APPLYING THE PRINCIPLES OF SUSTAINABLE FARMING

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FUNDAMENTALS OF SUSTAINABLE AGRICULTURE

Sustainable farming meets environmental, economic, and social objectives simultaneously. Environmentally sound agriculture is nature-based rather than factory-based. Economic sustainability depends on profitable enterprises, sound financial planning, proactive marketing, and risk management. Social sustainability results from making decisions with the farm family's and the larger community's quality of life as a value and a goal. This publication discusses the principles of environmental, economic, and social sustainability, and provides practical examples of how to apply them on the farm.

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INTRODUCTION

Farming sustainably means growing crops and livestock in ways that meet three objectives simultaneously:

- **Economic profit**
- **Social benefits to the farm family and the community**
- **Environmental conservation**

Sustainable agriculture depends on a whole-system approach whose overall goal is the continuing health of the land and people. Therefore it concentrates on long-term solutions to problems instead of short-term treatment of symptoms.

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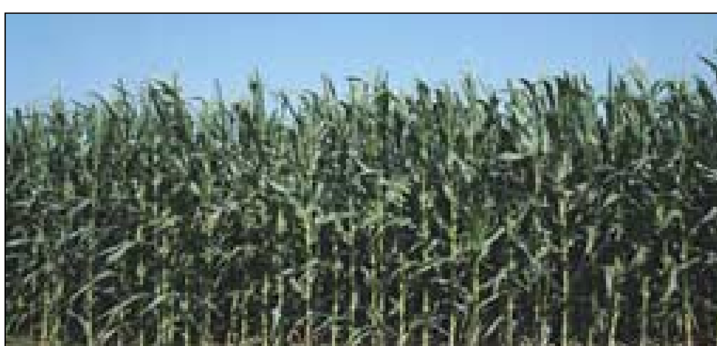

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Sustainable farming is more than a set of idealistic principles or a limited set of practices. Sustainability can be observed and measured; indicators that a farm or rural community is achieving the three objectives of sustainability include:

Economic Sustainability

- ◈The family savings or net worth is consistently going up
- ◈The family debt is consistently going down
- ◈The farm enterprises are consistently profitable from year to year
- ◈Purchase of off-farm feed and fertilizer is decreasing
- ◈Reliance on government payments is decreasing

Social Sustainability

- ◈The farm supports other businesses and families in the community
- ◈Dollars circulate within the local economy
- ◈The number of rural families is going up or holding steady
- ◈Young people take over their parents' farms and continue farming
- ◈College graduates return to the community after graduation

Environmental Sustainability

- ◈There is no bare ground
- ◈Clean water flows in the farm's ditches and streams
- ◈Wildlife is abundant
- ◈Fish are prolific in streams that flow through the farm
- ◈The farm landscape is diverse in vegetation

These three objectives are managed more as a single unit, even though we must discuss them separately. The three objectives overlap constantly. For example, economic decisions affect the local community—buying from out of state instead of from a local supplier. Environmental decisions affect the economic—allowing soil erosion increases the need for irrigation and more fertilizer. Each of these objectives is further examined below.

Environmental Sustainability

Sustainable agriculture can be viewed as ecosystem management of complex interactions among soil, water, plants, animals, climate, and people. The goal is to integrate all these factors into a production system that is appropriate for the environment, the people, and the economic conditions where the farm is located.

Farms become and stay environmentally sustainable by imitating natural systems—creating a farm landscape that mimics as closely as possible the complexity of healthy ecosystems. Nature tends to function in cycles, so that waste from one process or system becomes input for another. Industrial agriculture, in contrast, tends to function in a linear fashion similar to a factory: inputs go in one end, and products and waste come out the other. The wastes of industrial agriculture (non-point-source pollution) include suspended soil, nitrates, and phosphates in stream water, and nitrates and pesticides in ground water. It is a premise of sustainable agriculture that a farm is a nature-based system, not a factory.

The simpler we try to make agriculture, the more vulnerable we become to natural disasters and marketplace changes. When we try to produce a single product such as wheat, corn, or soybeans we are taking on huge risk. If instead we diversify crops and integrate plant and animal agriculture, overhead will be spread over several enterprises, reducing risk and increasing profit. Table 1 offers some comparisons between two models of agriculture—farming as an industrial factory and farming as a biological system.

Table 1 Comparison of the Industrial and Biological Models of Agriculture

Industrial model	Biological model
Energy intensive	Information intensive
Linear process	Cyclical process
Farm as factory	Farm as ecosystem
Enterprise separation	Enterprise integration
Single enterprise	Many enterprises
Monoculture	Diversity of plants and animals
Low-value products	Higher-value products
Single-use equipment	Multiple-use equipment
Passive marketing	Active marketing

On any farm, four major ecosystem processes are at work that, if functioning properly, will conserve the soil and water resources and eventually reduce the overall operating costs. These natural processes—energy flow, water and mineral cycles, and ecosystem dynamics—are observable and manageable.

√ **Energy flow** is the non-cyclical path of solar energy (sunlight) into and through any biological system (Figure 1). The natural world runs on sunlight. Our management decisions affect how much of it is captured and put to good use on the farm (Savory and Butterfield, 1999). Energy flow begins when sunlight is converted into plant growth, and continues when animals consume plants, when predator animals consume prey, and when microorganisms decompose dead plants and animals. Some energy is lost as heat at every transfer point in the food chain. On the farm, energy capture is enhanced by maximizing—both in space and in time—the leaf area available for photosynthesis, and by efficiently cycling the stored solar energy through the food chain. Off-season cover crops, perennial vegetation, and intercropping are among the tools for capturing more solar energy. Capturing sunlight and converting it to dollars is the original source of all wealth.

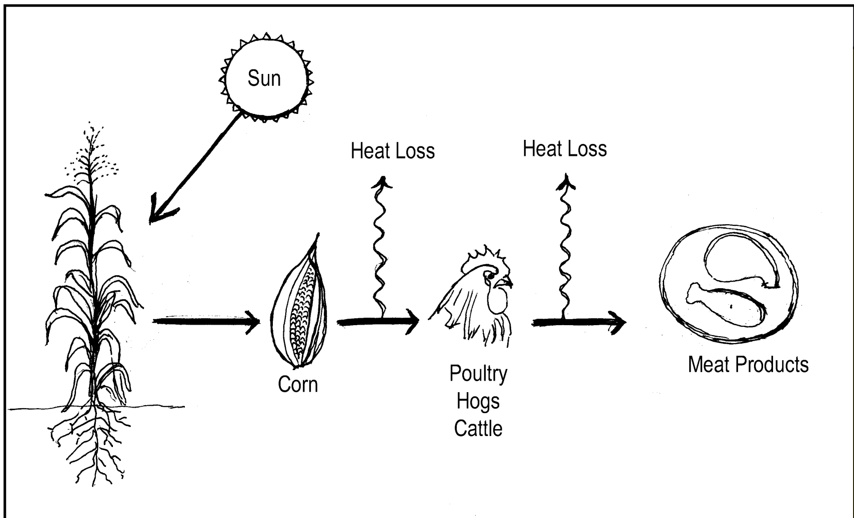

Figure 1. Energy Flow. Source: Sullivan, 1999. Illustration by Janet Bachmann.

√ An effective **water cycle** is typified by no soil erosion, fast water entry into the soil, and the soil's capacity to store large amounts of water (Figure 2). Streams flow year-round from the slow release of water stored in the soil. The water cycle is improved by management decisions that add to or maintain the groundcover percentage and soil organic matter levels—the goal is to get as much water as possible into the soil during each rainfall. A surface mulch layer speeds water intake while reducing evaporation and protecting the soil from erosion. Minimizing or eliminating tillage, growing high-residue crops and cover crops, and adding compost or manure to the soil maintains groundcover and builds organic matter. Management of soil organic matter is especially important in row cropping. One recent study (Hudson, 1994) showed that raising the percentage of organic matter from 1% to 2% in sandy soil increased the available water content of that soil by 60% (from 5% of total soil volume to 8%). Such an improvement in a soil's water-holding capacity will have a beneficial effect on crop growth, especially during drought periods.

The results of an effective water cycle are low surface runoff, low soil surface evaporation, low drought incidence, low flood incidence, high transpiration by plants, and high seepage of water to underground reservoirs (Savory and Butterfield, 1999).

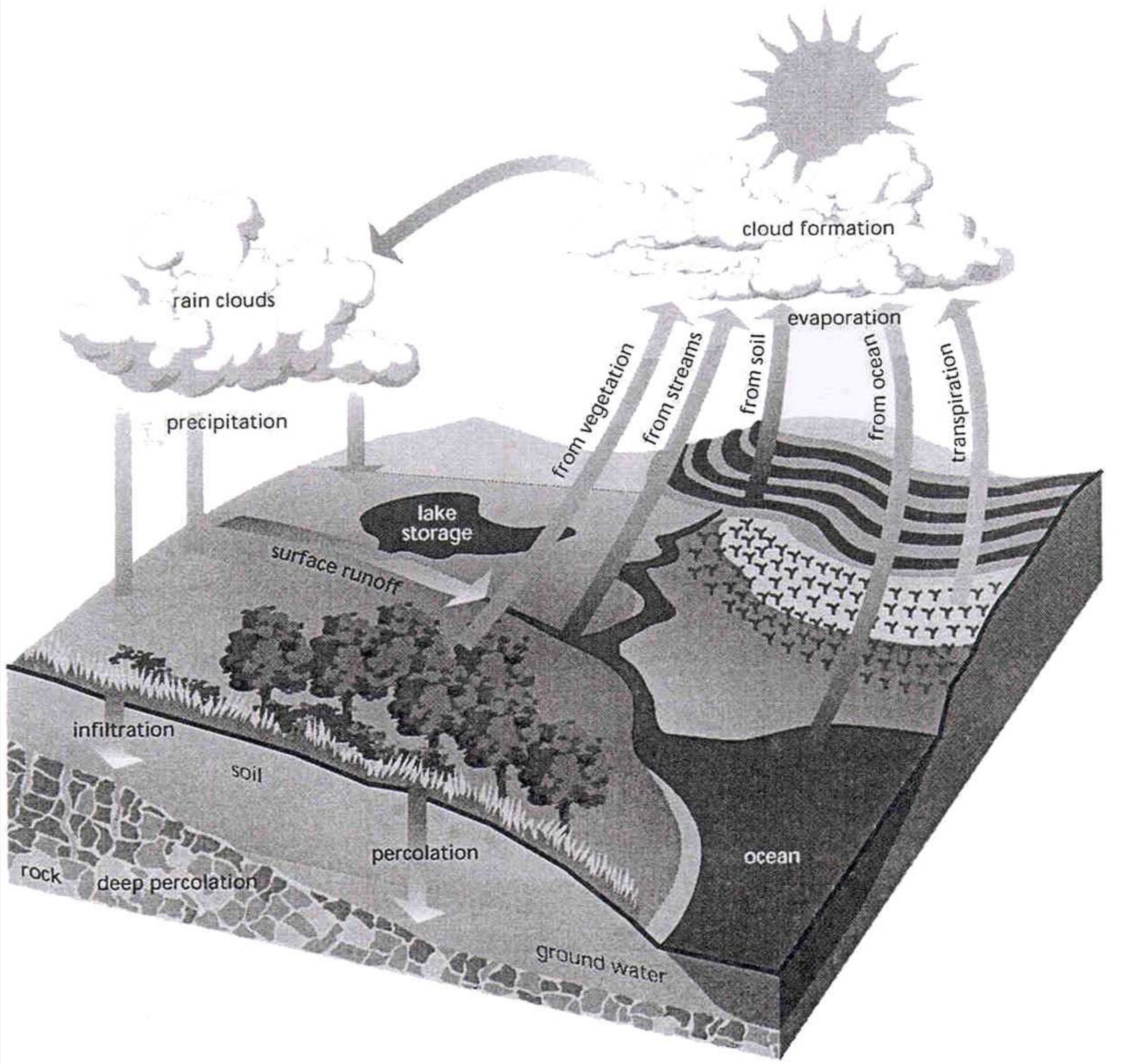

Figure 2. Water Cycle. Source: Federal Interagency Stream Restoration Working Group, 2001.

√ A well-functioning **mineral cycle**—the movement of nutrients from the soil through the crops and animals and back to the soil—means less need for fertilizer and feed from off the farm (Figure 3). In nature, minerals needed for plant and animal growth are continuously recycled within the ecosystem with very little waste and no need for added fertilizer. Ultimately, to be sustainable, we need to find ways to use the natural mineral cycle to minimize our off-farm purchase of minerals. Conditions and practices that inhibit the natural mineral cycle—erosion, nutrient leaching, organic matter depletion, selling hay or grain off the farm—tend to reduce the farm's sustainability. Practices that enhance the mineral cycle include on-farm feeding of livestock, careful management of manure and crop residues, use of catch crops to reduce nutrient leaching losses, and practices that prevent erosion.

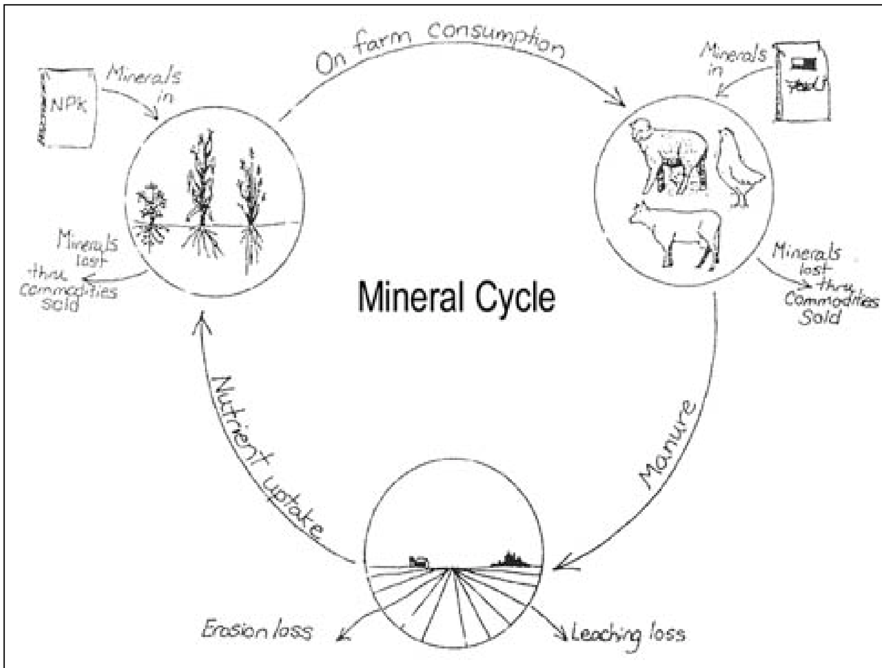

Figure 3. Mineral Cycle. Source: Sullivan, 1999.
Illustration by Andrea Fournet.

√ An effective **ecosystem dynamic** is indicated by a high diversity of plants and animals both above and below ground. "Diversity" refers not only to numbers of species, but also to genetic diversity within species and to a broad age structure in each population. Greater diversity produces greater stability within the system and minimizes pest problems. Our choices of practices and tools directly affect the level of biodiversity we have on the farm (Table 2).

The first step toward increasing biodiversity on the farm is crop rotation, which helps break weed and pest life cycles and provides complementary fertilization among the crops in the planting sequence. Advancing from rotation to strip intercrops brings a higher level of biodiversity and increases sunlight capture. Strip intercropping of corn and soybeans or cotton and alfalfa are two examples. Borders, windbreaks, and special plantings for natural enemies of pests provide habitat for beneficial organisms, further increasing biodiversity and stability. The addition of appropriate perennial crops, shrubs, and trees to the farmscape enhances ecosystem dynamics still further. For more information on practices that increase biodiversity, request the ATTRA publications *Agroforestry Overview*, *Intercropping Principles and Production Practices*, and *Farmscaping to Enhance Biological Control*.

TABLE 2

Listing of tools by their effect on	
Increased Biodiversity	▸Intercropping ▸Crop rotation ▸Cover crops ▸Multispecies grazing
Decreased Biodiversity	▸Monocropping ▸ Tillage ▸ Herbicides ▸ Insecticides

These four ecosystem processes (energy flow, water cycle, mineral cycle, and ecosystem dynamics) function together as a whole, each one complementing the others. When we modify any one of these, we affect the others as well. When we build our farm enterprises around these processes, we are applying nature's principles to sustain the farm for our family and for future generations. When we fight nature's processes, we incur extra costs and create more problems, hurting ourselves and the ecosystem on which we depend.

Selecting Profitable Enterprises to Ensure Economic Sustainability

Economic sustainability increasingly depends on selecting profitable enterprises, sound financial planning, proactive marketing, risk management, and good overall management. The key for row-crop producers may be to explore income opportunities other than traditional commodity crops, such as contract growing of seed corn, specialty corn, food-grade soybeans, or popcorn. These specialty crops are not for everyone; only a certain number of acres can be grown because of limited markets. Expanding organic markets suggest another possible niche. "Alternative" crops like safflower, sunflower, flax, and others may be an option for lengthening a corn and soybean rotation; learn more in the ATTRA publication Alternative Agronomic Crops. Other examples of diversification strategies are available in the ATTRA publications *Evaluating a Rural Enterprise* and *Moving Beyond Conventional Cash Cropping*.

Author and successful small farmer Joel Salatin (1998) advocates going with several "centerpiece" enterprises to which can be added several "complementary" enterprises. The complementary enterprises overlap with the centerpiece enterprises by sharing some of the same overhead requirements, thus lowering overall costs for all the enterprises. When we try to produce a single product such as wheat, corn, or soybeans, our risk is high because "all our eggs are in one basket." When we integrate plant and animal agriculture we distribute overhead and risk among several enterprises.

> A profitable farm has a threadbare look (Salatin, 1998), primarily because money is not spent on flashy items that don't produce profit. Amish farmer David Kline says one of the secrets of staying profitable is "don't spend money" (Myers, 1998).

Comprehensive financial planning is a must

The holistic financial planning process used in Holistic Management™ provides a monthly roadmap to help people navigate through their financial year, assured that the profit will be there at year's end. The income is planned first, then a planned profit is allocated as the first expense item. The remaining expense money is allocated sequentially where it will do the most good. This sequential allocation requires that the farmer spend no more than necessary to run the enterprise for a year, while preserving the planned profit. This potent financial planning process empowers people to make decisions that are simultaneously good for the environment, the local community, and the bottom line. Learn more by requesting the ATTRA publication entitled *Holistic Management*. Also evaluate other financial planning tools that allow enterprise budgeting, cost calculations, partial budgeting analysis, and more—these should be available from your local Extension agent. Business planning software is available from local software retail stores.

Every farm needs a marketing plan of some type. Marketing can take many forms, ranging from passive marketing in the commodity chain to marketing a retail product directly to consumers. Which marketing method you choose will have a profound effect on the price your product commands. Doing some market research is essential in order to understand your market, competition, and consumer trends, and to project potential sales volume and prices. Specialty and direct markets such as organic, GMO-free, and other "green" markets yield more income but require more marketing by the producer. Direct marketing is not for everyone.

Social Sustainability

Decisions made on the farm have effects in the local community. For example, the decision to expand your operation requires the acquisition of your neighbor's farm. To have your neighbor's farm, you must make the decision that your neighbor's farm is more important to you than your neighbor. Other examples of social decisions include: buying supplies locally rather than ordering from out of state, figuring out ways to connect local consumers with your farm, taking a consumer-oriented approach to production and management practices where both the farmer and consumer win, and finding opportunities to ensure that neighboring communities can learn about sustainable food production.

Marketing strategies such as community supported agriculture (CSA), direct marketing through farmers' markets, school tours, and internships all have a positive impact on the local community. When people have a choice between supporting local producers or paying a little less for the products of the industrial food system, they will often choose to support their neighbors. Farmers selling locally benefit from differentiating their products and services by qualities other than price. Fresh produce, specialty items, and locally grown and processed foods are competitive in the market place, especially when consumer education and personal contact with the farmer are part of the marketing plan.

Social sustainability also includes the quality of life of those who work and live on the farm, including good communication, trust, and mutual support. Full family participation in farm planning is an indication that the quality of life is high. Other indicators include talking openly and honestly, spending time together, a feeling of progress toward goals, and general happiness. Quality of life will be defined somewhat differently by each individual and family, based on their values and goals. More information on ensuring that quality of life is accounted for in farm planning is available from the ATTRA publication *Holistic Management* and in books like *Rut Buster: A Visual Goal Setting Book* (Burleson and Burleson, 1994).

Planning and Decision Making

Managing for three objectives simultaneously (economics, society, environment) depends on clear goal-setting and effective decision-making. Several good tools for decision-making, goal-setting, and whole-farm management are available to farmers. The Kerr Center for Sustainable Agriculture, for example, has developed a sustainability checksheet with 72 criteria for quick evaluation of farming systems (Horne and McDermott, No date). ATTRA has produced sustainability checksheets for beef and dairy enterprises, available by request and on our website. A more comprehensive approach is Holistic Management™, mentioned above. Request the ATTRA publication entitled *Holistic Management* for more information, or contact:

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A successful transition to sustainable farming depends on the farmer's careful monitoring both of progress towards the goal and of the overall health of the system. It is useful to assume that your plan will not work and develop a system for determining (as soon as possible) if it isn't working. For example, if the goal includes increased biodiversity, the farmer needs to know—quickly —if the grazing or cropping system being used is actually increasing the number of plant species per acre. Monitoring is particularly important in sustainable agriculture, which relies on natural systems to replace some of the work done by input products like fertilizer and pesticides.

The ability to evaluate and replan is vital to the farmer who wishes to farm more sustainably. When part of the plan is not working as intended, it becomes necessary to replan. The concept of planning-monitoring-controlling-replanning is a key characteristic of Holistic Management and is referred to as the *feedback loop*.

The transition toward more sustainable farming requires not only planning and decision-making skills but access to appropriate and helpful information. Fortunately, increased interest in sustainable agriculture has stimulated greater investment in research and education. As a result, much more usable information is available today than ever before, accessible through various means, one of them being ATTRA. In addition to publications and custom reports on production and marketing, ATTRA provides resource lists covering sustainable agriculture organizations, educational programs, internships, and related resources. Request an ATTRA Publications List or go to the ATTRA website for online access to all our publications.

Applying the Principles

When beginning the transition, the big question is how to apply the principles of economic profitability, social enhancement, and ecological improvement in the field, in the community, and in the financial process. The decisions we make on our farms and the tools and practices we choose will determine the extent to which sustainability is realized. The ultimate goal is to farm in such a way that we extract our living as the interest, while preserving the social, water, and soil capital. We want to ensure that our activities do not compromise the landscape and community resources over the long term. Now let's look at some management concepts aimed at fostering the four ecosystem processes discussed earlier.

Strive to keep the soil covered throughout the year

Under natural conditions the soil remains covered with a skin of dead plant material, which moderates temperature extremes, increases water penetration and storage, and enhances soil aeration. Most importantly, the soil skin maintains soil structure and prevents erosion by softening the impact of falling raindrops. Bare ground, on the other hand, is vulnerable to water and wind erosion, dries out more quickly, and loses organic matter rapidly.

The major productivity costs associated with soil erosion come from the replacement of lost nutrients and reduced water holding ability, accounting for 50 to 75% of productivity loss (Pimentel et al., 1995). Soil removed by erosion typically contains about three times more nutrients than the soil left behind and is 1.5 to 5 times richer in organic matter (Pimentel et al., 1995). This organic matter loss not only results in reduced water holding capacity and degraded soil aggregation, but also loss of plant nutrients, which must then be replaced with fertilizers. Five tons of topsoil (the USDA "tolerance level" for erosion) can easily contain 100 pounds of nitrogen, 60 pounds of phosphate, 45 pounds of potash, 2 pounds of calcium, 10 pounds of magnesium, and 8 pounds of sulfur. Table 3 shows the effect of slight, moderate, and severe erosion on organic matter, soil phosphorus level, and plant-available water on a silt loam soil in Indiana (Schertz et al., 1984).

Table 3.

Effect of erosion on organic matter, phosphorus, and plant-available water

Erosion level	Organic matter	Phosphorus	Plant-available water
	%	lbs / ac	%
Slight	3	62	7.4
Moderate	2.5	61	6.2
Severe	1.9	40	3.6

Source: Schertz et al., 1984

When erosion by water and wind occurs at a rate of 7.6 tons / acre / year it costs $40 / acre / year to replace the lost nutrients as fertilizer, and around $17 / acre / year to pump irrigation water to replace the water holding capacity of that lost soil (Troeh et al., 1991). Soil and water lost from U.S. cropland causes productivity loss of approximately $27 billion each year (Pimentel et al., 1995).

Avoid moldboard plowing at all costs

Soil is damaged considerably whenever it is turned over. The moldboard plow brings subsoil to the surface and buries the crop residue layer so deep it is unable to decay properly. Virtually no soil residue is left on the surface, exposing the soil to erosion and impairing the water and mineral cycles. Today, millions of acres are being farmed without any tillage at all (no-till) or in such a way that adequate groundcover remains afterwards (ridge till, zone till, minimum till). Production systems that reduce or eliminate tillage in a manner consistent with effective weed control foster the four ecosystem processes discussed above. Read about an innovative no-till system that uses annual cover crops in the "Examples of Successful Transitions" section. For more information, request the two ATTRA publications *Conservation Tillage* and *Pursuing Conservation Tillage for Organic Crop Production*.

Diversify

Enterprise diversification reduces financial risk by spreading income and costs (e.g., of pest control and fertilizer) out over several crops or livestock operations. Sustainability is increased when animal wastes become inputs to crop production on the same farm.

Rotate crops

Moving from simple monoculture to a higher level of diversity begins with crop rotations, which break weed and pest life cycles, provide complementary fertilization to crops in sequence with each other—nitrogen-fixing legume crops preceding grain crops such as corn—and prevent buildup of pest insects and weeds. In many cases, yield increases follow from the "rotation effect." Including forage crops in the rotation will reduce soil erosion and increase soil quality.

> Intercropping is the growing of two or more crops in proximity to promote interaction between them. Read the ATTRA publications *Intercropping Principles and Production Practices* and *Companion Planting* for more information.

When planning crop rotations, it is important to consider that cultivated row crops—such as corn and soybeans or vegetables— tend to be soil-degrading. Since the soil is open and cultivated between rows, microbes break down organic matter at a more rapid pace. Furthermore, row crops have modest root systems and consequently do not contribute enough new organic matter to replace that lost from the open soil between rows; in most cases above-ground crop residues make only minor contributions to replacing lost organic matter.

Cereals and other crops (including annual green manures) planted with a grain drill or broadcast-seeded are more closely spaced and have more extensive root systems than row crops, greatly reducing the amount of soil exposed to degradation. In addition, they receive little or no cultivation after planting, which reduces organic-matter loss even more. As a result, cereals and green manures can be considered neutral crops, replacing soil organic matter at roughly the same rate at which it breaks down. Crops that make a perennial sod cover—such as grasses, clovers, and alfalfa—not only keep the soil entirely covered, but also have massive root systems, producing far more organic matter than is lost. Sod crops are the best soil-building crops—they can heal the damage done to soil by row cropping.

Incorporating sod crops as a fundamental part of a crop rotation not only builds soil but supports weed-control strategies as well. Weed control improves because the types of weeds encouraged by row-cropping systems are usually not adapted to growing in a sod / hay crop. An ideal rotation might include one year of sod crop for each year of row crop, and as many years of "neutral" crops as makes sense in the circumstances.

The challenge of incorporating sod crops into a rotation is to include livestock in the system or to find a market for the hay. Sustainable production is much easier when livestock are present in the system to recycle wastes and assist in transferring (via manure) nutrients from one part of the farm to another. Fortunately, land capable of producing a 100-bushel corn yield will generally be able to produce 5-ton hay yields. With prices of $60–$70 per ton being common for ordinary hay, gross revenues per acre from hay will exceed those from corn so long as corn is under $3.00 per bushel. The net- income picture is even more encouraging, however, because conventional production costs for an acre of corn are quite a bit higher than for hay. A good crop of alfalfa fixes at least $50 worth of nitrogen every year, thus reducing fertilizer costs for the subsequent corn crop.

Besides equipment costs, the major drawback to selling hay is that the nutrients it contains are shipped off the farm. Since, however, something like 75–90% of the minerals going into the front end of cattle come out the back end, keeping cattle helps retain nutrients on the farm. Cattle can serve as a very profitable method of adding value to the forage crops they consume. ATTRA offers an extensive series of publications on sustainable beef production and "grass farming."

Grazing animals and other livestock can be managed on croplands to reduce costs, increase income, and increase diversity. There are ways of incorporating animals into cropping without the farmer getting into animal husbandry or ownership directly. Collaboration with neighbors who own animals will benefit both croppers and livestock owners. Grazing or hogging-off of corn residue is one example where a cost can be turned into a profit. The animals replace the $6 per-acre stalk mowing cost and produce income in animal gains.

Use cover crops and green manures

Perennial and biennial sod crops, annual green manures, and annual cover crops are important for building soil in field-cropping systems. Hairy vetch, for example, not only is a soil-conserving cover crop, but is capable of providing all the nitrogen required by subsequent crops like tomatoes (Abdul-Baki and Teasdale, 1994).

The soil-building crops most appropriate for a given farm depend not only on regional factors (harshness of winter, etc.) but also on the type of production system involved: each farmer will have to determine which cover crops are most appropriate to his or her system. For more information see the ATTRA publication *Overview of Cover Crops and Green Manures*.

Composts, Manures, and Fertilizers

Crop rotations, cover-cropping, and green-manuring are key strategies for soil building, which is the foundation of sustainable farming. However, modern production systems place high demands on land resources, requiring additional attention to soil fertility management. ATTRA's *Sustainable Soil Management* publication provides practical information about alternative soil management approaches. Since some of these approaches entail the use of off-farm inputs, two additional ATTRA publications, *Alternative Soil Amendments* and *Sources of Organic Fertilizers & Amendments*, are also recommended.

Manures and composts, especially those produced on-farm or available locally at low cost, are ideal resources for cycling nutrients on-farm. From the standpoint of overall soil and crop health, composts or aged manures are preferred. Compost has a unique advantage in comparison to unaged manure and other organic soil amendments in that it has a (usually) predictable, and nearly ideal, ratio of carbon to nitrogen (Parnes, 1990). Compost can be safely applied at rates of 10 tons per acre (Parnes, 1990) where quantities are available. Much higher rates are not unusual, especially where soil is being improved rather than maintained.

Compost has some particular advantages in row crop production, especially when used in conjunction with cover crops and green manures. In sandy soils, compost's stable organic matter is especially effective at absorbing and retaining water. Fresh plant material incorporated as green manure, on the other hand, retains its waxy leaf coating and cannot perform the same function until thoroughly digested by microbes.

There are several conventional fertilizers that should be avoided in sustainable farming because of their harmful effects on soil organisms and structure. These include anhydrous ammonia and potassium chloride. The use of dolomite—a liming material having a high magnesium-to-calcium ratio—has also been generally discouraged, but most problems result from the frequent misuse of dolomite for raising pH on soils already high in magnesium, not from any innate detrimental qualities. It is certainly appropriate for use on fields deficient in magnesium, as indicated by a proper soil test.

Some of the more "environmentally friendly" chemical fertilizers such as mono-ammonium phosphate (12-50-0), commonly called MAP, may also have a role in the transition away from the harsher chemical fertilizers. A very serviceable and affordable 4-16-16 transitional fertilizer with magnesium, sulfur, and other minor nutrients can be prepared from a combination of two-thirds sulfate of potash-magnesia and one-third mono-ammonium phosphate. When used in combination with composts and/or legume plowdowns (for nitrogen), this 4-16-16 can be banded at seeding or otherwise applied just like the regular 5-20-20, but with reduced negative impact on soil life.

Significant additions of lime, rock phosphate, and other fertilizers should be guided by soil testing to avoid soil imbalances and unnecessary expenditure on inputs. Cooperative Extension offers low-cost soil testing services in many states. Also refer to ATTRA's *Alternative Soil Testing Laboratories* publication.

Weed Management

Weed management poses one of the greatest challenges to the crafting of sustainable production systems. However, weed populations tend to decline in severity as soil health builds. A basic understanding of weed ecology and the influence of cropping patterns on weed communities will help growers refine their use of cultural and mechanical techniques, thereby reducing the time required for effective weed control.

Prevention of weed problems is a fundamental component of management. In general terms, weed prevention in crops is based on developing a sound rotation, thwarting all attempts by existing weeds to set seed, and minimizing the arrival of new weed seeds from outside the field. In a grazing system, weed management may be as simple as adding other animal species such as goats or sheep to a cattle herd to convert weeds into cash.

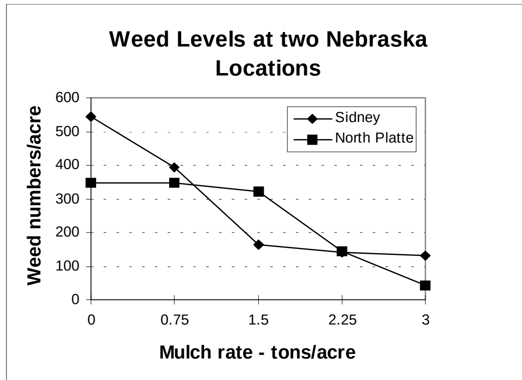

Figure 4. Effect of straw mulch on weeds at two locations in Nebraska. Source: Crutchfield et al., 1985.

Table 4.

Tillage and Cover Crop Mulch Effect on Weed Numbers and Production

Tillage	Cover crop	Weeds/foot^2	Weed weight pounds/foot^2
Conventional	None	12	0.22
None	None	5	0.14
None	Rye	0.9	0.1
None	Wheat	0.3	0.07
None	Barley	0.8	0.09

Source: Schertz et al., 1984

Certain crops can be used to smother weeds. Short-duration plantings of buckwheat and sorghum-sudangrass, for example, smother weeds by growing faster and out-competing them. In northern states, oats are commonly planted as a "nurse crop" for alfalfa, clover, and legume-grass mixtures—the oats simply take the place of weeds that would otherwise grow between the young alfalfa plants.

With enough mulch, weed numbers can be greatly reduced. Nebraska scientists applied wheat straw in early spring to a field where wheat had been harvested the previous August. At the higher straw rates, weed levels were reduced more than three times over (see Figure 3). Wheat, like rye, is also known to possess weed-suppressing chemicals in the straw itself. This quality is known as allelopathy.

Rye is one of the most useful allelopathic cover crops because it is winter-hardy and can be grown almost anywhere. Rye residue contains generous amounts of allelopathic chemicals. When rye is killed in place and left undisturbed on the soil surface, these chemicals leach out and prevent germination of small-seeded weeds. Weed suppression is effective for about 30–60 days (Daar, 1986). If the rye is tilled into the soil, the effect is lost.

Table 4 shows the effects of several cereal cover crops on weed production. Note that tillage alone, in the absence of any cover crop, more than doubled the number of weeds.

While a good weed-prevention program will decrease weed pressure substantially, successful crop production still requires a well-conceived program for controlling weeds to the point where they have no negative impact on net income. Weed control programs include a range of carefully timed interventions designed to kill as many young seedlings as possible. ATTRA has additional information on weed control options for both agronomic and horticultural crops, available on request, including the publication *Principles of Sustainable Weed Management for Croplands*.

Insect Pest Management

Insect pests can have a serious impact on farm income. In ecologically balanced farm production systems, insect pests are always present, but massive outbreaks resulting in severe economic damage are minimized. This results in good part from the presence of natural control agents—especially predatory and parasitic insects, mites, and spiders—that keep pest populations in check. To restore populations of beneficials on the farm, cease or reduce pesticide use and other practices that harm them, and establish habitats through farmscaping.

> "Farmscaping" refers to practices that increase diversity on the farm by providing habitat for beneficial organisms. Borders, windbreaks, and special plantings for natural enemies of pests serve this purpose. Request the ATTRA publication *Farmscaping to Enhance Biological Control* for more information.

In diverse farm systems, severe pest outbreaks are rare because natural controls exist to automatically bring populations back into balance. There is overwhelming evidence that plant mixtures (intercrops) support lower numbers of pests than pure stands (Altieri and Liebman, 1994). There are two schools of thought on why this occurs. One suggests that higher natural-enemy populations persist in diverse mixtures because they provide more continuous food sources (nectar, pollen, and prey) and habitat. The other thought is that pest insects who feed on only one type of plant have greater opportunity to feed, move around, and breed in pure crop stands because their resources are more concentrated than they would be in a crop mixture (Altieri and Liebman, 1994).

Intercropping also aids pest control efforts by reducing the ability of the pest insects to recognize their host plants. For example, thrips and white flies are attracted to green plants with a brown (soil) background, and ignore areas where vegetative cover is complete—including mulched soil (Ecological Agriculture Projects, No date). Some intercrops thus disguise the host plant from these pests by completely covering the soil. Other insects recognize their host plant by smell; onions planted with carrots mask the smell of carrots from carrot flies. For more information on companion planting for insect management see the ATTRA publications *Farmscaping to Enhance Biological Control* and *Companion Planting*.

Sooner or later, nearly every grower confronts unacceptable pest pressure, making some kind of intervention necessary. Integrated pest management (IPM) is the basic framework used to decide when and how pests are controlled. The primary goal of IPM is to give growers management guidelines in order to make pest control as economically and ecologically sound as possible.

> A working knowledge of the life cycles of pests and their natural enemies enables the grower to identify and exploit the weak link in a pest's life cycle. Several good books and publications on insect identification are available through Cooperative Extension; more can be found in libraries and bookstores.

IPM integrates habitat modification and cultural, physical, biological, and chemical practices to minimize crop losses. Monitoring, record keeping, and life-cycle information about pests and their natural enemies are used to determine which control measures are needed to keep pests below an economically damaging threshold. For more detailied information on IPM, see the ATTRA publication *Biointensive Integrated Pest Management*.

Biological control—the use of living organisms to control crop pests— is one of the pillars of IPM. Biocontrol agents may be predatory, parasitic, or pathogenic; they may also be either "natural" (from naturally occurring organisms such as wild beneficial insects) or "applied" (meaning the organisms are introduced). Biocontrol agents include insects, mites, bacteria, fungi, viruses, and nematodes. Certain beneficial nematodes (*Steinernema* species, for example) transmit pathogens to their prey and could be seen as a form of indirectly applied biocontrol.

When all other IPM tactics are unable to maintain insect pest populations below economic thresholds, insecticide application to control the pests and prevent economic loss is clearly justified. In such cases, farmers concerned with sustainability will usually attempt to obtain satisfactory control using one of the "biorational" pesticides, which are fairly pest-specific and usually non-persistent, causing a minimal amount of harm to beneficial organisms. Biorational pesticides include some conventional synthetic pest control materials, but more typically are microbial insecticides like *Bacillus thuringiensis* or *Beauveria bassiana*; insecticidal soaps; pheromones (for trapping or mating disruption), and insect growth regulators. Botanical plant extracts like neem and ryania are also known as least-toxic, narrow-spectrum controls, combining minimal negative impact on beneficial species with very rapid decomposition in the environment.

Farms exploring IPM concepts for the first time may limit their involvement to monitoring levels of one or two pests on a secondary crop, applying their usual insecticide if the threshold of economic injury is approached. Others may shift from a broad-spectrum insecticide to a more beneficial-friendly material. As operator comfort with IPM increases, it is common to apply basic concepts to the primary crop and expand IPM management on the secondary crop—perhaps through the introduction of beneficial parasites or predators of the target pest insect.

> Farmers need to consider carefully how to manage the shift to fewer pesticides during the first few years, before beneficial insect populations have rebuilt to levels where they can exert significant control of the major pests. Farmers should plan to work closely with local experts—especially farmers with transition experience—to ensure as smooth a shift as possible.

As they move towards greater sustainability, IPM programs tend to go through three phases, with each stage using and building on previous knowledge and techniques (Ferro, 1993):

a) The **pesticide management phase**, characterized by establishing economic thresholds, sampling, and spraying as needed.

b) The **cultural management phase**, based on a thorough understanding of the pest's biology and its relationship to the cropping system. Tactics employed to control pests include delayed planting dates, crop rotation, altered harvest dates, etc.

c) The **biological control phase**, or "bio-intensive IPM," requires thorough understanding of the biology of natural enemies (in addition to that of the pest) and an ability to measure how effective these agents are in controlling pests. When natural agents do not meet expected goals, the IPM practitioner uses "soft" pesticides (relatively non-toxic to nontarget organisms), and times applications for minimal impact on beneficials.

Plant Disease Management

The first step toward preventing serious disease problems in any cropping system is the production of healthy plants nurtured by a microbially active soil. Healthy soil suppresses root diseases naturally; the primary means to create disease-suppressive soil is to add biologically active compost at appropriate rates to a soil with balanced mineral levels. Supplemental strategies include crop rotation, resistant cultivars, good soil drainage, adequate air movement, and planting clean seed.

Biorational fungicides include compost teas (which add beneficial fungi capable of preventing colonization of the crop by pathogens), baking soda, and plant extracts. As with insect pest control, integrated management principles should be applied, including monitoring of environmental conditions to determine whether preventive fungicidal sprays are required. For more information on how healthy soil fosters a drastic reduction in root diseases, request the ATTRA publication *Sustainable Management of Soil-borne Plant Diseases*.

Examples of Successful Transitions

Steve Groff of Pennsylvania

Steve Groff and his family produce vegetables, alfalfa, and grain crops profitably on 175 acres in Lancaster County, Pennsylvania. When Steve took over operation of the family farm 15 years ago, his number-one concern was eliminating soil erosion (improving the water cycle). Consequently, he began using cover crops extensively (improving the water and mineral cycle and increasing community dynamics).

Steve uses a 10-foot Buffalo rolling stalk chopper to transform a green cover crop into a no-till mulch. Under the hitch-mounted frame, the stalk chopper has two sets of rollers running in tandem. These rollers can be adjusted for light or aggressive action and set for continuous coverage. Steve says the machine can be run up to 8 miles an hour and does a good job of killing the cover crop and pushing it right down on the soil. It can also be used to flatten down other crop residues after harvest. Groff improved his chopper by adding independent linkages and springs to each roller. This modification makes each unit more flexible, to allow continuous use over uneven terrain. Following his chopper, Groff transplants vegetable seedlings or plants no-till sweet corn and snap beans into the killed mulch. Under the cover-crop mulch system, his soils are protected from erosion and have become much mellower (as a result of the improved water cycle). For more information, order Steve's video listed in the Resources section below or visit his Web page, < http://www.cedarmeadowfarm.com/about.html>, where you can see photos of the cover-crop roller and no-till transplanter in action, as well as test-plot results comparing flail mowing, rolling, and herbicide killing of cover crops.

Dick and Sharon Thompson of Iowa

Dick and Sharon are well known in the sustainable agriculture community for an integrated family farm system that has broad implications for the larger agricultural community. Their system is based not on expansion but on maintenance of local community values. Excerpts from a Wallace Institute report describe the social sustainability of their farming operation. In Dick Thompson's own words:

"The size of a farm will be restricted when the major part of weed control depends on the rotary hoe and the cultivator. Two cultivations of the 150 acres of row crops with a four-row cultivator are enough along with hay making and caring for the livestock. An eight-row cultivator will handle 300 to 400 acres very easy , but not thousands of acres.... Harvesting ear corn puts another restraint on farm size. Picking 100 acres in the ear is enough. Mowing and baling 40 acres of hay three or four times during the summer is enough. Looking after 75 beef cows during calving is enough. There is no desire to have 150 cows. Including the cow in the farm operation keeps the farm and communities in balance. When the cow leaves the farm, the oats and hay crops leave also. The remainder is row crop corn and soybeans without manure for fertility which calls for purchased fertilizer and herbicides to control the weeds. As a result, farms can get larger and the rural communities decline. Cleaning pens every two weeks for a 75-sow farrow to finish hog operation is enough. This 300-acre farm with livestock is enough and there is no desire to farm the neighbor's land. The higher labor charges stay in the farmer's pocket making smaller farms profitable, and therefore results in more farm families. More farm families mean expansion of schools, churches, services and communities. " (Thompson, 1997)

The Moore family of Texas

For several generations the Moore family raised corn, milo, and cotton (Leake, 2001). Having had enough of rising production costs, persistent drought, and low commodity prices, they decided to break the family tradition and switch from row crops to cattle. After receiving training in Holistic Management™, Robert Moore and his son Taylor designed a system that gives them less personal stress and lower overhead costs. For years they battled Johnson grass, bermuda grass, and crab grass in their cotton fields. Now these grasses and others such as Dallis grass and bluestem are their allies. Moore says they are working with nature by letting the plants that want to be there return. Their cattle love the grasses and the wide variety allows them to graze from mid-February to mid-November. After giving up cropping, they increased their cow herd from 200 animals to 600. Their 2000 acres are divided into 50-acre paddocks, with about 200 head in each paddock at various times. With their cropping enterprise they had 20 employees working full time; now the father and son work together with one full-time employee. Before cattle, they worried about crop success and prices and were often relieved just to break even. Now they can live off what they make. Taylor says, "We're definitely happier now and have less stress." ATTRA has more than a dozen farmer-ready publications that provide details about grass farming enterprises and alternative marketing of animal products.

Summary

Sustainable farming meets economic, environmental, and social objectives simultaneously; because these three objectives always overlap, they are managed together. Economic sustainability requires selecting profitable enterprises and doing comprehensive financial planning. Social sustainability involves keeping money circulating in the local economy, and maintaining or enhancing the quality of life of the farm family. Environmental sustainability involves keeping the four ecosystem processes (effective energy flow, water and mineral cycles, and viable ecosystem dynamics) in good condition. Managing economics, society, and environment simultaneously depends on clear goal-setting, effective decision making, and monitoring to stay on track toward the goal. Wise decisions allow us to extract our living from the land as the interest, while preserving the social, water, and soil capital. As a result, the capability of the landscape and community resources will not be compromised over time by our activities.

Some specific land-use strategies to achieve sustainability include: keeping the soil covered throughout the year; avoiding moldboard plowing; increasing biodiversity wherever possible through crop rotation, intercropping, use of sod or cover crops, farmscaping, and integrated pest management; applying animal manures or compost; diversifying enterprises and planning for profit; integrating crop and animal enterprises; minimizing tillage, commercial fertilizer, and pesticides; buying supplies locally; employing local people; and including quality of life in your goals.

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Resources

No-till Vegetables by Steve Groff. 1997.

This video leads you through selection of the proper cover-crop mix to plant crops into and shows you how to take out the cover crops with little or no herbicide. You will see Groff's mechanical cover-crop-kill method, which creates ideal no-till mulch without herbicides. Vegetables are planted right into this mulch using a no-till transplanter. The Groffs grow high-quality tomatoes, pumpkins, broccoli, snap beans, and sweet corn. After several years of no-till production their soils are very mellow and easy to plant into. The video also includes comments from leading researchers working with no-till vegetables.

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