CHAPTER 6

Sustainable Agriculture

6.1 Definition

The word “sustain” is from the Latin sustinere (sus: from below; tenere: to hold) meaning to keep in existence or maintain, and implies a long-term support or permanence. As it pertains to agriculture, sustainable describes farming systems that are capable of maintaining their productivity and usefulness to society indefinitely. Such system must be resource-conserving, socially supportive, commercially competitive and environmentally sound. [John Ikerd, as quoted by Richard Duesterhaus in “Sustainability’s Promise”, Journal of Soil and Water Conservation (1990) 45(1): p. 4).

Sustainable agriculture is one that produces abundant food without depleting the earth’s resources or polluting its environment. It is agriculture that follows the principles of nature to develop systems for raising crops and livestock that are, like nature, self-sustaining. Sustainable agriculture is also the agriculture of social values, one whose success is indistinguishable from that of vibrant rural communities providing rich lives for families on the farms and wholesome food for everyone.

6.2 Historical Development of Sustainable Agriculture

In the first decade of the 21st Century, sustainable agriculture, as a set of commonly accepted practices or a model farm economy is merely the beginning of an idea. Although sustainability in agriculture was tied to broader issues of the global economy, declining petroleum reserves, and domestic food security, its modelers were not government policy makers but small farmers, environmentalists, and a persistent cadre of agricultural scientists. They saw the devastation that late 20th Century farming was causing to the very means of agricultural production, the water and soil, and as such began a search for better ways to farm, an exploration that continues to this day.

Conventional 20th Century agriculture took industrial production as its model. This industrial approach coupled with substantial government subsidies, made food abundant and cheap, especially in the developed world. However, farms are biological systems, not mechanical ones, and exist in a social context in ways that manufacturing plants do not. By emphasizing on high production, the industrial model has degraded soil and water, reduced the biodiversity that is a key element to food security, increased our dependence on oil, and driven more and more land areas into the hands of fewer and fewer “farmers”, crippling rural communities. In recent decades, sustainable farmers and researchers around the world have responded to the extractive industrial model with ecology-based approaches, variously called “natural, organic, low-input, alternative, regenerative, holistic, biodynamic, biointensive, and biological” farming systems.
6.3 Concept of Sustainable Agriculture

Sustainable systems share a vision of farming with nature, an agro-ecology that promotes biodiversity, recycles plant nutrients, protects soil from erosion, conserves and protects water, uses minimum tillage, and integrates crop and livestock enterprises on the farm. However, no agriculture is sustainable if it is not also profitable, able to provide a healthy family income and a good quality of life. Therefore, sustainable practices lend themselves to smaller, family-scale farms. These farms, in turn, tend to find their best niches in local markets, within local food systems, often selling directly to consumers. As alternatives to industrial agriculture evolve, so must their markets and the farmers who serve them. Creating and serving new markets remain one of the key challenges for sustainable agriculture.

Sustainable agriculture or farming sustainably means growing crops and livestock in ways that require a whole-system approach whose overall goals 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. Sustainable farming is more than just a set of idealistic principles or a limited set of practices.

Sustainability can be observed and measured. There are three objectives which a farm or rural community practicing sustainability has to fulfill. These are economic development, environmental conservation, and socio-political benefits.

6.3.1 Economic Development

Economic profit has to be made through proper production procedures, processing and marketing. It requires selecting profitable enterprises, sound financial planning, proactive marketing, risk control, and good overall management.

A farmer can explore income opportunities other than growing traditional commodity crops. Alternative crops like herbs or mushrooms may be an option. Mixed cropping could offer another economic advantage compared with single cropping. When producing only a single product such as maize, groundnuts or chili, the risk is high because “all our eggs are in one basket”. Integrating plant and animal production can distribute overhead cost and risk among several enterprises. Other enterprises which could be explored are contract farming of seeds of vegetables, rice, or specialty crops which involves only small hectareage, and organic farming. However, these involve niche limited markets.

There must be a comprehensive financial planning in an enterprise. Farm produce also requires marketing plan of some type, ranging from passive marketing to the commodity chain all the way up to directly marketing a retail product to consumers. Market research is essential for big enterprises to understand the market by analyzing competition, consumer trends and prices. Specialty and direct markets such as organic, GMO-free, and other “green” markets may yield more income but require more marketing by the producer.

Characteristics involved are:
1. Net financial worth of the family increase consistently through savings.
2. Family debt decreases.
3. Less reliance on government subsidies.
4. Farm enterprise reaps profits year after year.
5. External purchase of feed and fertilizer decreases.

6.3.2 Environmental Conservation

It involves keeping the four ecosystem processes (effective energy flow, water and mineral cycles, and viable ecosystem dynamics) in good condition.

Farms become and stay environmentally sustainable by imitating the complexity of natural 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 function, similar to a factory production line whereby inputs are at one end, and products and waste (such as suspended soil, nitrates, phosphates, and pesticides) come out at the other end. In sustainable agriculture, the farm is a nature-based system, not a factory.

Biodiversity is important in sustainable agriculture. The simpler we try to make agriculture, the more vulnerable we become to natural disasters and market place changes. When we try to produce a single product such as wheat, corn, or soybeans we are taking on a huge risk. If instead we diversify crops and integrate plant and animal agriculture, the overhead will be spread over several enterprises, reducing risk and increasing profit.

In an industrial model of agriculture farming is an industrial factory that is a linear process which concerns mainly with monoculture whereas a biological model views a farm as an ecosystem utilizing a cyclical process involving a diversity of plants and animals.

6.3.3 The Farm as an Ecosystem

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

Energy Flow is the non-cyclical path of solar energy (sunlight) going into and through any biological system. 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, 1990).

Energy flow begins when sunlight is converted into plant growth (photosynthesis), continues when animals consume plants, when predatory animals consume prey, plants and animals die and microorganisms ultimately 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.

Among the tools for capturing more solar energy are growing off-season cover crops, perennial vegetation, and having intercropping. Capturing sunlight and converting it to dollars is the original source of all wealth.
b) Water Cycle

An Effective Water Cycle is typified by little soil erosion, fast water entry into the soil, and a capacity of the soil to store large amount of water. 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. Hudson (1994) showed that raising the percentage of organic matter from 1% to 10% in sandy soil increased the available water content of that soil by 60%. Such an improvement in a soil’s water-holding capacity will benefit crop growth, especially during drought.

An effective water cycle can be summarized by having a low surface runoff and evaporation, and a reduction in droughts, floods, high transpiration by plants, and seepage of water to underground reservoirs. (Savory and Butterfield, 1999).
c) Mineral Cycle

**A Well Functioning Mineral Cycle** involves the movement of nutrients from the soil through the crops and animals and back to the soil thus reducing the need for fertilizer and feed. In nature, minerals needed for plant and animal growth are continuously recycled within the ecosystem with very little waste.

**An Effective Ecosystem Dynamics** is indicated by 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 habitat diversity. 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 1).

<table>
<thead>
<tr>
<th>Tools</th>
<th>Effects on biodiversity</th>
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<tbody>
<tr>
<td>Intercropping</td>
<td>Increased</td>
</tr>
<tr>
<td>Crop rotation</td>
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<tr>
<td>Cover crops</td>
<td>&quot;</td>
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<td>Multi-species grazing</td>
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<tr>
<td>Monocropping</td>
<td>Decreased</td>
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<td>Tillage</td>
<td>&quot;</td>
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<td>Herbicides</td>
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<tr>
<td>Insecticides</td>
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</table>
6.3.4 Intercropping

Advancing from rotation to strip intercrops brings a higher level of biodiversity and increases sunlight capture. Strip cropping of corn and soybeans or cotton and alfalfa are two examples.

Intercropping supports lower numbers of pests than pure stands. There are two possible explanations. One is that higher natural enemy populations persist in diverse mixtures; the other is pest insects that feed on only one type of plant which have greater opportunity to do so in pure crop stand than they would be in crop mixture. Intercropping also aids pest control by reducing the ability of the pest insects to recognize their host plants. For example, thrips and whiteflies are attracted to contrasting colours of green plants against brown (soil) background, but ignore areas where the vegetation is completely green consisting of plants and cover crops. Other insects recognize their host plant by smell; onions planted with carrots mask the smell of carrots from carrot flies.

Crop rotation

The first step towards increasing biodiversity and yield 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. 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, ie. nitrogen-fixing legume crops preceding grain crops such as corn, and prevent buildup of pest insects and weeds. In many cases, yield increased follow from the “rotation effect”. Including forage crops in the rotation will reduce soil erosion and increase soil quality.

When planning crop rotation, 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.

Cover crops, composts and fertilizers

These are important for building soil. Cover keeps the soil protected. Under natural conditions the soil remains covered with a skin of dead plant material, which prevents and 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 organic matter loss happens rapidly. Soil erosion necessitates the replacement of lost nutrients, reduces water holding ability, and accounts for 50-75% of productivity loss.
Composts and manures, especially those produced on-farm or available locally at low cost, are ideal resources for nutrient recycling on the farm. 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. In sandy soils, compost’s stable organic matter is especially effective at absorbing and retaining water. There are several conventional fertilizers that should be avoided in sustainable farming because of their harmful effects on soil organisms, structure and acidity. These include ammonium sulphate which will result in increasing the soil acidity (< pH). Significant addition of lime, phosphate rocks, and other fertilizers should be guided by soil testing to avoid soil imbalances and unnecessary expenditure on inputs.

Soil removed by erosion typically contains about three times more nutrients than the soil left behind and is 1.5-5 times richer in organic matter. This organic matter loss not only results in reduced water holding capacity and degraded soil aggregation, but also resulted in lost of plant nutrients, which must then be replaced with fertilizers. Table 2 below shows the effect of light, moderate, and severe erosion on organic matter, soil phosphorus level, and plant-available water on a silt loam soil in Indiana, USA.

Table 2. Effects of erosion on organic matter, phosphorus, and plant-available water.

<table>
<thead>
<tr>
<th>Erosion Level</th>
<th>Organic matter (%)</th>
<th>Phosphorus (kg/ha)</th>
<th>Plant-available water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>3.0</td>
<td>69.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.5</td>
<td>68.38</td>
<td>6.2</td>
</tr>
<tr>
<td>Severe</td>
<td>1.9</td>
<td>44.84</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Source: Schertz et al., 1984.
**Tillage**

Tillage is the agricultural preparation of the soil by digging it up. Soil is damaged considerably when ever it is turned over. The mold-board plough brings subsoil to the surface and buries the crop residuelayer 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)/minimum-till, adequate groundcover remains afterwards.

**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 landscape enhances ecosystem dynamics still further.

**Zero Burning**

This approach has been acknowledged by the world as an environment-friendly one that is sustainable. Zero burning is currently implemented in oil palm and rubber plantations. Upon felling, old oil palm and rubber trunks are not burned, but sliced thin and left to decompose. Nutrients such as N,P,K and Mg are recycled leading to 50% reduction in fertilizer cost. The rubber trunk can be marketed whole for the furniture industry.

**6.3.5 Pest Management**

Prevention of pest problems is a fundamental component of management in any agricultural production system as pests reduce the biodiversity and productivity. Chemical pesticides can be effectively employed to suppress pests; however, there are more environmental friendly methods of control.

**Weeds** pose one of the greatest challenges to the 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 farmers refine their use of cultural and mechanical techniques, thereby reducing the time required for effective weed control. General terms, weed prevention 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. Cover crops, mulch and minimum tillage will reduce weed numbers (Table 3). In estates, weed management may be as simple as adding cattle to eat away and convert weeds into cash.
Table 3. Tillage and cover crop (mulch) effects on weed numbers and production.

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Cover crop/mulch</th>
<th>Weeds/m²</th>
<th>Weed weight, kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>None</td>
<td>36</td>
<td>0.66</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
<td>15</td>
<td>0.42</td>
</tr>
<tr>
<td>None</td>
<td>Rye</td>
<td>2.7</td>
<td>0.3</td>
</tr>
<tr>
<td>None</td>
<td>Wheat</td>
<td>0.9</td>
<td>0.21</td>
</tr>
<tr>
<td>None</td>
<td>Barley</td>
<td>0.24</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Source: Putnam et al., 1983

**Insect pests** can have a serious impact on biodiversity and farm income. Sustainable agriculture utilizes biological (natural) control agents, crop barriers, nectariferous shrubs, intercropping, and crop rotation to suppress these pests.

**Plant diseases** reduce biological diversity and affect yield. Their incidence can be lessened by having intrinsically healthy plants nurtured by microbially active soil. Healthy soils that suppress root diseases naturally can result from adding biologically active compost with balanced mineral levels. Microbial antagonists are also used to control pathogens. Use of resistant cultivars and clean seeds aid reduction in plant disease.

**Integrated Pest Management** (IPM) is the basic framework used to decide when and how pests are controlled. It integrates habitat modification and cultural, physical, biological, and selective chemical practices to minimize crop losses. Its primary goal of IPM is to give growers management guidelines in order to make pest control as economically and ecologically sound as possible. Monitoring and surveillance, record keeping, and life-cycle information about the pests and their natural enemies are used to rationalise which control measures are needed to keep pests below an economic threshold.

These four ecosystem processes (energy flow, water cycle, mineral cycle and ecosystem dynamics) function together as a whole unit, each one complementing the other. When we modify anyone 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 resist nature’s processes, we incur extra costs and create more problems, hurting ourselves and the ecosystem on which we depend on.

### 6.4 Socio-political benefits

Social benefits are provided for the farm family and the community. In terms of food security, land tenure, good health and maintaining the fabric of rural communities. It involves keeping money circulating in the local economy, and maintaining or enhancing the quality of life of the farming family.
Decisions made on the farm affect local community. For example, the decision to expand your operation requires the acquisition of your neighbour's farm. This implies that your neighbour’s farm is more important to you than your neighbour. Other examples of social decisions are: buying supplies locally rather than ordering from out of state, networking with local consumers while adopting a consumer-oriented approach, and relaying information on sustainable food production to neighbouring communities.

Marketing strategies involving direct marketing through farmers markets or road side stalls have a positive impact on the local community. People will choose to support local producers or their neighbours by paying a little more compared to overall market price.

Quality of life of those who work and live on the farm includes 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 a general happiness. However, the quality of life is defined somewhat differently by each individual and family, based on their values and goals.

### 6.5 Planning and decision making

Managing for the three objectives simultaneously (economics, environment and society) depends on clear goal-setting and effective decision-making. Several good tools for goal-setting, decision-making, monitoring, and whole-farm management are available to farmers.

It is useful to assume that if your plan does not work, then a system should be develop to determine as soon as possible if it is not working. For example, if the goals include increased biodiversity, the farmer needs to know quickly if the grazing or cropping system being used is actually increasing the number of plant species in the area of concern. Monitoring is particularly important in sustainable agriculture, which relies on natural systems to replace some of the work done by input products like fertilizers and pesticides. The ability to evaluate and replan is vital to the farmer who wishes to farm more sustainably, especially when part of the plan is not working as intended, then it is necessary to replan. The concept of planning-monitoring-controlling-replanning is a key characteristic of Holistic Management, referred to as the feedback loop.

Farmers selling locally will benefit from differentiating their products and services by qualities other than price, such as fresh produce, specialty items, and locally grown and processed foods. This makes it more competitive in the market place, especially when consumer education and personal contact with the farmer are part of the marketing plan.

The transition toward more sustainable farming requires not only planning and decision-making skills but also access to appropriate and helpful information. Fortunately, increased interest in sustainable agriculture has stimulated greater investment in research and education. Now, much more usable information is available today than ever before through various means.