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Enhancing the productivity and multifunctionality of traditional farming in Latin America

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Key words: agriculture, Latin America, multiple use strategies

SUMMARY
An assessment is made of various grassroots development initiatives in Latin America which show that agroecological technologies can bring significant environmental and economic benefits to small farmers and rural communities in the region. Examined initiatives offer new ways of enhancing the multifunctional attributes of traditional agriculture through greater per unit area productivity and environmental services obtained in complex, integrated agroecological systems that feature many crop varieties, together with animals and trees. 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. The challenge now is to mobilize science, institutions and the right policies to increase the productivity of smallholder farming systems, while preserving the resource base and at the same time empowering local communities.

INTRODUCTION
Most agricultural scientists today recognize that traditional systems and indigenous knowledge will not yield panaceas for agricultural problems in the developing world (Altieri, 1995; Gliessman, 1998). This is not to say, however, that traditional ways of farming refined over many generations by intelligent land users cannot provide key insights into sustainably managing soils, water, crops, animals and pests (Thrupp, 1996). 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 than technical. When the subsistence farmer succeeds in providing food, there is no pressure to innovate or to enhance yields. As will be demonstrated herein, however, agroecological field projects led by NGOs show that traditional crop and animal combinations can be optimized to increase productivity when the biological structuring of the small farms is improved and labour and local resources are efficiently used.

For agroecologists committed to helping poor farmers to raise the productivity and sustainability of their smallholdings, a crucial task has been to understand the features of traditional agriculture, such as the ability to bear risk, biological folk taxonomies, the production efficiency of symbiotic crop mixtures, etc. Such research has provided important information on how to develop agricultural technologies best suited to the needs and circumstances of specific peasant groups,
thus becoming a critical input for the application of agroecology in rural development programmes. Since the early 1980s, more than 200 projects promoted by 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 alternative 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, 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 labour 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 alternative cropping 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.

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.

THE CONTRIBUTION OF TRADITIONAL AGRICULTURE TO FOOD PRODUCTION AND SUSTAINABILITY

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. 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 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 to 6.3 tonnes per ha. 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 tonnes per ha, and did not pass the 4 tonnes per ha mark until 1965. Sanders (1957) estimated that that each hectare of chinampa could produce enough food for 15 to 20 persons per year at modern subsistence levels. Recent research has indicated that each
Multifunctional agriculture in Latin America

Chinamparo can work about 0.75 ha of chinampa per year (Jimenez-Osornio and del Amo, 1986), meaning that each farmer can support 12 to 15 people.

The use of polycultures is a common peasant strategy of minimizing risk by planting several species and varieties of crops which 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). 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).

By the end of the twentieth century peasant production units will have reached about 16 million, 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 overall 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.

APPLYING AGROECOLOGY TO ENHANCE THE PRODUCTIVITY AND SUSTAINABILITY OF PEASANT AGRICULTURE

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. Biodiversity 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 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 starting 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 non-governmental organizations (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.

Stabilizing the hillsides 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 programme 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. Programme yields tripled or quadrupled from 400 kg per ha to 1200–1600 kg, depending on the farmer. This tripling in per-hectare grain production has ensured that the 1200 families participating in the programme 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 500 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 labour wages from US $2 to $3 per day in the project area. Out-migration has been replaced by in-migration, with many people moving back from the urban slums of Tegucigalpa to occupy farms they had previously abandoned, so increasing the population of Guinope. The main difficulties have been in marketing 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, as well as produce 35 tonnes of organic matter per year, has tripled maize yields to 2500 kg/ha. Labour 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 on the northern coast of Honduras are using velvet bean (Mucuna pruriens) with excellent results, including corn yields of about 5000 kg/ha, more than double the national average, erosion control, weed suppression and reduced land preparation costs. The velvet beans produce nearly 30 tonnes/ha of biomass per year, or about 90–100 kg of N/ha per year (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 (Holz-Gimenez, 1996). Economic analyses of these projects indicate that farmers adopting cover cropping have lowered their utilization of chemical fertilizers (from 1900 kg/ha to 400 kg/ha) while increasing yields from 700 kg to 2000 kg/ha, 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) and considerable reduction in labour 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 % of land, but as their benefits are recognized by farmers, they are spreading quickly. Such methods have strong potential and offer important advantages for other areas of Central America and beyond.

### Soil conservation in the Dominican Republic

Several years ago Plan Sierra, an ecodevelopment project, took on the challenge of breaking the
Multifunctional agriculture in Latin America

Altieri

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’s agroecological strategy was the development and diffusion of production systems that provided sustainable yields without degrading the soil, thus ensuring farmers reasonable 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 labour. 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 conucos 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, 1990).

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, NGOs 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 3000 yr 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 4000 m (Erickson and Chandler, 1989).

In 1984 several NGOs and State agencies created the Proyecto Interinstitucional de Rehabilitacion...
Multifunctional agriculture in Latin America

Table 1  First-year per hectare yields of crops on new bench terraces, compared to yields on sloping fields (kg/ha). (Source: Treacey, 1984)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Terraced*</th>
<th>Non-terraced*</th>
<th>% Increase</th>
<th>N*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>17 206</td>
<td>12 206</td>
<td>43</td>
<td>71</td>
</tr>
<tr>
<td>Maize</td>
<td>2982</td>
<td>1807</td>
<td>65</td>
<td>18</td>
</tr>
<tr>
<td>Barley</td>
<td>1910</td>
<td>1333</td>
<td>43</td>
<td>56</td>
</tr>
<tr>
<td>Barley (forage)</td>
<td>23 000</td>
<td>25 865</td>
<td>45</td>
<td>159</td>
</tr>
</tbody>
</table>

*All crops treated with chemical fertilizers

Water absorption terraces with earthen walls and inward platform slope

Fields sloping between 20 and 50% located next to terraced fields for control

N = number of terrace/field sites

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 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 and quinoa yields reached 2 tonnes/ha/yr in WaruWarus. It is estimated that the initial construction, rebuilding every 10 years, and annual planting, weeding, harvest and maintenance of raised fields planted with potatoes requires 270 person-days/ha/yr. Clearly, raised beds require strong social cohesion for the cooperative work needed on beds and canals. For the construction of the fields, NGOs organized labour at the individual, family, multi-family, and communal levels.

Elsewhere in Peru, several NGOs, in partnership with local government agencies have engaged in programmes 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 tonnes/ha to 8 tonnes/ha and oca yields jumped from 3 to 8 tonnes/ha.

Enhanced crop production, fattening of cattle and raising of alpaca for wool, have increased the income of families from an average of $108 per year 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 1). 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 labour 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 labour intensive, requiring only 300–500 worker-day/ha (Treacey, 1989).

NGOs have also evaluated traditional farming systems above 4000 masl, where maca (Lepidium meyenii) is the only crop capable of offering farmers secure yields. Research shows that maca grown in virgin soils or those fallowed between 5–8 years,
Multifunctional agriculture in Latin America

Table 2 Performance of traditional, modern, and agroecological potato-based production systems in Bolivia. (Source: Rist, 1992)

<table>
<thead>
<tr>
<th></th>
<th>Traditional low input</th>
<th>Modern high input</th>
<th>Agroecological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato yields (tonnes/ha)</td>
<td>9.2</td>
<td>17.6</td>
<td>11.4</td>
</tr>
<tr>
<td>Chemical fertilizer (N + P₂O₅, kg/ha)</td>
<td>0</td>
<td>80 + 120</td>
<td>0</td>
</tr>
<tr>
<td>Lupin biomass (tonnes/ha)</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Energy efficiency (output/input)</td>
<td>15.7</td>
<td>4.8</td>
<td>30.5</td>
</tr>
<tr>
<td>Net income per invested Boliviano</td>
<td>6.2</td>
<td>9.4</td>
<td>9.9</td>
</tr>
</tbody>
</table>

exhibited significantly higher yields (11.8 and 14.6 tonnes/ha, respectively) than maca grown after bitter potatoes (11.3 tonnes/ha). NGOs are now advising farmers to grow maca in virgin or fallow soils in a rotation pattern, to use areas not suitable for other crops and take advantage of the local labour and low costs of the maca-based system (UNDP, 1995, Altieri 1996).

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 quantity of imported fertilizer (Augstburger, 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 phosphorus. Therefore, AGRUCO recommends phosphate rock and bone meal, both of which can be obtained locally and inexpensively, to increase the phosphorus 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 300 kg of nitrogen per hectare per year, which becomes partly available to the associated or subsequent potato crop, thus significantly minimizing the need for fertilizers (Augstburger, 1983). Intercropped potato/lupin gave higher yields than corresponding potato monocultures, and also substantially reduced the incidence of viral diseases.

Other studies in Bolivia where lupin 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 2). Surveys indicate that farmers prefer this alternative system because it optimizes the use of scarce resources, labour and available capital, and is available to even poor producers (Rist, 1992).

Agroecological approaches in Brazil

The state government extension and research service, EPAGRI (Empresa de Pesquisa Agropecuaria e Difusao de Tecnologia de Santa Catarina), works with farmers in the southern Brazilian state of Santa Catarina. The technological focus is on soil and water conservation at 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 velvet bean, jack bean, 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, 1991).

The major on-farm impacts of the project have been on crop yields, soil quality and moisture retention, and labour demand. Maize yields have risen since 1987 from 3 to 5 tonnes/ha and

56 International Journal of Sustainable Development and World Ecology
soybeans from 2.8 to 4.7 tonnes/ha. Soils are darker in colour, moist and biologically active. The reduced need for most weeding and ploughing has meant significant labour 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 tonnes of green manure seed.

In the savannas 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 has increased yield, 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 attainturnum. 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. attainturnum is sown 30 days after the maize. Maize can also be intercropped with perennial pasture legumes such as Zornia sp. and Stylosanthes spp., a dual-purpose system: produces food and fodder (Spehar and Souza, 1996).

**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 programme 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 m² area surrounding the house is used as an orchard, and for animals, (cows, hens, rabbits, and langstroth beehives).

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 tonnes/ y 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 six 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
Table 3  Productive and efficiency performance of the 75% animal / 25% crop integrated module in Cuba. (Source: SANE, 1998)

<table>
<thead>
<tr>
<th>Productive parameters</th>
<th>1st year</th>
<th>3rd year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total production (tonnes/ha)</td>
<td>4.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Energy produced (mcal/ha)</td>
<td>3797.0</td>
<td>4885.0</td>
</tr>
<tr>
<td>Protein produced (kg/ha)</td>
<td>168.0</td>
<td>171.0</td>
</tr>
<tr>
<td>Number of people fed by one ha</td>
<td>4.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Inputs (energy expenditures, Mcal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Human labour</td>
<td>569.0</td>
<td>359.0</td>
</tr>
<tr>
<td>- Animal work</td>
<td>16.8</td>
<td>18.8</td>
</tr>
<tr>
<td>- Tractor energy</td>
<td>277.3</td>
<td>138.6</td>
</tr>
</tbody>
</table>

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 wholesale 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 three 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.

The use of Crotalaria juncea and Vigna unguiculata as green manure in Cuba have ensured a production of squash equivalent to that obtainable by applying 175 kg/ha of urea. In addition, such green manure legumes improved the physical and chemical characteristics of the soil and 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 labour 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 tonnes/ha after 3 years of integrated management. Energy inputs decreased, which resulted in enhanced energy efficiency from (4.4 to 9.5) (Table 3). Human labour demands for management also decreased over time from 13 h of human labour/day to 4–5 h. Such models have been promoted extensively in other areas, through field days and farmers cross visits (SANE, 1998).

CONCLUSIONS

Most research conducted on traditional and peasant agriculture in Latin America suggests that smallholder 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-
Table 4  Extent and impacts of agroecological technologies and practices implemented by NGOs in peasant farm systems throughout Latin America

<table>
<thead>
<tr>
<th>Country</th>
<th>Organisation involved</th>
<th>Agroecological intervention</th>
<th>No. of farmers or farming units affected</th>
<th>No. of ha affected</th>
<th>Dominant crops</th>
<th>Yield (tonnes/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>EPAGRI AS-PTA</td>
<td>Green manures, cover crops</td>
<td>38 000 families</td>
<td>1 330 000</td>
<td>Maize, wheat</td>
<td>1</td>
</tr>
<tr>
<td>Guatemala</td>
<td>Altertec and others</td>
<td>Soil conservation, green manures, organic farming</td>
<td>17 000 units</td>
<td>17 000</td>
<td>Maize</td>
<td>2</td>
</tr>
<tr>
<td>Honduras</td>
<td>CIDDICO, COSECHA</td>
<td>Soil conservation, green manures</td>
<td>27 000 Units</td>
<td>42 000</td>
<td>Maize</td>
<td>2</td>
</tr>
<tr>
<td>El Salvador</td>
<td>COAGRES</td>
<td>Rotations, green manures, compost, botanicals</td>
<td>&gt; 200 farmers</td>
<td>nd</td>
<td>Cereals</td>
<td>4</td>
</tr>
<tr>
<td>Mexico</td>
<td>Oaxacan Cooperatives</td>
<td>Compost, terracing, contour planting</td>
<td>3000 families</td>
<td>23 500</td>
<td>Coffee</td>
<td>1</td>
</tr>
<tr>
<td>Peru</td>
<td>PRAVTIR</td>
<td>Rehabilitation of ancient terraces</td>
<td>&gt; 1250 families</td>
<td>&gt; 1000</td>
<td>Andean crops</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>CIED</td>
<td>Raised fields, agroforestry, composting</td>
<td>nd</td>
<td>250</td>
<td>Andean crops</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>PIWA-CIED</td>
<td>Rehabilitation of ancient terraces</td>
<td>&gt; 100 families</td>
<td>N/A</td>
<td>Andean crops</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>IDEAS</td>
<td>Intercropping agroforestry composting</td>
<td>12 families</td>
<td>25</td>
<td>Several crops</td>
<td>2</td>
</tr>
<tr>
<td>Dominican</td>
<td>Plan Sierra, Sweedforest-Fudeco</td>
<td>Soil conservation, dry forest management, sheep/pastoral systems</td>
<td>&gt; 2500 families</td>
<td>&gt; 1000</td>
<td>Several crops</td>
<td>5</td>
</tr>
<tr>
<td>Republic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>CET</td>
<td>Integrated farms, organic farming</td>
<td>&gt; 1000 families</td>
<td>&gt; 2250</td>
<td>Several crops</td>
<td>&gt;</td>
</tr>
<tr>
<td>Cuba</td>
<td>ACAO</td>
<td>Integrated farms, organic farming</td>
<td>4 cooperatives</td>
<td>250</td>
<td>Several crops</td>
<td>5</td>
</tr>
</tbody>
</table>

nd = no data
Source: Browder, 1989; Altieri, 1995, Pretty, 1997

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. (Table 4; Altieri, 1995). In fact, most agroecological technologies promoted by NGOs can improve traditional agricultural yields, increasing output per area of marginal land from some 400–600 kg/ha to 2000–2500 kg/ha; 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 tonnes/ha (a typical highland peasant yield) to 5–4 tonnes/ha. 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.

In general, data show that over time agroecological systems exhibit more stable levels of total production per unit area than high-input systems; produce economically favourable rates of return; provide a return to labour 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.

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