3. The efficiency and degree of utilization of sunlight, soil, and water resources. Selected agricultural systems must be managed for optimal use, including continuous crop cover, good crop, and animal genetic potential, minimal pest damage, and optimal nutrient supply.

4. A small offtake (harvested removal) of nutrients in relation to total biomass. Where soils are erosive, have poor nutrient status, or are otherwise chemically or physically fragile, the maintenance of high biomass systems is critical.

5. Maintenance of a high residual biomass in the form of wood, herbaceous material, or soil organic material. A carbon source for both energy and nutrient retention is critical to the support of biomass in the soil and to crop and animal productivity.

6. The structure and preservation of biodiversity. The efficiency of nutrient cycling and the stability of pests and diseases in the system depend on the amount and type of biodiversity as well as its temporal and spatial arrangement (structural diversity). Traditional systems, particularly those in marginal production environments, often have significant stability and resiliency as a result of high structural diversity.

6

Traditional Agriculture

About 60 percent of the world's cultivated land is still farmed by traditional and subsistence methods (Ruthenberg 1971). This type of agriculture has benefitted from centuries of cultural and biological evolution that has adapted it to local conditions (Egger 1981). Thus, small farmers have developed and/or inherited complex farming systems that have helped them meet their subsistence needs for centuries, even under adverse environmental conditions (on marginal soils, in drought or flood-prone areas, with scarce resources) without depending on mechanization or chemical fertilizers and pesticides. Generally these farming systems consist of a combination of production and consumption activities (Figure 6.1).

Most small farmers have employed practices designed to optimize productivity in the long term rather than maximize it in the short term (Gliessman et al. 1981). Inputs characteristically originate in the immediate region and farm work is performed by humans or animals that are fueled from local sources (Figure 6.2). Working within these energy and spatial constraints, small farmers have learned to recognize and use locally available resources (Wilken 1977). Traditional farmers are much more innovative than many agriculturalists believe. In fact, most productivity comparisons between Green Revolution and traditional agriculture systems have been biased and unfair, as they ignore the fact that traditional farmers value total farming system production and not just yields of one commodity as it is the case in a Green Revolution system (Figure 6.3). Many scientists in developed countries are beginning to show interest in traditional agriculture, especially in small-scale mixed crop systems, as they search for ways to remedy deficiencies in modern agriculture. This transfer of learning must occur rapidly, however, or this wealth of practical knowledge will be lost forever.

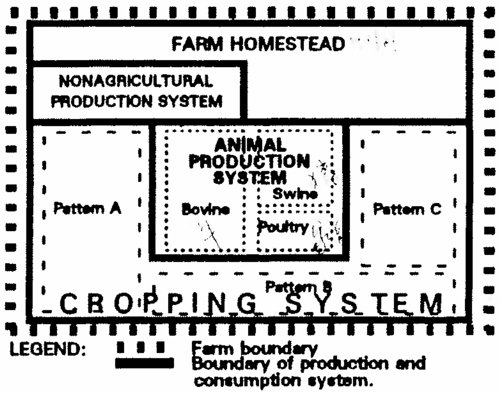

FIGURE 6.1 Scheme of a small farming system with four production/consumption systems (Zandstra et al. 1981).

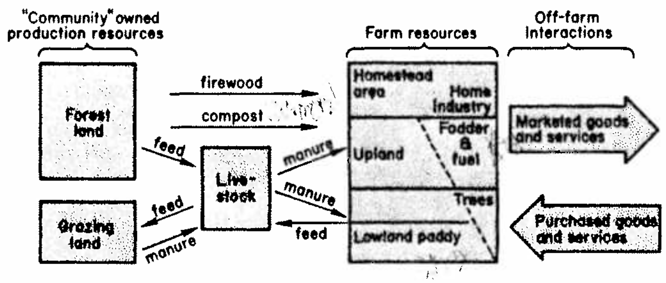

FIGURE 6.2 Conceptual model of the production system of a Nepalese hill farm (Harwood 1979a).

Ecological Features of Traditional Agriculture

As more research is conducted, many farming practices once regarded as primitive or misguided are being recognized as sophisticated and appropriate. Confronted with specific problems of slope, flooding, droughts, pests, diseases, and low soil fertility, small farmers throughout the world have developed unique management systems to overcome these constraints (Table 6.1). Traditional agriculturalists generally have met the environmental requirements of their food-producing systems by concentrating on a few principles and processes (Knight 1980):

Spatial and Temporal Diversity and Continuity. Multiple cropping designs are adopted to ensure constant food production and vegetation cover for soil protection. By ensuring a regular and varied food supply, a diverse and nutritionally adequate diet is assured. Extended crop harvest reduces the necessity for storage, often hazardous in rainy climates.

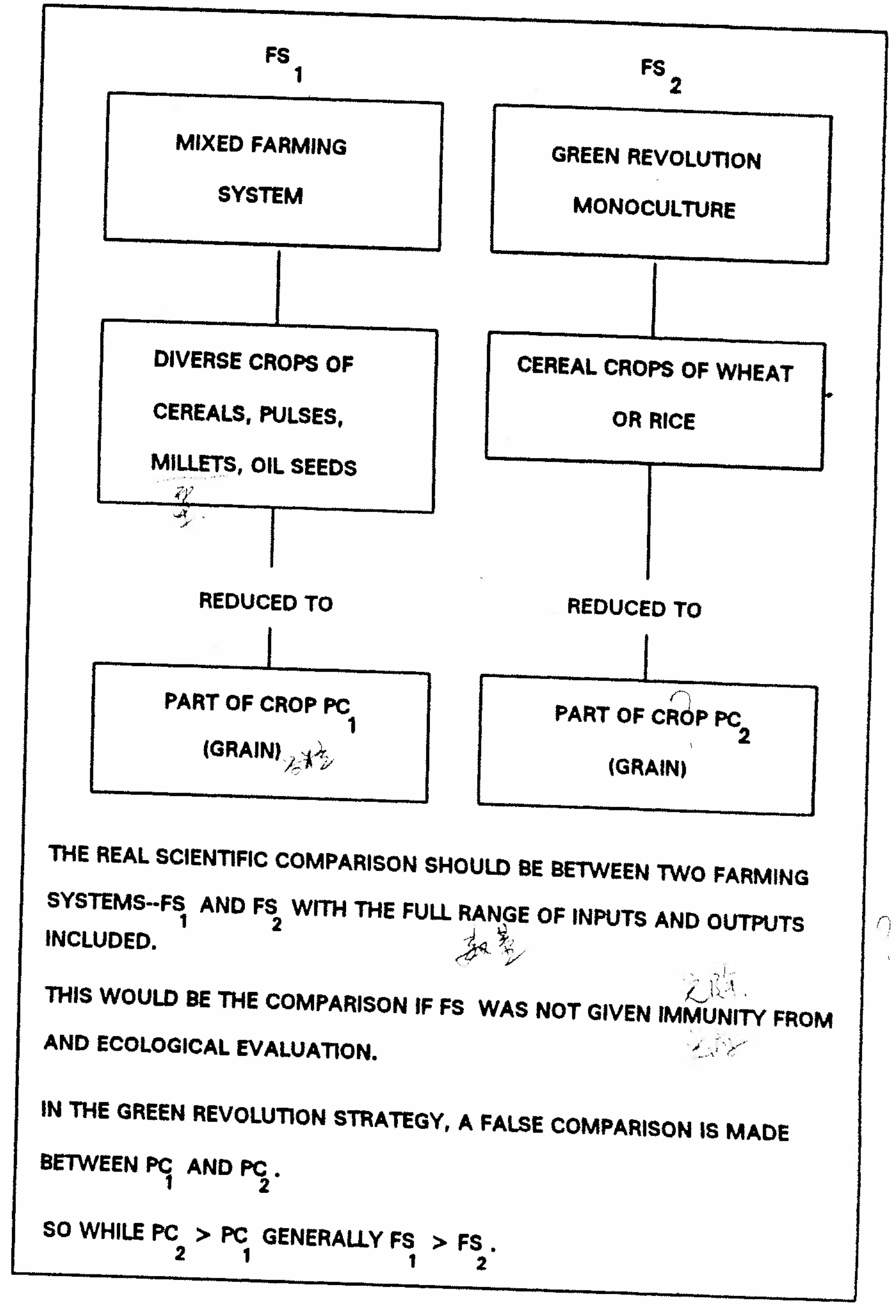

FIGURE 6.3 Unfair comparisons between Green Revolution and traditional agricultural systems.

TABLE 6.1 Some examples of soil, space, water, and vegetation management systems used by traditional agriculturalists throughout the world (after Klee 1980).

ENVIRONMENTAL CHARACTERISTIC	OBJECTIVE	RECOMMENDED PRACTICE
Limited space	Maximize use of environmental resources and land	Intercropping, agroforestry, multi-story cropping, home gardens, altitudinal crop zonation, farm fragmentation, rotation
Steep slopes	Control erosion and conserve water	Terracing, contour farming, living and dead barriers, mulching, leveling, continuous crop and/or fallow cover, stone walls
Marginal soil fertility	Sustain soil fertility and recycle organic matter	Natural or improved fallow, crop rotations and intercropping with legumes, litter gathering, composting, manuring, green manuring, grazing animals in fallow fields, night soil and household refuse, mounding with hoe, ant hills as source of fertilizer, use of alluvial deposits, use of aquatic weeds and muck, alley cropping with legumes, plowed leaves, branches and other debris, burning vegetation, and so on.
Flooding or excess water	Integrate agriculture with water supply	Raised field agriculture (chinampas, tablones), ditched fields, diking, and so on.
Excess water	Channel/direct available water	Control floodwater with canals and checkdams. Sunken fields dug down to groundwater level. Splash irrigation. Canal irrigation fed from ponded groundwater, wells, lakes, reservoir

TABLE 6.1 *continued.*

ENVIRONMENTAL CHARACTERISTIC	OBJECTIVE	RECOMMENDED PRACTICE
Unreliable rainfall	Best use of available moisture	Use of drought-tolerant crop species and varieties, mulching, weather indicators, mixed cropping using end of rainy season, crops with short growing periods
Temperature or radiation extremes	Ameliorate microclimate	Shade reduction or enhancement; plant spacings; thinning; shade-tolerant crops; increased plant densities; mulching; wind management with hedges, fences, tree rows; weeding; shallow plowing; minimum tillage; intercropping; agroforestry; alley-cropping, and so on.
Pest incidence (invertebrates, vertebrates)	Protect crops, minimize pest populations	Overplanting, allowing some pest damage, crop watching, hedging or fencing, use of resistant varieties, mixed cropping, enhancement of natural enemies, hunting, picking, use of poisons, repellents, planting in times of low pest potential

A continuous sequence of crops also maintains biotic relationships (predator/prey complexes, nitrogen fixing) that may benefit the farmer.

Optimal Use of Space and Resources. Assemblages of plants with different growth habits, canopies, and root structures allows for better use of environmental inputs such as nutrients, water, and solar radiation. Crop mixtures make fullest use of a particular environment. In complex agroforestry systems, crops can be grown underneath tree canopies if enough light filters through.

Recycling of Nutrients. Small farmers sustain soil fertility by maintaining closed cycles of nutrients, energy, water, and wastes. Thus, many farmers enrich their soils by collecting nutrient materials (such as manure and forest litter) from outside their fields, adopting fallow or rotational systems, or including legumes in their intercropping patterns.

Water Conservation. In rainfed areas, the rainfall pattern is the main cropping system determinant, and farmers use cropping patterns adapted to the amount and distribution of rainfall. Thus, in areas with little moisture, farmers prefer drought-tolerant crops (like *Cajanus*, sweet potato, cassava, millet, and sorghum), and management techniques emphasize soil cover (such as mulching) to avoid evaporation and runoff. Where precip-itation is more than 1,500 mm/year, most cropping systems are based on rice. Under constant flooding conditions, instead of investing in costly drainage systems, farmers develop integrated agriculture/aquaculture systems, such as the chinampas of Central Mexico.

Control of Succession and Protection of Crops. Farmers have developed a number of strategies to cope with competition from undesirable organisms. Crop species and variety mixtures provide insurance against catastrophic attacks from insect pests or disease.

Crop canopies can effectively suppress weed growth and minimize the need for weed control. In addition, cultural practices such as mulching, changes in planting times and durability, use of resistant varieties, and use of botanical insecticides and/or repellents can minimize pest interference.

Advantages of Crop Diversity

Perhaps one of the most striking features of traditional farming systems in most developing countries is the degree of crop diversity both in time and space. This diversity is achieved through multiple cropping systems, or polycultures. For example, in the Latin American tropics, 60 percent of the corn is grown in association with other crops.

Polyculture is a traditional strategy to promote diet diversity income generation, production stability, minimization of risk, reduced insect and disease incidence, efficient use of labor, intensification of production with limited resources, and maximization of returns under low levels of technology (Francis et al. 1976, Harwood 1979a). Polyculture systems offer many advantages over the monoculture agriculture practiced in modern countries, as follows (Ruthenberg 1971, Altieri 1983, Francis 1986):

Yields. Total yields per hectare are often higher than sole-crop yields, even when yields of individual components are reduced. This yield advantage is usually expressed as the land equivalent ratio (LER), which expresses the monoculture land area required to produce the same amount as one hectare of polyculture, using the same plant population. If the LER is greater than one, the polyculture overyields. Most corn/bean dicultures and corn/ bean/ squash tricultures studied are examples of overyielding in polycultures.

Efficient Use of Resources. Mixtures result in more efficient use of light, water, and nutrients by plants of different height, canopy structure, and nutrient requirements. There is some indication that long-duration intercrop

combinations have an advantage over monocultures when nutrients are limited. Thus, in polycultures combining perennial and annual crops, the minerals lost by annuals are rapidly taken up by perennials. On the other hand, the nutrient-robbing propensity of some crops is counteracted by the enriching addition of organic matter to the soil by other crops (like legumes) in the mixture.

Nitrogen Availability. In cereal/legume mixtures, fixed nitrogen from legumes is available to the cereal, thereby improving the nutritional quality. Corn and beans complement each other in essential amino acids.

Reduction of Diseases and Pests. Diseases and pests may not spread as rapidly in mixtures because of differential susceptibility to the pests and pathogens and because of enhanced abundance and efficiency of natural enemies. In Southeast Asia, for example, maize grown in rows two and three meters apart, intercropped with soybeans, groundnuts, upland rice, or mung beans suffers relatively little from downy mildew, normally a major maize disease. Similarly, in Costa Rica, cowpea mosaic and chlorotic viruses occurred at lower levels in cowpea intercropped with cassava than in cowpea monocultures (Altieri and Liebman 1986). Diversified crop systems can increase opportunities for natural enemies and consequently improve biological pest control. Two-thirds of the studies dealing with the effects of crop diversity on insect pests showed that pestiferous insects decreased in the diversified system when compared with the corresponding monoculture. In many cases this was due to the abundance and efficiency of natural enemies. Cabbage aphids, flea beetles, diamondback moths, and corn earworms, are all insect pests that can be regulated with specific crop mixes (Altieri and Letourneau 1982).

Weed Suppression. The shading provided by complex crop canopies helps to suppress weeds, thereby reducing the need and cost of weed control. In the Philippines, shade-sensitive weeds such as nutsedge and *Imperata cylindrica* may be eliminated entirely by a combination like maize/mungbean, which intercepts 90 percent of the light after 50 days of growth.

Insurance Against Crop Failure. Polycultures provide insurance against crop failure, especially in areas subject to frosts, floods, or droughts. Thus, when one crop in a combination is damaged early in the growing season, the other crops may compensate for the loss. For example, in the highlands of Tlaxcala, Mexico, farmers intercrop corn with fava beans because fava beans survive frosts, whereas corn does not.

Other Advantages. Polycultures provide effective soil cover and reduce the loss of soil moisture. They enhance opportunities for marketing, ensuring a steady supply of a range of products without much investment in storage, thus increasing the marketing success. Mixtures spread labor costs more evenly throughout the cropping season and usually give higher gross returns per unit of labor employed, especially during periods of labor scarcity.

Polycultures also improve the local diet; 500 grams of maize and 100 grams of black beans per day provide about 2,118 calories and 68 grams of protein.

The Nature of Traditional Farming Knowledge

The terms traditional knowledge, indigenous technical knowledge, rural knowledge, and ethnoscience (or people's science) have been used interchangeably to describe the knowledge system of an ethnic rural group that has originated locally and naturally. This knowledge has many dimensions, including linguistics, botany, zoology, craft skills, and agriculture and is derived from the direct interaction between humans and the environment. Information is extracted from the environment by special cognition and perception systems that select for the mostly adaptive or useful information, and successful adaptations are preserved and passed on from generation to generation through oral or experiential means. Only recently has some of this knowledge been described and written down by researchers. Evidence suggests that the finest discrimination evolves (1) from communities where the environments have great physical and biological diversity and/or (2) in communities living near the margins of survival (Chambers 1983). Also, older members of the communities possess greater, more detailed knowledge than younger members.

For agroecologists, several aspects of these traditional knowledge systems are relevant:

1. Knowledge about the physical environment (soils, climate, etc.)
2. Biological folk taxonomies (or classification systems)
3. The experimental nature of this traditional knowledge

Indigenous people's knowledge about soils, climates, vegetation, animals, and ecosystems usually results in multidimensional productive strategies (i.e., multiple ecosystems with multiple species), and these strategies generate (within certain ecological and technical limits) the food self- sufficiency of farmers in the region (Toledo et al. 1985).

Knowledge About the Environment

Indigenous knowledge about the physical environment is often very detailed. Many farmers throughout the world have developed traditional calendars to control the scheduling of agricultural activities. In east Africa, for example, many farmers sow according to the phase of the moon, believing that there are lunar phases of rainfall. Many farmers also cope with climatic seasonality by utilizing weather indicators based on the phenologies of local vegetation. For example, in West Java, *Gadung*, sp. is a weather

indicator because the rainy season can be expected to begin shortly after its leaves start to grow. In the same region, pomelo has a similar function. When its fruits start to grow, the season of annual plant cultivation begins (Christianty et al. 1985).

Soil Classification Systems and Use

Soil types, degrees of soil fertility, and land-use categories are also discriminated in detail by farmers. Soil types are usually distinguished by color, texture, and even taste. Shifting cultivators usually classify their soils based on vegetation cover. In general, peasant soil classification types are dependent on the nature of the peasant's relationship to the land (Williams and Ortiz Solorio 1981). Aztec soil classification systems were very complex, recognizing more than two dozen soil types identified by source of origin, color, texture, smell, consistency, and organic content. These soils were also ranked according to agricultural potential and used in both land value evaluations and rural census. Andean peasants in Coporaque, Peru, recognize four main soil classes. Each soil class has specific characteristics that define the most adequate cropping system (McCamant 1986). Examples of rurally developed land/soil categories can be found in Chambers (1983).

Biological Folk Taxonomies

Many complex systems used by indigenous people to group together plants and animals have been documented (Berlin et al. 1973). In general, the traditional name of a plant or animal usually reveals that organism's taxonomic status. Researchers have found that, in general, there is a good correlation between folk taxa and scientific taxa. Classification of animals, especially insects and birds, is widespread among farmers and indigenous groups (Bulmer 1965). Insects and related arthropods have major roles as crop pests, as causes of disease, as food, and as medicinals and are important in myth and folklore. In many regions, agricultural pests are tolerated because they also constitute agricultural products; that is, indigenous people may consume plants and animals that would otherwise be considered pests. In Indonesia, a grasshopper pest in rice is trapped at night and eaten (with salt, sugar, and onions) or sold as bird food in the market. The major bird pest in Indonesian rice fields (*Lonchura*) is caught in spring-loaded traps and eaten. Squirrels and termites, both of which damage crops, are also consumed. Shifting cultivars in Borneo trap and eat wild pigs that are attracted to their crops. In northeast Thailand, rural inhabitants eat rats, termites, and a crab that damages rice stalks (Brown and Marten 1986).

Ants, some major crop pests, are one of the most popular insect foods, gathered in tropical regions. In his studies of the ethnoentomology of the

Brazilian Amazon, Posey (1986) described the Indians' detailed knowledge of insect life cycles, uses, and management. The complex management of stingless bees (Meliponinae) for honey production illustrates a deep ecological knowledge of their biology. The role of social insects as "natural models" for the Kayapo Indians is especially interesting; insect behaviors are symbolically recognized in rituals and ceremonies (Posey 1986).

Traditional Ethnobotanical Knowledge

Ethnobotanies are the most commonly documented folk taxonomies. The ethnobotanical knowledge of certain campesinos in Mexico is so elaborate that the Tzeltals, P'urepechas, and Yucatan's Mayans recognize more than 1,200, 900, and 500 plant species respectively (Toledo et al. 1985). Similarly !ko bushwomen in Botswana could identify 206 out of 266 plants collected by researchers (Chambers 1983), and Hanunoo swidden cultivators in the Philippines can distinguish more than 1,600 plant species (Conklin 1979).

Polycultures and agroforestry patterns are not developed at random; rather, they are based on a deep understanding of agricultural interactions guided by complex ethnobotanical classification systems. These classification systems have allowed peasants to assign each landscape unit a given productive practice, thus obtaining a diversity of plant products through a multiple-use strategy (Toledo et al. 1985). In Mexico, for example, Huastec Indians manage a number of agricultural and fallow fields, complex home gardens, and forest plots, totalling about 300 plant species. Small areas around the houses commonly average 80 to 125 useful plants, mostly native medicinal plants (Alcorn 1984). Similarly, the traditional Pekarangan in West Java commonly contains about 100 or more plant species. Of these plants about 42 percent provide building materials and fuelwood, 18 percent are fruit trees, 14 percent are vegetables and the reminder constitute ornamentals, medicinal plants, spices, and cash crops (Christianty et al. 1985).

The Experimental Nature of Traditional Knowledge

The strength of rural people's knowledge is that it is based not only on acute observation but also on experimental learning. The experimental approach is very apparent in the selection of seed varieties for specific environments, but it is also implicit in the testing of new cultivation methods to overcome particular biological or socioeconomic constraints. In fact, Chambers (1983) argues that farmers often achieve a richness of observation and a fineness of discrimination that would be accessible to western scientists only through long and detailed measurement and computation.

In studying the variegated grasshopper (*Zonocerus variegatus*) in southern Nigeria, Richards (1985) found that the local farmers' knowledge was equivalent

to that of his scientific team concerning the grasshoppers' food habits, life cycle, mortality factors, and degree of damage to cassava and concerning the egg-laying behavior and egg-laying sites of the females. Local knowl-edge added facts to the researchers' data regarding the dates, severity, and geographic extent of some of the outbreaks, plus the fact that the grasshoppers were eaten and sold and were of special importance to women, children, and poor people. Thus, the final control recommendation by scientists, which was to clear the egg-laying sites from a block of farms, did not require most farmers to learn new concepts and for some the practice was nothing new.

Some Examples of Traditional Management Practices

Soil Fertility Management Practices

Indigenous farmers have developed various techniques to improve or maintain soil fertility. For example, farmers in Southern Sudan and Zaire noticed that the sites of termite mounds are particularly good for growing sorghum and cowpea (Reijntjes et al. 1992). Farmers in Oaxaca, Mexico, use *Atta* ant refuse to fertilize high-value crops such as tomatoes, chili, and onions (Wilken 1987).

In Quezaltenango, Guatemala, leaf litter is brought in large quantities from nearby forests to improve till and moisture retention of intensively worked vegetable plots. Use rates for leaf litter vary between 20–30 t/ha/yr. It is estimated that a hectare of mixed pine/oak forest produces about 4,000 kg of litter annually, thus a hectare of cropped land requires the litter production from 5–10 ha of forest (Wilken 1987).

In Senegal, the indigenous agrosilvopastoral system takes advantage of the multiple benefits provided by *Faidherbia* (formerly *Acacia*) *albida*. The tree sheds its leaves at the onset of the wet season, permitting enough light to penetrate for the growth of sorghum and millet, yet still providing enough shade to reduce the effects of intense heat. In the dry season, the tree's long tap roots draw nutrients from beyond the reach of other plants; the nutrients are stored in the fruits and leaves. The tree also fixes nitrogen from the air, thus enriching the soil and improving crop yields. In the wet season, the fallen leaves provide mulch that enriches the topsoil as well as highly nutritious forage. The soil is also enriched by the dung of livestock, which feed on the *F. albida* leaves and the residues of the cereal crop (Reijntjes et al. 1992).

Microclimate Management Practices

Farmers influence microclimate by retaining and planting trees, which reduce temperature, wind velocity, evaporation, and direct exposure to sunlight and intercept hail and rain. They apply mulches of ground-covering plants or straw to reduce radiation and heat levels on newly planted surfaces, inhibit moisture losses, and absorb the kinetic energy of falling rain and hail. When night frost is expected, some farmers burn straw or other waste materials to generate heat and produce smog, which traps outgoing radiation. The raised planting beds, mounds, and ridges often found in traditional systems serve to control soil temperatures and to reduce waterlogging by improving drainage (Wilken 1987; Stigter 1984).

Indigenous Insect Pest Control Methods

Traditional farmers rely on a variety of management practices to deal with agricultural insect pest problems. Two main strategies can be distinguished. One is the use of direct, non-chemical pest control methods (i.e., cultural, mechanical, physical, and biological practices) (Table 6.2). The second is reliance on built-in pest control mechanisms, inherent to the biotic and structural diversity of complex farming systems, commonly used by traditional farmers (Brown and Marten 1986). This ensemble of cultural practices can be grouped into three main strategies, depending on which element of the agroecosystem is manipulated.

Manipulation of Crops in Time. Farmers often manipulate the timing of planting and harvest carefully and use crop rotations to avoid pests. These techniques obviously require considerable ecological knowledge of pest phenology. Although these techniques often have other agronomic benefits (e.g., improved soil fertility), the farmers sometimes explicitly mention that they are done to avoid pest damage. For example in Uganda, farmers utilize time of planting to avoid stem borers and aphids in cereals and peas, respectively (Richards 1985). Many farmers are aware that planting out of synchrony with neighboring fields can result in heavy pest pressure and therefore use a kind of "pest satiation" to avoid extensive damage. In the central Andes, a potato fallow rotation is carefully observed, apparently to avoid buildup of certain insects and nematodes (Brush 1982).

Manipulation of Crops in Space. Traditional farmers often manipulate plot size, plot site location, density of crops and crop diversity to achieve several respectively (Richards 1985). Many farmers are aware that planting out of production purposes, although most are aware of the links between such practices and pest control (Altieri 1993a).

1. Overplanting. One of the most common methods of dealing with pests is planting at a higher density than one expects to harvest. This strategy is most effective in dealing with pests that attack the plant during the early stages of growth. When infested plants are detected, they are carefully removed long before actual death to avoid contaminating healthy plants.

TABLE 6.2 Pest management strategies and specific practices used by traditional farmers throughout the developing world.

STRATEGY	PRACTICES
Mechanical and physical control	Scarecrows, sound devices
	Wrapping of fruits, pods
	Painting stems, trunks with lime or other materials
	Destroying ant nests
	Digging out eggs/larvae
	Hand picking
	Removal of infested plants
	Selective pruning
	Application of materials (ash, smoke, salt, etc.)
	Burning vegetation
Cultural practices	Intercropping
	Overplanting or varying seeding rates
	Changing planting dates
	Crop rotation
	Timing of harvest
	Mixing crop varieties
	Selective weeding
	Use of resistant varieties
	Fertilizer management
	Water management
	Plowing and cultivation techniques
Biological control	Use of geese and ducks
	Transfer of ant colonies
	Collecting and/or rearing predators and parasites for field release
	Manipulation of crop diversity
Insecticidal control	Use of botanical insecticides
	Use of plants or plant parts as repellents and/or attractants
	Use of chemical pesticides
Religious/ritual practices	Addressing spirits or gods
	Placement of crosses or other objects in the field
	Prohibition of planting dates

2. Farm plot location. In Nigeria many farmers, linked by kinship ties, age grouping, or friendship, locate their farm plots lying contiguous to each other but leaving room for the expansion of each farm in a particular direction. In accounting for this practice, farmers reported that all pests in the area will discover and concentrate on an isolated farm. Plots are therefore grouped together to spread pest risk among many farmers. Conversely, in tropical

America, Brush (1982) reports that farmers deliberately use small isolated plots to avoid pests.

3. Selective weeding. Studies conducted in traditional agroecosystems show that peasants deliberately leave weeds in association with crops by not completely clearing all weeds from their cropping system. This "relaxed'" weeding is usually seen by agriculturalists as the consequence of a lack of labor and low return for the extra work, however, a closer look at farmer attitudes toward weeds reveals that certain weeds are managed and even encouraged if they serve a useful purpose. In the lowland tropics of Tabasco, Mexico, there is a unique classification of non-crops according to use potential on the one hand and effects on soil and crops on the other. According to this system, farmers recognized 21 plants in their cornfields classified as *mal monte* (bad weeds), and 20 as *buen monte* (good weeds) that serve, for example, as food and medicines, ceremonial materials, teas, and soil improvers (Chacon and Gliessman 1982).

Similarly, the Tarahumara Indians in the Mexican Sierras depend on edible weed seedlings (*Amaranthus, Chenopodium, and Brassica*) from April through July, a critical period before maize, bean, cucurbits, and chiles mature in the planted fields in August through October. Weeds also serve as alternate food supplies in seasons when the maize crops are destroyed by frequent hailstorms. In a sense the Tarahumara practice a double crop system of maize and weeds that allows for two harvests: one of weed seedlings or *quelities* early in the growing season (Bye 1981). Some of these practices have important insect pest control implications since many weed species play important roles in the biology of herbivorous insects and their natural enemies in agroecosystems. Certain weeds, for example, provide alternate food and/or shelter for natural enemies of insect pests during the crop season but, more importantly, during the off-season when prey/hosts are unavailable.

4. Manipulation of crop diversity. Although most farmers use intercropping mainly because of labor and land shortages or other agronomic purposes, the practice has obvious pest control effects (Altieri and Letourneau 1982). Many farmers know this and use polycultures as a play-safe strategy to prevent buildup of specific pests to unacceptable levels or to survive in cases of massive pest damage. For example, in Nigeria, farmers are aware of the severe damage done to an isolated cassava crop by the variegated grasshopper after all other crops have been harvested. To reduce this damage, farmers deliberately replant maize and random clusters of sorghum on the cassava plot until harvest time.

Manipulation of Other Agroecosystem Components. In addition to manipulating crop spatial and temporal diversity, farmers also manipulate other cropping system components such as soil, microclimate, crop genetics, and chemical environment to control pests.

1. Use of resistant varieties. Through both conscious and unconscious selection, farmers have developed crop varieties that are resistant to pests. This is probably the most widely used and effective of all the traditional methods of pest control. Litsinger et al. (1980) found that 73% of the peasant farmers in the Philippines were aware of varietal resistance even if they had not consciously tried to manipulate it. There is evidence in traditional varieties for all the modes of resistance that modern plant breeders select for, including pubescence, toughness, early ripening, plant defense chemistry, and vigor.

In Ecuador, Evans (1988) found that infestations of Lepidoptera larvae in ripening corn ears were significantly higher in new varieties than in traditional ones, a factor that influenced the adoption of new varieties by small farmers.

2. Water management. Manipulation of water level in rice fields is a practice widely used for pest control (King 1927). Water management is also practiced in many other annual crops for the same purpose. For example, in Malaysia, control of cutworms and army worms is effected by cutting off the tip of infested leaves in a number of annual crops and raising the water level, which carries the larvae into the field ridges, where birds congregate to eat them.

3. Plowing and cultivation techniques. Farmers frequently report that they deliberately mange the soil (sometimes using more and sometimes less cultivation) to destroy or avoid pest problems. In Peru, for example, peasants use *high tilling* of potatoes to protect the tubers from insect pests and disease (Brush 1983). In shifting cultivation, after clearing a piece of land farmers set it on fire after a week or two. Farmers reported that this is done, among other reasons, to reduce weeds and pest populations during the first year of cropping (Atteh 1984).

4. Use of repellents and/or attractants. Farmers have been experimenting with various natural materials found in their immediate environment (especially in plants) for many centuries, and a remarkable number have some pesticidal properties. Use of plant or plant parts either placed in the field or applied as herbal concoctions for pest inhibition is wide-spread. Litsinger et al. (1980) interviewed small farmers in the Philippines about materials used in the fields to attract or repel insects. In Alboburo, Ecuador, small farmers place castor leaves in recently planted corn fields to reduce populations of a nocturnal tenebrionid beetle. These beetles prefer castor leaves over corn, but when associated with castor leaves for 12 hectares or more, beetles exhibit paralysis. In the field, the paralysis prevents beetles from hiding in the soil, which increases their mortality by direct exposure to the sun (Evans 1988). In southern Chile, peasants placed branches of *Cestrum parqui* in potato fields to repel *Epicauta pilme* beetles (Altieri 1993a). Many times a plant is carefully grown near the household and its sole

function is apparently to provide the raw material for preparing a pesticidal concoction. In Tanzania, farmers cultivate *Tephrosin* spp. on the borders of their maize fields. The leaves are crushed and the liquid is applied to control maize pests. In Tlaxcala, Mexico, farmers "sponsor'"volunteer *Lupinus* plants within their corn fields, because those plants act as trap crops for *Macrodactylus* sp. (Altieri 1993a).

Plant Disease Management in Traditional Agriculture

Thurston (1992) reviewed most of the literature available on the cultural practices used by thousands of small traditional farmers in developing countries, and he concluded that although some are highly labor-intensive, they are sustainable and deserve more respect than they receive. He considered a number of traditional agricultural systems and compared them for their productivity (crop yield or income produced), sustainability (ability to maintain the system in existence over a very long period of time even when subjected to stress), stability (obtaining consistent and reliable yields in both the short and long run), and equitability (relative distribution of wealth in a society) (Table 6.3). The main recommendations derived from Thurston's survey include:

1. Many sustainable agricultural systems incorporate large quantities of organic matter into soil. soilborne disease, in addition to other important agronomic benefits.
2. Some diseases are suppressed by shade, whereas others increase in importance under shade. Manipulation of shade should be considered as a possible component of disease management systems.
3. The use of antagonistic plants (trap crops/trap plants) is useful for the management of nematodes and other soilborne pathogens .
4. Clean seed or healthy propagating material, or such material treated to kill pathogens, often has positive and dramatic effects on plant health and crop yields.
5. Plant pathogens are often transmitted when vegetative propagating material is cut. Using sterile tools for cutting propagating material and the use of uncut propagation materials are important practices. For example, planting whole rather than cut potato tubers prevents losses due to fungi and bacteria that occur when tubers are cut.
6. The density of crop or plant stands has important effects on disease incidence and severity. Dense plant stands generally increase disease, but in some cases (i.e., with some virus diseases) may reduce disease. Crop density can be altered by manipulating the rate of plant and row spacing.
7. The depth at which seeds and propagating materials are planted may affect disease incidence or severity and should be looked into when designing disease management strategies. Shallow planting is often an effective disease management practice, as plants emerge from the soil quickly when not planted too deeply.
8. Fallow periods are beneficial in reducing losses from plant diseases, especially soilborne diseases. Fallowing is generally more effective in combination with rotations.
9. Fire and heat are often overlooked as plant disease management practices. The high temperatures produced by burning can eliminate the inoculum of many pathogens.
10. Traditional agriculture has utilized flooding extensively for the management of plant pathogens. For example, the paddy rice system, in addition to its various agronomic benefits, has an important role in reducing the importance of soilborne diseases.
11. Mulches reduce plant diseases by reducing soil splashing, in influencing the moisture content and temperature of the soil, and enhancing the microbiological activities that suppress plant pathogens.
12. It is difficult to generalize with any degree of accuracy about disease management through the use of multiple cropping.• Recommendations on multiple cropping should be thoroughly tested, and site-specific recommendations will often be necessary.
13. Multistory systems existed for centuries in tropical areas without major disease problems. Combining manipulations of plant architecture and shade, the use of land races, and a diversity of species, multistory systems may provide useful models for other areas in the tropics.
14. Raised fields, raised beds, ridges, and mounds were used widely by traditional farmers for millennia. Better drainage and irrigation, enhanced fertility, and frost control are other important benefits of these systems, but planting in soil raised above the soil surface is also an important disease management practice for soilborne pathogens.
15. The use of rotation should be carefully investigated and utilized in schemes designed to aid traditional farmers, keeping in mind that the value of crop rotation for the management of specific diseases is highly location specific.

In-Situ Conservation and Management of Crop Genetic Resources

Traditional agroecosystems are genetically diverse, containing populations of variable and adapted land races as well as wild relatives of crops (Harlan 1976). Land race populations consist of mixtures of genetic lines, all of which are reasonably adapted to the region in which they evolved, but which differ in reaction to diseases and insect pests. Some lines are resistant or tolerant to certain races of pathogens and some to other races (Harlan 1976). The resulting genetic diversity confers at least partial resistance to diseases that

TABLE 6.3 Sustainability, external inputs needed, and labor requirements of selected plant disease management practices of traditional farmers (Thurston 1992).

Practice	Sustainable?	Externnal Inputs	Labor
Adjusting crop density	Yes	Low	Low
Adjusting depth of planting	Yes	Low	Low
Adjusting time of planting	Yes	Low	Low
Altering of lant and crop architecture	Yes	Low	High
Biological control(soilborne pathogens)	Yes	High	High
Burning	Yes*	Low	High
Fallowing	Yes	Low	Low
Flooding	Yes	Low	High
Manipulating shade	Yes	Low	Low
Mulching	Yes	High	High
Multistory cropping	Yes	Low	Low
Multiple cropping	Yes	Low	High
Planting diverse crops	Yes	Low	Low
Planting in raised beds	Yes	High	High
Rotation	Yes	Low	Low
Site selection	Yes	Low	Low
Tillage	No	Low	High
Using organic amendments	Yes	High	High
Weed control	No	Low	High

* Under high population pressure the slash and burn system is neither stable nor sustainable.

are specific to particular strains of the crop and allows farmers to exploit different microclimates and derive multiple uses from the genetic variation of a given species.

Andean farmers cultivate as many as 50 potato varieties in their fields and have a four-tiered taxonomic system for classifying potatoes (Brush et al. 1981). Similarly, in Thailand and Indonesia, farmers maintain a diversity of rice varieties that are adapted to a wide range of environmental conditions. Evidence suggests that folk taxonomies become more relevant as areas become more marginal and risky. In Peru, for example, as altitude increases, the percentage of native stock increases steadily. In Southeast Asia, farmers

plant modern semi-dwarf rice varieties during the dry season and sow traditional varieties during the monsoon season, thus taking advantage of the productivity of irrigated modern varieties during dry months, and of the stability of native varieties in the wet season when pest outbreaks commonly occur (Grigg 1974). Clawson (1985) described a number of systems in which traditional tropical farmers plant multiple varieties of each crop, providing both intraspecific and interspecific diversity, thus enhancing harvest security.

A number of plants within or around traditional cropping systems are wild relatives of crop plants. Thus, through the practice of nonclean cultivation, farmers have inadvertently increased the gene flow between crops and their relatives (Altieri and Merrick 1987). For example, in Mexico, farmers allow teosinte to remain within or near cornfields so that natural crosses occur when the wind pollinates corn (Wilkes 1977). Through this continual association, fairly stable equilibria have developed among crops, weeds, diseases, cultural practices, and human habits (Bartlett 1980). The equilibria are complex, and difficult to modify without upsetting the balance, thus risking loss of genetic resources. For this reason Altieri and Merrick (1987) have supported the concept of in-situ conservation of many land races and wild relatives. They argue that in-situ conservation of native crop diversity is achievable only through preservation of agroecosystems under traditional management, and furthermore, only if this management is guided by the local knowledge of the plants and their requirements (Alcorn 1984).

Many peasants preserve and use naturalized ecosystems (forests, hillsides, lakes, grasslands, streamways, swamps) within or adjacent to their properties. These areas provide valuable food supplements, construction materials, medicines, organic fertilizers, fuels, and religious items (Toledo 1980). Although gathering has normally been associated with poverty (Wilken 1969), recent evidence suggests that this activity is closely associated with a strong cultural tradition. In addition, vegetation gathering has an economic and ecological basis, as wild plants provide significant input to the subsistence economy, especially when agricultural production is low due to natural calamities or other circumstances (Altieri et al. 1987). In fact, in many areas of semi-arid Africa, peasant and tribal groups maintain their nutritional level through gathering even when drought strikes (Grivetti 1979). Gathering is also prominent among shifting cultivators whose fields are widely spaced throughout the forest. Many farmers collect wild plants for the family cooking pot while traveling between fields (Lenz 1986). Gathering is also prevalent in desert biomes. For example, the Pima and Papago Indians of the Sonora Desert supply most of their subsistence needs from more than 15 species of wild and cultivated legumes (Nabhan 1983). In humid, tropical conditions the procurement of resources from the primary and secondary forest is even more impressive. For example, in the

Uxpanapa region of Veracruz, Mexico, local peasants exploit about 435 wild plant and animal species, of which 229 are used as food (Toledo et al. 1985).

Examples of Traditional Farming Systems

Paddy Rice Culture in Southeast Asia

Beneath the simple structure of the rice paddy monoculture (*sawah*) lies a complex system of built-in natural controls and genetic crop diversity (King 1927). Although these systems are more prevalent in Southeast Asia, upland rice farmers in the Latin American tropics also grow a number of photoperiod-sensitive rice varieties adapted to differing environmental conditions. These farmers regularly exchange seed with their neighbors because they observe that any one variety begins to suffer from pest problems if grown continuously on the same land for several years. The temporal, spatial, and genetic diversity resulting from farm-to-farm variations in cropping systems confers at least partial resistance to pest attack. Depending on the degree of diversity, food web interactions among the insect pests of rice and their numerous natural enemies in paddy fields can become very complex, often resulting in low but stable insect populations (Matteson et al. 1984).

The rice ecosystem, where it has existed over a long period, also includes diverse animal species. Some farmers allow flocks of domestic ducks to forage for insects and weeds in the paddies. Many farmers allow aquatic weeds, which they harvest for food (Datta and Banerjee 1978). Frequently one finds paddies where farmers have introduced a few pairs of prolific fish (such as common carp, *Sarotherdon mossambicus*). When the water is drained off to harvest the rice, the fish move to troughs or tanks dug in the corners of fields and are then harvested.

The techniques used for rice/fish culture differ considerably from country to country and from region to region. In general, exploitation of rice field fisheries may be classified as *captural* or *cultural* (Pullin and Shehadeh 1980), In the captural system, wild fish populate and reproduce in the flooded rice fields and are harvested at the end of the rice-growing season. Captural systems occupy a far greater area than cultural systems and are important in all the rice-growing areas of Southeast Asia. In the cultural system the rice field is stocked with fish. This system may be further differentiated into a *concurrent* culture, in which fish are reared concurrently with the rice crop, and a *rotation* culture, in which fish and rice are grown alternately. Fish can also be cultured as an intermediate crop between two rice crops (Ardiwinata 1957).

Traditional paddy rice growers usually produce only one rice crop each year during the wet season, even when irrigation water is readily available.

This practice is partly an attempt to avoid damage by rice stem borers. For the remainder of the year the land may lie fallow and be grazed by domestic animals. This annual fallow, along with the dung dropped by the grazing animals and the weeds and stubble plowed into the soil, will usually sustain acceptable rice yields (Webster and Wilson 1980).

Alternatively, farmers may follow rice with other annual crops in the same year where adequate rainfall or irrigation water is available. Planting alternative rows of cereals and legumes is common, as farmers believe it uses the soil resources more efficiently. Well-rotted composts and manures are applied to the land to provide nutrients for the growing crops. Sowing cowpeas or mung beans into standing rice stubble reduces damage by bean flies, thrips, and leafhoppers, by interfering with their ability to find their host (Matteson et al. 1984).

The micro-environment of the *sawah* also helps the wet-rice cultivator to produce constant crop yields from the same field year after year. First, the water-covered *sawah* is protected from high temperatures and the direct impact of rain and high winds, thus reducing soil erosion. Second, the high water table reduces the vertical movement of water, thus limiting nutrient leaching. Third, both floods and irrigation water bring silt in suspension and other plant nutrients in solution, renewing soil fertility each year. Fourth, the water in the *sawahs* contains *Azolla* spp. (a symbiotic association of blue-green alga and fern), which promotes the fixation of nitrogen—adding up to 50 kg per hectare of nitrogen.

Javanese Traditional Agriculture

In Java, Indonesia, many traditional agricultural systems combine crops and/or animals with tree crops or forest plants. Some of these are agroforestry systems and can be grouped into two major types (Marten 1986):

Talun-kebun. This is an indigenous Sundanese agricultural system that appears to have derived from shifting cultivation. It usually consists of three stages—*kebun, kebun-campuran* and *talun*—each of which serves a different function. In the kebun, the first stage, a mixture of annual crops is usually planted. This stage is economically valuable since most of the crops are sold for cash. After two years, tree seedlings have begun to grow in the field and there is less space for annual crops. At this point the kebun gradually evolves into a kebun-campuran, where annuals are mixed with half-grown perennials. This stage has economic value but also promotes soil and water conservation. After the annuals are harvested, the field is usually abandoned for two to three years to become dominated by perennials. This third stage is known as talun and has both economic and biophysical values.

After the forest is cleared, the land can be planted to *huma* (dryland rice) or *sawah* (wet rice paddy), depending on whether irrigation water is available. Alternatively, the land can be turned directly into kebun by planting a mixture of annual crops. In some areas kebun is developed after harvest-ing the huma by following the dryland rice with annual field crops. If the kebun is planted with tree crops or bamboo, it becomes kebun-campuran (mixed garden), which after several years will be dominated by perennials and become talun (perennial crop garden). It is not uncommon to find talun-kebun composed of up to 112 species of plants. Of these plants about 42 percent provide for building materials and fuelwood, 18 percent are fruit trees, 14 percent are vegetables, and the remainder constitute ornamentals, medicinal plants, spices, and cash crops.

Pekarangan (Home Garden). The *pekarangan* is an integrated system of people, plants, and animals with definite boundaries and a mixture of annual crops, perennial crops, and animals surrounding a house. A talun-kebun is converted into a perkarangan when a house is built upon it. Instead of clearing the trees to cultivate field crops as in talun-kebun, the home garden trees are kept as a permanent source of shade for the house and the area around it, and field crops in the home garden are planted beneath the trees.

A typical home garden has a vertical structure from year to year, though there may be some seasonal variation. The number of species and individuals is highest in the lowest story and decreases with height. The lowest story (less than one meter in height) is dominated by food plants like spices, vegetables, sweet potatoes, taro, *Xanthosoma*, chili pepper, eggplant, and legumes. The next layer (one to two meters in height) is also dominated by food plants, such as ganyong (*Canna edulis*), *Xanthosoma*, cassava, and gembili (*Dioscorea esculenta*). The next story (two to five meters) is dominated by bananas, papayas, and other fruit trees. The five to ten meter layer is also dominated by fruit trees, for example soursop, jack fruit, pisitan (*Lansium domesticum*), guava, mountain apple, or other cash crops, such as cloves. The top layer (10 meters) is dominated by coconut trees and trees for wood production, like *Albizzia* and *Parkia*. The overall effect is a vertical structure similar to a natural forest, a structure that optimizes the use of space and sunlight. The most common plants in the pekarangan are cassava (*Manihot esculenta*) and ganyong (*Canna edulis*). Both have a high calorie content and are important as rice substitutes.

There are definite groupings of plants in the home garden. For example, wherever gadung is found, petai (*Parkia speciosa*), kemlakian, and rambutan, possibly guava (*Psidium guajava*), and suweg (*Amorphophalus campanulatus*) will probably also be present.

An important plant association consists of rambutan (*Nephelium lappaceum*), kelor (*Moringa pterygosperma*), rose (*Rosa hybrida*), mangkokan (*Polyscias scutelaria*), gadung (*Dioscorea hispida*), and grapefruit (*Citrus grandis*). Each of the plants in this association provides the farmer with

something useful. Rambutan fruit is sold and eaten; kelor is used as a vegetable and is also believed to be a magical plant; rose is grown for pleasure; mangkokan is grown as an aesthetic plant and is used occasionally for hedges and hair tonic; gadung is a food plant that can also be used as a weather indicator because the rainy season usually begins a short time after its leaves start to grow; grapefruit has a similar function, and when its fruits start to grow the season of annual plant cultivation begins. These weather and planting-time indicators are important; many farmers believe agricultural failures are due mainly to improper planting times.

Livestock form an important component of this agroforestry system, particularly poultry, but also sheep freely grazing or fenced in sheds and fed with forage gathered from the vegetation. The animals have an important role in nutrient recycling. Also fish ponds are common and the fish are fed with animal and human wastes.

Mixed Tree Systems in Mexico

Mixed tree systems or home gardens are also common in the tropical lowlands of Mexico where they constitute a common but understudied form of agriculture. These systems involve the planting, transplanting, sparing, or protecting of a variety of useful species (from tall canopy trees to ground cover and climbing vines) for the harvest of various forest products, including firewood, food for the household and marketplace, medicines, and construction materials (Gliessman 1990).

Home gardens in Mexico are plots of land that include a house surrounded by or adjacent to an area for raising a variety of plant species and sometimes livestock. They are also known as kitchen gardens, dooryard gardens, *huertos familiares*, or *solares*. The home garden is representative of a household's needs and interests, providing food, fodder, firewood, market products, construction material, medicines, and ornamental plants for the household and local community. Many of the more common trees are those same species found in the surrounding natural forests, but new species have been incorporated, including papaya (*Carica papaya*), guava (*Psidium* spp.), banana (*Musa* spp.), lemon (*Citrus limon*), and orange (*Citrus aurantium*). In light gaps or under the shade of trees, a series of both indigenous and exotic species of herbs, shrubs, vines, and epiphytes is grown. Seedlings from useful wild species brought into the garden by the wind or animals are often not weeded out and are subsequently integrated into the home garden system.

One of the most striking features of present-day Mayan towns in the Yucatan Peninsula is the floral richness of the home gardens. In a survey of the home gardens in the town of Xuilub, 404 species were found where only 1,120 species are known for the whole state. Home gardens also provide diverse environments where many wild species of animals and plants can live, although the diversity of species depends on the size of the gardens and the degree of management. Estimated average family plots range from 600 m^2 to 6,000 m^2. Taking into consideration that most house-holds in rural communities of the Yucatan Peninsula have some type of home garden, local traditional practices of orchard management have already contributed to the forest cover in the peninsula and have the potential for contributing more (Gliessman 1990).

Shifting Cultivation

Shifting cultivation is also called slash-and-burn or *swidden* agriculture and is usually defined as an agricultural system in which temporary clearings are planted for a few years with annual or short-term perennial crops, and then allowed to remain fallow for a period longer than they were cropped. Conditions that limit crop yields, such as soil fertility losses, weeds, or pest outbreaks, are overcome during the fallow time, and after a certain number of years the area is ready to be cleared again for cropping. Thus, these systems involve a few years of cultivation alternating with several years of fallow to regenerate soil fertility. Typically there are three types of fallow: forest fallow (20 to 25 years), bush fallow (six to 10 years) and grass fallow (less than five years).

Within the tropics, shifting cultivation is most important in Africa. In Asia and tropical America it is practiced by disadvantaged people in remote rural areas where the lack of roads precludes the development of markets for cash crops. In South and Southeast Asia, about 50 million people are shifting cultivators, cropping 10 to 18 million hectares each year. With the gradual development of rice cultivation in lowland areas, shifting cultivation has retreated to hilly areas unsuitable for paddy. In tropical America, shifting cultivation was practiced before 1,000 B.C. It is based on corn, beans, and squash in the drier tropical areas of Mexico, and on tubers, cassava, and sweet potatoes in the wetter lowlands (Norman 1979). The features of shifting cultivation include (Grigg 1974):

- The size and number of plots managed by each family varies with the soil fertility, population density, length of the fallow, and degree of commercialization.
- It may or may not require a shift of domicile.
- Land tenure is usually communal, and most farmers have cooperative arrangements to work the land, particularly to clear the vegetation.
- Methods of cultivation are based on human and animal power, characterized by hand tools.
- Farm livestock play a minor role.

- Little cultivation and management are done once the crops are sown.
- Generally, soil fertility is maintained with some animal manure, but mostly with the nutrients provided by the ash and decomposing vegetation. In warm wet conditions, relatively rapid decomposition of the mulch provides nutrient recycling benefits unavailable through burning, while protecting the soil surface and increasing the amount of organic matter in the soil (Thurston 1991).

It is common in shifting cultivation to cut a parcel of forest and burn the area to release nutrients and eliminate weeds. A mixture of short-term crops, sometimes followed by perennials, is grown until the soil loses its fertility and competition from successional plant species is severe. Then the farmer prepares a new field and the old one returns to long-term fallow. During the fallow period, large quantities of nutrients are stored in the plant biomass. These nutrients are released when the fallow vegetation is burned to clear the land for the next cropping cycle (Rutenberg 1971). Where land is abundant and resources scarce, it is generally agreed this is an efficient and stable system that has sustained farm families for many generations. Due to recent population pressure, to the pressure of poverty, and factors like weed growth and declining soil fertility, the fallow cycle has been reduced from a more favorable 20 to 30 years to a period as short as five years, leading in many cases to soil losses and nutrient depletion. Unless there are substantial social and economic changes, including land redistribution, short-term cycles will continue and more land will be cleared.

Although there is generally a random generation of species during the fallow periods, in certain parts of the humid tropics farmers intentionally retain certain species such as *Acioa baterii*, *Anthonata macrophylla*, and *Alchornia* sp. The small trees are only trimmed and the big branches are left for staking crops. The cut tops are spread on the soils and burned. Thus, the bush fallow functions doubly to provide staking materials and recycle nutrients (Nye and Greenland 1961). The distinction between an agricultural plot and the adjacent mature forest in the humid tropics may not be as clearly evident as in temperate regions. Rather than being separate categories of vegetation, *milpas* (small cleared fields) and mature forest patches are different stages of the cyclical process of shifting agriculture. Even mature vegetation is part of a more extensive management system that includes sparing trees in the milpa and protecting and cultivating useful plant species during the regrowth of the forest patch. These forest patches, along with other uncut areas where the mature vegetation is protected or where useful tree species have been encouraged or transplanted, can be considered forest gardens, managed forests, or modified forests.

It has been speculated that bush fallows are potentially valuable in controlling insects. The great diversity of crops grown simultaneously in shifting cultivation helps prevent pest buildup on the comparatively isolated plants of each species. Increased parasitoid and predator populations, decreased colonization and reproduction of pests, chemical repellency or masking, feeding inhibition from non-host plants, prevention of pest movement or stimulation of pest emigration and optimal synchrony between pests and their natural enemies are presumably important temporal and spatial factors in regulating pests in polycultures. Shade from forest fragments still standing in new fields, coupled with a partial canopy of fruit, nut, firewood, medicinal and/or lumber tree species reduces shade-intolerant weed populations and provides alternative hosts for beneficial (or sometimes detrimental) insects. Clearing comparatively small plots in a matrix of secondary forest vegetation permits easy migration of natural control agents from the surrounding jungle (Matteson et al. 1984).

The Nkomanjila System of the Nyhia Shifting Cultivators

This is a typical shifting cultivation system and involves a cycle of cutting woodland, burning, cropping, and fallow (King 1978). The Nyhia cultivators prefer fully regrown or virgin woodland composed of specific trees, such as *Brachystegia* spp. and *Acacia macrothyrsa*. In burning the *nkomanjila*, cut wood is stacked around tree trunks and burned just before the rainy season. If much unburned material remains, it is gathered and reburned. After one month, during which other fields are prepared, the crops are planted. Before planting, ash from the burned trees is spread with hoes evenly through the field, and weeds are hoed into the soil. Seeds are broadcast and lightly hoed.

The nkomanjila must be weeded, usually once but sometimes twice. Women do the weeding and harvesting, while men do the cutting, burning, and some of the initial hoeing. After harvesting, the crop is dried in the sun and then stored.

Nkomanjila crops include finger millet, perennial sorghum, pulses (including pigeon peas, lima beans, and cowpeas), and cucurbits (including pumpkins and gourds) in intercropping patterns.

The standard crop sequence in nkomanjila is the finger millet/sorghum complex the first year, followed by sorghum ratoons or suckers the second year. A portion of the first-year field may be planted to an early maturing variety of finger millet. The second year of sorghum ratoons (*lisala*) is virtually untended except for harvesting. Traditionally, the cropping sequence ended here and the field was abandoned to fallow. Today, however, so much acreage is needed for food production that these long crop sequences are no longer possible. The basic two-year nkomanjila sequences may be repeated. Alternatively, if the finger millet yield the first year is good, the basic pattern may be reinitiated in the second year. Once the nkomanjila is abandoned (which may be due to weed growth or lower soil fertility), the land is allowed to rest about five to seven years. Given current population densities in Africa, the nkomanjila system is no longer viable since farmers can no longer afford long fallow periods. As a result of frequent cultivation and burning, a cultivation system involving a grass- dominated fallow has replaced the woodland-dominated fallow.

The Nkule System. The *nkule* system is the grassland alternative to nkomanjila (King 1978). Techniques used in nkule cultivation can be applied both to upland grass communities, resulting in fields known as nkule, and at higher elevations, where the fields are called *ihombe*. Indicators for the nkule method include tall grasses of the *Hyparrhenia* genus and *Trachypogon spicatus*. The distinctive feature of the nkule system is that turf and soil are mounded over grass, which is then burned under the mound. Maize and cucurbits are planted under the mound. In December the mounds around these crops are hoed down. Ash and burned soil are then spread and finger millet is sowed. The field requires two weedings, one in the course of hoeing down the mounds and preparing the seedbed, and a second during the growing season. The finger millet crop is harvested and stored as under the nkomanjila system. In ihombe fields, mounds are made and burned, but finger millet is the only crop planted after the mounds have been spread.

Burning both vegetative matter and surface soil is important in the nkule system. Usually, fallow grassland is plowed during the dry season to break the sod, which is then hoed into mounds. Cow dung is put on the windward side of the mound and set afire. The soil and turf of the mound is slowly hoed over the burning dung until all vegetative matter has been burned.

The important difference between nkule and ihombe fields is that in the nkule crops are virtually always growing, while the ihombe is used for just one year and fallowed at least three years. In upland nkule fields, the crop sequences are as varied as after nkomanjila. An upland nkule field is ideally put into a legume/grain rotation for two to four years, then rested one or two years. Now, many fields of nkule origin are cultivated for six or more years. As in nkomanjila, cassava often ends the cropping sequence, although the wheat/early beans rotation appears to be viable over a long period.

Occasionally an ihombe field will be planted to finger millet a second year or, if well up on the margin, hoed into large ridges for beans and groundnuts. Failure of a second crop of finger millet (or most other crops) may be due to a lack of particular micronutrients in ihombe fields or to alterations of the soil structure. When the soils are continuously cultivated, iron can accumulate in the soil, impeding drainage in subsequent years. A short fallow may reverse this condition.

Slash/Mulch Systems and the "Frijol Tapado" System in Central America

Frijol tapado is a traditional agricultural system used to produce beans in mid-elevation areas of Central America on steep slopes with high amounts of rainfall where most beans in the region are grown. Originally devised by the indigenous inhabitants of Central America, it is one of the few agricultural technologies transferred to the Spanish colonizers. To begin the process, farmers choose a fallow field that is two to three years old so that the woody vegetation dominates the grasses. If the fallow period is less than two years, then the grasses will be able to out-compete the emerging bean plants and soil fertility will not have been fully restored since last harvest. Next, paths are cut through the field with machetes. Then bean seeds are thrown into the fallow vegetation, or broadcasted. Finally, the fallow vegetation with bean seed is cut down into a mulch that is allowed to decay and provide nutrients to the maturing bean seedling. Approximately twelve weeks after broadcasting a harvest is made. In Costa Rica, the estimate is that sixty to seventy percent of the beans in the country are produced by frijol tapado. Compared to the other more labor- and chemical- intensive methods of bean production used by the small holder, the tapado system has a higher rate of return because of lower costs.

The tapado system allows production of beans for both home consumption and cash to supplement meager incomes during times of financial hardship. The cost- effective benefits include: (1) no need for expensive and potentially toxic agricultural chemicals such as fertilizers and pesticides and (2) a relatively low labor requirement. Soil erosion is minimized because of a continuous vegetation cover that prevents exposing the bare ground to heavy rainfall.

The alternative to the tapado system is the *espequeado* system where the farmer plants the beans into the bare soil with a stick. In comparison to the tapado system, espequeado has higher costs of production and therefore a lower rate of return. The system requires agricultural chemicals and more labor, which creates the higher expense. Small farmers do not have access to the cash and credit required to buy the needed agricultural chemicals. Technical assistance is also not readily available. Incomplete implementation of the guidelines for the espequeado system as established by the government agricultural agencies results in soil degradation and a decline in productivity. A loss of money is the economic consequence for the small farmer's partial use of the espequeado system. The government agricultural agencies are promoting it over the tapado system because it is supposed to have higher yields per hectare, but this has not been established by the literature. In addition, pests seem to be a greater problem in the espequeado system.

Scientists studying and promoting slash/mulch systems similar to the frijol tapado in Central America report several advantages for the farmers (Thurston et al. 1984):

1. The slash/mulch systems can add large quantities of organic matter to the soil. Velvet beans (*Stizilobium* spp. and *Mucuna pruriens*) commonly produce up to 50 T/ha organic matter each year. These mulches can also fix large amounts of nitrogen in the soil. For example, velvet beans can fix up to 150 kg N/ha and *Lathyrus nigrivalvis* almost as much. The combination of nitrogen and organic matter has meant that farmers using several of the mulch systems, without added chemical fertilizers, can harvest up to 3 T/ha corn per year.
2. Mulches can reduce the amount of work spent in weeding. In some cases they can eliminate the second weeding and in others eliminate the weeding in the second corn crop. Farmers in several parts of Central America, Africa, and Asia use velvet beans to eliminate the worst of the weeds such as *Cyperus rotundus* and *Imperata cylindrica.*
3. Another advantage is conferred by the alternative uses for these crops. Velvet beans, lablab, and *L. nigrivalvis* provide good forage. The last two can withstand drought and thus provide high-quality forage during the dry season. The velvet bean, jack bean, runner bean, and lablab are all nutritious, high protein foods for human consumption, which can be prepared in various ways. Velvet beans are used to make coffee, chocolate, bread, and tortillas. Lablabs can be eaten fresh like peas or dried like other dried pulses. In many cases, the consumption of these beans, which are a free by-product of the operation, has resulted in a surprising improvement in the nutrition of children.
4. Other advantages may arise depending on the mulch species used. Velvet beans can be used as a wide spectrum nematicide and jack bean leaves are sometimes used to eliminate leaf cutter ant colonies.

Agropastoral Systems

Farming systems that combine animal and crop production vary across agroecological zones (McDowell and Hildebrand 1980). In Asian lowland rice farming areas, buffalos are important animal components and provide (1) traction for cultivating fields and (2) milk and meat that are consumed domestically or sold in markets. Cattle, fowl (mainly chickens and ducks), and swine are also commonly raised on these farms. Feeds include crop residues, weeds, peelings, tops of root crops, bagasse, hulls, and other agricultural by-products. In highland areas, swine, poultry, buffalo, and cattle are raised in combination with rice, maize, cassava, beans, and small grains. The cropping systems of tropical humid Africa are dominated by rice, yams, and plantains (McDowell and Hildebrand 1980, Ruthenberg

1971). Goats and poultry are the dominant animals. Sheep and swine are less abundant, but still common. Feeds include fallow land forage, crop residues, cull tubers, and vines. The small farms of Latin America typically include crop mixtures of beans, maize, and rice (McDowell and Hildebrand 1980, Ruthenberg 1971). Cattle are common and maintained for milk, meat, and draft. Swine and poultry are raised for food or for sale. Pastures, crop residues, and cut feeds support animal production.

Several other benefits accrue from agropastoral systems. In effect, incorporation of livestock into farming systems adds another trophic level to the system. Animals can be fed plant residues, weeds, and fallows with little impact on crop productivity. This serves to turn otherwise unusable biomass into animal protein, especially in the case of ruminants. Animals recycle the nutrient content of plants, transforming them into manure and allowing a broader range of fertilization alternatives in managing farm nutrients. The need for animal feed also broadens the crop base to include species useful for conserving soil and water. Legumes are often planted to provide quality forage and serve to improve nitrogen content in soils.

Beyond their agroecological interactions with crops, animals serve other important roles in the farm economy. They produce income from meat, milk, and fiber. Livestock increase in value over time and can be sold for cash in times of need or purchased when cash is available (McDowell and Hildebrand 1980).

Integrated Agriculture-Aquaculture

In many parts of Asia, the productive use of land and water resources has been integrated into traditional farming systems. Farmers have transformed wetlands into ponds separated by cultivable ridges. An example is the dike-pond system which has existed for centuries in South China. To produce or maintain the ponds, soil is dug out and used to repair the dikes around it. Before being filled with river water and rainwater, the pond is prepared for fish rearing by clearing, sanitizing, and fertilizing with local inputs of quicklime, tea-seed cake, and organic manure. The fish stocked in the pond include various types of carp, which are harvested for home consumption and sale. Mulberry is planted on the dikes, fertilized with pond mud and irrigated by hand with nutrient-rich pond water. Mulberry leaves are fed to silkworms; the branches are used as stakes to support climbing vegetables and as fuelwood. In sheds, silkworms are reared for yarn production. Their excrements, mixed with the remains of mulberry leaves are used as fish feed. Sugarcane plants on the dikes provide sugar. Young leaves are used to feed fish and pigs, and old leaves to shade crops, for roofing thatch, and for fuel; the roots are also used as fuel. Grass and vegetables are also grown on the dikes to provide food for the fish and

family. Pigs are raised mainly to provide manure but also for meat. They are fed sugarcane tops, by-products from sugar refining, aquatic plants, and other vegetable wastes. Their feces and urine, as well as human excrement and household wastes, form the principle organic inputs into the fish pond (Ruddle and Zhong 1988).

Overall integrated farming systems that include semi-intensive aquaculture are less risky for the resource-poor farmer than intensive fish farms, because of their efficiency derived from synergisms among enterprises, their diversity of produce, and their environmental soundness. In many traditional systems aquaculture goes beyond fish production and cash income as pond water and pond biota perform many ecological, social, and cultural services on an integrated farm. Thus aquaculture and water management act as an engine driving the sustainability of the entire farming system (Lightfoot 1990).

Andean Agriculture

Between 3,000 and 4,000 years ago, a nomadic, hunting and gathering way of life in the Central Andes was supplanted by a village-based agropastoral economy, a system that still prevails despite competition for land between haciendas and peasant communities (Brush 1982). The impact of the complex Andean environment on the human economy has resulted in vertical arrangements of settlements and agricultural systems (Table 6.4). The pattern of verticality derives from climatic and biotic differences related to altitude and geographical location. The most important cultural adaptation to these environmental constraints has been the subsistence system: crops, animals, and agropastoral technologies designed to yield an adequate diet with local resources while avoiding soil erosion (Gade 1975).

The evolution of agrarian technology in the Central Andes has produced extensive knowledge about using the Andean environment. This knowledge affected the division of the Andean environment into altitudinally arranged agroclimatic belts, each characterized by specific field and crop rotation practices, terraces and irrigation systems, and the selection of many animals, crops, and crop varieties (Brush et al. 1981). About 34 different crops (corn, quinoa, *Amaranthus caudatus*), legumes (beans, lupine, lima beans), tubers (species of potato, manioc, *Arrachocha*, etc.), fruits, condiments, and vegetables are grown. The main crops are corn, chenopods (*Chenopodium quinoa* and *C. pallidicaule*), and potatoes. Individual farmers may cultivate as many as 50 varieties of potatoes in their fields, and up to 100 locally named varieties may be found in a single village. The maintenance of this wide genetic base is adaptive since it reduces the threat of crop loss due to pests and pathogens specific to particular strains of the crop (Brush 1982).

Crop Patterns in the Agroclimatic Belts. The local inhabitants recognize three to seven agroclimatic belts, distinguished according to altitude, moisture, temperature, vegetation, land tenure, crop assemblages, and agricultural technology (Table 6.4). There is considerable regional variation in the cultivation patterns of each belt. For example, in the communities of Amaru and Paru-Paru in Cuzco, Peru, three main belts can be distinguished (Gade 1975). Sites in the corn belt have soft slopes, located between 3,400 and 3,600 meters. These sites are irrigated and farmed in three alternative four-year rotations: (1) corn/fava beans/corn/fallow; (2) corn/corn/potato or fallow; and (3) potato and barley/fava beans/corn/corn. The potato/fava/ cereals belt is composed of sites with steep slopes, located from 3,600 to 3,800 meters. Potatoes are intercropped with barley, wheat, fava beans and peas. In rainfed areas there are two main four-year rotations: (1) fava beans/wheat/ peas/barley and (2) *Lupinus mutabilis*/barley/fava beans/fallow. In irrigated areas common rotations are: (1) potato/wheat/fava beans/barley and (2) potato or *C. quinoa*/barley/ peas/fallow. The bitter potato/pasture belt is a cold belt located above 3,800 meters. Rainfed rotations in this belt usually

TABLE 6.4 Agroclimatic crop zones of the central Andes (based on Brush 1982).

Zone	Major Crops/ Animals	Agricultural Technology	Land Tenure	Focus of Production
Pasture above 3,800.	alpacas llamas sheep cattle		communal ownership & communal use	market (esp. wool) and subsistence
Tuber 3,000–4,200m.	potatoes quinoa/ canihua barley other native tubers (mashua, ulluca, oca)	hoe foot plow dung as fertilizer	communal ownership with individual use	subsistence
Cereal 1,500–3,000m.	corn wheat cucurbits beans temperate fruits and vegetables	draft animals some mechaniza- tion and chemical fertilizer	private ownership and use	subsistence (grains) and market (fruits and vege- tables)
Tropical/fruit 500–1,500m.	cocoa sugarcane cotton tropical fruit corn	mainly agro- industrial technology	private ownership and use	market

include a four- to five- year fallow period, after a four-year sequence of potato/*Oxalis tuberosa* and *Ullucus tuberosus*/*U. tuberosus* and *Tropaeolum tuberosum*/barley.

Traditional Farming Systems of Mediterranean Chile

The small farmers (campesinos) of mediterranean Chile emphasize diversity to use scarce resources most efficiently. Farming systems are usually either small-scale and intensive or more extensive and semi-commercial.

Small-Scale Intensive Systems

These systems rarely exceed one hectare in size and therefore usually do not provide all the food requirements of the family. All items produced are used on the farm, and other needs are bought with earnings from off-farm work. Campesinos typically produce a great variety of crops and animals, and it is not unusual to find as many as five to 10 tree crops, 10 to 15 annual crops, and three to four animal species on a single farm.

These farms often include an arbor of grapes (parron) to provide shade, along with fruit, herbs, medicinal plants, and flowers in addition to the tree and annual food crops. The typical animals on these farms are rabbits, free-ranging chickens and ducks, and occasionally a few pigs feeding on kitchen waste and crop residue. Intensive annual cropping usually makes use of simple crop patterns (growing annual crops only during the spring and summer), or, more typically, crop sequencing (planting a second crop after the harvest of the first). In both crop patterns, campesinos may practice intercropping. Common intercropping systems include corn/beans, garlic and/or onion mixed with lettuce and cabbage, and corn/potatoes.

Figure 6.4 depicts one very complex system in the central coast range. The land, characterized by a 25 percent slope, was divided into two sections. Half of it is devoted to annual crops and herbs grown in rows running parallel to the hill contour. The fruit trees include several varieties of grapes, a few non-crop trees such as pine (*Pinus radiata*), aromo (*Acacia* spp.), *Datura* spp. and a small stand of bamboo and cactus (*Opuntia* spp.). A living fence of cypress separates the two sections. Chickens and rabbits are raised under the orchard in cages, and their manure, mixed with sawdust, is used to fertilize crops and trees. In addition to the fruit trees, *Eucalyptus* spp. are planted as a living fence on the lower boundary and harvested for fuelwood and poles. Additional fuelwood was gathered from the native "espino" (*Acacia cavens*) growing naturally on the hillside above the property. Beneath

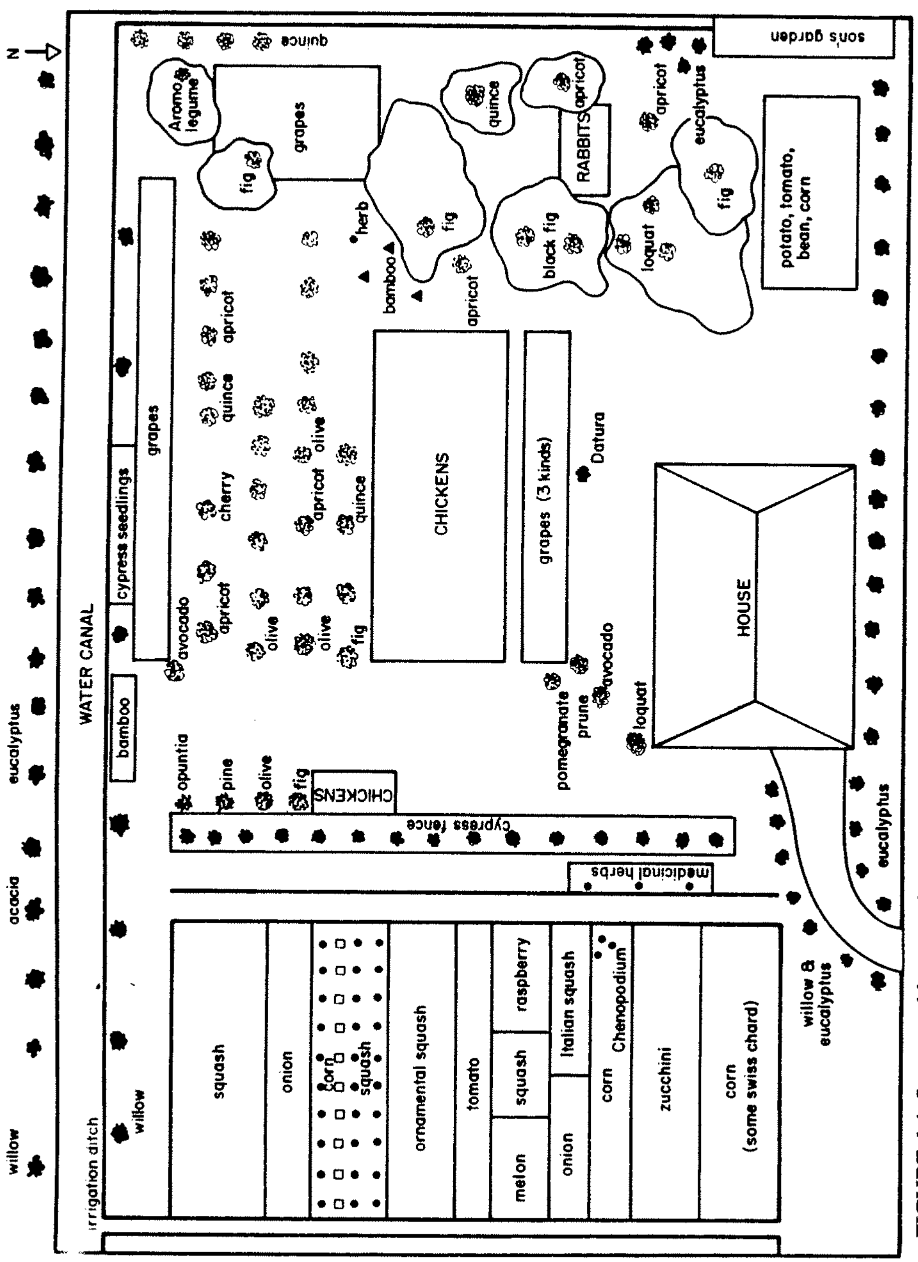

FIGURE 6.4 Structural layout of a small-scale intensive farming system in the coastal zone of central Chile (Altieri and Farrel 1984).

the orchard trees, herbs are grown for medicinal purposes or to keep chickens healthy, as in the case of Ruda (*Ruda tracteosa*). According to some campesinos the presence of this plant in the chicken yard prevents infectious poultry diseases. Hinojo (*Hinojo officinalis*) is allowed to grow freely in the property margins and its cane is later used to construct fences or small huts. Irrigation water is diverted from the canal passing along the upper boundary of the property. The campesinos plant willows (*Salix* spp.) along the canal to hold the soil down and prevent soil sliding. The penetrating root systems, along with the dense canopy from the other trees, provides soil protection on this sloping site.

Extensive Semi-Commercial Systems. Semi-commercial farms range from five to 20 hectares in size. These systems are also diversified, but the crop and animal combinations are designed to increase production to yield a market-able surplus. With more land, the campesino devotes much of it to more extensive activities such as pasture for livestock and grain cultivation. The additional land also affords more space for wood-producing trees. In this way, nearly all of the household requirements are provided for on the farm.

Typically, campesinos grow crops preferred by the local community for commercial purposes. These crops, however, may entail relatively high risks. Therefore they hedge against this risk by growing several less variable or risky crops, like beans, squash, potato, or corn, between rows of high-value fruit trees, like peach, cherry or apple.

Figure 6.5 shows the design of a 12-hectare farm about 10 kilometers east of Temuco, south of Chile, where the campesino balanced his farm to provide food, clothing, housing, and capital. The farm consists of an inter-planted area of annual crops and fruit trees, a mixed orchard of fruit trees, approximately five hectares of pasture, two to three hectares of wheat, and a stand of pine (*Pinus radiata*). He harvested 280 kg of honey from 26 beehives per year, obtained 10 to 12 liters of milk per day from three cows, collected 10 to 11 eggs per day from his chickens, and from the wheat, supplied all of his flour for making bread. Pine trees were planted to provide wood. The fast-burning wood is also used in constructing the house and barns. Guano from the animals and crop residues are collected in a compost pile for later use as fertilizer.

Raised Field Agriculture

Raised field agriculture is an ancient food production system used extensively by the Aztecs in the Valley of Mexico, but also found in China, Thailand, and other areas to exploit the swamplands bordering lakes.

Called *chinampas* in the Aztec region, these "islands" or raised platforms (from 2.5 to 10 meters wide and up to 100 meters long) were usually constructed

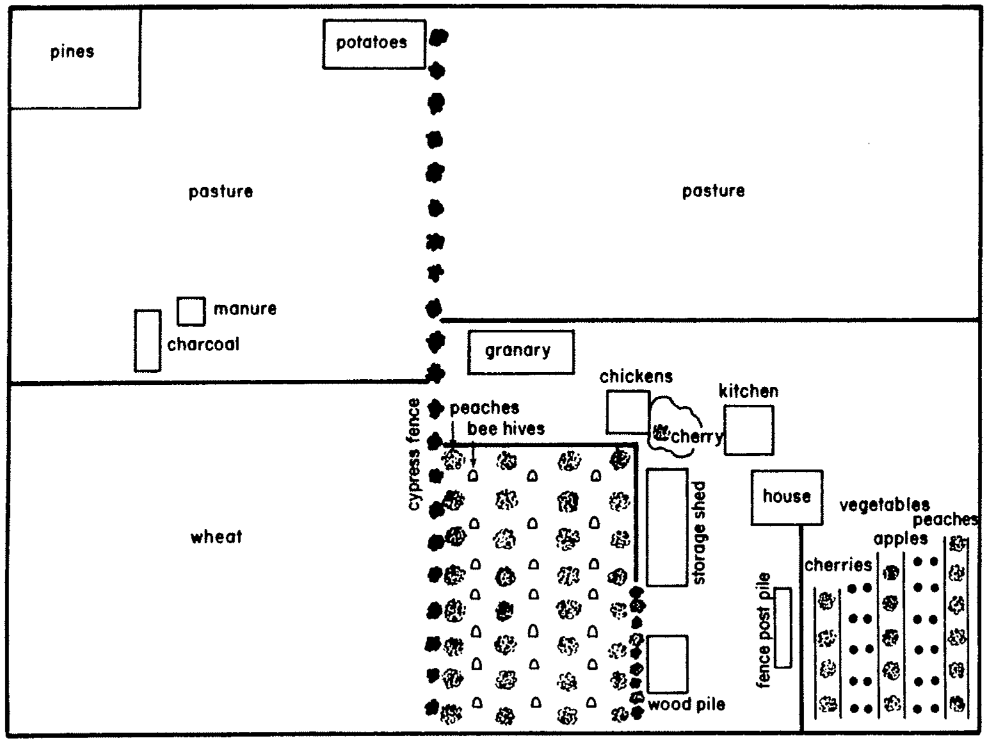

FIGURE 6.5 Structural layout of a twelve-hectare, semi-commercial farming system in southern Chile (Altieri and Farrell 1984).

with mud scraped from the surrounding swamps or shallow lakes. The Aztecs built their platforms up to a height of 0.5 to 0.7 meters above water level and reinforced the sides with posts interwoven with branches and with trees planted along the edges (Armillas 1971).

The soil of the platforms is constantly enriched with organic matter produced by the abundant aquatic plants, as well as with sediments and muck from the bottom of the reservoirs. A major source of organic matter today is the water hyacinth (*Eichornia crassipes*), capable of producing up to 900 kg per hectare of dry matter daily. Supplemented with relatively small amounts of animal manure, the chinampas can be made essentially self-sustaining. The animals, such as pigs, chickens, and ducks, are kept in small corrals and fed the excess or waste produce from the chinampas. Their manure is incorporated back into the platforms (Gliessman et al. 1981). On the chinampas, farmers concentrate the production of their basic food crops well as vegetables. This includes the traditional corn/bean/squash

polyculture, cassava/corn/bean/peppers/amaranth, and fruit trees associated with various cover crops, shrubs, or vines. Farmers also encourage the growth of fish in the water courses.

In Asia, raised field agriculture consists of livestock/fowl/fish farming systems. Aquatic vegetation is fed to animals, and in turn, their wastes are used as fertilizer for fish ponds. A common system is pig/fish farming, in which 2,000 to 5,000 kg of fish per hectare are produced every six months. There are about 60 pigs per hectare and fish are stocked at a rate of 25,000 to 30,000 per hectare (Pullin and Shehadeh 1980).

Conclusions

All traditional agroecosystems described above have proved to be sustainable in their historical and ecological context (Cox and Atkins 1979). Although the systems evolved in very different times and geographical areas, they share structural and functional commonalities (Beets 1982, Marten 1986):

- They combine species and structural diversity in time and space through both vertical and horizontal organization of crops.
- The higher biodiversity of plants, microbes, and animals inherent to these systems support production of crops and stock and mediate a reasonable degree of biological recycling of nutrients.
- They exploit the full range of micro-environments, which differ in soil, water, temperature, altitude, slope, and fertility within a field or region.
- They maintain cycles of materials and wastes through effective recycling practices.
- They rely on biological interdependencies that provide some biological pest suppression.
- They rely on local resources plus human and animal energy, using little technology.
- They rely on local varieties of crops and incorporate wild plants and animals. Production is usually for local consumption.
- The level of income is low, so the influence of noneconomic factors on decisionmaking is substantial.

Despite the onrush of modernization and economic change, a few traditional agricultural management and knowledge systems still survive. These systems exhibit important elements of sustainability, namely, they are well adapted to their particular environment, rely on local resources, are small-scale and decentralized, and tend to conserve the natural resource base. Therefore, these systems comprise a neolithic legacy of considerable importance, yet modern agriculture constantly threatens the stability of this inheritance. The study of traditional agroecosystems can speed considerably the emergence of agroecological principles, which are greatly needed in order to develop more sustainable agroecosystems both in the industrial and developing countries. Realistically, sustainable agriculture models are needed that combine elements of both traditional and modern scientific knowledge. Complementing the use of conventional varieties and inputs with ecologically sound technologies will ensure a more affordable and sustainable agricultural production.

1. Throughout this book the terms traditional, peasant, small-scale, and small farming are used synonymously to describe systems that rely on human and animal power and on locally available resources (Wilken 1977).

2. $LER = Px/Kx + Py/Ky$, where Kx and Ky are the yields per unit area when the crops are grown in monoculture, and Px and Py are the production of the two crop species in a polyculture (Vandermeer 1981).

7

Ecologically Based Agricultural Development Programs

Most developing countries' economies have gone through major economic crisis with extraordinary social and environmental costs. Despite numerous internationally and state-sponsored development projects, poverty, food scarcity, malnutrition, health deterioration, and environmental degradation continue to be widespread problems (Altieri and Masera 1993). As developing countries are pulled into the existing international order and change their policies in order to serve the unprecedented debt, governments increasingly embrace neo-liberal economic models that promote export-led growth. Despite the fact that in some countries, the model appears successful at the macro-economic level, deforestation, soil erosion, industrial pollution, pesticide contamination, and loss of biodiversity (including genetic erosion) proceed at alarming rates and are not reflected in the economic indicators. So far, there is no clear system to account for the environmental and social costs of such models.

The crisis has demonstrated that conventional development strategies are fundamentally limited in their ability to promote equitable and sustainable development (Altimir 1982, Annis and Hakim 1988). So far, the end result of most development programs has been what is termed "growth with poverty". In the realm of agriculture, modernization has proceeded in the absence of effective land distribution and research/development programs have emphasized high-input production, all factors contributing to environmental problems in the region (Redclift 1989). A major technological problem of development projects is that global recommendations frequently prove unsuitable for the conditions of specific peasant farms (de Janvry 1981). The many forms of agriculture found in Third World countries result from variations in local climate, soils, crop types, demographic factors, and