 per ton (1990), used for various purposes, including cosmetics and pharmaceuticals
- Neem extracts may have toxic effects on certain insects
- Neem is effective against certain fungi that infect humans
- Farmers use Neem cake – residue left after extracting the oil from seeds – as an organic manure and soil amendment.

Conservation and commercialization of the multipurpose Neem tree
Neem trees, originally from India and Myanmar, were brought to Africa in the 19th century. They include two

main species: *Azadirachta excelsa* and *Azadirachta indica*. First planted in Cameroon, Ethiopia, Ghana, Kenya, and Tanzania, the larger populations within the country are found in Kenya's coastal belt. Primarily found on farms, roadsides, and on undeveloped government land, no Neem plantations exist today.

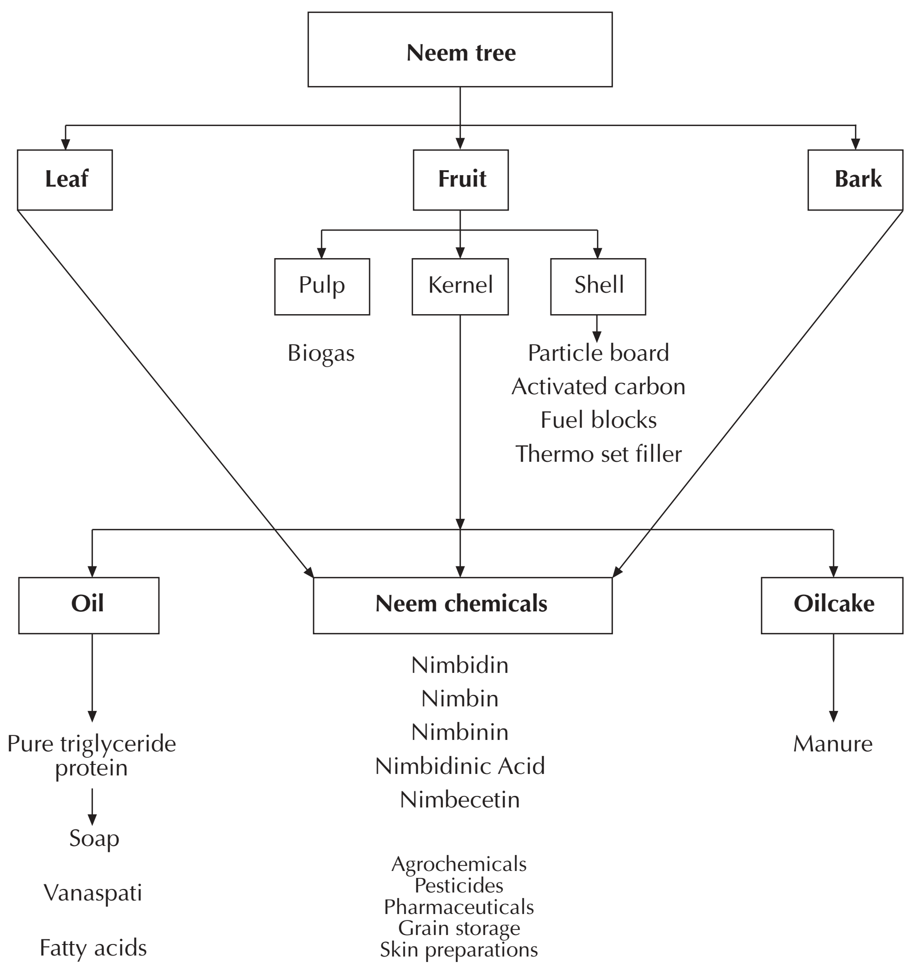
Yet the Neem tree offers great economic potential and long-term sustainability due to its multi-purpose natural resource benefits and vast commercialization options (Figure 2). A need exists to move from being Neem gatherers to becoming scientific Neem farmers. Neem use should be closely researched, including its socio-economic, legal, and policy aspects in order to tap into diverse potential benefits. Some of these benefits include: functional uses, commercial uses, and natural resource services.

Functional uses

Food – The fruit can be eaten fresh or cooked, or prepared as a lemonade-type drink. Young twigs and flowers are also, on occasion, consumed as vegetables.

Fodder – Leaves, though very bitter, are used as a dry season fodder. Fruit, particularly from the *A. indica* species, is an important food source for birds, bats and other wildlife.

Figure 2 Neem tree utilization



Commercial uses

Fuel – *A. indica* is used as fuel-wood and also makes charcoal of excellent quality. Throughout India, Neem oil is burned in lamps.

Timber – Neem wood is used for wardrobes, bookcases, closets, and even packing cases. Its insect repellent quality protects the contents from insect damage. And its resistance to termites makes it ideal for construction posts or fencing.

Gum or resin – This high-protein material has strong potential as a food additive. It is widely used in Southeast Asia as 'Neem glue'.

Tannin or dyestuff – Tree bark contains 12–14% tannins, which have been used for centuries to 'tan' animal hides and convert them to leather.

Lipids – Seeds contain a substantial amount of essential oil (as much as 50% of the kernel's weight) known as Neem oil. The oil constitutes about one-third of the oil content used in the economics of Neem production. It is widely used for soaps, cosmetics, pharmaceuticals and other non-edible products throughout Asia.

Poison – Azadirachtin, found in Neem leaves, tissues and seeds, has been identified as *A. indica*'s principal active compound acting as an insect repellent, inhibiting feeding and disrupting insect growth, metamorphosis, and reproduction. Insecticides based on *A. indica* alter insect behaviour to reduce pest damage to crops and lower their reproductive potential by affecting egg production and hatching rates. It has proven effective as an anti-feedant on about 100 insect species without interfering with beneficial insects, such as pollinating honeybees.

Scientists have found that salannin, a limnoid compound, makes the Neem leaf unpalatable to locusts. Neem extract tests have shown results on about 300 insect species, including beetles, weevils and cockroaches.

Traditional agricultural practices such as the production of 'Neem tea', where seeds are dried, crushed and soaked in water overnight to produce a liquid pesticide that can be applied directly to crops, are also being studied. If Neem powder is put in each hole prior to planting, the plant will absorb the powder and be protected from most insect damage [personal communication Dr. Saxena, International Centre for Insect Physiology and Ecology (ICIPE)].

Importantly, Neem extracts may have toxic effects on fish, other aquatic wildlife and on certain beneficial insects. Care should therefore be taken to ensure that any unused extracts are properly disposed of by exposing them to heat or sunlight to break down the active compounds.

Medicine – Laboratory tests have shown Neem to be effective against certain fungi that infect humans and have also suppressed several species of pathogenic bacteria, including *Salmonella typhosa* and *Staphylococus aureus*. One study showed Neem preparation toxicity to 14 common fungi cultures. Neem oil has been used traditionally as a treatment for skin disorders in both humans and livestock by acting 'like a raincoat' against fungal spores.

Various parts of the tree have anthelmintic, antiseptic, diuretic, and purgative properties and can be used to treat boils, pimples, eye diseases, high blood pressure, hepatitis, leprosy, rheumatism, scrofula, ringworm, and ulcers. Leaf teas are used to treat malaria. Neem bark powder is also an excellent tooth powder. In Japan, patented hot water Neem bark extracts have shown remarkable effectiveness against several types of tumours. Neem oil is a powerful spermicidal and a Neem oil-based product, Sensal, is marketed in India as an intravaginal contraceptive. Finally, Neem has also been shown to be of value in the treatment of East Coast Fever, a key tick-borne disease of cattle in Eastern Africa.

Natural resource services

Erosion control – Neem trees, with a root system capable of extracting nutrients from lower soil levels, are resistant to drought, making them ideal for dune fixation.

Soil improver – Neem cake – the remaining residue after seed oil extraction – is used by farmers in India as an organic manure and soil amendment to enhance nitrogen fertilizers and inhibit soil pests such as nematodes, fungi and insects. Kenya's horticulture sector is also doing trials. Leaves and twigs are used as mulch and green manure.

Shade or shelter – Neem's large crown makes it an effective shade tree. It is planted as an avenue tree in many tropical towns and villages.

Intercropping – In India, intercropping with pearl millet has yielded encouraging results.

Pests and diseases

Azadirachta indica has few serious pests, though some scale insects have been reported to infest it. *Aonidiella orientalis*, for example, feeds on sap from young branches and stems; *Pulvinaria maxima* also feeds on sap and covers tender shoots and stems; and shoot borers in India have damaged the plant. Occasional infestations by the insect species *Micotermes* and *Lorantus* were recorded in Nigeria, though trees usually recovered.

A. indica is affected by the *Dendrophtoe falcata* and *Tapinanthus* spp. mistletoes. In India, the *Psuedocercospora subsesessilis* fungus attacked the leaves, though no fungal attacks were recorded in Southeast Asia. The bacterium *Pseudomonas azadirachtae* may also damage leaves, though more study is needed.

Finally, rats and porcupines can occasionally kill seedlings and trees by gnawing at the bark around the base.

Neem's economic exploitation potential

Kenya's Neem tree population is currently about 2–5 million, mainly in the coastal areas, but also to a limited extent in Kenya's Eastern Province. There are plans to plant trees through an ICIPE-funded project in Southern Nyanza (Mbita Point Research Project). The overall tree population, however, is quickly falling as the tree has been targeted by the carving industry as high-quality wood. A significant portion of economic potential is therefore lost. Though cash is generated through sales, providing an income source for local communities, such commercial exploitation is leading to resource depletion. To reverse this trend and help find new income opportunities for the country and the resource-poor further study is required to fully appreciate Neem's economic potential.

Neem offers considerable potential for agricultural utilization. Through research on cultural and traditional farming use of Neem, more can be learned to respond to the economic interests of the farming, forestry, and industrial sectors.

Marginal semi-arid regions also offer considerable potential for Neem plantations, adding rural development options for these resource-poor areas. To achieve this potential, capacity must be built through training on extraction, processing, packaging and marketing of Neem products in order to move from simply gathering and tending Neem to becoming scientific Neem farmers.

Studies should be carried out to: identify all ecological zones where Neem can be grown and harvested; classify all the pests that can be controlled by Neem under varying conditions in different ecological zones; establish the medicinal value of the tree's components; and examine the cultural practices used in order to identify and harness new products and potential uses. An analysis of economic, societal, and environmental impacts should also be implemented.

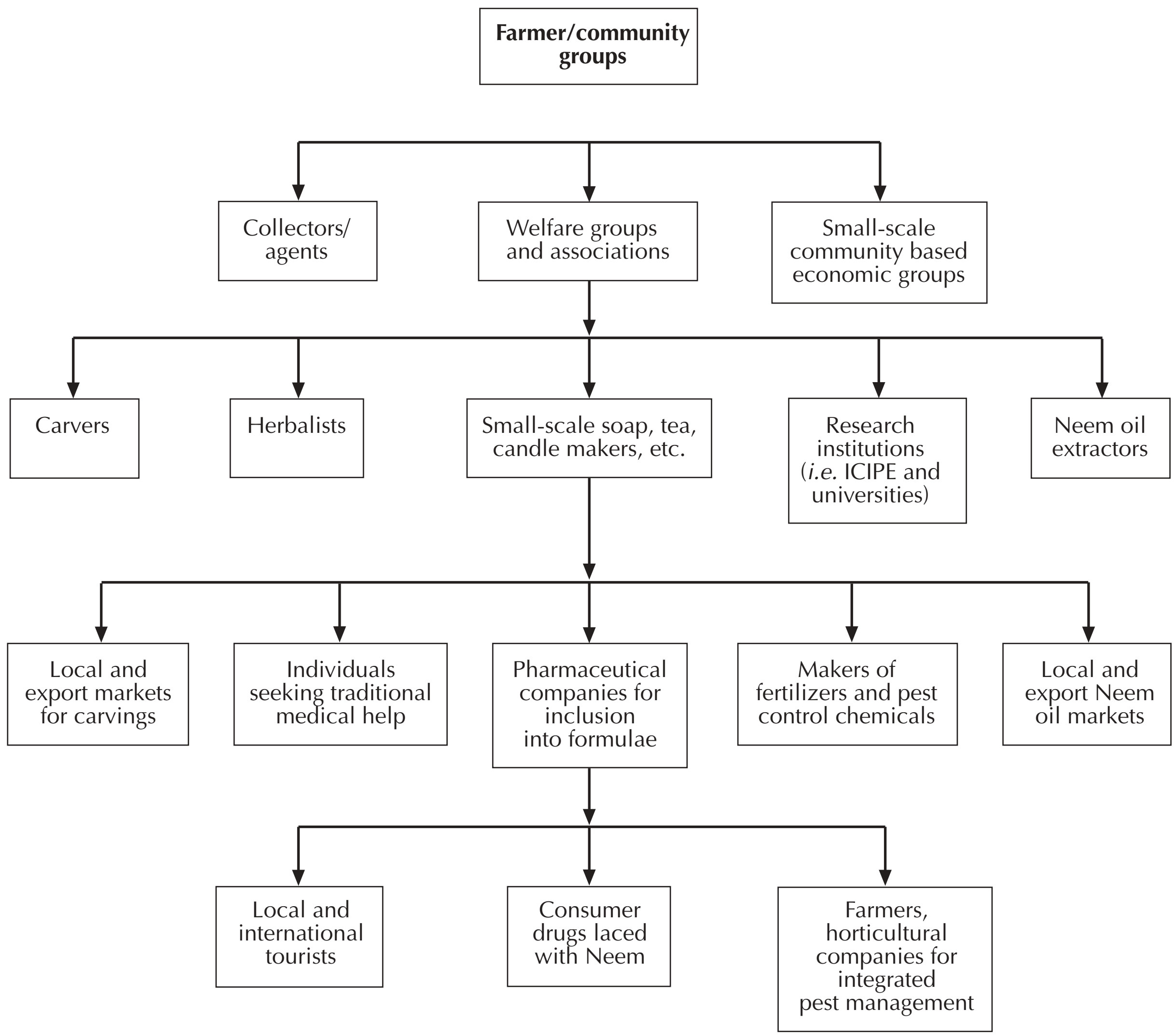
Official recommendations should be developed for certain products, such as pesticides and medication, including dosages, application procedures, and safety of use. Once more is known about Neem, a major multi-media promotional campaign could be launched to promote the development of this sector. Finally, policies to promote Neem's propagation, processing, marketing, and market access should be more fully identified (Figure 3).

Exploitation constraints

Before Neem's full economic potential can be attained, existing constraints must be addressed. Many are similar to those found within the farm forestry sector in general, such as:

- Poor access to raw materials
- Lack of quality-assured commercial products (certification)
- Lack of information and awareness

Figure 3 Neem supply chain



- Lack of extension services for forest management techniques, seed harvesting, and product processing
- Poor access to markets
- Lack of cottage industries for processing
- Strong competition from more sophisticated international manufacturers.

Other practical problems currently limit the use of Neem for pest control. These include the seasonality of Neem cake supply, limitations in seed collection, as well as poor trade and processing options. Seed processing, for example, is only a seasonal operation which lasts roughly 100 days. Variations in Neem progenies and harvesting, storing and extraction techniques, are creating differences in pest control strength and quality. Finally, seeds and kernels may also develop fungal growth during storage and produce toxins.

Most of these issues can be addressed through proper training, capacity building and effective policies, including finding incentives for private sector involvement.

The greatest potential constraint to Kenya's Neem tree economic development is through an agreement drafted under the World Trade Organization (WTO) that would control the use and ownership of biodiversity. The draft, presented at the September 2003 WTO talks in Mexico and included under the Trade Related Intellectual Property Rights (TRIPS), has been criticized as targeting the traditional technologies of the developing world with the potential to deny Third World regions the benefits from traditional uses that have sustained them for centuries. The draft allows multi-national corporations and research institutions to patent creations of unique plant and animal species or their genes. Whereas a large number of the world's curative plants are unique to Africa, the continent lacks the resources and technology to research and patent inventions.

Should the draft be approved, Kenya would be required to cede ownership of any Neem related patents. Kenyans, forced to pay for using herbs native to their own countries, will have lost an economic livelihood opportunity.

Recommendations

1. Build awareness of Neem tree uses within the supply chain and certification process
2. Support small-scale farmers in implementing forest management plans and in acquiring Neem timber certification
3. Support the position of women in family land use due to their important role in farming and harvesting
4. Establish and develop Neem production and marketing teams
5. Link producers to markets by establishing a networking facility with stakeholders from the supply chain
6. Build the business capacity of stakeholders, especially in marketing and operational management
7. Develop effective policies which promote forest conservation, Neem product certification and market access.

3. The New East Africa Business Summit: The environmental committee and private sector's role in afforestation

Padeep Paunrana and **Douglas Miheso**, *Environment Group, East Africa Business Summit (EABS) and Athi River Mining Ltd.*

In September 2003 the New East Africa Business Summit (EABS) was founded as part of a greater East African Business Leaders Public–Private Sector Partnership Initiative. EABS's Environmental Committee were charged with the responsibility of trying to interest the private sector to partner with national governments in order to reverse forest destruction and share reforestation responsibilities. Progress to date includes:

- High-level interaction with government representatives
- Effective action and implementation of recommendations emerging from environmental deliberations
- Official government recognition of Tree Biotechnology potential
- Initiation of On-farm Forestry Programmes

Forestry concerns among EABS stakeholders

Forestry concerns vary according to the stakeholder. EABS stakeholders include:

- Large-scale industrial timber and pulp producers
- Medium-scale timber producers
- Charcoal producers
- Institutions involved in rural community forestry

Table 15 summarizes their respective concerns.

Suggestions for creating the right environment for successful forestry

In order to create the right, long-term environment for successful afforestation initiatives, both national governments and the private sector need to work together. National governments initiatives could foster such an environment by:

- Making land available for long-term commercial lease
- Adopting and implementing strict measures to address unregulated and illegal logging
- Encouraging the private sector to manage reforestation projects
- Liberalizing timber pricing, trade and charcoal production

Table 15 Forestry concerns among stakeholder groups in East Africa

Large-scale industrial timber and pulp producers	Medium-scale timber producers	Charcoal producers	Rural/community level forestry
• Access to long-term timber sources • Security of tenure and property • Leasing costs • Investment incentives • Market pricing mechanisms	• Reliance on government forests and 'middlemen', or illegal and unregulated loggers • Need affirmative policy on government forests logging and reforestation • Need to establish other private sector timber growers and suppliers • Need for cheaper sources and varieties of timber	• Need to recognize charcoal industry, as other sources of fuel for domestic use are not yet readily available • Legalize and regulate efficient charcoal production, and provide rural area producers with land, e.g. municipality owned land, parts of government forests, etc. • Encourage, educate, and illustrate by examples cultivation of fast growing trees as with the Woodlands Trust • Encourage large-scale land owners to enter the charcoal market, e.g. Kakuzi	• Timber still very important as building material and as fuel-wood, but current regulations deter proper forestry practice, and need to address this area • Adopt the EABS On-farm Forestry programme and introduce fast growing trees to every family • Make seedlings readily available and create awareness of market potential • The provincial administration can play a major role in promoting biotechnology trees in the rural areas.

- Abolishing the permit system
- Providing fiscal and other incentives for commercial forestry investment.

Private sector initiatives could include:

- Creating a strong lobby of seedling nurseries, pulp and timber producers, NGOs and East African Business partners
- Identifying and promoting tree growing zones with high potential outside of gazetted forests
- Setting up private commercial nurseries
- Promoting on-farm forestry through pilot schemes at the rural level
- Inviting potential timber exporters to join the lobby.

4. Group discussions

Facilitated by **David Hopkins, Bruce Hulett, Oluka-Akileng** and **L. Nshumbemuki**

Participants divided themselves into three groups to discuss the following:

A. Strategies for scaling-up clonal forestry in East Africa
B. Improving marketing and distribution amongst small-scale farmers
C. The role and encouragement of private sector involvement in clonal forestry.

The main out comes of the discussion are summarized below.

Group A: Strategies for scaling-up clonal forestry in East Africa

The group noted that in order to develop sound strategies for scaling up clonal forestry, there was need to identify the issues and develop guidelines. The main issue is to address the time taken to produce wood for use. In this regard, it was agreed that clonal forestry would be best utilized in promoting the technology for fast growing trees and in those that take a long time to seed. Guidelines for end-use products were identified as follows: for fuelwood, focus should be on tress that provide resources in 2–4 years; 1–4 years for small poles; 5–10 years for big poles; timber 8–15 years; and pulp 5–8 years. The group noted that market availability of products would be a major driving force to technology adoption.

Identification of pure species was paramount in initiating the establishment of seed orchards from which clones can be developed and on which a breeding programme can be anchored. For imported materials, there is need to establish clonal materials from which careful testing, selection, and production will be based.

To help scale-up clonal production and distribution, it was recommended that current production facilities be decentralized. Site matching of species and quality control of the production process were recognized as most critical in promoting clonal technology. In addition, training in disease and pest management, as well as enhancing the right policy, funding, and species prioritization on which to develop would help a great deal in promoting clonal forestry in East Africa.

Group B: Improving marketing and distribution amongst small-scale farmers

The following steps were identified to improve marketing and distribution of clones amongst small-scale farmers:

- Decentralize clonal nurseries in East Africa to enable clonal material access for farmers
- Provide extension services to promote quality management of clones at farm level
- Develop incubator nurseries as links to onsite training
- Encourage the establishment of Savings and Credit Cooperatives (SACCOs) for tree planting. This would help smallholder farmers access the required funds to purchase clonal material for planting.
- Establish specialized funding to encourage smallholders to plant trees
- Encourage active collaboration with other distribution networks, such as ICRAF
- Promote hands-on training of entrepreneurs wishing to invest in clonal forestry through visits and training at central clonal nurseries. Visits by villagers who can then adopt the planting of clonal trees would also promote marketing
- Use schools as demonstration centres: the project should form strong linkages with the Ministry of Education
- Social marketing through videos and in agricultural shows would further promote the marketing of clones.

Group C: The role and encouragement of private sector involvement in clonal forestry

The group identified production and distribution of clones as the private sector's major role. To encourage private involvement, the following strategies were discussed:

- Identify interested members of the private sector in clonal forestry
- Create greater awareness
- Help provide business plans on which can be used to operate clonal nurseries and promote distribution of clones
- Help provide market information
- Improve access to capital to enable private sector clonal nursery investment
- Lobby for affirmative action public policies – tax incentives, opening trade barriers, etc.
- Ensure that technology availability is sustainable
- Provide consistent research backing.

Session V Closing address

Honourable Kate Kamba, *Member, East African Community Parliament*

This important event has brought together scientists, managers, policymakers, and other stakeholders from Ethiopia, Kenya, Tanzania, South Africa, Uganda and the United Kingdom. Through this effective forum, detailed deliberations on the workshop's important objectives were made possible.

Six objectives were achieved:

1. The sharing of country experiences, including some broad discussion on the current means by which farmers are replanting *Eucalyptus*, and the overall adoption of clonal forestry.
2. Ways of encouraging private sector involvement were identified, along with new opportunities.
3. Discussions were held on how clonal forestry fits into broader national programmes, including questions on species and multiplication systems.
4. Clonal production and distribution approaches were assessed *vis-à-vis* long established village-based systems.
5. Marketing and distribution options for both seeds and cuttings – government versus private nurseries – were considered in each of the three countries.
6. Ways forward have been identified for specific projects.

Forests and trees play an enormous role in the lives of people within the region. Forestry biotechnology, or clonal forestry, is a relatively new research area in our countries, yet its application has the potential to improve the livelihoods of our people.

Forests are among the most vital resources that any country can possess. In developing countries, they fulfil essential livelihood functions by providing rural populations with many of their subsistence needs, including fuel, food and fodder. Forests are critically important for soil and water conservation. They also harbour vast biodiversity and fix carbon dioxide – a greenhouse gas – thus contributing to the stabilization of the global climate. They are inextricably woven into the rural and household economies of developing countries, a factor that has led to this precious resource's over exploitation. Finally, forests are also an important source of industrial products and, in many cases, foreign exchange.

According to the United Nations Environment Programme (UNEP) forests are disappearing at a rate of 7.5 million hectares per year for closed forests, and 3.8 million hectares per year for open forests. Deforestation, largely attributed to agricultural expansion due to rapid population growth and urbanization, is leading to a fuel-wood crisis – the main energy source for most sub-Saharan African countries. Fuel-wood accounts for over 58%of total energy consumption on the African continent. An estimated 93% of rural household uses are met by fuel-wood. The economic importance of forest resources cannot be emphasized enough.

As the fuel-wood crisis deepens, women – the main collectors of fuel-wood – must spend more time collecting it. In doing so, they must sacrifice the time which would otherwise be spent on other productive activities and family time. In some cases, children must miss school in order to help find scarce firewood. Put simply, deforestation perpetuates the poverty cycle.

The regional and experience sharing approach adopted for this workshop to target improved living standards for rural families, particularly the resource-poor population segment, is commendable. The tour to the Karura clonal nursery was an eye opener and the field trip to small-scale farmers in Githunguri clearly demonstrated the willingness to accept new technologies. Our people need to be further educated about the importance of safeguarding the forest resources. It is hoped that the workshop's outcomes will reach a wider population.

Unlike crops, only a small percentage of current world forest plantings comprise material resulting from genetic improvement. Genetic improvement of forest species has essentially been limited to the selection and multiplication of well-adapted genotypes. For industrial forestry species though, especially *Eucalyptus* and pines, recurrent selection for population improvement has been widely adopted.

Eucalyptus plantations are one of the leading forestry systems. Reproductive biology and variation patterns for these species have been reasonably well documented. Vigour, form and wood quality are the priority selection criteria. Non-industrial tree species, on the other hand, are poorly understood and selection criteria are also not well defined. Forest tree breeding work is essentially confined to species testing, assessing biological features and genetic conservation activities. Biotechnology use to improve tree species requires intimate knowledge of biology, breeding systems and variations in the pattern of the target species. To date, such knowledge is limited to a few species. Another major constraint to tree improvement programmes, perhaps one which our universities and research institutions can address, is the lack of skilled tree breeders. Much can also be learned from developed countries, especially in the Nordic region, which have made considerable progress in exploiting tree biotechnology.

Proceedings from this workshop are a valuable contribution to East Africa's development of clonal forestry. They should be made available to all stakeholders in the region, including relevant ministries, research institutions, universities and non-governmental organizations dealing with environmental matters.

I would like to thank the Gatsby Charitable Foundation, Mondi Forest and ISAAA for spearheading a people-centred partnership in the region where our people will be sharing experiences and speeding up the process of development. Indeed your partnership has made this workshop a success.

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