APPLYING AGROECOLOGY TO ENHANCE THE PRODUCTIVITY OF PEASANT FARMING SYSTEMS IN LATIN AMERICA

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Abstract. The great majority of farmers in Latin America are peasants who still farm small plots of land, usually in marginal environments utilizing traditional and subsistence methods. The contribution of the 16 million peasant units to regional food security is, however, substantial. Research has shown that peasant systems, which mostly rely on local resources and complex cropping patterns, are reasonably productive despite their land endowments and low use of external inputs. Moreover analysis of NGO-led agroecological initiatives show that traditional crop and animal systems can be adapted to increase productivity by biologically re-structuring peasant farms which in turn leads to optimization of key agroecosystem processes (nutrient cycling, organic matter accumulation, biological pest regulation, etc.) and efficient use of labor and local resources. Examples of such grassroots projects are herein described to show that agroecological approaches can offer opportunities to substantially increase food production while preserving the natural resource base and empowering rural communities.

Key words: agroecology, Latin America, NGOs, sustainable agriculture.

1. Introduction

Although most traditional agricultural systems and practices encompass mechanisms to stabilize production in risk-prone environments without external subsidies, most agroecologists recognize that traditional systems and indigenous knowledge will not yield panaceas for agricultural problems (Altieri, 1995; Gliessman, 1998). Nevertheless, traditional ways of farming refined over many generations by intelligent land users, provide insights into sustainably managing soils, water, crops, animals and pests (Thrupp, 1998). Perhaps the most rewarding aspect of agroecological research has been that by understanding the features of traditional agriculture, such as the ability to bear risk, biological folk taxonomies, the production efficiency of symbiotic crop mixtures, etc., important information on how to develop agricultural technologies best suited to the needs and circumstances of specific peasant groups has been obtained. This information has been a critical input for the application of agroecology in rural development programs.

Since the early 1980s, more than 200 projects promoted by non-governmental organizations (NGOs) in Latin America have concentrated on promoting agroecological technologies which are sensitive to the complexity of peasant farming systems (Altieri and Masera, 1993). This agroecological approach offers an alternate path to agricultural intensification by relying on local farming knowledge and techniques adjusted to different local conditions, management of diverse on-farm resources and inputs, and incorporation of contemporary scientific understanding of biological principles and resources in farming systems. Second,

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it offers the only practical way to actually restore agricultural lands that have been degraded by conventional agronomic practices. Third, it offers an environmentally sound and affordable way for smallholders to sustainably intensify production in marginal areas. Finally, it has the potential to reverse the anti-peasant biases inherent in strategies that emphasize purchased inputs and machinery, valuing instead the assets that small farmers already possess, including local knowledge and the low opportunity costs for labor that prevail in the regions where they live (Altieri et al., 1998).

This paper contends that there is enough evidence available – despite the fact that researchers have paid little attention to these systems – to suggest that agroecological technologies promise to contribute to food security on many levels. Critics of such alternative production systems point to lower crop yields than in high-input conventional systems. Yet all too often, it is precisely the emphasis on yield a measure of the performance of a single crop that blinds analysts to broader measures of sustainability and to the greater per unit area productivity and environmental services obtained in complex, integrated agroecological systems that feature many crop varieties together with animals and trees. Moreover, there are many cases where even yields of single crops are higher in agroecological systems that have undergone the full conversion process (Lampkin, 1992).

Assessments of various initiatives in Latin America show that agroecological technologies can bring significant environmental and economic benefits to farmers and communities (Altieri, 1995; Pretty, 1995; Thrupp, 1996). If such experiences were to be scaled up, multiplied, extrapolated, and supported in alternative policy scenarios, the gains in food security and environmental conservation would be substantial. This article summarizes some cases from Latin America that explore the potential of the agroecological approach to sustainably increase productivity of smallholder farming systems, while preserving the resource base and at the same time empowering local communities.

2. The productivity of traditional farming systems

Despite the increasing industrialization of agriculture, the great majority of the farmers in Latin America are peasants, or small producers, who still farm the valleys and slopes of rural landscapes with traditional and subsistence methods. Peasant production units reached about 16 million in the late 1980s occupying close to 160 million hectares, involving 75 million people representing almost two thirds of the Latin America's total rural population (Ortega, 1986).

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 (Table I).

In Brazil, small peasant producers control about 33% of the area sown to maize, 61% of that under beans, and 64% of that planted to cassava. 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).

TABLE I. Estimated arable land and population on steep slopes of selected latin american countries and their contribution to total agricultural output[a]

Country	% land farmed on slopes	Agricultural population (%)	Percent contribution to agricultural output (including coffee)	Contribution to country's total agricultural production	
				Corn (%)	Potato (%)
Ecuador	25	40	33	50	70
Colombia	25	50	26	50	70
Peru	25	50	21	20	50
Guatemala	75	65	25	50	75
El Salvador	75	50	18	50	—
Honduras	80	20	19	40	100
Haiti	80	65	30	70	70
Dominican Republic	80	30	31	40	50

[a] Modified after Posner and McPherson (1982).

Most peasant systems are productive despite their low use of chemical inputs. Generally, agricultural labor has a high return per unit of input. The energy return to labor expended in a typical highland Mayan maize farm is high enough to ensure continuation of the present system. To work a hectare of land, which normally yields 4 230 692 calories requires some 395 h; thus, an hour's labor produces about 10 700 calories. A family of three adults and seven children eat about 4 830 000 calories of maize per year, thus current systems provide food security for a typical family of 5 or 7 people (Gladwin and Truman, 1989). Also in these systems, favorable rates of return between inputs and outputs in energy terms are realized. On Mexican hillsides, maize yields in hand-labor dependent swidden systems are about 1940 kg ha^{-1}, exhibiting an output/input ratio of 11 : 1. In Guatemala, similar systems yield about 1066 kg ha^{-1} of maize, with an energy efficiency ratio of 4.84. Yield per seed planted vary from 130 to 200. When animal traction is utilized, yields do not necessarily increase but the energy efficiency drops to values ranging from 3.11 to 4.34. When fertilizers and other agrochemicals are utilized yields can increase to levels of 5–7 t ha^{-1}, but energy ratios are highly inefficient (less than 2.5). In addition, most peasants are poor and generally cannot afford such inputs unless agrochemicals are subsidized (Pimentel and Pimentel, 1979).

In many areas of the region, traditional farmers have developed and/or inherited complex farming systems, adapted to the local conditions, that have helped 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 (Denevan, 1995).

The persistence of more than three million hectares under traditional agriculture 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 peasants throughout Latin America. These microcosms of traditional agriculture offer promising models for other areas as they promote biodiversity, thrive without agrochemicals, and

TABLE II. Maize yields from chinampa plots during the 1950s

Location	Plot Size (ha)	Yield (kg/ha)
Tlahuac	0.32	5500
	0.10	3750–4500
	0.16	4650–5500
	0.10	3750–4500
	0.16	4650
	0.16	6300
San Gregorio	0.20	3750–4500
	0.21	3600–4350
	0.10	3750–4500
	0.12	4950

Source: Sanders (1957).

sustain year-round yields. An example are the chinampas in Mexico which according to Sanders (1957) in the mid 1950s exhibited maize yields of 3.5–6.3 t ha^{-1} (Table II). At the same time, these were the highest long-term yields achieved anywhere in Mexico. In comparison, average maize yields in the United States in 1955 were 2.6 t ha^{-1}, and did not pass the 4 t ha^{-1} mark until 1965 (USDA, 1972). Sanders (1957) estimated that each hectare of chinampa could produce enough food for 15–20 persons per year at modern subsistence levels. Recent research has indicated that each chinampero can work about three quarters of a hectare of chinampa per year (Jimenez-Osornio and del Amo, 1986), meaning that each farmer can support 12–15 people.

A salient feature of traditional farming systems is their degree of plant diversity in the form of polycultures and/or agroforestry patterns (Chang, 1977; Clawson, 1985; Thrupp, 1998). This peasant strategy of minimizing risk by planting several species and varieties of crops, stabilizes yields over the long term, promotes diet diversity, and maximizes returns under low levels of technology and limited resources (Harwood, 1979). Much of the production of staple crops in the Latin American tropics occurs in polycultures. More than 40% of the cassava, 60% of the maize, and 80% of the beans in that region are grown in mixtures with each other or other crops (Francis, 1986; Table III). In most multiple cropping systems developed by smallholders, productivity in terms of harvestable products per unit area is higher than under sole cropping with the same level of management. Yield advantages can range from 20% to 60%. These differences can be explained by a combination of factors which include the reduction of losses due to weeds, insects and diseases and a more efficient use of the available resources of water, light and nutrients (Beets, 1982).

In Mexico, 1.73 ha of land has to be planted with maize to produce as much food as one hectare planted with a mixture of maize, squash, and beans. In addition, a maize–squash–bean polyculture can produce up to 4 t ha^{-1} of dry matter for plowing into the soil, compared with 2 t in a maize monoculture (Table III). In Brazil, polycultures containing 12,500 maize plants ha^{-1} and 150,000 bean plants ha^{-1} exhibited a yield advantage of 28%. In drier environments, maize is replaced by sorghum in the intercropping without affecting the productive capacity of cowpeas or beans and yielding LER values of 1.25–1.58. This system exhibits a greater stability of production as sorghum is more tolerant to drought.

TABLE III. Yields and total biomass of maize, beans, and squash (kg ha^{-1}) in polyculture as compared with several densities (plants ha^{-1}) of each crop in monoculture

Crop	Monoculture				Polyculture
Maize					
Density	33 000	40 000	66 600	100 000	50 000
Yield	990	1150	1230	1170	1720
Biomass	2823	3119	4487	4871	5927
Beans					
Density	56 800	64 000	100 000	133 200	40 000
Yield	425	740	610	695	110
Biomass	853	895	843	1390	253
Squash					
Density	1200	1875	7500	30 000	3330
Yield	15	215	430	225	80
Biomass	241	841	1254	802	478
Total polyculture yield					1910
Total polyculture biomass					6659

Source: Gliessman (1998).

Tropical agroecosystems composed of agricultural and fallow fields, complex home gardens, and agroforestry plots, commonly contain well over 100 plant species per field, which are used for construction materials, 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 basin and many other ethnic groups who incorporate trees into their production systems (Wilken, 1987). Such 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 tropical forests, with diverse species and a layered configuration (Denevan et al., 1984). Because of the nearly year-round growing conditions, indigenous farmers are able to stagger crop and tree plantings and harvesting to increase overall yields. For example the Bora plant a wide variety of crops, including some 22 varieties of sweet and bitter manioc interspersed among pineapples, fruit trees and minor annual crops.

In the Amazon, the Kayapo yields are roughly 200% higher than colonist systems and 175 times that of livestock (Hecht, 1984). In Mexico, Huastec Indians manage a number of agricultural and fallow fields, complex home gardens and forest plots totaling about 300 species. Small areas around the houses commonly average 80–125 useful plant species, mostly native medicinal plants (Alcorn, 1984).

3. Ecological mechanisms underlying the productivity of traditional farming systems

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, 3–4 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 (Gliesman et al., 1981).

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^{-1} $year^{-1}$. 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 plants (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 habitat 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% parasitization rate in the polycultures as opposed to only 29% 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).

4. Building on traditional farming: NGO-led agroecological initiatives

In Latin America, economic change, fueled by capital and market penetration, is leading to an ecological breakdown that is starting to destroy the sustainability of traditional agriculture. After creating resource-conserving systems for centuries, traditional cultures in areas such as Mesoamerica, the Amazon, and the Andes are now being undermined by external political and economic forces. Biodivesity is decreasing on farms, soil degradation is accelerating, community and social organizations are breaking down, genetic resources are being eroded and traditions lost. Under this scenario, and given commercial pressures and urban demands, many developers argue that the performance of subsistence agriculture is unsatisfactory, and that intensification of production is essential for the transition from subsistence to commercial production (Blauert and Zadek, 1998). In reality the challenge is to guide such transition in a way that it yields and income are increased without threatening food security, raising the debt of peasants, and further exacerbating environmental degradation. Many agroecologists contend that this can be done by generating and promoting resource conserving technologies, a source of which are the very traditional systems that modernity is destroying (Altieri, 1991).

Taking traditional farming knowledge as a strategy point, a quest has begun in the developing world for affordable, productive, and ecologically sound small scale agricultural alternatives. In many ways, the emergence of agroecology stimulated a number of NGOs and other institutions to actively search for new kinds of agricultural development and resource management strategies that, based on local participation, skills and resources, have enhanced small farm productivity while conserving resources (Thrupp, 1996). Today there are hundreds of examples where rural producers in partnership with NGOs and other organizations, have promoted and implemented alternative, agroecological development projects which incorporate elements of both traditional knowledge and modern agricultural science, featuring resource-conserving yet highly productive systems, such as polycultures, agroforestry, and the integration of crops and livestock etc.

5. Stabilizing the hillside of Central America

Perhaps the major agricultural challenge in Latin America is to design cropping systems for hillside areas, that are both productive and reduce erosion. Several organizations have taken on this challenge with initiatives that emphasize the stewardship of soil resources, utilization of local resources, and inputs produced on farm.

Since the mid 1980s, the private voluntary organization World Neighbors has sponsored an agricultural development and training program in Honduras to control erosion and restore the fertility of degraded soils. Soil conservation practices were introduced – such as drainage and contour ditches, grass barriers, and rock walls – and organic fertilization methods were emphasized, such as chicken manure and intercropping with legumes. Program yields tripled or quadrupled from 400 kg ha^{-1} to 1,200–1,600 kg, depending on the farmer. This tripling in per-hectare grain production has ensured that the 1,200 families participating in the program have ample grain supplies for the ensuing year. Subsequently, COSECHA, a local NGO promoting farmer-to-farmer methodologies on soil conservation and agroecology, helped some 300 farmers experiment with terracing, cover crops, and other new techniques. Half of these farmers have already tripled their corn and bean yields; 35 have gone beyond staple production and are growing carrots, lettuce, and other vegetables to sell in the local markets. Sixty local villagers are now agricultural extensionists and 50 villages have requested training as a result of hearing of these impacts. The landless and near-landless have benefited with the increase in labor wages from US $2 to $3 per day in the project area. Outmigration has been replaced by inmigration, with many people moving back from the urban slums of Tegucigalpa to occupy farms and houses they had previously abandoned, so increasing the population of Guinope. The main difficulties have been in marketing of new cash crops, as structures do not exist for vegetable storage and transportation to urban areas (Bunch, 1987).

In Cantarranas, the adoption of velvetbean (*Mucuna pruriens*), which can fix up to 150 kg N ha^{-1} as well as produce 35 t of organic matter per year, has tripled maize yields to 2500 kg ha^{-1}. Labor requirements for weeding have been cut by 75% and, herbicides eliminated entirely. The focus on village extensionists was not only more efficient and less costly than using professional extensionists, it also helped to build local capacity and provide crucial leadership experience (Bunch, 1990).

Throughout Central America, CIDDICO and other NGOs have promoted the use of grain legumes to be used as green manure, an inexpensive source of organic fertilizer to build up organic matter. Hundreds of farmers in the northern coast of Honduras are using velvet bean (*M. pruriens*) with excellent results, including corn yields of about 3,000 kg ha^{-1}, more than double than national average, erosion control, weed suppression and reduced land preparation costs. The velvet beans produce nearly 30 t ha^{-1} of biomass per year, or about 90–100 kg N ha^{-1} $year^{-1}$ (Flores, 1989). Taking advantage of well established farmer to farmer networks such as the *campesino a campesino* movement in Nicaragua and elsewhere, the spread of this simple technology has occurred rapidly. In just one year, more than 1000 peasants recovered degraded land in the Nicaraguan San Juan watershed (Holtz-Gimenez, 1996). Economic analyses of these projects indicate that farmers adopting cover cropping have lowered their utilization of chemical fertilizers (from 1.900 kg ha^{-1} to 400 kg ha^{-1})

while increasing yields from 700 kg to 2000 kg ha^{-1}, with production costs about 22% lower than farmers using chemical fertilizers and monocultures (Buckles et al., 1998).

Scientists and NGOs promoting slash/mulch systems based on the traditional ‘tapado’ system, used on the Central American hillsides, have also reported increased bean and maize yields (about 3000 kg ha^{-1}) and considerable reduction in labor inputs as cover crops smother aggressive weeds, thus minimizing the need for weeding. Another advantage is that the use of drought resistant mulch legumes such as *Dolichos lablab* provide good forage for livestock (Thurston et al., 1994). These kinds of agroecological approaches are currently being used on a relatively small percentage of land, but as their benefits are being recognized by farmers, they are spreading quickly. Such methods have strong potential and offer important advantages for other areas of Central America and beyond.

6. Soil conservation in the Dominican Republic

Several years ago, Plan Sierra, an ecodevelopment project took on the challenge of breaking the link between rural poverty and environmental degradation. In the central cordillera of the Dominican Republic, the strategy consisted in developing alternative production systems for the highly erosive conucos used by local farmers. Controlling erosion in the Sierra is not only important for the betterment of the life of these farmers but also represents hydroelectric potential as well as an additional 50 000 ha of irrigated land in the downstream Cibao valley (Altieri, 1990).

The main goal of Plan Sierra is agroecological strategy was the development and diffusion of production systems that provided sustainable yields without degrading the soil thus ensuring the farmers’ productivity and food self-sufficiency. More specifically, the objectives were to allow farmers to more efficiently use local resources such as soil moisture and nutrients, crop and animal residue, natural vegetation, genetic diversity, and family labor. In this way it would be possible to satisfy basic family needs for food, firewood, construction materials, medicinals, income, and so on.

From a management point of view the strategy consisted of a series of farming methods integrated in several ways:

1. Soil conservation practices such as terracing, minimum tillage, alley cropping, living barriers, and mulching;
2. Use of leguminous trees and shrubs such as *Gliricidia, Calliandra, Canavalia, Cajanus*, and *Acacia* planted in alleys, for nitrogen fixation, biomass production, green manure, forage production, and sediment capture;
3. Use of organic fertilizers based on the optimal use of plant and animal residues;
4. Adequate combination and management of polycultures and/or rotations planted in contour and optimal crop densities and planting dates;
5. Conservation and storage of water through mulching and water harvesting techniques.

In various farms animals, crops, trees, and/or shrubs, are all integrated to result in multiple benefits such as soil protection, diversified food production, firewood, improved soil fertility, and so on. Since more than 2000 farmers have adopted some of the improved practices an important task of Plan Sierra was to determine the erosion reduction potential of the proposed systems. This proved difficult because most of the available methods to estimate erosion are not applicable for measuring soil loss in farming systems managed by resource-poor farmers under marginal conditions. Given the lack of financial resources and research infrastructure at Plan Sierra it was necessary to develop a simple method using measuring sticks to estimate soil loss in a range of concuos including those traditionally managed by farmers and the 'improved ones' developed and promoted by Plan Sierra.

Based on field data collected in 1988–1989 on the accumulated erosion rates of three traditional and one improved farming system, the alternative systems recommended by Plan Sierra exhibited substantially less soil loss than the traditional shifting cultivation, cassava and guandul monocultures. The positive performance of the agroecologically improved conuco seemed related to the continuous soil cover provision through intercropping, mulching, and rotations, as well as the shortening of the slope and sediment capture provided by alley cropping and living barriers (Altieri, 1985).

7. Recreating incan agriculture

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, NGO's 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 plans of the Peruvian Andes about 3000 years ago. According to archeological evidence 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 4,000 m (Erickson and Chandler, 1989).

In 1984 several NGO's and state agencies created the Proyecto Interinstitucional de Rehabilitacion de Waru-Warus (PIWA) to assist local farmers in reconstructing ancient systems. 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 t ha^{-1} $year^{-1}$. These figures contrast favorably with the average Puno potato yields of 1–4 t ha^{-1} $year^{-1}$. In Camjata the potato fields reached 13 t ha^{-1} $year^{-1}$ and quinoa yields reached 2 t ha^{-1} $year^{-1}$ in Waru-Warus. It is estimated that the initial construction, rebuilding every ten years, and annual planting, weeding, harvest and maintenance of raised fields planted in potatoes requires 270 person-days ha^{-1} $year^{-1}$. Clearly, raised beds require strong social cohesion for the cooperative work needed on beds and canals. For the construction of the fields, NGOs organized labor at the individual, family, multi-family, and communal levels.

Elsewhere in Peru, several NGOs in partnership with local government agencies have engaged in programs to restore abandoned ancient terraces. For example, in Cajamarca, in

1983, EDAC-CIED together with peasant communities initiated an all-encompassing soil conservation project. Over 10 years they planted more than 550,000 trees and reconstructed about 850 ha of terraces and 173 ha of drainage and infiltration canals. The end result is about 1124 ha of land under construction measures (roughly 32% of the total arable land), benefiting 1247 families (about 52% of the total in the area). Crop yields have improved significantly. For example, potato yields went from 5 to 8 t ha^{-1} and oca yields jumped from 3 to 8 t ha^{-1}. Enhanced crop production, fattening of cattle and raising of alpaca for wool, have increased the income of families from an average of \$108 $year^{-1}$ in 1983 to more than \$500 today (Sanchez, 1994).

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 and seeds or other inputs to restore large areas (up to 30 ha) of abandoned terraces. The advantages of the terraces is that they minimize risks in terms of frost and/or drought, reducing soil loss, broadening cropping options because of the microclimatic and hydraulic advantages of terraces, thus improving productivity. First year yields from new bench terraces showed a 43–65% increase of potatoes, maize, and barley, compared to the crops grown on sloping fields (Table IV). The native legume *Lupinus mutabilis* is used as a rotational or associated crop on the terraces; it fixes nitrogen, which is available to companion crops, minimizing fertilizer needs and increasing production. One of the main constraints of this technology is that it is highly labor intensive. It is estimated that it would require 2000 worker-days to complete the reconstruction of 1 ha, although in other areas reconstruction has proven less labor intensive, requiring only 300–500 worker day^{-1} ha^{-1} (Treacey, 1989).

NGOs have also evaluated traditional farming systems above 4000 msnm, where maca (*Lepidium meyenii*) is the only crop capable of offering farmers secure yields. Research shows that maca grown in virgin soils or fallowed between 5–8 years, exhibited significantly higher yields (11.8 and 14.6 t ha^{-1} respectively) than maca grown after bitter potatoes (11.3 t ha^{-1}). NGOs now are advising farmers to grow maca in virgin or fallow soils in a rotative pattern, to use areas not suitable for other crops and taking advantage of the local labor and low costs of the maca-based system (UNDP, 1995; Altieri, 1996).

TABLE IV. First year per hectare yields of crops on new bench terraces, compared to yields on sloping fields (kg ha^{-1})

Crop[a]	Terraced[b]	Non-terraced[c]	Percent increase	N[d]
Potatoes	17 206	12 206	43	71
Maize	2982	1807	65	18
Barley	1910	1333	43	56
Barley (forage)	23 000	25 865	45	159

[a] All crops treated with chemical fertilizers.
[b] Water absorption terraces with earthen walls and inward platform slope.
[c] Fields sloping between 20% and 50% located next to terraced fields for control.
[d] N = number of terrace/field sites.
Source: Treacey (1984).

8. Organic farming in the Andes

In the Bolivian highlands, average potato production is falling despite a 15% annual increase in the use of chemical fertilizers. Due to increases in the cost of fertilizer, potato farmers must produce more than double the amount of potatoes compared with previous years to buy the same quality of imported fertilizer (Augustburger, 1983). Members of the former Proyecto de Agrobiologia de Cochabamba, now called AGRUCO, are attempting to reverse this trend by helping peasants recover their production autonomy. In experiments conducted in neutral soils, higher yields were obtained with manure than with chemical fertilizers. In Bolivia, organic manures are deficient in phosphorous. Therefore, AGRUCO recommends phosphate rock and bone meal, both of which can be obtained locally and inexpensively, to increase the phosphorous content of organic manures. To further replace the use of fertilizers and meet the nitrogen requirements of potatoes and cereals, intercropping and rotational systems have been designed that use the native species *Lupinus mutabilis*. Experiments have revealed that *L. mutabilis* can fix 200 kg N ha^{-1} $year^{-1}$, which becomes partly available to the associated or subsequent potato crop, thus significantly minimizing the need for fertilizers (Augustburger, 1983). Intercropped potato/lupine overyielded corresponding potato monocultures, and also substantially reduced the incidence of virus diseases.

Other studies in Bolivia, where Lupine has been used as a rotational crop, show that, although yields are greater in chemically fertilized and machinery-prepared potato fields, energy costs are higher and net economic benefits lower than with the agroecological system (Table V). Surveys indicate that farmers prefer this alternative system because it optimizes the use of scarce resources, labor and available capital, and is available to even poor producers.

In the Interandean valleys of Cajamarca, near San Marcos traditional farming systems have been drastically modified through elements of conventional farming and urban influences, creating a market-oriented monoculture agriculture which favors cash crops rather than Andean crops. Centro IDEAS, an agricultural NGO, has implemented an organic agriculture proposal in order to revert the above process, supporting a more appropriate rural

TABLE V. Performance of traditional, modern, and agroecological potato-based production systems in Bolivia

	Traditional low-input	Modern high-input	Agroecological system
Potato yields (metric tons/ha)	9.2	17.6	11.4
Chemical fertilizer ($N + P_2O_5$, kg ha^{-1})	0.0	80 + 120	0.0
Lupine biomass (metric t ha^{-1})	0.0	0.0	1.5
Energy efficiency-fossil and renewable (output/input)	15.7	4.8	30.5
Net income per invested Boliviano	6.2	9.4	9.9

Source: Rist (1992).

development strategy that rescues elements of the local traditional agriculture and ensuring food self-sufficiency as well as the preservation of natural resources (Chavez et al., 1989). The basic aspects of the proposal are:

- Rational use of local resources, conservation of natural resources, and intensive use of human and animal labor.
- High diversity of native (Andean) and exotic crops, herbs, shrubs, trees, and animals grown in polycultural and rotational patterns.
- Creation of favorable microclimates through the use of shelterbelts, and living fences and reforestation with native and exotic fruit and trees.
- Recycling of organic residues and optimal management of small animals.

This proposal was implemented in a 1.9 ha model farm inserted in an area with similar conditions facing the average campesino of the region. The farm was divided into 9 plots, each following a particular rotational design (Table VI). After 3 years of operation, field results showed the following trends:

- Organic matter content increased from low to medium and high levels, and N levels increased slightly. Addition of natural fertilizers were necessary to maintain optimum levels of organic matter and nitrogen.
- Phosphorous and potassium increased in all plots.
- Crop yields varied among plots, however in plots with good soils, (plot 1) high yields of corn and wheat were obtained.
- Polycultures overyielded monocultures in all instances.
- To farm 1 ha of the model farm it was necessary to use 100 man-hours, 15 oxen-hours, and about 100 kg of seeds.

These preliminary results indicate that the proposed farm design enhances the diversity of food crops available to the family, increases income through higher productivity, and maintains the ecological integrity of the natural resource base.

Since then, this model experience extended to 12 farmers who have undergone conversion to agroecological management in the Peruvian Sierra and Coast. A recent evaluation of the

TABLE VI. Model farm rotational design

Plot	Year 1	Year 2	Year 3
1	Maize, beans, quinoa, kiwicha, squash, and chiclayo	Wheat	Barley
2	Barley	*Lupinus* and lentils	Linaza
3	Wheat	Favas and oats	Maize, beans, quinoa, kiwicha
4	Rye	Wheat	Lentils
5	Lupinus	Maize, beans, quinoa, kiwicha, squash, and chiclayo	Wheat
6	Fallow	Linaza	Barley and Lentils

Source: Chavez et al., 1989.

experiences showed that after a 2–5 year conversion process, income increased progressively due to a 20% increase in productivity (Alvarado de la Fuente and Wiener Fresco, 1998). Of the 33 different organic technologies offered by the IDEAS, the 12 case study farmers favored: organic fertilization (11 cases), intercropping (10 cases), animal integration (10 cases), and agroforestry systems (8 cases).

9. Agroecological approaches in Brazil

The state government extension and research service, EPAGRI (Empresa de Pesquisa Agropecuaria e Difusao de Technologia de Santa Catarina), works with farmers in the southern Brazilian state of Santa Catarina. The technological focus is on soil and water conservation at the micro-watershed level using contour grass barriers, contour ploughing and green manures. Some 60 cover crop species have been tested with farmers, including both leguminous plants such as velvetbean, jackbean, lablab, cowpeas, many vetches and crotalarias, and non-legumes such as oats and turnips. For farmers these involved no cash costs, except for the purchase of seed. These are intercropped or planted during fallow periods, and are used in cropping systems with maize, onions, cassava, wheat, grapes, tomatoes, soybeans, tobacco, and orchards (Monegat, 199l).

The major on-farm impacts of the project have been on crop yields, soil quality and moisture retention, and labor demand. Maize yields have risen since 1987 from 3 to 5 t ha^{-1} and soybeans from 2.8 to 4.7 t ha^{-1}. Soils are darker in color, moist and biologically active. The reduced need for most weeding and ploughing has meant significant labor savings for small farmers. From this work, it has become clear that maintaining soil cover is more important in preventing erosion than terraces or conservation barriers. It is also considerably cheaper for farmers to sustain. EPAGRI has reached some 38 000 farmers in 60 micro-watersheds since 1991 (Guijt, 1998). They have helped more than 11 000 farmers develop farm plans and supplied 4300 t of green manure seed.

In the savannahs of the Brazilian Cerrados where soybean monoculture dominates many problems associated with inappropriate land development have become evident. A key to production stability in the Cerrados is soil conservation and soil fertility replenishment as maintenance and increase of soil organic content is of paramount importance. For this reason NGOs and government researchers have concentrated efforts on the design of appropriate crop rotation and minimum tillage systems. The adoption of maize–soybean rotations have increased yields, slowed soil erosion and decreased pest and disease problems that affected soybean monocrops. Better weed control as well as soil organic maintenance has also been observed in such rotational systems (Spehar and Souza, 1996).

Another promoted alternative technique has been the use of green manures such as *Crotalaria juncea* and *Stizolobium atterrimum*. Researchers have shown grain crops following green manure yielded up to 46% more than monocultures during normal rainy seasons . Although the most common way of using green manures is to plant a legume after the main crop has been harvested, green manures can be intercropped with long cycle crops. In the case of maize – green manure intercrop, best performance is observed when *S. atterrimum* is sown 30 days after the maize. Maize can also be intercropped with perennial pasture legumes such as *Zornia* sp. and *Stylosanthes* spp., a system of double purpose: produces food and fodder (Spehar and Souza, 1996).

In the hot and dry climate of Ceara, farmers combine production of sheep, goats, maize and beans, but productivity is low and environmental degradation is increasing. In the period between 1986 and 1991, ESPLAR, a local NGO engaged in a broad development program, involving the whole state of Ceara, through a massive training program in agroecology for village leaders. The training spearheaded a series of village-level activities reaching about 600 farmers which resulted in (VonderWeid, 1994):

1. The return of arboreal cotton cultivation in mixed cropping with leucaena, algarrobo (*Prosopis juliflora*) and sabia (*Mimosa caesalpiniaefdia*). A shorter cycle variety was introduced, which together with integrated control of the boll weevil, made it possible to restore cotton fields.
2. The use of small dams for irrigated vegetable production.
3. Enriching the capoeiras (areas with secondary vegetation regrowth) with selected plant species made it possible to support 50% more goats per land unit.
4. Introduction of herbaceous legumes for fodder (especially cunha [*Bradburya sagittata*]), in crop mixtures or rotated with maize and beans.
5. Planting along contour lines to reduce runoff.

In a similar semi-arid environment, as part of its research for alternatives to slash and burn, the Center for Alternative Technologies of Ouricouri developed a three year experiment to demonstrate the viability of land clearing without burning. The strategy had four components: the rationalized use of labor; the use of crops that compete with natural vegetation regrowth; efficient soil protection; and the harvesting and retention of rainwater. The work reaches at least 500 farmers in 30 communities (Guijt, 1998). The no-burning alternative involved cutting and clearing bush and tree vegetation, sowing crops more densely, and using cattle and horse manure. The first-year results indicated that reasonable production was possible and that tree and bush regrowth can be controlled. One negative aspect, however was the need to use over one-sixth of the available area for the storage of trunks and branches. In the second year bean output increased by over 100% relative to the historical average, though the low productivity of maize raised doubts as to its suitability under semi-arid agroecological conditions. Sorghum exhibited a better performance.

The accumulation of plant material by the third year was enough to use as mulch. Unfortunately, the initial rains were followed by prolonged drought, and bean output fell sharply because of fungal disease. Nevertheless, the maize yield (552 kg ha^{-1}) was above the regional average of 500 kg ha^{-1} (Vonder Weid, 1994).

10. Integrated production systems

A number of NGOs promote the integrated use of a variety of management technologies and practices. The emphasis is on diversified farms in which each component of the farming system biologically reinforces the other components; for instance, where wastes from one component become inputs to another. Since 1980, CET, a Chilean NGO has engaged in a rural development program aimed at helping peasants reach year-round food self sufficiency while rebuilding the productive capacity of their small land holdings (Altieri, 1995). The approach has been to set up several 0.5 ha model farms, which consist of a spatial and temporal rotational sequence of forage and row crops, vegetables, forest and fruit trees, and animals. Components are chosen according to crop or animal nutritional contributions to subsequent rotational steps, their adaptation to local agroclimatic conditions, local peasant consumption patterns and finally, market opportunities. Most vegetables are grown in heavily composted raised beds located in the garden section, each of which can yield up to 83 kg of fresh vegetables per month, a considerable improvement to the 20–30 kg produced in spontaneous gardens tended around households. The rest of the 200-square meter area surrounding the house is used as an orchard, and for animals (cows, hens, rabbits, and langstroth behives).

Vegetables, cereals, legumes and forage plants are produced in a six-year rotational system within a small area adjacent to the garden. Relatively constant production is achieved (about 6 t year^{-1} of useful biomass from 13 different crop species) by dividing the land into as many small fields of fairly equal productive capacity as there are years in the rotation. The rotation is designed to produce the maximum variety of basic crops in 6 plots, taking advantage of the soil-restoring properties and biological control features of the rotation.

Over the years, soil fertility in the original demonstration farm has improved, and no serious pest or disease problems have appeared. Fruit trees in the orchard and fencerows, as well as forage crops are highly productive. Milk and egg production far exceeds that on conventional farms. A nutritional analysis of the system based on its key components shows that for a typical family it produces a 250% surplus of protein, 80% and 550% surplus of vitamin A and C, respectively, and a 330% surplus of calcium. A household economic analysis indicates that, the balance between selling surpluses and buying preferred items provides a net income beyond consumption of US $790. If all of the farm output were sold at whole sale prices, the family could generate a monthly net income 1.5 times greater than the monthly legal minimum wage in Chile, while dedicating only a relatively few hours per week to the farm. The time freed up is used by farmers for other on-farm or off-farm income generating activities.

In Cuba, the Asociacion Cubana de Agricultura Organica (ACAO), a NGO formed by scientists, farmers, and extension personnel, has played a pioneering role in promoting alternative production modules (Rosset, 1997). In 1995, ACAO helped establish three integrated farming systems called ‘agroecological lighthouses’ in cooperatives (CPAs) in the province of Havana. After the first 6 months, all 3 CPAs had incorporated agroecological innovations (i.e. tree integration, planned crop rotation, polycultures, green manures, etc.) to varying degrees, which, with time, have led to enhancement of production and biodiversity, and improvement in soil quality, especially organic matter content. Several polycultures such as cassava–beans–maize, cassava–tomato–maize, and sweet potato–maize were tested in the CPAs. Productivity evaluation of these polycultures indicates 2.82, 2.17 and 1.45 times greater productivity than monocultures, respectively (Table VII).

The use of *Crotalaria juncea* and *Vigna unguiculata* as green manure have ensured a production of squash equivalent to that obtainable applying 175 kg ha^{-1} of urea. In addition, such legumes improved the physical and chemical characteristics of the soil and

TABLE VII. Performance of designed polycultures in two Cuban cooperatives

Polyculture	Yield (t ha^{-1})			LER	Lighthouse
	Year 1	Year 2	Year 3		
Cassava–beans–maize	15.6	1.34	2.5	2.82	‘28 de Septiembre’
Cassava–tomato–maize	11.9	21.2	3.7	2.17	‘Gilberto Leon’
Cassava–maize	13.3	3.39	—	1.79	‘Gilberto Leon’
Beans–maize–cabbage	0.77	3.6	2.0	1.77	‘28 de Septiembre’
Sweet potato–maize	12.6	2.0	—	1.45	‘Gilberto Leon’
Sorghum–squash	0.7	5.3	—	1.01	‘28 de Spetiembre’

Source: SANE (1998) (LER= land equivalent ratio).

TABLE VIII. Productive and efficiency performance of the 75% animal/25% crop integrated module in Cuba

Productive parameters	1st year	3rd year
Area (ha)	1	1
Total production (t ha^{-1})	4.4	5.1
Energy produced (Mcal ha^{-1})	3797	4885
Protein produced (Kg ha^{-1})	168	171
Number of people fed by one ha.	4	4.8
Inputs (energy expenditures, Mcal)		
Human labor	569	359
Animal work	16.8	18.8
Tractor energy	277.3	138.6

Source: SANE (1998).

effectively broke the life cycles of insect pests such as the sweet potato weevil (SANE, 1998).

At the Cuban Instituto de Investigacion de Pastos, several agroecological modules with various proportions of the farm area devoted to agriculture and animal production were established. Monitoring of production and efficiencies of a 75% pasture/25% crop module, reveals that total production increases over time, and that energy and labor inputs decrease as the biological structuring of the system begins to sponsor the productivity of the agroecosystem. Total biomass production increased from 4.4 to 5.1 t ha^{-1} after 3 years of integrated management. Energy inputs decreased, which resulted in enhanced energy efficiency from (4.4–9.5) (Table VIII). Human labor demands for management also decreased over time from 13 h of human labor/day to 4–5 h. Such models have been promoted, extensively in other areas through field days and farmers cross visits (SANE, 1998).

11. Conclusions

Most research conducted on traditional and peasant agriculture in Latin America suggests that small holder systems are sustainably productive, biologically regenerative, and energy-efficient, and also tend to be equity enhancing, participative, and socially just. In general, traditional agriculturalists have met the environmental requirements of their food-producing systems by relying on local resources plus human and animal energy, thereby using low levels of input technology.

While it may be argued that peasant agriculture generally lacks the potential of producing meaningful marketable surplus, it 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. Productivity may be low but the causes appear to be more social, not technical. When the subsistence farmer succeeds in providing food, there is no pressure to innovate or to enhance yields. Nevertheless, agroecological field projects show that traditional crop and animal combinations can often be adapted to increase productivity when the biological structuring of the farm is improved and labor and local resources are efficiently used (see Table IX; Altieri, 1995). In fact, most agroecological technologies

TABLE IX. Extent and impacts of agroecological technologies and practices implemented by NGOs in peasant farming throughout Latin America

Country	Organization involved	Agroecological intervention	No. of farmers or farming units affected	No. of hectares affected	Dominant crops	Yield inc
Brazil	EPAGRI AS-PTA	Green manures cover crops	38 000 families	1 330 000	Maize, wheat	198–246%
Guatemala	Altertec and others	Soil conservation, green manures, organic farming	17 000 units	17 000	Maize	250%
Honduras	CIDDICO COSECHA	Soil conservation, green manures	27 000 units	42 000	Maize	250%
EL Salvador	COAGRES	Rotations, green manures, compost, botanical pesticides	> 200 farmers	nd	Cereals	40–60%
Mexico	Oaxacan Cooperatives	Compost, terracing, contour planting	3000 families	23 500	Coffee	140%
Peru	PRAVTIR CIED	Rehabilitation of ancient terraces	> 1250 families	> 1000	Andean Crops	141–165%
	PIWA-CIED	Raised fields	nd	250	Andean crops	333%
	CIED	Watershed agricultural rehabilitation	> 100 families	N/A	Andean Crops	30–50%
	IDEAS	Intercropping, agroforestry, composting	12 families	25	Several Crops	20%
Dominican Republic	Plan Sierra Swedforest-Fudeco	Soil conservation, dry forest management silvopastoral systems	> 2500 families	> 1000	Several Crops	50–70%
Chile	CET	Integrated farms, organic farming	> 1000 families	> 2250	Several Crops	> 50%
Cuba	ACAO	Integrated farms	4 cooperatives	250	Several Crops	50–70%

nd = no data.
Source: Browder (1989), Altieri (1995), Pretty (1997).

TABLE X. Coefficient of variability of yields registered in different cropping systems during 3 years in Costa Rica

Cropping system	Monoculture (mean of sole crops)	Polyculture
Cassava/bean	33.04	27.54
Cassava/maize	28.76	18.09
Cassava/sweet potato	23.87	13.42
Cassava/maize/sweet potato	31.05	21.44
Cassava/maize/bean	25.04	14.95

Source: Francis (1986).

promoted by NGOs can improve traditional agricultural yields increasing output per area of marginal land from 400–600 to 2000–2500 kg ha^{-1} enhancing also the general agrodiversity and its associated positive effects on food security and environmental integrity. Some projects emphasizing green manures and other organic management techniques can increase maize yields from 1–1.5 t ha^{-1} (a typical highland peasant yield) to 3–4 t ha^{-1}. Polycultures produce more combined yield in a given area than could be obtained from monocultures of the component species. Most traditional or NGO promoted polycultures exhibit LER values greater than 1.5. Moreover, yield variability of cereal/legume polycultures are much lower than for monocultures of the components (Table X).

In general, data shows that over time agroecological systems exhibit more stable levels of total production per unit area than high-input systems; produce economically favorable rates of return; provide a return to labor and other inputs sufficient for a livelihood acceptable to small farmers and their families; and ensure soil protection and conservation as well as enhance biodiversity.

For a region like Latin America which is considered to be 52.2% self-reliant on major food crops as it produces enough food to satisfy the needs of its population, agroecological approaches that can double yields of the existing 16 million peasant units can safely increase the output of peasant agriculture for domestic consumption to acceptable levels well into the future. To address hunger and malnutrition, however, it is not only necessary to produce more food, but this must be available for those who need it most. Land redistribution is also a key prerequisite in order for peasants to have access to acceptable land and thus perform their role in regional self-reliance.

References

Alcorn, J.B.: 1981, 'Huastec noncrop resource management', *Human Ecol*. **9**, 395.

Alcorn, J.B.: 1984, *Huastec Mayan Ethnobotany*, Austin, University of Texas Press.

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', *Am. J. Alternative Agri*. **1**, 30–38

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.

Altieri, M.A. and Merrick, L.C.: 1987, '*In situ* conservation of crop genetic resources through maintenance of traditional farming systems', *Econ. Bot*. **4**, 86–96.

Altieri, M.A.: 1990, 'Stabilizing hillside farming systems in the Sierra of Dominican Republic', IAHS-AISH Pub. No. 192, pp. 355–363.

Altieri, M.A.: 1991, 'Traditional farming in Latin America', *The Ecologist* **21**, 93–96.
Altieri, M.A. and Hecht, S.B.: 1991, *Agroecology and Small Farm Development*. Boca Raton, CRC Press.
Altieri, M.A. and Masera, O.: 1993, 'Sustainable rural development in Latin America: building from the bottom up', *Ecological Economics* **7**, 93–121.
Altieri, M.A. 1994, *Biodiversity and Pest Management in Agroecosystems*. New York, Haworth Press.
Altieri, M.A.: 1995, 'Agroecology: The Science of Sustainable Agriculture. Boulder, Westview Press.
Altieri, M.A.: 1996, 'Enfoque agroecologico para el desarrollo de sistemas de produccion sostenibles en los Andes', Centro de Investigacion, Lima, Educacion y Desarrollo.
Altieri, M.A., Rosset, P. and Thrupp, L.A.: 1998, 'The potential of agroecology to combat hunger in the developing world. *2020 Brief*. Washington, DC, IFPRI.
Alvarado de la Fuente, F. and Wiener, H.: 1998, 'Ofertas agroecologicas para pequenos agricultores: doce experiencias exitosas de agricultura ecologica', Lima, Centro IDEAS.
Augustburger, F.: 1983, 'Agronomic and economic potential of manure in Bolivian valleys and highlands', *Agric. Ecosystem Environ*. **10**, 335–346.
Beets, W.C.: 1982, *Multiple Cropping and Tropical Farming Systems*, Boulder, Westview Press.
Beets, W.C.: 1990, Raising and sustaining productivity of smallholders farming systems in the Tropics. Holland, AgBe Publishing.
Blauert, J. and Zadek, S.: 1998, *Mediating Sustainability*, Connecticut, Kumarian Press.
Brokenshaw, D.W., Warren, D.M. and Werner, O.: 1980, *Indigenous Knowledge Systems and Development*, Lanham, University Press of America.
Brookfield, H. and Padoch, C.: 1994, 'Appreciating agrobiodiversity: a look at the dynamism and diversity of indigenous farming practices', *Environment* **36**, 7–20.
Browder, J.O.: 1989, *Fragile Lands of Latin America: Strategies for Sustainable Development*. Boulder, Westview Press.
Brush, S.B.: 1982, 'The natural and human environment of the central Andes', *Mountain Res. Develop*. **2**,14–38.
Buckles, D., Triomphe, B. and Sain, G.: 1998, Cover crops in hillside agriculture, Mexico D.F., IDRC-CIMMYT.
Bunch, R. : 1987, 'Case study of the Guinope Integrated Development Program', in Proceedings IIED Conference on Sustainable Development, London.
Bunch, R.: 1990, Low-input soil restoration in Honduras: the Cantarranas farmer-to-farmer extension project. *Sustainable Agriculture Gatekeeper Series* SA23, London, IIED.
Chambers, R.: 1983, *Rural Development: Putting the Last First*, Essex, Longman Group Limited.
Chavez, J. et al.: 1989, Propuesta de agricultura organica para la sierra, Lima, IDEAS-CONYCET.
Chang, J.H.: 1977, 'Tropical agriculture: crop diversity and crop yields', *Econ. Geogr*. **53**, 241–254.
Clarke, W.C. and Thaman, R.R.: 1993, *Agroforestry in the Pacific: Systems for Sustainability*, Tokyo, United Nations University Press.
Clawson, D.L.: 1985, 'Harvest security and intraspecific diversity in traditional tropical agriculture'. *Econ. Bot*. **39**, 56–67.
Denevan, W.M., Treacey, 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**, 346–357.
Denevan, W.M.: 1995, 'Prehistoric agricultural methods as models for sustainability', *Advanced Plant Pathology* **11**, 21–43.
Erickson, C.L. and Chandler, K.L.: 1989, Raised fields and sustainable agriculture in lake Titicaca Basin of Peru, in J.O. Browder (ed.), *Fragile Lands of Latin America*, Westview Press, Boulder, pp. 230–243.
Flores, M.: 1989, 'Velvetbeans: an alternative to improve small farmers' agriculture', *ILEIA Newsletter* **5**, 8–9.
Francis, C.A.: 1986, *Multiple Cropping Systems*, New York, MacMillan.
Gladwin, C. and Truman, K.: 1989, *Food and Farm: Current Debates and Policies*, Lantham, MD, University Press of America.
Gliessman, S.R., Garcia, E. and Amador, A.: 1981, 'The ecological basis for the application of traditional agricultural technology in the management of tropical agro-ecosystems', *Agro-Ecosystems* **7**, 173–185.
Gliessman, S.R.: 1998, *Agroecology: Ecological Process in Sustainable Agriculture*. Michigan, Ann Arbor Press.
Grigg, D.B.: 1974, *The Agricultural Systems of the World: An Evolutionary Approach*, Cambridge, Cambridge University Press.

Guijt, I.: 1998, 'Assessing the merits of participatory development of sustainable agriculture: experiences from Brazil and Central America', in: J. Blauert and S. Zadek (eds.) *Mediating Sustainability*, pp. Conn, Kumarian Press, 100–128.
Harwood, R.R.: 1979, *Small Farm Development – Understanding and Improving Farming Systems in the Humid Tropics*, Boulder, Westview Press.
Hecht, S.B.: 1984, 'Indigenous soil management in the Amazon basin: some implications for development', in J.O. Browder (ed.), *Fragile Lands of Latin America*, Boulder, Westview Press, pp. 166–181.
Holtz-Gimenez, E.: 1996, 'The campesino a campesino movement: farmer-led, sustainable agriculture in Central America and Mexico', in: *Food First Development Report* No. 10, Oakland, Institute of Food and Development Policy.
Jimenez-Osornio, J. and del Amo, S.: 1986, 'An intensive Mexican traditional agroecosystem: the chinampa', in: Procedings of the 6th International Scientific Conference IFOAM, Santa Cruz, California.
Lampkin, N.: 1992, *Organic Farming*, Ipswhich, England, Farming Press.
Marten, G.C.: 1986, *Traditional agriculture in South-East Asia: A Human Ecology Perspective*, Boulder, Westview Press.
Nair, P.K.R.: 1984, *Soil Productivity Aspects of Agroforestry*, Nairobi, ICRAF.
Norman, M.J.T.: 1979, Annual Cropping Systems in the Tropics, Gainesville, University Presses of Florida.
Ortega, E.: 1986, *Peasant agriculture in Latin America*, Santiago, Joint ECLAC/FAO Agriculture Division.
Pimentel, D. and Pimentel, M.: 1979, *Food, Energy and Society*, London, Edward Arnold.
Posey, D.A.: 1985, 'Indigenous management of tropical forest ecosystems: the case of the Kayapo indians of the Brazilian Amazon', *Agroforestry Systems* **3**, 139–158.
Posner, J.L. and McPherson, M.F.: 1982, 'Agriculture on the steep slopes of tropical America', *World Development* **10**, 341–53.
Pretty, J.: 1995, *Regenerating Agriculture*, Washington, DC, World Resources Institute.
Pretty, J.: 1997, 'The sustainable intensification of agriculture', *Natural Resources Forum* **21**, 247–256.
Reijntes, C., Haverkort, B. and Ann Waters-Bayer: 1992, *Farming for the Future*, London, MacMillan.
Richards, P.: 1985, *Indigenous Agricultural Revolution*, Boulder, Westview Press.
Rist, S.: 1992, 'Ecologia, economia y technologia campesina', *Ruralter* **10**, 205–227.
Rosset, P.M.: 1997, 'Alternative agriculture and crisis in Cuba', *Technol. Soc*. **16**, 19–25.
Sanchez, J.B.: 1994, 'A seed for rural development: the experience of EDAC-CIED in the Mashcon watershed of Peru', *J. Learnings* **1**, 13–21.
Sanders, W.T.: 1957, *Tierra y agua: a study of the ecological factors in the development of Meso-American civilizations*, Ph.D. Dissertation, Harvard University.
SANE: 1998, *Farmers, NGOs and Lighthouses: Learning from Three Years of Training, Networking and Field Activities*, Berkeley, SANE-UNDP.
Thrupp, L.A.: 1996, *New Partnerships for Sustainable Agriculture*, Washington, DC, World Resources Institute.
Thrupp, L.A.: 1998, '*Cultivating Diversity: Agrobiodiversity and Food Security*, Washington, DC, World Resources Institute.
Thurston, H.D.: 1991, *Sustainable Practices for Plant Disease Management in Traditional Farming Systems*. Boulder, Westview Press.
Thurston H.D. et al.: 1994, *Slash/Mulch: How Farmers Use It and What Researchers Know About It*. Ithaca, NY, CIIFAD-CATIE.
Toledo, V.M.: 1980, 'La ecologia del modo campesino de produccion', *Antropologia y Marxismo* **3**, 35–55.
Toledo, V.M., Carabias, J., Mapes, C. and Toledo. C.: 1985, *Ecologia y Autosuficiencia Alimentaria*, Mexico City, Siglo Veintiuno Editores.
Treacey, J.M.: 1989, 'Agricultural terraces in Peru's Colca Valley: promises and problems of an ancient technology', in: J.O. Browder (ed.), *Fragile Lands of Latin America*. Boulder, Westview Press.
VonderWeid, J.M.: 1994, 'Agroecology in Taua (AS-PTA)', *J. Learnings* **1**, 28–37.
UNDP: 1995, *Benefits of Diversity*, New York, UNDP.
Wilken, G.C.: 1987, *Good Farmers: Traditional Agricultural Resource Management in Mexico and Guatemala*, Berkeley, University of California Press.