# Globally Important Ingenious Agricultural Heritage Systems (GIAHS): extent, significance, and implications for development

by

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**Introduction**

Agroecosystems cover more than one quarter of the global land area, reaching about 5 billion hectares. Agroecosystems are ecosystems in which people have deliberately selected crop plants and livestock animals to replace the natural flora and fauna. Highly simplified agroecosystems, (such as intensive cereal cropping, orchards and plantations, and intensive livestock raising), vary enormously in their intensity of human intervention, from those with only low-intensity management (e.g. shifting cultivation, home gardens, nomadic pastoralism, traditional farms, rotational fallows and savanna mixed farming), and from those of middle-intensity management (including multiple cropping, mixed horticulture, improved pasture mixed farming and alley farming).

Five criteria can be used to classify agroecosystems in a region: (1) the types of crop and livestock; (2) the methods used to grow the crops (chemical or organic) and produce the livestock; (3) the relative intensity of use of labor, capital, and organization, and the resulting output of product; (4) the disposal of the products for consumption (whether used for subsistence or supplement on the farm or sold for cash or other goods); and (5) the structures used to facilitate fanning operations (Norman 1979).

Based on these criteria, it is possible to recognize seven main types of agricultural systems in the world (Grigg 1974, also see Table 1 for a more detailed classification):

1. Shifting cultivation systems
2. Semipermanent rain-fed cropping systems
3. Permanent rain-fed cropping systems
4. Arable irrigation systems
5. Perennial crop systems
6. Grazing systems
7. Systems with regulated led farming (alternating arable cropping and sown pasture).

Systems 4 and 5 have evolved into habitats that are much simpler in form and poorer in species than the others, which can be considered more diversified, permanent, and less disturbed. Within the range of world agricultural systems, traditional polycultures require less energy and external inputs than modern orchards, field crops, and vegetable cropping systems to achieve a similar level of desired stability. This greater stability apparently results from certain ecological and management attributes inherent to polycultural systems. Modern systems require more radical modifications of their structure to approach a more diversified, less disturbed state.

Across the world, agroecosystems differ in age, diversity, structure, and management. In fact, there is great variability in basic ecological and agronomic patterns among the various dominant agroecosystems. In general, agroecosystems that are more diverse, more permanent, isolated, and managed with low input technology (i.e. agroforestry systems, traditional polycultures) take fuller advantage of work usually done by ecological processes associated with higher biodiversity than highly simplified, input-driven and disturbed systems (i.e. modern vegetable monocultures and orchards).

Increasing human intervention has resulted in a deliberate reduction of the diversity of plant, microbial and animal species in whole landscapes. The current dominance of intensified cereal production has led to a significant reduction of diversity of species and of production systems. Such change in ecosystem diversity and complexity associated with intensification affect a variety of ecosystem functions. Modern agriculture relies on a narrow range of crop species and genetic varieties which have been bred for high yield, including response to inorganic fertilizers and resistance to selected pests and diseases. Less intensive systems commonly incorporate a wider range of species and genotypes which serve a variety of production goals and/or are used for differential exploitation of microhabitats, and for their resistance to diseases and pests. Decreased plant diversity often reduces the overall biomass and almost invariably the structural complexity of the ecosystem. Also, decreases in the diversity of plant species have lead to increased pest and disease problems in many modern agroecosystems.

A hypothetical pattern in pest regulation according to agroecosystem temporal and spatial diversity is depicted in Figure 1. According to this "increasing probability for pest buildup" gradient, agroecosystems on the left side of the gradient are more biodiverse, tend to be more amenable to manipulation since polycultures already contain many of the key environmental factors required by natural enemies. There are, however habitat manipulations that can introduce appropriate diversity into the important (but biodiversity impoverished) grain, vegetable and row crop systems lying in the right half of Figure 1.

In the midst of these extreme types of agriculture are regional microcosms of traditional farming systems (i.e. in Mesoamerica, the Andean region, and the Amazon Basin, the rice-based systems of Asia, and the silvopastoral systems of Africa) that have emerged over centuries of cultural and biological evolution and represent accumulated experiences of peasants interacting with the environment without access to external inputs, capital, or scientific knowledge (Chang 1977; Wilken 1987). Using inventive self-reliance, experiential knowledge, and locally available resources, indigenous farmers have often developed farming systems with sustained yields (Harwood 1979; Reinjtes et al. 1992). These agroecosystems, based on cultivation of a diversity of crops and varieties in time and space, have allowed traditional farmers to maximize harvest security under low levels of technology and with limited environmental impact (Clawson 1985).

In Latin America, alone, the persistence of more than three million hectares under ancient, traditional agricultural management in the form of raised fields, terraces, polycultures, agroforestry systems, etc., document a successful indigenous agricultural strategy and comprises a tribute to the 'creativity' of traditional farmers. These microcosms of traditional agriculture also found in Asia and Africa comprise "globally important ingenious agricultural heritage systems" (GIAHS) and as such offer promising models of sustainability as they promote biodiversity, thrive without agrochemicals, and sustain year-round yields (Altieri 1999). GIAHS have resulted not only in outstanding aesthetic beauty, maintenance of globally significant agricultural biodiversity, resilient ecosystems and valuable cultural inheritance, but above all, in the sustained provision of multiple goods and services, food and livelihood security and quality of life for millions of people. 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 sustainability of this inheritance. Because of their significance and the wealth and breadth of accumulated knowledge and experience in the management and use of resources that GIAHS represent, it is imperative that they be considered globally significant resources and should be protected and preserved as well as allowed to evolve. Such ecological and cultural resource is of fundamental value for the future of humankind.

**The rural populations of GIAHS**

GIAHS can be found, in particular, in highly populated regions or in areas where the population has, for various reasons, had to establish complex and innovative land-use/management practices e.g. due to geographic isolation, fragile ecosystems, political marginalisation, limited natural resources, and/or extreme climatic conditions. In the majority of cases, GIAHS have been under the management of resource-poor farmers (peasants and indigenous people) with limited access to capital, technology or government services.

Although estimates of the number and location of resource-poor farmers vary considerably, it is estimated that about 1.9 to 2.2 billion people remain directly or indirectly untouched by modern agricultural technology (Pretty 1995). In Latin America, the rural population is projected to remain stable at 125 million until the year 2000, but over 61% of this population are poor and are expected to increase. The projections for Africa are even more dramatic. The majority of the world's rural poor (about 370 million of the poorest) live in areas that are resource-poor, highly heterogeneous and risk-prone. Despite the increasing industrialization of agriculture, the great majority of the farmers are peasants, or small producers, who still farm the valleys and slopes of rural landscapes with traditional and subsistence methods. Their agricultural systems are small scale, complex and diverse and peasants are confronted with many constraints. The worst poverty is often located in arid or semi-arid zones, and in mountains and hills that are ecologically vulnerable (Conway 1997). These areas are remote from services and roads and agricultural productivity is often low on a crop-by-crop basis, although total farm output can be significant. Such resource-poor farmers and their complex systems pose special research challenges and demand appropriate technologies (Netting 1993).

In Latin America, peasant production units reached about 16 million in the late 1980s occupying close to 60.5 million hectares, or 34.5% of the total cultivated land, which reaches about 175 million hectares (DeGrandi 1996). The peasant population includes 75 million people representing almost two-thirds of the Latin America's total rural population (Ortega 1986). Average farm size of these units is about 1.8 hectares, although the contribution of peasant agriculture to the general food supply in the region is significant. In the 1980s, it reached approximately 41% of the agricultural output for domestic consumption, and is responsible for producing at the regional level 51% of the maize, 77% of the beans, and 61% of the potatoes.

In Brazil alone, there are about 4.8 million family farmers (about 85% of the total number of farmers) that occupy 30% of the total agricultural land of the country. Such family farms control about 33% of the area sown to maize, 61% of that under beans, and 64% of that planted to cassava, thus producing 84% of the total cassava and 67% of all beans (Veiga 1991). In Ecuador, the peasant sector occupies more than 50% of the area devoted to food crops such as maize, beans, barley and okra. In Mexico, peasants occupy at least 70% of the area assigned to maize and 60% of the area under beans (Ortega 1986; DeGrandi 1996).

In addition to the peasant and family farm sector, there are about 50 million individuals belonging to some 700 different ethnic indigenous groups who live and utilize the humid tropical regions of the world. About two million of these live in the Amazon and southern Mexico. In Mexico, half of the humid tropics is utilized by indigenous communities and "ejidos" featuring integrated agriculture-forestry systems with production aimed at subsistence and local-regional markets (Toledo 2000).

In Africa, the majority of farmers (many of them women) are smallholders with 2/3 of all farms below 2 hectares and 90% of farms below 10 hectares. Most small farmers practice "low-resource" agriculture based primarily on the use of local resources, but that may make modest use of external inputs. Low-resource agriculture produces the majority of grain; almost all root, tuber and plantain crops, and the majority of legumes. Most basic food crops are grown by small farmers with virtually no or little use of fertilizers and improved seed (OTA 1988). This situation however has changed in the last two decades as food production per capita has declined and Africa, once self-sufficient in cereals, now has to import millions of tons to fill the gap (Harrison 1996). Despite this increase in imports, small farmers still produce most of Africa's food (Benneh 1996).

The majority of more than 200 million rice farmers who live in Asia, a few farm more than 2 ha of rice. In China alone there are probably 75 million rice farmers who still practice farming methods similar to those used more than one thousand years ago (Greenland 1947). Local cultivars, grown mostly on upland ecosystems and/or under rainfed conditions make up the bulk of the rice produced by Asian small farmers.

Table 2 depicts the millions of peasants, family farmers and indigenous people practicing resource-conserving farming throughout the developing world and their contribution to food security. Many of the peasants are located in areas characterized by GIAHS. The location and biodiversity features of GIAHS reflect often rich and sometimes unique agricultural biodiversity, within and between species but also at ecosystem and landscape level. Having been founded on ancient agricultural civilizations, certain of these systems are linked to important centers of origin and genetic diversity (Table 3) of domesticated plant and animal species, the conservation of which is of great global value.

GIAHS are found throughout the developing world, linked to centers of diversity. Some of these systems include (see also more detailed descriptions starting in page 9):

- Outstanding terraced mountain sides with rice and complex agro-ecosystems in Asia, such as the Cordillera Mountain Range, Philippines; biodiverse systems in the Himalayas and Andes; and Mediterranean fruit gardens.
- Complex agro-silvo-pastoral and aquatic systems and diverse tropical/subtropical home gardens, producing multiple foods, medicines, ornamentals and materials, e.g. East Kalimantan and Butitingui, Indonesia; highlands of Rwanda and Uganda; Titicaca in Peru; Kayapo in Brazil.
- Traditional soil and water management systems for agriculture, including ancient water distribution systems allowing specialized and diverse cropping systems in Iran; traditional valley bottom and wetland food management e.g. Lake Chad, Niger river basin and interior delta.
- Specialized dryland systems, including outstanding range/pastoral systems for the management of grasses, forage, water resources and adapted indigenous animal races e.g. Maasai in East Africa; pastoral systems of Ladakh, Tibet, parts of India, Mongolia and Yemen, as well as oases in deserts of North Africa and Sahara and ingenious systems in pays Dogon, Mali and pays Diola, Senegal.

**Biodiversity features of GIAHS**

One of the salient features of GIAHS is their high degree of biodiversity. Such systems support a high degree of plant diversity in the form of polycultures and/or agroforestry patterns (Chang 1977; Clawson 1985). This strategy of minimizing risk by planting several species and varieties of crops stabilizes yields over the long term, promotes diet diversity and maximizes returns even with low levels of technology and limited resources (Harwood 1979). Such biodiverse farms are endowed with nutrient-enriching plants, insect predators, pollinators, nitrogen-fixing and nitrogen-decomposing bacteria, and a variety of other organisms that perform various beneficial ecological functions.

Many GIAHS, such as the traditional multiple-cropping systems, provide as much as 15-20 percent of the world food supply (Francis 1986). Polycultures constitute at least 80 percent of the cultivated area in West Africa and predominate in other parts of Africa as well (Norman 1979). At the same time, much of the production of staple crops in the Latin American tropics occurs in polycultures. More than 40 percent of the cassava, 60 percent of the maize, and 80 percent of the beans in the region grow in mixtures with each other or other crops (Francis 1986). Polycultures are also very common in parts of Asia where upland rice, sorghum, millet, maize, and irrigated wheat are the staple crops. Lowland (flooded) rice is generally grown as a monoculture, but in some areas of Southeast Asia, farmers build raised beds to produce dryland crops amid strips of rice (Beets 1982).

Tropical agroecosystems composed of agricultural and fallow fields, complex home gardens, and agroforestry plots commonly contain well over 100 plant species per field, and these are used as construction material, firewood, tools, medicines, livestock feed, and human food. Examples include multiple-use agroforestry systems managed by the Huastecs and Lacondones in Mexico, the Bora and Kayapo Indians in the Amazon River basin, and many other ethnic groups who incorporate trees into their production systems (Wilken 1977).

In the Latin American tropics, home gardens are a highly efficient form of land use, incorporating a variety of crops with different growth habits. The result is a structure similar to that of tropical forests, with diverse species and a layered physical configuration (Denevan et al. 1984). In Mexico, for example, Huastec Indians manage a number of fields, gardens, and forest plots that may harbor a total of about 300 species. Small areas around their houses commonly average 80-125 useful plant species, mostly native and medicinal plants. Huastec management of the non-crop vegetation in these complex farm systems has influenced the evolution of individual plants and the distribution and composition of the crop and non-crop communities.

Because most traditional agroecosystems are located in centers of crop diversity, they contain populations of variable and adapted landraces as well as wild and weedy relatives of crops (Harlan 1976). Clawson (1985) described several systems in which tropical farmers plant multiple varieties of each crop; this practice supports both intraspecific and interspecific diversity, and also enhances harvest security. For example, in the Andes, farmers cultivate as many as 50 potato varieties in their fields (Brush 1982). Similarly, in Thailand and Indonesia, farmers maintain a diversity of rice varieties adapted to a wide range of environmental conditions, and they regularly exchange seeds with each other (Grigg 1974). The resulting genetic diversity heightens resistance to diseases that attack particular strains of the crop and enables farmers to exploit different microclimates and to derive multiple nutritional and other uses from the genetic variation among the species.

Many plants within or around traditional cropping systems are wild or weedy relatives of crop plants. In fact, many farmers "sponsor" certain weeds in or around their fields that my have positive effects on soil and crops, or that serve as food, medicines, ceremonial items, teas, soil improvers, or pest repellents. In the Mexican Sierras, the Tarahumara

Indians depend on edible weed seedlings or "quelites" (e.g. *Amaranthus, Chenopodium, Brassica*) in the early season from April through July, a critical period before crops mature from August through October. Weeds also serve as alternative food supplies in seasons when maize or other crops are destroyed by frequent hail storms (Bye 81). In barley fields, it is common for Tlaxcalan farmers to maintain *Solanum mozinianum* at levels up to 4500 plants/ha; this yields about 1300 kg of fruit, a significant contribution to agricultural subsistence (Altieri and Trujillo 1987).

Farmers also derive other benefits from weeds, such as increased gene flow between crops and their relatives. In Mexico, when the wind pollinates maize, natural crosses occur with wild teosinte growing in the field borders, resulting in hybrid plants. Certain weeds are used directly to enhance the biological control of insect pests, as many flowering weeds attract predators and parasites of pests to their pollen and nectar. Other farmers allow weeds such as goosegrass (*Eleusine indica*) in bean fields to repel *Empoasca* leafhoppers, or wild *Lupinus* as a trap plant for the pestiferous scarab beetle (*Macrodactylus* sp.), which otherwise would attack corn (Altieri 1993).

However, diversity is maintained not only within a cultivated area. Many farmers maintain natural vegetation adjacent to their fields, and thus obtain a significant portion of their subsistence requirements through gathering, fishing, and hunting in habitats that surround their agricultural plots. For the P'urhepecha Indians who live around Lake Patzcuaro in Mexico, gathering is part of a complex subsistence pattern that is based on multiple uses of their natural resources. These people use at least 224 species of native and naturalized vascular plants for dietary, medicinal, household, and fuel needs (Caballero and Mapes 1985).

Depending on the level of biodiversity of closely adjacent ecosystems, farmers accrue a variety of ecological services from surrounding natural vegetation. For example, in western Guatemala, the indigenous flora of the higher-elevation forests provide valuable native plants that serve as a source of organic matte to fertilizer marginal soils, for each year farmers collect leaf litter from nearby forests and spread it over intensively cropped vegetable plots to improve tilth and water retention. Some farmers may apply as much as 40 metric tons of litter per hectare each year; rough calculations indicate that a hectare of cropped land requires the litter production of 10 ha of regularly harvested forest (Wilken 1977).

Clearly, traditional agricultural production commonly encompasses the multiple uses of both natural and artificial ecosystems, where crop production plots and adjacent habitats are often integrated into a single agroecosystem.

**Ecological mechanisms underlying the productivity and sustainability of GIAHS**

In many areas, traditional farmers have developed and/or inherited complex farming systems, adapted to the local conditions helping them to sustainably manage harsh environments and to meet their subsistence needs, without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science (Altieri, 1995). Indigenous farmers tend to combine various production systems as part of a typical household resource management scheme. Much research on the features of these systems suggests that a series of factors and characteristics underlie the sustainability of multiple use systems:

1. Farms are small in size with a continuous production serving subsistence and market demands;
2. Diversified farm systems based on several cropping systems, featuring mixtures of crops, trees, and/or animals with varietal and other genetic variability.
3. Maximum and effective use of local resources and low dependence on off-farm inputs;
4. High net energy yield because energy inputs are relatively low;
5. Labour is skilled and complementary, drawn largely from the household or community relations. Dependency on animal traction and manual labour shows favourable energy input/output ratios;
6. Heavy emphasis on recycling of nutrients and materials;
7. Building on natural ecological processes (e.g. succession) rather than struggling against them.

A number of ecological interaction and ecosystem properties emerge from such diversified crop spatial/temporal arrangements which in turn determine ecosystem function. By interplanting, farmers achieve several production and conservation objectives simultaneously. With crop mixtures, farmers can take advantage of the ability of cropping systems to reuse their own stored nutrients and the tendency of certain crops to enrich the soil with organic matter (Francis 1986). In "forest like" agricultural systems cycles are tight and closed. In many tropical agroforestry systems such as the traditional coffee under shade trees (*Inga* sp., *Erythrina* sp., etc.) total nitrogen inputs from shade tree leaves, litter and symbiotic fixation can be well over ten times higher than the net nitrogen output by harvest which usually averages 20 kg/ha/year. In other words, the system amply compensates the nitrogen loss by harvest with a subsidy from the shade trees. In highly co-evolved systems, researchers have found evidence of synchrony between the peaks of nitrogen transfer to the soil by decomposing litter and the periods of high nitrogen demand by flowering and fruiting coffee plans (Nair 1984).

Crops grown simultaneously enhance the abundance of predators and parasites, which in turn prevent the build-up of pests, thus minimizing the need to use expensive and dangerous chemical insecticides. For example, in the tropical lowlands, corn-bean-squash polycultures suffer less attack by caterpillars, leafhoppers, thrips, etc., than corresponding monocultures, because such systems harbor greater numbers of parasitic wasps. The plant diversity also provides alternative havitat and food sources such as pollen, nectar, and alternative hosts to predators and parasites. In Tabasco, Mexico, it was found that eggs and larvae of the lepidopteran pest *Diaphania hyalinata* exhibited a 69 percent parasitation rate in the polycultures as opposed to only 29 percent rate in monocultures. Similarly, in the Cauca valley of Colombia, larvae of *Spodoptera frugiperda* suffered greater parasitization and predation in the corn-bean mixtures by a series of Hymenopteran wasps and predacious beetles than in corn monocultures (Altieri 1994).

This mixing of crop species can also delay the onset of diseases by reducing the spread of disease carrying spores, and by modifying environmental conditions so that they are less favorable to the spread of certain pathogens. In general, the peasant farmers of traditional agriculture are less vulnerable to catastrophic loss because they grow a wide variety of cultivars. Many of these plants are landraces grown from seed passed down from generation to generation and selected over the years to produce desired production characteristics. Landraces are genetically more heterogeneous than modern cultivars and can offer a variety of defenses against vulnerability (Thurston 1991).

Integration of animals (cattle, swine, poultry) into farming systems in addition to providing milk, meat, and draft adds another tropic level to the system, making it even more complex. Animals are fed crop residues and weeds with little negative impact on crop productivity. This serves to turn otherwise unusable biomass into animal protein. Animals recycle the nutrient content of plants, transforming them into manure. The need for animal fed also broadens the crop base to include plant species useful for conserving soil and water. Legumes are often planted to provide quality forage but also serve to improve nitrogen content of soils (Beets 1990).

**Specific examples of GIAHS around the world**

**Latin America**

Chinampas of Mexico

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 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 levels 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 with 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 as well as vegetables. This includes the traditional corn/bean/squash polyculture, cassava/ corn/bean/peppers/amaranth, the fruit trees associated with various cover crops, shrubs, or vines. Farmers also encourage the growth of fish in the water courses.

The high levels of productivity that characterize the chinampas result from several factors. First, cropping is nearly continuous; only rarely is the chinampa left without a crop. As a result, 3 to 4 crops are produced each year. One of the primary mechanisms by which this intensity is maintained are the seedbeds, in which young plants are germinated before the older crops are harvested. Second, the chinampa maintain a high level of soil fertility despite the continual harvest of crops because they are supplied with high quantities of organic fertilizers. The lakes themselves serve as giant catch basins for nutrients. The aquatic plants function as nutrient concentrators, absorbing nutrients that occur in low concentration in the water and storing them inside their tissue. The use of these plants along with canal mud and muddy water (for irrigation) insures that an adequate supply of nutrients is always available to the growing crops. Third, there is plenty of water for the growing crop. The narrowness of the chinampas is a design feature that ensures that water from the canal infiltrates the chinampa, giving rise to a zone of moisture within reach of the crop's roots. Even if during the dry season the lake levels fall below the rooting zone, the narrowness of the chinampa allows the chinampero to irrigate from a canoe. Fourth, there is a large amount of individual care given to each plant in the chinampa. Such careful husbandry facilitates high yields (Gliessman et al. 1981).

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*0, legumes 9beans, 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 Andean inhabitants recognize three to seven agroclimatic belts, distinguished according to altitude, moisture, temperature, vegetation, land tenure, crop assemblages, and agricultural technology. This 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;
3. and 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 about 3,800 meters. Rainfed rotations in this belt usually include a four-to-five-year rotation, after a 4-year sequence of potato/*Oyxalis tuberosa*/*Ullucus tuberosus* and *Trapaeolum tuberosum*/barley.

*Waru-Warus of Titicaca*

Researchers have uncovered remnants of more than 170,000 ha of 'ridged fields' in Surinam, Venezuela, Colombia, Ecuador, Peru, and Bolivia (Denevan 1995). Many of these systems apparently consisted of raised fields on seasonally-flooded lands in savannas and in highland basins. In Peru, many researchers have studied such pre-Columbian technologies in search of solutions to contemporary problems of high altitude farming. A fascinating example is the revival of an ingenious system of raised fields that evolved on the high plains of the Peruvian Andes about 3,000 yr ago. According to archaeological evidenc these Waru-Warus platforms of soil surrounded by ditches filled with water, were able to produce bumper crops, despite floods, droughts, and the killing frost common at altitudes of nearly 4000 m (Erickson and Chandler 1989).

The combination of raised beds and canals has proven to have important temperature moderation effects, extending the growing season and leading to higher productivity on the Waru-Warus compared to chemically fertilized normal pampa soils. In the Huatta district, reconstructed raised fields produced impressive harvest, exhibiting a sustained potato yield of 8-14 tonnes/ha/yr. These figures contrast favourably with the average puno potato yields of 1-4 tonnes/ha/yr. In Camjata the potato fields reached 13 tonnes/ha/yr in Waru-Warus. It is estimated that the initial construction, rebuilding every 10 years, and annual planting, weeding, harvest and maintenance of raised fields planted requires 270 persons-days/ha/yr.

*Home gardens of Mexico and Belize*

Kitchen gardens are important agroecological systems in many cultural landscapes in the tropics and subtropics. According to Gomez-Pompa and Kaus (1990), kitchen gardens (also known as home gardens, dooryard gardens, or *huertos familiares*) are the second most important agroecological feature among traditional tropical societies after swidden cultivation. They provide subsistence and cash income and offer a repository and domestication experimentation site for many plant varieties (Kimber 1973; Landauer and Brazil 1990). Yet, compared to other forms of tropical agriculture, the research conducted on kitchen gardens is scant, especially regarding their ecological importance (Gomez-Pompa and Kaus 1990).

Mixed tree systems or home gardens are 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. The home garden is representative of a household's needs and interests, providing food, fodder, firewood, market products, construction materials, 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 households 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).

The Mopan Maya of southern Belize have kitchen gardens that are multi-storied and contain a mixture of minor crops, fruits, ornamental, and medicinal plants. Like coffee plantation with an overstory canopy, shrub, and canopy layers. Mopan Mayan kitchen contain dozens of tree species, shrubs, and herb species, so they are more diverse than coffee plantations, in which the overstory layer usually contains just a few species. Trees are usually the most important component of Mopan Mayan kitchen gardens, usually containing 35-40 species. Fruit trees are the most common in the kitchen gardens, with timber and ornamental trees making up a smaller percentage. A dominant group of trees in most gardens include the coconut palm (*Cocos nucifera*), papaya (*Carica papaya*), mango (*Mangifera indica*), orange (*Citrus sinsenis*), cacao (*Theobroma cacao*), avocado (*Persea americana*), custard apple (*Annona reticulata*), calabash (*Crescentia cuiete*), mammee apple (*Mammea americana*), breadfruit (*Artocarpus altilis*), coffee (*Coffea arabica*), and several palm species in both the canopy and shrub layer. Palms often provide fruit during times of the year when other trees are barren.

*Coffee systems of Mexico and Central America*

In Mesoamerica, coffee is cultivated on the coastal slopes of the central and southern parts of the region in areas where two or more types of vegetation make contact. Based on management level and vegetational and structural complexity, it is possible to distinguish five main coffee production systems in Mexico: two kinds of traditional shaded agroforests (with native trees), one commercially oriented polyspecific shaded system, and two "modern" systems (shaded and unshaded monocultures). Traditional shaded coffee is cultivated principally by small-scale, community-based growers, most of whom belong to some indigenous culture group. Traditional shaded coffee plantations are important repositories of biological richness for groups such as trees and epiphytes, mammals, birds, reptiles, amphibians, and arthropods. In Mexico, coffee fields are located in a biogeographically and ecologically strategic elevational belt that is an area of overlap between the tropical and temperate elements and of contact among the four main types of Mexican forests. Betewen 60% and 70% of these coffee areas are under traditional management and many coffee regions have been selected by experts as having high numbers of species and endemics overlap with or are near traditional coffee-growing areas. Regretably, original levels of biodiversity are being lost as coffee systems convert into modern coffee plantations.

As with other major ecosystem transformations in tropical latitudes, the transformation of the coffee agroecosystem involves spectacular landscape changes. In the "modern" monocultural system that is being promoted all over the world, all the shade trees are eliminated, the traditional coffee varieties are replaced by new sun-tolerant and shorter varieties, which are genetically homongeneous and pruned either by row or by plot, and are heavily dependent on agrochemicals, especially herbicides and fertilizers.

*Agroforestry in tropical South America*

In South America plant associations that resemble the contemporary and purposefully pursued agroforestry alternative have been in use since pre-Hispanic times by the Amerindians, and even the agricultural techniques employed by the Amazon basin Indians today qualify as agroforestry systems.

The agroforsetry systems that function in the humid Amazonian lowlands are largely based on the mixing of tree species with assured cash value for their wood or their products (rubber in the case of *Hevea brasilensis*) or by the association of shade trees of potential timber value with tree crops such as cacao, pepper or coffee. Particularly convenient is the combination of cacao with *Erythrina*, a legume that provides much of the nitrogen demanded by the cacao trees, and the use of *Cordia alliodora* as a shade tree with good returns as a timber species. Pepper, which tolerates a maximum of 20 percent shading, can be grown under *Erythrina* and *Gliricidia* trees that are easily pruned and provide additional income from their wood. Coffee has been traditionally associated with *Erythrina* and *Gliricidia* (Hecht 1982).

Agroforestry systems in the non-Brazilian segments of the South American tropical lowlands have also developed locally, although less elaborate and diverse. On the margins of the Amazon River, close to Iquitos, Peruvian Amazonia, different vegetal species have been grown in associations. Umari (*Paragueiba sericea*), uvilla (*Pourouma cecropiaefolia*) and Brazil nuts are grown for their fruits, and their wood is used for charcoal. In the shade of *Bactric gasipaes, Inga edulis* or cashew, food staples such as manioc, plantains, and rice are cultivated. It is also common to find papaya, pineapple and passion fruit in the shade of Amazonian palms (Padoch et al. 1985). Multi-strata mixtures of perennial species, such as forage legumes (*Desmodium ovalifolium*) at ground level and *Canna edulis*, whose roots are eaten by hogs, form the basis for hog farming in Ecuador's Oriente (Bishop 1982).

Away from the humid and warm environment of Amazonia, in South-east Bahia, better results in agroforestry strategies are achieved – in combinations of cacao with rubber trees, clove with pepper, cacao with clove in the wake of decayed pepper plants (Alvim and Nair 1986). In the drier environment of north-eastern Brazil, cultivation of perennial crops such as cashew, coconut, babassu palm (*Orbignya phalerata*), and the carnauba wax palm (*Copernicia prunifera*) in combination with natural pastures to which some herbaceous foreign species have been added, provide good grazing for sustainable silvopastoral systems (cattle, sheep and donkeys). In grazing areas the babassu palm provides shade for the cattle, while in agriculturally oriented places, it serves as shade for rice, maize, cassava and even bananas and plantains (May et al. 1985). The cashew tree provides shelter for other productive crops such as sorghum, groundnuts and sesame (Johnson and Nair 1985).

## Asia

### 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). Farmers 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 nutrient 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* contain *Axolla* spp. (a symbiotic association of the blue-green alga and fern), which promotes the fixation of nitrogen—adding up to 50 kg per hectare of nitrogen.

*Agroforestry in Southeast Asia*

According to Adeyoju (1982), agroforestry in Southeast Asia has been practiced for over a century under different conditions and in various locations. Cultivation of Sago palms and sago production practiced in supplemented stands similar to the natural forest have been a traditional form of land use in Malaysia for thousands of years (Bruenig 1984). The successful use of tree species and food staples or cash crops has been common in Sri Lanka since the nineteenth century and it is thought that the Sri Lankan Kandy gardens are the best examples of that farming system's potential for the humic tropics (Watson 1982). Kandy gardens refer to small farms based on a close association of coconut, kitul and betel palms with cloves, cinnamon, nutmeg, citrus, mango, durian, jackfruit, rambutan and breadfruit, with a lower story of bananas and pepper vines, and a peripheral ground story of maize, cassava, beans, pineapples and other, often supplemented by an outside field of paddy rice (McConnell and Dharmapala 1978).

In Indonesia, manioc, pepper and benzoin are grown under the canopy provided by coconut palms and plantains. In most parts of Sumatra, today more than half of the farming area is planted with tree and bush cultures, where rubber, coffee and spices such as cloves, cinnamon and pepper, prevail as cash crops. Tree and bush cultures in combination with fields of paddy rice dominate Sumatra's agrarian landscape today.

In West Java the Talun-kebun is an indigenous Sundanese agricultural system that appears to have derived from shifting cultivation. It usually consists of three stage—*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 harvesting 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 material and fuelwood, 18 percent are fruit trees, 14 percent are vegetables, and the remainder constitute ornamentals, medicinal plants, spices, and cash crops.

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*), guaga, 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 caloric content and are important as rice substitutes.

The *taungya* system of Southeast Asia is considered as one of the most successful agroforestry systems. Among the most common agroforestry products of Southeast Asia are the association of commercial timber (particularly teak) or tree crops such as tea, cocoa, bananas, breadfruit, mangoes or kitul with groundnuts, pepper, maize, manioc or pineapples

*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, thepond 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 planed 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 intergrated farm. Thus aquaculture and water management act as an engine driving the sustainability of the entire farming system (Lightfoot 1990).

**African traditional agriculture**

African traditional food production systems

African farmers have over centuries developed farming systems that have adequately responded to the challenges posed by their physical and socio-cultural environments. In the past these systems have been sustainable, providing adequate food to feed the population without causing much damage to the natural resource base. Most food production across Africa is by low-resource agriculture. Low-resource agriculture produces the majority of grain, except wheat and perhaps maize. Almost all root, tuber, and plantain crops, and the majority of food legumes are produced on low-resource farms. In addition, a great variety of secondary crops such as fruits and vegetable are grown under low-resource conditions to supplement these staples.

An estimated 75 percent of all livestock in Sub-Saharan Africa is raised on farms where crop production is the principle source of subsistence, and livestock are an important source of cash income. Many of these livestock receive little supplementary feed or health care and their production can be considered "low input." The major food farming systems include shifting cultivation, the bush fallow system or land rotation, the planted fallow system, compound or homestead farming, terrace farming, flood land cultivation, and transhumance pastoralism. Table 5 summarizes major characteristics of each system and indicates the driving forces undermining its stability.

By far the most important system of farming is the bush fallow system, which is widely practiced in all ecological regions of Sub-Saharan Africa. Although no distinction is usually made between shifting cultivation and bush fallow, the latter is a more intensive system. It involves rotation of land within fixed farmland, whereas shifting cultivation in its original form was characterized by movement of cultivators from one site to another in search of virgin land without making a conscious attempt to return to former cultivated sites.

The bush fallow system is an extensive system of food crop production in which natural forest, secondary forest, or open woodlands are cleared and burnt. This system is often called slash-and-burn agriculture. Farmers carefully select sites for cultivation using indicator plants as guides, judging the luxuriance of plant growth and the volume of vegetable material that will produce the best chemical-yielding ash when burnt. Temporary clearings are cultivated until crop yields begin to decline, usually after two or three cropping seasons when the soil fertility begins to fall. Then the land is abandoned to return to forest or bush fallow for a period ranging from 4 to 20 years. During the fallow period, conditions such as low soil fertility, weeds, or pest outbreaks are overcome (Sanchez 1976). The system depends on natural capital with no external inputs. The farm implements are simple: hoe, machete, ax, and dibble stick.

Today, as a result of increased population pressure, fallow periods are being reduced. Where fallow period are too short—less than two years—soil fertility deteriorates and crop yields decline. Between 1980 and 1985, nearly half of the 40 Sub-Saharan countries for which data exist recorded declines in yield growth rates for major cereal crops ranging from –0.5 percent to –16.9 percent (World Bank 1996a). Declines in crop yields force farmers to clear more forests and woodlands, including fragile and marginal lands where soil and climatic conditions are poorly suited to the cultivation of annual crops and yields are therefore low. Thus, much of the increased agricultural production in Sub-Saharan Africa has been achieved through expansion in cultivated area. According to the FAO, Africa's arable land expanded by 14 million hectares between 1973 and 1988. Most countries reflected this general experience. Between 1965 and 1985 untouched primary forests in Cote d'Ivoire were reduced by about 66 percent, whereas the area under cultivation doubled (Uhui 1993). The cultivated area in northern Nigeria increased from about 11 percent of the total area in the mid-1950s to 34 percent in 1990 (Mortimore 1995). There are a number of reasons why agricultural expansion on this scale cannot be sustained.

Traditional Marka systems in the Sahel

The climate in the Sahel region of Africa, made up in part by what is now Mali and Niger, is very dry. Average rainfall is less than 600 mm per year. As a result, the welfare of the Marka, a local ethnic group who are experts in the cultivation of rice, is highly influenced by climatic fluctuations. They have been cultivating native rice since prehistoric times, and they make complex and sophisticated decisions about when to plant and what varieties to plant (McIntosh 1993). Their decisions are influenced by environmental clues—different varieties of rice have different vegetative periods, different adaptations to various flood depths, flood timing, pH tolerance, and fish predation. Different varieties are sown at different time intervals on different soil types.

The knowledge that the Marka possess about rice and its cultivation is secret and has been developed over a long period of time. It is a means of maintaining a specific ethnic identity. Social relations with other groups have become instituted as buffering mechanisms against potential bad times, allowing trade to occur without the necessity of immediate equal compensation. This buffering is useful, for example, with the Bozo fishers who trade labor, goods, and services because weather that favors one group may disfavor the other.

Another important aspect of the Marka system is prioritized tenure on property held in common with the entire ethnic group. A hierarchical system prioritizes access to land, and the rules regulating access to common property have been encoded into local Islamic law. Prioritized access ensures that those with the specialized knowledge are those that make decisions on varieties of rice to be planted, as well as the timing of the planting (Park 1992).

Agroforestry in tropical Africa

In Africa, regional differentiations are reflected in the combinations of trees and agricultural crops that prevail in particular landscapes. In the populated humid tropical belt of western Africa, particularly on the northern edge of the Gulf of Guinea where the density rises above 80 inhabitants per square kilometer, agroforestry is practiced at the edge of the natural evergreen forests. The cultivators grow food staples such as manioc, yam, maize and plantains, in combination with cacao, bananas, coffee or oil-palm. In terms of both area covered and population involved, southern Nigeria is the heart of agroforestry in the Gulf of Guinea states. Ball and Umeh (1982) estimate that 9269 ha and 17,744 cultivators were involved in agroforestry in 1979. Southeast Nigeria, spreading over an area of evergreen forests on ferrallitic soils and ferrisols, tends to combine productive trees, such as banana, cacao and oil-palms, with food staples and pastures, whereas western Nigeria (with slightly lower precipitation rates and less population density) specializes in exportable timber species (teak), mixed with cacao, bananas or oil-palm.

'Managed *taungya*' makes intensive use of certain tree species for protection against wind or excessive insolation, such as *Gmelina arborea*, one of the most utilized trees in African agroforestry or *Terminalia superba* and *Albizzia spp.* Other species, such as the woody legume *Leucaena leucocephala* and *Gliricidia sepium*, help restore fertility to the soil. *Gmelina arborea* appears to be beneficial when planted at particularly convenient interspaces with yams and maize, but not in combination with manioc (Agbede and Ojo 1982). *Gliricidia* increases the content of sodium, potassium, calcium and manganese in the soil. Concurrently, a measurable decrease in soil acidity has been observed when *Gliricidia* is associated with maize, yams, vegetables and manioc for subsistence purposes (Agboola et al. 1982).

In the more semi-arid regions of Africa such as Senegal and the Zinder region of Niger highly productive agrosilvopastoral systems based on the use of *Acacia albida* have continued to evolve. This tree species has several characteristics that are valuable in agricultural systems. For instance, at the onset of the rainy season the species drops its leaves. These leaves provide a leaf litter mulch that enriches the topsoil. During this wet season, which is when sorghum and millet are produced, the defoliated canopy permits enough light to reach the ground for cereal growth and provides enough shading to reduce the effects of intense heat. During the dry season, the *Acacia's* long taproot draws nutrients from beyond the reach of other plants and stores these in its fruits and leaves. These drop to the ground at the beginning of the next rainy season and are consumed by livestock. Because the fodder has more nutritive value per unit weight than many other fodder crops, more livestock can be supported than without the *Acacia*. In addition, the livestock manure helps enrich the soil further. Thus, crop yields are greater when an *Acacia* is in a field than when it is not.

Using the tree with a proper balance of crop and livestock can also considerably extend the length of cropping without loss of productivity. For example, using the *Acacia* helped maintain continuous cropping of millet in the Sudan for 15-20 years in areas where the norm was 3 to 5 years.

**Animal integration**

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).

**Mediterranean systems**

The dehesa system of southern Spain and Portugal

A very peculiar agroforestry system, named dehesa in Spain and montado in Portugal, dominates the landscape of southwestern Iberian Peninsula (Joffre et al. 1988b; San Miguel 1994; Gomez Guttierez and Perez Fernandez 1996). Characterized by the presence of a savannah-like open tree layer, mainly dominated by Mediterranean evergreen oaks – holm oak (*Quercus ilex*) and cork oak (*Q. suber*) – and to a lesser extent by the deciduous *Q.pyrenaica* and *Q. faginea*, they occupy more than 5,800,000 ha in the western and south-western provinces of Spain, representing 52% of total utilized agrarian area within these province (Campos Palacin 1992) and more than 500,00 ha in southern Portugal.

*Dehesas* are an agrosilvopastoral system that has enhanced the maintenance of an extraordinarily high biodiversity. The traditional use is characterized by mixed livestock raising at low stocking densities, employment of hardy regional breeds and an elaborated maintenance and exploitation of holm oaks. Livestock production has traditionally been accompanied by arable systems with long rotations and closed nutrient cycles without external inputs of fodder, fertilizer and agro-chemicals. Modern trends threatening these systems are a specialization toward lamb and beef production and the employment of intensive techniques like free-range grazing at high stocking levels or crossbreeding with high-performance breeds.

*The agroforests of the vinho verde region of Portugal*

The agricultural landscape of Northwestern Portugal is characterized by a pattern of small, fragmented farms that produce mainly for family consumption, interspersed with somewhat larger and more mechanized farms that specialize in commercial crops.

At least since the ninth century, Portuguese peasants have developed complex farming systems, the sustainability of which has stood the test of time. These traditional agroecosystems, which consist of crop polycultures surrounded by vines (*Vitis vinifera*) upon tree-hosts, reflect the priorities of peasant farmers, meeting the needs of a simple, largely self-sufficient peasant society. These vineyard-based agroforestry systems are found mainly in the designated regions of 'Vinho verde' including Minho and a portion of northern Beira Litoral (Stanislawski 1970).

Vinho verde grapes traditionally are grown on trees bordering crop fields. The combination of high vine and maize is characteristic of the area. There are a number of traditional agroforestry patterns, all of which represent an ingenious response to land constraints by allowing vertical agriculture (Stanislawski 1970):

1. Association of vines and trees dispersed within fields. This simple system consists of a tree with 4-8 vines planted around the base. The vines ascend and follow the branches.
2. The 'festoon' system where younger cross-branches of the vines join together every year from the nearest trees planted along field margins.
3. The 'arjoado' system is a form of festoon, but with vertical wires attached to the wire that runs between the trees. In addition to planting vines against the tree trunks, several vines can be planted in the intervening area.
4. In the 'ramada' system, grapes are grown on elevated arbors (about three meters high and four meters wide) supported by stone columns with iron crossbars connected to steel wires.

In systems a-c, preferred host trees are Portuguese Oak (*Quercus lusitanica*), elm (*Ulmus* sp.), poplar (*Populus* sp.), and wild cherry (*Prunus* sp.). The trees tolerate heavy trimming, have deep roots, grow fast and are long lived. Most yield products such as wood, bark, and fruits. Many trees provide additional benefits such as altering the microclimate (interception of winds and lower evaporation rates) and protecting vines from winter frosts of the valley bottom. Trees can also reduce dispersion of weed seeds, insects, and pathogen inocula by forming a physical barrier.

The centers of the fields are available for grain (mostly maize, *Zea mays*), legumes, and vegetables. Normal crop rotations include oat grain (*Holcus lanatus*), rye grain (*Lolium multiflorum*) and the legumes *Ornithopus sativa* and *Trifolium incarnatum*, all used as fodder. Some fields are left fallow for the growth of volunteer legumes, (mostly species of *Ulex* and *Spartium*) used fro 'cattle beds' in the stalls. After semi-decomposed materials fo the beds are worked into the soil of the farms as organic amendment.

**Common features of GIAHS**

Many of the above described traditional agroecosystems considered GIAHS are small-scale, geographically discontinuous, located on a multitude of different slopes, microclimates, elevational zones, soil types, surrounded by many different vegetation associations. The combinations of diverse physical factors are numerous and are reflected in the diverse cropping patterns chosen by farmers to exploit site-specific characteristics. Many of the systems are surrounded by physical barriers (i.e. forest, river, mountain, etc.) and therefore are relatively isolated from other areas where the same crops are grown in large scale. Small farmers living in GIAHS dominated areas are more likely to plant various crops on the same field, plant multiple times during the year, and integrate crops, livestock, and even aquaculture, making more intensive use of space and time.

Most GIAHS 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 hortizontal 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 level of 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 non-economic factors on decision-making is substantial.

Perhaps the most striking commonality among such systems includes:

1. the ecosystem resilience and robustness that has been developed and adapted to cope with change (human and physical) so as to ensure food and livelihood security and alleviate risk and
2. the human management strategies and processes that allow the maintenance of biodiversity and essential ecosystem services (water

recharge and quality, nutrient recycling, soil conservation, pest control, etc.).

**The landscape ecology of GIAHS**

In peasant-dominated areas, the use of traditional farming practices with minimal industrial inputs has resulted in a varied, highly heterogeneous landscape—possibly even more heterogeneous than would exist naturally. In such heterogeneous environments, natural and semi-natural ecosystem patches included in the landscape can become a resource for agroecosystems.

Most of the above studies of traditional agriculture have focused on the productive units where crops are grown, ignoring the fact that many peasants utilize, maintain, and preserve, within or adjacent to their properties, areas of natural ecosystems (forests, hillsides, lakes, grasslands, streamways, swamps, etc.) that contribute valuable food supplements, construction material, medicines, organic fertilizers, fuels, religious items, etc. (Toledo et al. 1985). In fact, the crop production units and adjacent ecosystems constitute a continuum where plant gathering, fishing, and crop production are actively undertaken. For many peasant societies agriculture is considered a part of a bigger system of land use. For example, the P'urhepecha Indians who live in the region of lake Patzcuaro in Michoacan, Mexico, in addition to agriculture, include gathering a part of their complex subsistence pattern based on multiple uses of their natural resources (Caballero and Mapes 1985). These people use more than 224 species of wild native and naturalized vascular plants for dietary, medicinal, household, and fuel needs.

Agriculture-natural ecosystem interfaces are of key significance, and it has been shown that farmers accrue general ecological services from natural vegetation growing near their properties. An area of non-crop habitat adjacent to a crop field, for example, can harbour populations of natural enemies, which can move into the field and parasitize or prey upon pest populations (Altieri 1994). A riparian corridor vegetated by native plant species can filter out dissolved fertilizer nutrients leaching from crop fields, promote the presence of beneficial species, and allow the movement of native animal species into and through the agricultural components of the landscape. In fact several studies have shown that such vegetation permits easy emigration of natural enemies of insect pests from the surrounding jungle (Altieri 1984). In western Guatemala, small farms depend on nearby forests to manage marginal infertile soils. Leaf litter is carried from nearby forests and spread each year over intensively cropped vegetable plots to improve tilth and water retention. Litter is raked up, placed in bags or nets, and carried to fields by men or horses, or from more distant sources, by trucks. After spreading, the leaf litter is first placed beneath stable animals, and then, after a week or so the rich mixture of pulverized leaves, manure, and urine is spread over the fields and turned under. Although the quantities applied vary, farmers in Almolonga, Zunil, and Quezaltenango apply as much as 40 tonnes of litter/ha each year. Rough calculations made in mixed pine-oak stands indicate that one hectare of cropped land requires the litter production from 10 ha of regularly harvested forest, or less, if harvesting is sporadic (Wilken 1987).

On the other hand, agroecosystems can begin to assume a positive rather than a negative role in preserving the integrity of natural ecosystems. Many small-scale diversified argoecosystems have been designed and managed in ways that make them more friendly to native species. For example, by encouraging hedgerows, vertebrates can be provided with large habitats, better food sources, and corridors for movement. Native plants can have more suitable habitats and find fewer barriers to dispersal. Smaller organisms, such as belowground microbes and insects, can flourish in organically managed soils and thus benefit other species since they are such important elements in ecosystem structure and function (Gliessman 1998).

By managing agricultural landscapes from the point of view of biodiversity conservation as well as sustainable production, the multiple-use capacity of agriculture can be enhanced, providing several benefits simultaneously (Thrupp 1998):

1. Increase agricultural productivity;
2. Build stability, robustness, and sustainability of farming systems;
3. Contribute to sound pest and disease management;
4. Conserve soil and increase natural soil fertility and soil health;
5. Diversify products and income opportunities from farms;
6. Add economic value and increase net returns to farmers;
7. Reduce or spread risks to individuals, communities, and nations;
8. Increase efficiency of resource use and restore ecological health;
9. Reduce pressure of agriculture on fragile areas, forests, and endangered species;
10. Reduce dependency on external inputs; and
11. Increase nutritional values and provide sources of medicines and vitamins.

The ecological services derived from diversified systems can be realized when examining the effects of agrobiodiversity in mitigating extreme climatic effects, such as the drought promoted by El Nino. An agroforestry project reviving the Quezungal method, an ancient agricultural system, spared about 84 farming communities from destruction. Farmers using the method lost only 10% of their crops in 1998's severe drought, and actually obtained a grain surplus of 5-6 million pounds in the wake of Hurricane Mitch. On the other hand, nearby communities which continued the use of slash and burn, were severely affected by El Nino, which left a legacy of human misery and destruction of vitally important watersheds.

Surveys conducted in hillsides after Hurricane Mitch in Central America showed that farmers using sustainable practices such as cover crops, intercropping and agroforestry suffered less damage than their conventional neighbors. The survey, spearheaded by the Campesino a Campesino movement, mobilized 100 farmer-technician teams and 1,743 farmers to carry out paired observations of specifid agroecological indicators on 1,804 neighboring, sustainable and conventional farms. The study spanned 360 communities and 24 departments in Nicaragua, Honduras and Guatemala. Sustainable plots had 20% to 40% more topsoil, greater soil moisture, less erosion and experienced lower economic losses than their conventional neighbors.

Agroforestry programmes which reduce deforestation and burning of plant biomass can provide a sink for atmospheric carbon dioxide and also considerably reduce emissions of nitrous oxide. Recent research shows that promoting techniques already familiar to thousands of small farmers in Latin America, such as crop rotation and cutting back on chemical fertilizers through the use of composting and crop covers, can act as important sinks for atmospheric carbon dioxide, storing it below the soil surface.

The benefits of agrobiodiversity in enhancing multifunctional agriculture extend beyond the above-described effects, as shown by the impacts of shaded coffee farms in Latin America. Farmers typically integrate into their coffee farms many different leguminous trees, fruit trees, and types of fuelwood and fodder. These trees provide shade, a habitat for birds and animals that benefit the farming system. In Mexico, shade coffee plantations support up to 180 species of birds, including migrating species, some of which play key roles in pest control and seed dispersal. Mopan kitchen gardens appear to provide important habitat for Neotropical migratory bird species that winter or pass through Belize. Around Mopan villages, kitchen gardens are sometimes the only "forest" that remains with any structural complexity. Although kitchen gardens may not house avifauna that require large tracts of unbroken forest habitat, any habitat that supports species whose numbers are in decline should be considered important.

Learning how to manage an agriculture that promotes both environmental as well as productive functions will require inputs from disciplines not previously exploited by scientists, including agroecology, ethnoscience, conservation biology, and landscape ecology. The bottom line, however, is that agriculture must adopt ecologically sound management practices, including diversified cropping systems, biological control, and organic soil management as replacements for synthetic pesticides, fertilizers, and other chemicals. Only with such a foundation can we attain the goal of a multifunctional agriculture.

**Some efforts aimed at preserving or vitalizing GIAHS**

By understanding the common features of traditional agriculture, such as the capacity to bear risk, the use of biological folk taxonomies, and the production efficiencies derived from multiple and symbiotic crop mixtures, agricultural scientists have been able to develop technologies that support the needs and circumstances of specific farmer groups. While subsistence farming generally lacks the potential for producing a meaningful marketable surplus, ti does ensure food security. Many scientists wrongly believe that traditional systems do not produce more because hand tools and draft animals put a ceiling on productivity. However, where productivity is low, the cause appears to be social, not technical. When the subsistence farmer succeeds in providing food, there is no pressure to innovate or to enhance yields. Yet research shows that increased productivity is possible when traditional crop and animal combinations are adjusted and when labor and local resources are used more efficiently (Pretty 1995).

As the inability of the Green Revolution to improve production and farm incomes for the very poor became apparent, growing enthusiasm for established, traditional agricultural practices generated a renewed quest in the developing world for affordable, productive, and ecologically sound technologies that could enhance small farm productivity while conserving resources. In the Andean altiplano, development workers and farmers have reconstructed a 3000-year-old indigenous farming system at an altitude of almost 4000m. These indigenous farmers were able to produce food in the face of floods, droughts, and severe frosts by growing crops such as potatoes, quinoa, oca, and amaranthus in raised fields or "waru-warus," which consisted of platforms of soil surrounded by ditches filled with water (Browder 1989). Technicians have now assisted local farmers in re-constructing 10 ha of these ancient farms, with encouraging results, which later led to a substantial expansion of the area under warus. For instance, yields of potatoes from waru-warus produce 10 tons of potatoes per hectare compared to the regional average of 1-4 tons/ha.

In a completely different ecoregion in the Andes, several institutions have engaged in programs to restore abandoned farming terraces and build new ones. In the Colca Valley of southern Peru, PRAVTIR (Programa de Acondicionamiento Territorial y Vivienda Rural) sponsors terrace reconstruction by offering peasant communities low-interest loans, seeds, and other inputs to restore large areas of abandoned terraces. The main advantages of using terraces are that they minimize risk in times of frost or drought, reduce soil loss, amplify the cropping options because of microclimate and hydraulic differences, and thus improve crop yields. Yield data from new bench terraces show a 43-65 percent yield increase in potatoes, maize, and barley compared to yield of these crops grown on sloping fields. One of the main constraints of this technology is its high labor intensity, requiring about 350-500 worker-days per hectare for the initial buildling of the terraces. Such demands, however, can be buffered when communities organize and share tasks (Browder 1989).

One of the early projects advocating the reconstruction of traditional farming systems occurred in Mexico in the mid-1970s when the then existing Instituto Nacional de Investigaciones sobre los Recursos Bioticos (INIREB) unveiled a plan to build "chinampas" in the swampy region of Veracruz and Tabasco. Chinampa agriculture was perfected by the Aztec inhabitants of the Valley of mexico prior to the Spanish Conquest. It involves the construction of raised farming beds in shallow lakes or marshes, and represents a self-sustaining system that has operated for centuries as one of the most intensive and productive ever devised by humans. Until the last several decades, chinampas demanded no significant capital inputs yet maintained extraordinarily high yields year after year. A wide variety of staple crops, vegetable, and flowers are often mixed with an array of fruit trees and bushes. Abundant aquatic life in the canals provides valuable sources of protein for local diets (Gliessman 1998).

Now threatened by the sprawling growth of Mexico City and its suburbs, chinampas have nearly vanished except in a few isolated areas. Regardless, this system still offers a promising model as it promotes biological diversity, thrives without chemical inputs, and sustains year-round yields. When INIREB first began to establish the chinampa system in the lowland tropics of Tabasco, implementation and adoption met with mixed success. Some critics felt that not market outlets were explored or developed for the new outputs produced by the community. Nevertheless, the "raised beds" of Tabasco (or camellones chontales) are still in full operation in the swamps of this region, and apparently the local Chontal Indians have full control of them. The Chontal practice traditional agriculture, and these raised beds produce a great variety of products, which in turn have enhanced the income and food security of these "swamp farmers."

The analysis of dozens of NGO-led agroecological projects throughout the developing world have shown convincingly that agroecological systems are not limited to producing low outputs, as some critics have asserted. Increases in production of 50-100 percent are fairly common with most alternative production methods. In some of these systems, yields for crops that the poor rely on most—rice, beans, maize, cassava, potatoes, barley—have been increased by several-fold, relying on labour and know-how more than on expensive purchased inputs, and capitalizing on processes of intensification and synergy (Uphoff 2002).

In a recent study of 208 agroecologically based projects and/or initiatives throughout the developing world, Pretty and Hine (2000) documented clear increases in food production over some 29 million hectares, with nearly 9 million households benefiting from increased food diversity and security. Promoted sustainable agriculture practices led to 50-100% increases in per hectare food production (about 1.71 Mg per year per household) in rain-fed areas typical of small farmers living in marginal environments; that is an area of about 3.58 million hectares, cultivated by about 4.42 million farmers. Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions.

**Approaches to preserve the biodiversity of traditional agroecosystems**

As many rural societies undergo the conversion from a subsistence economy to a cash agricultural economy, the loss of biodiversity in their ecosystems is mounting at an alarming rate. Because many peasants are directly linked to the market economy, external economic forces are increasingly influencing production by favoring genetically uniform crops and mechanized and/or agrochemical practices. Many landraces and wild plant relatives are being abandoned, which may cause them to become relic populations or even extinct. In some areas, land scarcity (mostly a result of uneven land distribution) has forced changes in land use and agricultural practices, which in turn have caused the disappearance of habitats that formerly maintained useful noncrop vegetation, including wild progenitors and weedy forms of crops (Altieri et al. 1987).

In many parts of the world, genetic erosion is occurring at a fast pace because farmers are having to quickly change their farming systems because of economic, technical, and social pressures. As farmers adopt high-yield modern varieties (HYVs), they often subdivide their farming systems into commercial (mostly devoted to HYVs) and subsistence sectors, growing native varieties in the latter. The greatest loss of traditional plant varieties is occurring in lowland valleys close to urban centers and markets (Brusth 1986).

Given these destructive trends, many scientists and development workers have emphasized the need for *in situ* conservation of native crop genetic resources and the environments in which they occur (Prescott-Allen and Prescott-Allen 1981). However, most researchers believe that *in situ* preservation of landraces would require a return to or the preservation of microcosms of traditional agricultural systems, which some regard as an unacceptable and impracticable proposition (Frankel and Soule 1981). Nevertheless, the maintenance of traditional agroecosystems may be the only sensible strategy to preserve *in situ* repositories of crop germplasm. Although most traditional agroecosystems are undergoing some process of modernization or drastic modifcation, the conservation of crop genetic resources can still be integrated into agricultural development, especially in regions where rural development projects preserve the vegetation diversity of traditional agroecosystems and are anchored in the peasant rationale to utilize local resources and their intimate knowledge of the environment (Alcorn 1984; Nabhan 1983).

Previous recommendations for *in situ* conservation of crop germplasm emphasized the development of a system of village-level landrace custodians (a farmer curator system) whose purpose would be to continue growing a limited sample of endangered landraces native to the region (Mooney 1983). One suggestion for preserving crop-plant diversity was for governments to set aside carefully chosen 5-by-20 km strips of land at as few as 100 sites around the world where native agriculture is still practiced (Wilkes and Wilkes 1972). But given the increasing impoverishment and lack of income-generating alternatives for many rural populations in less developed countries, a proposition of this kind is clearly unrealistic since it fails to address the subsistence needs of these populations. In many areas where the urgent short-term goal of the local people is survival, diverting the limited land available for conservation purposes per se might prove totally inappropriate. A more feasible approach would be to support sustainable farming systems that incorporate native crops and wild/weedy relatives within and around production fields, as well as appropriate technologies aimed at upgrading food production for self-sufficiency (Altieri and Merrick 1987). Such efforts would ensure that germplasm preservation remains linked to the economic and agricultural viability of local populations.

An example of how a biodiversity-based grassroots approach can support or even resurrect traditional agriculture is occurring on Chiloe Island in southern Chile. This is a secondary center of origin of potatoes, and development workers are currently tapping the ethnobotanical knowledge of elderly female Huilliche Indians in an effort to slow genetic erosion and to recover some of the original native potato germplasm. They intend to provide impoverished farmers with locally adapted varieties that can produce without the use of agrochemical fertilizers. After surveying several agroecosystems on Chiloe, NGO technicians collected hundreds of samples of native potatoes still grown by local farmers, and with this material, and in collaboration with farmers, they established community seed banks where more than 120 traditional varieties are grown year after year and are subjected to selection and seed enhancement. In this way, an *in situ* conservation program has been initiated involving farmers from various rural communities, thus ensuring the active exchange of varieties among participating farmers. As more farmers become involved, this strategy will provide a continuous supply of seeds to resource-poor farmers and will also create a repository of vital genetic diversity for future regional crop improvement programs (Altieri 1995).

If biodiversity conservation is to succeed among small farmers, conservation goals and rural development efforts must be integrated to give equal importance to local resource conservation, food self-sufficiency, and equitable market participation. Any attempt at *in situ* crop genetic conservation must struggle to preserve the agroecosystem in which these resources occur (Nabhan 1983). In the same vein, preservation of traditional agroecosystems cannot be achieved unless the sociocultural stability of the community is also assured (Altieri 1995).

*Needed policy changes*

Technological or ecological intentions are not enough to preserve the integrity of GIAHS. Many factors constraint the implementation of conservation efforts and major changes must be made in policies, institutions and research and development agendas to make sure that GIAHS are preserved and revitalized. The evidence shows that sustainable agricultural systems can be both economically, environmentally and socially viable, and contribute positively to local livelihoods (Uphoff and Altieri 1999). But without appropriate policy support, they are likely to remain localized in extent. Therefore, a major challenge for the future entails promoting institutional and policy changes to realize the potential of GIAHS. Necessary changes include:

- Increasing public investments in agroecological – participatory methods.
- Changes in policies to stop subsidies of conventional technologies and to provide support for agroecological approaches.
- Improvement of infrastructure for poor and marginal areas.
- Appropriate equitable market opportunities including fair market access and market information to small farmers.
- Security of tenure.
- Changes in attitudes and philosophy among decision-makers, scientists, and others to acknowledge and promote alternatives.
- Strategies of institutions encouraging equitable partnerships with local NGOs and farmers: replace top-down transfer of technology model with participatory technology development and farmer-centered research and extension.

**Outlook and prospects**

There is no question that thousands of small farmers that have inherited or developed GIAHS throughout the developing world can produce much of the needed food while conserving biodiversity and material resources (Uphoff and Altieri 1999; Pretty and Hine 2000). The evidence is conclusive: approaches and technologies spearheaded by farmers around the world are already making a sufficient contribution to food security at the household, national, and regional levels. A variety of agroecological and participatory approaches supporting farmers' efforts in many countries show very positive outcomes even under adverse conditions. Potentials include: raising cereal yields from 50 to 200 percent, increasing stability of production through diversification, improving diets and income, contributing to national food security and even to exports and conservation of the natural resource base and agrobiodiversity (Pretty 1995; Uphoff and Altieri 1999).

Whether the potential of GIAHS is preserved or re-vitalized so as to spread local agroecological innovations to other communities depends on several factors and actions. First, proposed strategies have to deliberately target the poor, and not only aim at increasing production and conserving natural resources, but also create employment, and provide access to local inputs and output markets. New strategies must focus on the facilitation of farmers learning to become experts on agroecology, and at capturing the opportunities in their diverse environments (Uphoff 2002).

Second, researchers and rural development practitioners will need to translate general ecological principles and natural resource management concepts into practical advice directly relevant to the needs and circumstances of small-holders. The new pro-poor technological agenda must incorporate agroecological perspectives. A focus on resource conserving technologies that uses labor efficiently, and on diversified farming systems based on natural ecosystem processes will be essential. This implies a clear understanding of the relationship between biodiversity and agroecosystem function and identifying management practices and designs that will enhance the right kind of biodiversity which in turn will contribute to the maintenance and productivity of agroecosystems.

Technological solutions will be location-specific and information-intensive rather than capital-intensive. The many existing examples of traditional and NGO-led methods of natural resource management provide opportunities to explore the potential of combining local farmer knowledge and skill with those of external agents in order to develop and/or adapt appropriate farming techniques.

Any serious attempt at developing sustainable agricultural technologies must bring to bear local knowledge and skills on the research process (Richards 1995; Toledo 2000). Particular emphasis must be given to involving farmers directly in the formulation of the research agenda and on their active participation in the process of technological innovation and dissemination. The focus should be in strengthening local research and problem-solving capacities. Organizing local people around natural resource management projects that make effective use of traditional skills and knowledge provides a launching pad for additional learning and organizing, thus improving prospects for community empowerment and self-reliant development.

Third, major changes must be made in policies, institutions, and research. In fact, Pretty and Hine (2001) concluded from their worldwide survey of sustainable agriculture initiatives that if sustainable agriculture is to spread to larger numbers of farmers and communities, then future attention needs to be focused on:

1. Ensuring the policy environment is enabling rather than disabling;
2. Investing in infrastructure for markets, transport and communications;
3. Ensuring the support of government agencies, in particular, for local sustainable agricultural initiatives;

4. Developing social capital within rural communities.

There is also a need to increase rural incomes through interventions other than enhancing yields, such as complementary marketing and processing activities. Therefore, equitable market opportunities should also be developed, emphasizing fair trade and other mechanisms that link farmers and consumers more directly. The ultimate challenge is to increase investment and research in agroecology and scale up projects that have already proven successful to thousands of other farmers. This will generate a meaningful impact on the income, food security, and environmental well-being of the world's population, especially for the millions of poor farmers yet untouched by modern agricultural technology.

**Conclusions**

A key conclusion that emerges from the relevant anthropological and ecological literature is that, when not disrupted by economic or political forces, indigenous modes of food production (GIAHS) generally preserve rather than destroy biodiversity and natural resources. In fact, in any particular region, capitalist development through the promotion of large-scale, energy-intensive, commercial agricultures is bound to deplete natural resources more than any of the existing traditional systems.

Development goals of increasing production usually result in ecological deterioration. For example, in Senegal, 25,000 hectares put under irrigation for rice are now degraded, as inexperienced people quickly erected poorly built irrigation structures in order to satisfy a government requirement for establishing tenure (Ba and Crousse 1985). Polders constructed to control water flow are not flexible enough in times of drought. Polders also affect fishing enough in times of drought. Polders also affect fishing, as changes in the flow of the river and the displacement of water through polders affect fish breeding and feeding. The transition to a market economy ignores the nature of the Sahelian climate and soils and deprives traditional Marka groups of their ability to respond flexibly in times of environmental distress.

Introduction of transgenic crops into such regions will further accelerate the loss of indigenous knowledge and culture that make the traditional system sustainable. For example, Nigh and colleagues (2000) have pointed out that characteristics of genetically altered grain could spread to local varieties favored by small-scale farmers and dilute the natural sustainability of these races.

At the landscape scale, intensification of agriculture commonly includes an increase in the size of fields and progressive specialization in production goals leading to homogenization of the landscape both within farms and across substantial areas or even regions (Wolman and Fournier 1987). This entails a move away from GIAHS with a diversity of different production systems, e.g. home gardens (gardens for fruit, vegetables, spices and medicines), a variety of specialized or species-diverse crop fields, including systems related to specific micro-environments (e.g. wetlands used for rice cultivation) and associated livestock production areas (including aquaculture in wetlands) (Okigbo and Greenland 1976). This homogenization reduces the complexity of the interface between units on the landscape and leads to reduced biological migration, habitat diversity (particularly of ecotones) and disruption of nutrient flows.

A number of studies have proven that many traditional agricultural systems are highly sustainable and productive, offering an alternative to the capital-intensive agriculture currently promoted by many development and government agencies. Besides employing crop diversity, traditional farmers use a set of practices that often cause minimal land degradation. These include the use of terraces and hedgerows in sloping areas, minimal tillage, mulching, small field sizes, and long fallow cycles (Grigg 1974; Brush 1982; Richards 1985; Netting 1993). Confronted with specific problems of slope, flooding, drought, pests, diseases and low fertility, small farmers have developed unique management systems to overcome these constraints (Table 6). It is clear that this more traditional strategy is both ecologically informed and environmentally sound, as the agricultural practices that are most likely to endure are those that deviate least from the natural plant communities within which they exist (Altieri 1995; Gliessman 1998).

Plant resources are directly dependent on management by human groups; thus, both species and genetic diversity have evolved in part under the influence of farming practices shaped by particular cultures and the forms of sophisticated knowledge they represent (Nabhan 1983). Today, it is widely accepted that indigenous knowledge is a powerful resource in its own right and complementary to knowledge available from Western scientific sources. Therefore, in studying such systems, it is not possible to separate the study of agricultural biodiversity from the study of the culture that nurtures it.

This assessment of traditional subsistence agriculture does not romanticize its origins or practitioners, nor does it consider development per se to be detrimental. The intention is rather to stress the demonstrated value of traditional agriculture in the preservation of biodiversity, native crop diversity, and the adjacent vegetation communities (Toledo 1980). Basing a rural development strategy on traditional farming and ethnobotanical knowledge not only assures the continual use and maintenance of valuable genetic resources, but also allows for the diversification of peasant or other indigenous subsistence strategies (Alcorn 1984; Caballero and Mapes 1985), which is a crucial issue in times of economic uncertainty.

Ensuring sustainability of production requires a deep understanding of how various social systems work. Social systems have deep ties to the environment through culturally mediated and specialized relationships (Halstead and O'Shea 1989). To know the physical needs of a particular crop is not enough information to produce consistent quantities in a sustainable manner. Farmers make decisions based on variables that may seem "unscientific," because the farmers are considering these variables from a different temporal and spatial scale than normally understood in the developed world. One needs to understand the evolutionary nature of "secret knowledge" and intergroup relations that function together as part of a subsistence system and that buffer the system against environmental and political variability.

The study of traditional agroecosystems and the ways in which indigenous peoples maintain and use biodiversity can facilitate the discovery of valuable agroecological principles, which in turn can contribute to the development of more sustainable agroecosystems and biodiversity conservation strategies in both developed and less developed countries.

Traditional agriculture is rapidly disappearing in the face of major social, political, and economic changes. The conservation and management of these systems and associated agrobiodiversity will be possible only if they are linked to the preservation of the cultural diversity and economic viability of the local farming populations. The conservation of GIAHS is vital to the future of humankind, and should be treated at the international level as an ecological/cultural resource of utmost global significance.

**References**


1. Alcorn, J.B. 1984. *Huastec Mayan Ethnobotany.* Austin: University of Texas Press.
2. Altieri, M.A. 1987. Agroecology: The scientific basis of alternative agriculture. Boulder: Westview Press.
3. Altieri, M.A. 1991. Traditional Farming in Latin America. *The Ecologist*, 21:93-96.
4. Altieri, M.A. 1994. *Biodiversity and pest management in agroecosystems*. New York: Haworth Press.
5. Altieri, M.A. 1995. *Agroecology: the science of sustainable agriculture.* Boulder: Westview Press.
6. Altieri, M.A. and Anderson, M.K. 1986. An ecological basis for the development of alternative agricultural systems for small farmers in the Third World. *Amer. J. Alternative Agriculture,* 1:30-38.
7. Altieri, M.A., Anderson, M.K., and Merrick, L.C. 1987. Peasant agriculture and the conservation of crop and wild plant resources. *J. Soc. Conservation Biol.,* 1:49-58.
8. Altieri, M.A. and Hecht, S.B. 1991. Agroecology and small farm development. Boca Raton: CRC Press.
9. Altieri, M.A. and Merrick, L.C. 1987. Peasant agriculture and the conservation of crop and wild plant resources. *J. Cons. Biol.,* 1:49-58.
10. Altieri, M.A. and Merrick, L.C. 1987. In situ conservation of genetic resources through maintenance of traditional farming systems. *Economic Botany,* 4:86-96.
11. Beets, W.C. 1982. *Multiple cropping and tropical farming systems.* Boulder: Westview Press.
12. Beets, W.C. 1990. *Raising and sustaining productivity of smallholders farming systems in the Tropics.* Holland: AgBe Publishing.
13. Brokenshaw, D.W., Warren, D.M. and Werner, O. 1980. *Indigenous Knowledge Systems and Development.* Lanham: University Press of America.
14. Brookfield, H. and Padoch, C. 1994. Appreciating agrobiodiversity: a look at the dynamism and diversity of indigenous farming practices. *Environment,* 36:7-20.

15. Brush, S.B. 1982. The natural and human environment of the central Andes. *Mountain Research and Development*, 2:14-38.
16. Brush, S.B. 1986. Genetic diversity and conservation in traditional farming systems. *J. Ethnobiol.,* 6:151-67.
17. Caballero, J.N. and Mapes, C. 1985. Gathering and subsistence patterns among the P'urepecha Indians of Mexico. *J. Ethnobiol.,* 5:31-47.
18. Chang, J.H. 1977. Tropical agriculture: crop diversity and crop yields. *Econ. Geogr.,* 53:241-54.
19. Clarke, W.C. and Thaman, R.R. 1993. *Agroforestry in the Pacific: systems for sustainability.* Tokyo: United Nations University Press.
20. Clawson, D.L. 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. *Econ. Bot.,* 39:57-67.
21. Denevan, W.M. 1995. Prehistoric agricultural methods for sustainability. *Advanced Plant Pathology*, 11:21-43.
22. Denevan, W.M., Treace, J.M., Alcorn, J.B., Padoch, C., Denslow, J., and Paitan, S.T. 1984. Indigenous agroforestry in the Peruvian Amazon: Bora Indian management of swidden fallows. *Interciencia,* 9:346-57.
23. Erickson, C.L. and Chandler, K.L. 1989. Raised fields and sustainable agriculture in lake Titicaca Basin of Peru. In: Browder, J.O. (Ed.) *Fragile Lands of Latin America*, pp. 230-43. Boulder: Westview Press.
24. Francis, C.A. 1986. *Multiple cropping systems*. New York: MacMillan.
25. Gliessman, S.R. 1998. *Agroecology: ecological process in sustainable agriculture*. Michigan: Ann Arbor Press.
26. Gliessman, S.R., Garcia, E., and Amador, A. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems. *Agro-Ecosystems*, 7: 173-85.
27. Grigg, D.B. 1974. *The agricultural systems of the world: an evolutionary approach*. Cambridge: Cambridge University Press.
28. Harwood, R.R. 1979. *Small farm development – understanding and improving farming systems in the humid tropics*. Boulder: Westview Press.
29. Holtz-Gimenez, E. 1996. The campesino a campesino movement: farmer-led, sustainable agriculture in Central America and Mexico. *Food First Development Report* No. 10. Oakland: Institute of Food and Development Policy.
30. Jimenez-Osornio, J. and del Amo, S. 1986. An intensive Mexican traditional agroecosystem: the chinampa. Proc. 6th International Scientific Conference IFOAM, Santa Cruz, California.
31. Klee, G.A. 1980. *World Systems of Traditional Resource Management.* New York: J. Wiley and Sons.
32. Marten, G.C. 1986. *Traditional agriculture in Southeast Asia: a human ecology perspective.* Boulder: Westview Press.
33. Norman, M.J.T. 1979. *Annual cropping systems in the tropics.* Gainesville: University Presses of Florida.
34. Ortega, E. 1986. *Peasant agriculture in Latin America.* Santiago: Joint ECLAC/FAO Agriculture Division.
35. Pretty, J. 1995. *Regenerating agriculture*. Washington, DC: World Resources Institute.

36. Reinjtes, C., Haverkort, B. and Waters-Bayer, A. 1992. *Farming for the future.* London: MacMillan
37. Richards, P. 1985. *Indigenous Agricultural Revolution.* Boulder: Westview Press.
38. Swift, M.S., Vandermeer, J., Ramakrishnan, P.S., Anderson, J.M., Ong, C.K., and Hawkins, B.A. 1996. Biodiversity and agroecosystem function. In: Mooney, H.A. et al. (Eds.) *Functional Roles of Biodiversity: A Global Perspective,* pp. 261-98. New York: J. Wiley and Sons.
39. Thrupp, L.A. 1998. *Cultivating diversity: agrobiodiversity and food security*. Washington DC: World Resources Institute.
40. Toledo, V.M., Carabias, J., Mapes, C., and Toledo, C. 1985. *Ecologia y Autosuficiencia Alimentaria*. Mexico City: Siglo Vientiumo Editors.
41. Treacey, J.M. 1989. Agricultural terraces in Peru's Colca Valley: promises and problems of an ancient technology. In: Browder, J.O. (Ed.) *Fragile lands of Latin America.* Boulder: Westview Press.
42. Vandermeer, J. and perfecto, I. 1995. *Breakfast of biodiversity: the truth about rainforest destruction.* Oakland: Food First Books.
43. Wilken, G.C. 1987. *Good Farmers: traditional agricultural resource management in Mexico and Guatemala.* Berkeley: University of California Press.

## Table 1. Classification of Farming Systems

| | Tree Crops | | Tillage with or without livestock | | Alternating tillage with grass, bush or forest | | Grassland or Grazing of land consistently in 'indigenous' or man-made pasture | |
|---|---|---|---|---|---|---|---|---|
| | **Temperate** | **Tropical** | **Temperate** | **Tropical** | **Temperate** | **Tropical** | **Temperate** | **Tropical** |
| Very extensive | Cork collection from Maquis in southern France | Collection from wild trees, e.g. shea butter | | | Shifting cultivation in Negev Desert, Israel | Shifting cultivation in Zambia | Reindeer herding in Lapland. Nomadic pastoralism in Afghanistan | Camel-herding in Arabia and Somalia |
| Extensive Examples | Self-sown or planted blue berries in the northeast of the USA | Self-sown oil palms in West Africa | Cereal growing in Interior Plains of N. America, pampas of S. America, in unirrigated areas, e.g. Syria | Unirrigated cereals in central Sudan | | Shifting cultivation in the more arid parts of Africa | Wool-growing in Australia. Hill sheep in the U.K. (Sheep in Iceland). Cattle ranching in the USA. | Nomadic cattle-herding in East and West Africa. Llamas in South America |
| Semi-intensive Examples | Cider apple orchards in the U.K. Some vineyards in France | Cocoa in West Africa. Coffee in Brazil | Dry cereal farming in Israel or Texas, USA | Continuous cropping in congested areas of Africa. Rice in S.E. Asia | Cotton or tobacco with livestock in the southeast of the USA. Wheat with leys and sheep in Australia | Shifting cultivatio nin much of tropical Africa | Upland sheep country in North Island, New Zealand | Cattle and buffaloes in mixed farming in India and Africa |
| Intensive Examples | Citrus in California or Israel | Rubber in S.E. Asia. Tea in India and Ceylon | Corn Belt of the USA. Continuous barley growing in the U.K. | Rice and vegetable growing in south China. Sugar-cane plantations throughout | Irrigated rice and grass beef farms in Australia. Much of the east and south of the | Experiment stations and scattered settlement schemes | Parts of the Netherlands, New Zealand and England | Dairying in Kenya and Rhodesia highlands |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | tropics | U.K., the Netherlands, northern France, Denmark, southern Sweden | | | |
| Typical Food Chains | A | A | A,B | A | A,B,C,D | A (C) | C (D) | C |

### Table 2. Partial Distribution and Extent of Peasant Agriculture in the Developing World

| **Region** | **Number of Farmers** | **Area (hectares or %)** | **Contribution to food security** |
|---|---|---|---|
| Latin America | a. 160 million peasant units<br>b. 50 million indigenous people | 38% of total land devoted to agriculture, about 60.5 million hectares. Half of humid tropics in Mexico and Amazon | a. 41% of food crop consumed domestically |
| Africa | a. 60-80% labor force involved in agriculture<br>b. 70% of population living in rural areas (about 375 million) of Sub-Saharan Africa | 100-150 million hectares | 80% of cereals<br>95% of meat |
| Asia | 200 million small scale rice farmers | a. 7.3 million hectares of upland rice<br>b. 20.5 million hectares of rainfed rice | 200 million people supported by upland shifting cultivation |

## Table 3. The Vavilou Centers of Origin of Crop Plants and Agriculture

| |
|---|
| **I. The Chinese Center:** in which he recognizes 138 distinct species of which probably the earlier and most important were cereals, buckwheats and legumes. |
| **II. The Indian Center (including the entire subcontinent):** based originally on rice, millets and legumes, with a total of 117 species. |
| **IIa. The Indo-Malayan Center (including Indonesia, Philippines, etc.):** with root crops (*Dioscorea* spp., *Tacca,* etc.) preponderant, also with fruit crops, sugarcane, spices, etc., some 55 species. |
| **III. The Inner Asiatic Center (Tadjikistan, Uzbekistan, etc.):** with wheats, rye and many herbaceous legumes, as well as seed-sown root crops and fruits, some 42 species. |
| **IV. Asia Minor (including Transcaucasia, Iran and Turkmenistan):** with more wheats, rye, oats, seed and forage legumes, fruits, etc., some 83 species. |
| **V. The Mediterranean Center:** ofm roe limited importance than the others to the east, but including wheats, barleys, forage plants, vegetables and fruits – especially also spices and ethereal oil plants, some 84 species. |
| **VI. The Abyssinian (now Ethiopian) Center:** of lesser importance for maize, *Phaseolus* and Cucurbitaceous species, with spices, fruits and fibre plants, some 49 species. |
| **VII. The South Mexican and Central American Center:** important for maize, *Phaseolus* and Cucurbitaceous species, with spices, fruits and fibre plants, some 49 species. |
| **VIII. South America Andes region (Bolivia, Peru, Ecuador):** important for potatoes, other root crops, grain crops of the Andes, vegetables, spices and fruits, as well as drugs (cocaine, quinine, tobacco, etc.), some 45 species. |
| **VIIIa. The Chilean Center:** only four species – outside the main area of crop domestication, and one of these (*Solanum tuberosum*) derived from the Andean center in any case. This could hardly be compared with the eight main centers. |
| **VIIIb. Brazilian-Paraguayan Center:** again, outside the main centers with only 13 species, though *Manihot* (cassava) and *Arachis* (peanut) are of considerable importance; others such as pineapple, *Hevea* rubber, *Theobroma cacao* were probably domesticated much later. |

**Table 4. Agroclimatic crop zones of the central Andes (Brush 1982).**

| Zone | Major Crops/Animals | Agricultural Technology | Land Tenure | Focus of Production |
|---|---|---|---|---|
| Pasture above 3,800 | Alpacas<br>Llamas<br>Sheep<br>Cattle | | Communal ownership and communal use | Market (esp. wool) and subsistence |
| Tuber 3,000-4,200m. | Potatoes<br>Quinoa/canihua<br>Barley<br>Other native tubers (mashua, ulluca, oca) | Hoe<br>Foot plow<br>Dung as fertlizer | Communal ownership with individual use | Subsistence |
| Cereal 1,500-3,000m. | Corn<br>Wheat<br>Cucurbits<br>Beans<br>Temperate fruits and vegetable | Draft animals<br>Some mechanization and chemical fertilizer | Private ownership and use | Subsistence (grains) and market (fruits and vegetables) |
| Tropical/fruit 500-1,500m. | Cocoa<br>Sugarcane<br>Cotton<br>Tropical fruit<br>Corn | Mainly agro-industrial technology | Private ownership and use | Market |

**Table 5. African Traditional Food Farming Systems and Threats to Sustainability (after Benneh 1996)**

| System | Major characteristics | Geographic spread |
| --- | --- | --- |
| Shifting cultivation | ▪ Rainfed agriculture.<br>▪ Slash-and-burn cultivation.<br>▪ Simple hand tools.<br>▪ Soil fertility restored by fallow vegetation.<br>▪ Intercropping.<br>▪ Communal tenure.<br>▪ No permanent settlements.<br>▪ Orientation is subsistence. | ▪ Formerly widespread, now almost extinct |
| Bush fallow system or land rotation | ▪ Same characteristics as above; however, soil fertility is restored through land rotation within fixed area of farmland<br>▪ Permanent farming settlements.<br>▪ Orientation is both subsistence and commercial.<br>▪ Communal tenure, sharecropping, and renting. | ▪ Widely practiced in all ecological regions of Sub-Saharan Africa. |
| Planted fallow system | ▪ Same characteristics as above, except more permanent cultivation.<br>▪ Soil fertility restored by planted fallow (*Acioa barterri* and *Macrolobium macrophyllum*).<br>▪ Agroforestry. | ▪ Areas of high population density, such as Ibo, Aba, and Ibibio districts of eastern Nigeria. |

| | | |
|---|---|---|
| | ▪ Family and individual ownership, sharecropping, and renting. | |
| Compound or homestead farming | ▪ Permanent system of cultivation.<br>▪ Soil fertility maintained through application of household refuse, night soil, and manure.<br>▪ Mixed cropping.<br>▪ Orientation is subsistence.<br>▪ Family ownership. | ▪ Densely settled areas in the different ecological zones.<br>▪ Sometimes combined with bush fallow systems. |
| Terrace farming | ▪ Intensive cultivation as above.<br>▪ Family or individual ownership.<br>▪ Special terraces constructed to check erosion and control water.<br>▪ Mixed cropping. | ▪ Upland or hilly areas in different ecological zones. |
| Flood land cultivation | ▪ Intensive seasonal cultivation.<br>▪ Cultivation of different crops according to whether flood is rising or reducing.<br>▪ Orientation is subsistence and commercial. | ▪ Draw-down areas of major rivers, streams, and lakes.<br>▪ Valley bottom during the dry season. |
| Transhumance pastoralism | ▪ Nomadic grazing of livestock determined by seasonal rainfall. | ▪ Arid regions. |

**Table 6. Some examples of soil, space, water and vegetation management systems used by traditional agriculturalists throughout the world (after Klee 1980).**

| Environmental constraint | 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, and use of aquatic weeds and muck, alley |

| | | |
|---|---|---|
| | | cropping with legumes, plowed leaves, branching and other debris, burning vegetation, etc. |
| Flooding or excess water | Integrate agriculture with water supply. | Raised field agriculture (chinampas, tablones), ditched fields, diking, etc. |
| Excess water | Channel/direct available water. | Control floodwater with canals and check dams. Sunken fields dug down to groundwater level. Splash irrigation. Canal irrigation fed from ponded groundwater, wells, lakes, and reservoirs. |
| 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; thinnings; shade-tolerant crops; increased plant densities; mulching; wind management with hedges, fences, tree rows; weeding; shallow plowing; minimum tillage; intercropping; agroforestry; alley-cropping, etc. |
| Pest incidence (invertebrates, vertebrates) | Protect crops, minimize pest populations. | Over planting, allowing pest damage, crop watching, hedging or fencing, use of resistant varieties, mixed cropping, enhancement of natural enemies, hunting, picking, use of poisons, repellants, planting in times of low pest potential. |