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Sustainable agricultural development in Latin America: exploring the possibilities

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ABSTRACT

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This paper concentrates on what are perceived as critical issues which should be addressed if a productive and sustainable agriculture is to be achieved in Latin America. The attainment of such an agriculture is dependent on new technological innovations, policy changes and more socio-equitable economic schemes.

By using several examples of biological control and integrated pest management programs as case studies, ways of promoting the transition of chemical intensive commercial agriculture to low-input management are explored. Similarly, the paper describes non-governmental efforts utilizing the agroecological approach to help the great mass of resource-poor farmers, mostly confined to marginal soils, hillsides and rainfed areas, to achieve year-round food self-sufficiency, reduce their reliance on scarce and expensive agricultural chemical inputs, and develop production systems that rebuild the productive capacities of their smallholdings.

INTRODUCTION

In the 1980s, Latin American economies went through a major economic crisis with extraordinary social and environmental costs; it was called 'the lost decade'. Despite numerous internationally and state-sponsored development projects, poverty, food scarcity, malnutrition, health deterioration and environmental degradation continue to be widespread problems (Instituto Interamericano de Cooperación para la Agricultura, 1988). As Latin American countries are pulled into the existing international order and change their policies in order to serve the unprecedented debt, governments increasingly embrace neo-liberal economic models that promote export-led growth. Despite the fact that in some countries, such as Chile, Mexico and Brazil, the model appears successful at the macro-economic level, deforestation, soil erosion, industrial pollution, pesticide contamination and loss of biodiversity (including genetic erosion) proceed at alarming rates and are not reflected in the

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economic indicators. So far, there is no clear system to account for the environmental costs of such models.

The crisis has demonstrated that conventional development strategies are fundamentally limited in their ability to promote equitable and sustainable development (Altimir, 1982; Annis and Hakim, 1988). So far, the end result of most development programs has been what is termed 'growth with poverty'. In the realm of agriculture, modernization has proceeded in the absence of effective land distribution and research/development programs have emphasized high-input production, with all factors contributing to environmental problems in the region (Redcliff, 1989). Sustainable agriculture is difficult to implement where institutional arrangements, market forces, policies and research efforts are biased against such a type of agriculture. A major challenge is, therefore, to create a new policy framework that enhances sustainable agricultural development and conservation efforts through the promotion of agroecological technologies directed at: (a) increasing agricultural land and labor productivity to satisfy food needs, increase rural income and curb the advancement of the agricultural frontier; (b) introducing ecological rationality in agriculture to rationalize the use of chemical inputs, complement watershed and soil conservation programs, plan agriculture according to the land-use capabilities of each region, and promote efficient use of water, forests and other non-renewable resources; (c) coordinating agricultural and environmental/economic policies related to pricing and taxing policies, land and resource distribution and access, technical assistance, etc.

This paper explores the main issues thought to be critical in achieving a sustainable and productive agriculture in Latin America. The complex technical, socioeconomic, political and environmental factors affecting the implementation of biological pest control in large-scale agriculture are analyzed as a case study.

THE NATURAL RESOURCE ENDOWMENT

Latin America is blessed with abundant renewable and non-renewable resources (Table 1). It is an ecologically diverse region as it spans almost all 107 life zones identified by Holdridge (1987). Latin America includes four megadiversity countries: Brazil, Colombia, Mexico and Peru, containing about 90 000 species of vascular plants (United Nations, Food and Agriculture Organization (UN-FAO), 1986). The region is also a center of origin of important crops such as maize, beans, potato, cassava and about 35 different Andean crop species (i.e. lupine, quinoa, ulluco, etc., (National Academy of Sciences, 1989)).

Latin America is also a culturally heterogeneous continent. There are about 460 different ethnic groups that still manage local ecosystems with indigenous technologies (Altieri and Hecht, 1990). The ethnoecological knowledge of

TABLE 1

Agricultural indicators in Latin America (after FAO (1988) and Ortega (1986))

Total agricultural area (thousand ha)	1 716 361
Total arable land (thousand ha)	194 907
Total population (thousands)	404 886
Population annual growth rate (%)	2.5
Economically active population in agriculture (millions)	40.5
Rural population (millions)	127
Crop land per capita (ha)	
Total population	0.44
Rural population	4.4
Area covered by steep land (%)	18
Area with more than 3 dry months (ha)	898 094
Poor in rural population (%)	53.4
Agricultural units < 20 ha (%)	75.4
Area occupied by units < 20 ha (%)	7.3
Production for domestic consumption by small farms (%)	41
Unevenness in land distribution (Gini coefficient)	0.84–0.94
Average annual growth in crop production	2.63
Annual fertilizer consumption per hectare of land (kg ha^{-1})	40.1
Average number of tractors in use	1 379 920
Pesticide expenditure per year (million US$)	3000

some of these groups is impressive. For example, the Mayans recognize about 908 botanical taxa and the Huastecs of Mexico about 861. These indigenous knowledge systems have led to management systems now considered sustainable and, therefore, proper to guide modern resource management. Sustainable traditional farming systems still in existence today include the chinampas of Mexico, the waru-warus of the Andean Altiplano and the agroforestry systems of certain Amazonian tribes. The array of traditional slope, water, soil, pest and vegetation management techniques used by these farmers is very diverse, including composting, rotations, polycultures, agroforestry and watershed management systems (Altieri, 1987; Wilken, 1987).

About 1.7 million ha of land (8.7% of the total land area) is under cultivation. However, only 12.3% of the arable land is free of production constraints. About 20–30% of the arable land is in slopes, between 17 and 32% of the area is subjected to droughts, and in some areas soils with fertility problems reach up to 47% (Banco Interamericano de Desarrollo (BID), 1990).

TECHNOLOGICAL CHANGE IN LATIN AMERICAN AGRICULTURE

Historically, the problem of hunger and rural poverty in Latin America has been perceived fundamentally as a problem of production (Pinstrup-Andersen, 1982). Attempts to solve the problem of hunger have focused on developing a system by which 'low-productivity' subsistence-oriented agriculture

could be transformed into 'high-productivity' commercial, cash crop-oriented agriculture (Twomey, 1987). Thus, attempts at modernizing Latin American agriculture started after World War II when land- and labor-saving technologies were promoted. The diffusion of these technologies was related to agroclimatic and socioeconomic conditions, and was introduced in a pattern of sequential cycles. After an extensive initial period in which agronomic practices were the most important technology, mechanization became the dominant technology in the early 1970s. Next came the dissemination of improved seeds, especially hybrids. Pesticides and fertilizers represent the last of this technological cycle, which has still to reach its inflection point (de Janvry et al., 1987). Three aspects characterize this process of technological diffusion.

(1) Technological change concentrated mainly in temperate and subtropical areas where conditions are similar to those in the industrial countries and/or agricultural experiment stations where the technology was generated.

(2) Many countries have become net importers of chemical inputs and agricultural machinery, increasing government expenditures and exacerbating technological dependence. For example, between 1980 and 1984, Latin America imported about $430 million worth of pesticides, used about 6.5 million tons of fertilizers and had well over 850 000 tractors (Ortega, 1986).

(3) Technological change has mainly benefited the production of export and/or commercial crops produced primarily in the large farm sector, marginally impacting the productivity of food crops which are largely grown by the peasant sector (Ortega, 1986). In areas where conversion from subsistence to a cash agricultural economy progressively occurred, a number of ecological and social problems became evident: loss of food self-sufficiency, genetic erosion, loss of traditional farming knowledge, permanence of rural poverty, etc. (Altieri and Hecht, 1990).

A fifth technological diffusion cycle may soon be initiated in Latin America as biotechnological research (mainly promoted by the private sector) starts offering innovations. Recent discoveries in biotechnology are starting to challenge countries to reassess their technological development. Since biotechnological research and development is mainly concerned with specialty and industrial crops, and/or with crops tailored to specific input needs, it is presumed that, as in the case of the green revolution, it will only benefit resource-rich farmers who can afford to adopt biotechnological products, thus again bypassing resource-poor farmers, especially those confined to rainfed, hillside areas (Hobbelink, 1987). Biotechnology can speed up the technological treadmill, increase production and put downward pressure on prices, which may cause peasants to become increasingly marginal producers without assistance (de Janvry et al., 1987).

Today, in Latin America, the private sector has become increasingly predominant in the process of technological innovation and diffusion. This pre-

dominance is particularly true of the transnational firms that manufacture the inputs and capital goods generated by technological innovations. Agricultural modernization has made it increasingly attractive for the private sector to participate in technology generation and transfer activities. This sector, however, only focuses on those types of technology that offer easy means for private appropriation of their benefits (i.e. biotechnology, pesticides and fertilizers). Alternative technologies, such as crop rotations, biological control, green manuring, etc. are not subjected to development by the private sector. Given the gradual breakdown of the governments' abilities to guide the technological process, market forces have become the major factor governing technological patterns (Piñeiro and Trigo, 1986).

ENVIRONMENTAL PROBLEMS ASSOCIATED WITH AGRICULTURE

The environmental problems linked to the productive activities of thousands of farmers have now become very apparent, and have started to produce important consequences that threaten many aspects of the social and economic life of Latin America. These externalities range from declines in the local and regional productivity of soil and water (through erosion, sedimentation and chemical pollution) to the destruction of biodiversity and reduction in genetic diversity (through deforestation, habitat alteration, etc.), and probable changes in regional climate (de Janvry and Garcia, 1988).

In Latin America, environmental degradation associated with agriculture is clearly a symptom of underdevelopment and reinforces that condition. There is a strong linkage between rural poverty and environmental degradation, whereby resource-poor farmers become agents of economic and structural forces (i.e. unequal land distribution, small farm fragmentation, etc.) that push them to invade and farm fragile environments (Blaikie and Brookfield, 1987). As a result, they abandon the traditional systems of agriculture which are rich in elements of resource conservation. Nevertheless, the environmental impact of the masses of rural poor is low compared to the damaging effects of the economic activities of capital-intensive large landowners, cattle ranchers and corporations engaged in agricultural modernization. Their overuse or careless use of mechanical technology and agrochemicals create major ecological threats.

In Latin America, the major environmental problems associated with agriculture are soil erosion, pesticide pollution, deforestation and genetic erosion, all processes linked to the overexploitation of natural resources. This overuse is a consequence of poverty and/or massive transformation and perturbation of the environment in areas subjected to export agriculture or recent colonization. Solutions to the major environmental problems in these countries require. first, a solution to the problem of resource distribution, social inequality and rural poverty (Redcliff, 1989).

Ecological impacts of pesticides

Between 1980 and 1984, Latin America imported about $430 million worth of pesticides and these expenditures are expected to triple over the next 10 years, especially in Brazil, Mexico, Argentina and Colombia (Maltby, 1980). The use of organochlorine insecticides, with the exception of endosulfan, is expected to decline. However, the use of organophosphates, carbamates and, especially, pyrethroids will increase considerably. While some pesticide formulation and production does occur at the local level, Latin America must rely on importing most of its chemically based pest control products from industrialized countries (Gonzalez, 1976). Unfortunately, many pesticides that are banned in the developed countries are widely employed in Latin America (Bull, 1982).

Under current law, it is perfectly legal for transnational companies to export restricted pesticides. Some countries have not enacted legislation to govern the importation, domestic use and disposal of these pesticide materials. Even with laws, the governments frequently lack the infrastructures required to enforce them.

The growing use of pesticides is influenced by government subsidies which lower the costs of supplying pesticides to farmers. In countries such as Honduras, Colombia and Ecuador, the rate of subsidies can be as high as 45% of the full retail costs (Repetto, 1985). These subsidies are large enough to affect farmers' decisions about pesticide use. By lowering the financial cost, subsidies raise the expected net returns from heavier and more frequent pesticide applications, and induce farmers to substitute chemicals for non-chemical methods of pest management.

Cotton accounts for most of the insecticide use in Latin America at a level of about 6 kg of pesticide per hectare. A few years ago, in El Salvador and Guatemala, 75% of the total pesticide consumption of these countries was devoted to cotton, which received up to 35 applications per season. Such an excessive number of pesticide treatments resulted in serious public health problems, as well as ecological disturbances. Apple and pear orchards still receive up to 8–16 treatments per season in the southern cone countries (Chile, Argentina, Uruguay, Southern Brazil), and most fruit trees in the subtropical and tropical countries are routinely sprayed for protection against fruit flies. Among the vegetable crops, tomatoes and potatoes by far account for the greatest pesticide use (Maltby, 1980).

Although there has been general concern about the environmental and public health impacts of pesticides and their toxic residues in the region, comparatively little information is available on the dimensions of environmental contamination (Burton and Philogene, 1984).

The few available data, however, suggest that the indiscriminate use of pesticides has taken a heavy toll of biotic resources, wildlife and the human pop-

ulation. Between 1971 and 1976, more than 19 000 pesticide poisonings were reported in Central America, mostly occurring in Guatemala and El Salvador. In countries like Nicaragua, more than 3000 cases of poisoning and over 400 deaths occurred yearly from 1962 to 1972. In Costa Rica, pesticide poisonings average about 550 per year. Parathion has been largely responsible for intoxication in many countries (Leonard, 1986). Organochlorine concentrations in human blood, fat tissue and mothers' milk have also reached alarming levels in many countries (Central American Research Institute for Industry – Guatamala, 1977).

In cotton-growing areas of Central America, malaria resurgence frequently reoccurs, mainly due to the fact that mosquitoes have developed pesticide resistance (Leonard, 1986). Residues of organochlorine insecticides have been detected in fish and several other invertebrate species, especially in estuaries and areas near cotton fields (Giam, 1971). Up to 1970, over 35 cases of insecticide resistance had already been detected, including important cotton, banana and stored-grain arthropod pests (Gonzalez, 1976).

Soil erosion

Approximately 25% of Latin America is comprised of hillsides and plateaus susceptible to erosion and land degradation. Many Latin American countries have more than 45% of their territory in hillsides. From 20 to 65% of the rural population in the tropical Latin American countries live and produce in the mountain ranges. Fifty to 75% of the small farms of each country are concentrated in these areas. In 1980, they totaled almost 8×10^6 farms (Posner and McPherson, 1982).

Although it is clear that poor peasants have opened to cultivation an important proportion of the total land in steep slopes, they are not solely responsible for the erosion affecting the watersheds of the region. In tropical areas, cattle ranching and capital-intensive agriculture fueled deforestation which, in turn, is a major contributor to soil erosion.

Data on the extent of soil erosion in the region are not abundant, at times not reliable and difficult to interpret. Using large-scale aerial and satellite photographs, several authors consider the overall extent of land erosion in Latin America to be severe.

Baldwin (1954) found that 42% of the Mexican territory suffers from accelerated erosion. In his soil erosion survey, he also reported the following percentages of seriously eroded or degraded land in Central America: Guatemala, 25–35%; El Salvador, 45%; Panama, 17%; Costa Rica, 17%; Honduras, 6–8%; Nicaragua, 5–10%; Belize, 10%. The survey also reported high erosion rates in the mountain ranges of Peru and Northern Ecuador.

In Chile, a LANDSAT study covering 34 500 ha of the Chilean land surface estimated that about 78.5% of the surveyed area exhibited moderate to serious levels of erosion. Much of this area includes agroecosystems located in

the coastal ranges, Andean slopes and watersheds of the Central valley (Instituto de los Recursos Naturales, 1965). Cultivation on these steeper slopes significantly increases the potential for soil erosion.

Tropical deforestation

Latin America contains about 5.6×10^6 ha of closed and open forests. It represents 56.9% of the closed tropical forests of the world. These forests are suffering an unprecedented process of destruction, in part linked to colonist and peasant agriculture, but more so to road and infrastructure (e.g. dams, wharfs, refineries) construction, mining (e.g. gold in the Amazonia) and oil exploration, subsidized livestock production, logging and commercial extraction. Nevertheless, the absence of effective programs to redistribute land has stimulated the colonization of humid tropical areas, unfolding a chain of environmental problems (Mahar, 1988).

Rates of forest losses in Latin America reach about 4 116 000 ha $year^{-1}$ with the highest rates experienced in Brazil (1.48×10^6), Colombia (0.8×10^6), Mexico (0.53×10^6), Ecuador (0.3×10^6) and Peru (0.253×10^6). In these countries, deforestation has taken a heavy toll of ecosystems, displacing indigenous peoples and enabling extensive ranching to become established (Redcliff, 1989). Another negative effect of deforestation is the impact on fuelwood and charcoal supplies. It is estimated that by the year 2000, almost 50×10^6 people in Latin America will face substantial degradation of fuelwood supplies (Moran, 1983).

Genetic erosion

Latin America contains several centers of diversity and, therefore, is a repository of valuable crop genetic resources, including traditional varieties, land races and wild relatives of crops. The major threat to traditional varieties in the region is the process of agricultural modernization. In 20 years, a handful of scientifically bred, modern varieties (high yielding varieties (HYV)) have replaced ancient crop varieties as part of international and national efforts to develop agriculture (Brush, 1982). This process of loss of genetic resources is called 'genetic erosion'. As peasants link directly to the market economy, economic forces increasingly influence the mode of production, characterized by genetically uniform crops and a mechanized and/or agrochemical package. Land races and wild relatives are progressively abandoned, becoming relics or extinct. In some areas, land scarcity (resulting mostly from uneven land distribution) has forced changes in land use and agricultural practices, resulting in the disappearance of habitats that formerly maintained wild progenitors and weedy forms of crops (Wilkes, 1983).

Although genetic erosion is a major concern in Latin America, very few

systematic studies have been conducted on the causes, rates and implications of this genetic change. Preliminary assessments of genetic erosion in Mexico and Peru, however, indicate several trends that may be generalized to most crops in the region (Brush et al., 1988).

(a) Genetic erosion is occurring because farmers are changing their farming systems, pushed by social, economic and technical forces.

(b) The pattern and rate of adoption of HYV is very uneven across geographic regions.

(c) As adoption occurs, farmers tend to subdivide their farming systems into commercial (mostly devoted to HYV) and subsistence sectors where they still grow native varieties.

(d) The greatest loss of traditional varieties has occurred in lowland valleys close to urban centers and markets.

(e) The least genetic erosion occurs in higher zones (especially mountain areas), more distant from urban centers and markets.

Although the data are still inadequate to predict future trends of losses of crop genetic resources in Latin America, it is possible to identify several factors that promote them (Brush, 1982): (a) changes in the numbers and distribution of human populations; (b) national and international crop improvement and extension programs that promote HYV; (c) changing consumption patterns in urban and rural populations; (d) increasing demand for specific varieties from urban markets; (e) improvement in transportation and communication systems, allowing quicker access to HYV; (f) general factors in the agricultural economy such as human capital, labor availability, credit, tenure and the availability of technological components such as fertilizers and irrigation.

ALTERNATIVES TO PESTICIDES IN LATIN AMERICA

Integrated pest management (IPM) programs

Pesticide use is expected to increase in Latin America by 280% over the period from 1980 to 2000 if current trends continue. During the same period, insecticide expenses are expected to increase from $320 million to over $1.1 billion, even though insecticides' share of the total pesticide market is expected to decrease slightly from 32.5 to 30% (Burton and Philogene, 1984). The tremendous growth forecast in insecticide sales will have a substantial importance in terms of environmental impact, the economics of crop production and increased pressure on foreign exchange. The challenge is clear. The development of alternatives to pesticides, implemented through successful IPM programs, illustrates a potential of significant ecological and economic impact.

Fortunately, there are a few documented cases where withdrawals from

pesticide use and the implementation of biological and cultural controls resulted in viable crop production (Hansen, 1987). One of the earliest examples occurred in the mid-1950s in the Cañete Valley of Peru, where cotton production for export dominated. Organochlorinated insecticides were intensively used, and several pests had developed resistance requiring heavier dosages and more frequent applications. In addition, six new species of secondary pests appeared and cotton yields fell sharply. In response to the crisis, a number of changes in pest control practices were dictated, including banning the use of synthetic organic pesticides, the reintroduction of beneficial insects, crop diversification schemes, planting early maturing varieties and destroying cotton crop residue. Pest problems declined dramatically and pest control costs were reduced (Hansen, 1987).

In Nicaragua, cotton also exhibited the classic 'pesticide treadmill' observed earlier in Peru. After a successful production phase in which cotton yields peaked in 1964–1965 at 2635 kg ha^{-1}, the pesticide-induced ecological disruption began to be evident: insecticide-resistant pests, secondary pests and elimination of natural enemies. Average yields fell by 15–30% owing to insect damage, despite 28 insecticide applications per season. Starting in 1971, a program sponsored by UN-FAO yielded key information on economic thresholds, season of natural enemy abundance, cotton phenology, etc., which directed researchers to the best time for planting to give cotton the best possible growth conditions and to escape boll weevil and bollworm attack. Later, a 'trap cropping' system was developed. It consisted of the planting of small cotton plots at the beginning and end of the growing seasons to attract and concentrate weevils where they are killed off by pesticides (Swezey et al., 1986).

In Colombia, during the 1970s, cotton was receiving from 22 to 28 applications of insecticides per growing cycle. In 1980, the Instituto Colombiano Agropecuario and the Cotton Growers Federation initiated research in IPM programs to reduce insecticide inputs. Economic thresholds were established and scouting was implemented. Natural enemies, such as *Trichogramma* spp. and *Apanteles* spp., were reared and released, and more selective insecticides were utilized. At present, only two to three insecticide applications of selective pyrethroids per crop cycle are required for control. Cotton yields during this period of reduced insecticide inputs have increased steadily (Altieri et al., 1989).

Another case of insecticide-induced ecological disruption comes from the Pacific coastal plains of Southwest Costa Rica. In 1954, over 12 000 ha of United Fruit Company banana plantations were treated with an aerial application of dieldrin granules against banana weevil and rust thrips. This aerial application of dieldrin killed off many natural enemies, which led to the appearance of other pests that had previously been of no importance. An outbreak of the banana stalk borer, *Castniomera humboldti*, a moth larva that

bores into the pseudostem and greatly weakens it, caused heavy losses. United Fruit responded to these outbreaks by spraying more insecticides.

By 1958, insect pest problems had become very serious. In spite of increasing pesticide use, that year brought an unprecedented outbreak of pests, including six major Lepidoptera pests that had not previously been a problem, such as the ceramidia moth, owleye and the West Indian bagworm. Ceramidia soon exhibited resistance to dieldrin. In 1973, the crisis promoted United Fruit entomologists to stop all insecticide sprays in the entire Golfito banana division. Insect pests fell to below economic thresholds within one to three generations (a period of several months) with little or no fruit loss. Within 2 years, virtually all of the previous pest species had almost disappeared. Indeed, Ceramidia, the owleyes and *Platynota rostrana* were rarely seen. There were occasional small outbreaks of larvae of the West Indian bagworm or the genus *Sibine*, but their numbers always remained below the economic threshold, as did those of the banana weevil. Stopping pesticide sprays allowed natural enemies to become abundant and re-exert a natural control over many of the pest populations. The banana rust thrip remained a problem, but the company discovered it could prevent damage by putting a plastic bag over each bunch of developing fruit (Stephens, 1984).

By 1970, total soybean production in Brazil had reached 2.278×10^6 tons, especially in the states of Parana and Rio Grande do Sul, covering an area of about 5.5×10^6 ha. As soybean acreage increased, so did the number of insect pests. In 1974, Brazil adopted an IPM program relying primarily on monitoring for pest damage, establishing economic thresholds and the application of specific insecticides. This IPM program was so successful that between 1974 and 1982 insecticide applications fell by 80–90%. In the 1980s, this program was expanded to include the use of Nuclear Polyhedrosis Virus virus against the velvetbean caterpillar. This virus is host specific and it can be readily mass-produced by farmers themselves (Hansen, 1987).

In Colombia, the tomato is an important vegetable crop. During the late 1970s and early 1980s, tomato typically received between 20 and 30 pesticide applications per crop. Implementation of an IPM program in the Cauca Valley during 1985 reduced pesticide applications to two or three, resulting in savings of over $650 per hectare. Use of the biological insecticide derived from *Bacillus thuringiensis*, combined with the release of natural enemies such as *Trichogramma* spp. and *Apanteles* spp., were particularly effective in reducing the key pest, *Scrobipalpula absoluta*, a leafminer/fruit borer (Altieri et al., 1989).

Also, in Colombia, the aerial application of insecticides is common on large rice plantations. The principal pest is the planthopper *Sogatodes orizycola*, a vector of the hoja blanca virus. An IPM program that includes the use of natural enemies, resistant rice varieties, appropriate agronomic practices and scouting to determine pest levels and to time insecticide applications was re-

cently initiated. It is estimated that insecticide inputs can be reduced from 6.8% of total production costs to 0.2% and that overall savings in pesticide inputs can reach 22% of production costs (Altieri et al., 1989).

Biological control efforts

Although still restricted to a few countries, biological control represents the most economically viable, environmentally sound and self-sustained method of insect pest control in Latin America (Greathead and Waage, 1983). The earliest recorded efforts of classical biological control in the region date back to the beginning of the 19th century. For example, in 1903, the coccinellid beetles, *Hippodamia convergens* and *Rhizobius ventralis*, were introduced to Chile from California for the control of scale insects (Gonzalez and Rojas, 1966). In 1904, natural enemies were introduced into Peru for the control of white scale (*Pinnaspis strachani*) in cotton and in 1908 *Prospaltella (encarsia) berlesi* (Hymenoptera: Aphelinidae) was introduced to Argentina to combat white peach scale (*Pseudaulacaspis pentagona*) (Hagen and Franz, 1973). These efforts were supplemented by the establishment of specialized insectaries in Mexico in 1928, in Chile (La Cruz) in 1929 and later in Peru (CICIU), Argentina (Instituto Nacional de Tecnologia Agropecuaria-Castelar, Centro de Investigaciones de Regulacion de Poblaciones de Organisinos Nocivos), Brazil, Colombia and Nicaragua.

Most of the early work on biological control was concentrated on citrus pests (mostly Homoptera), mainly because it was citrus that marked the beginning of biological control history in 1888. Other efforts were later initiated, in decreasing order of magnitude, in sugarcane, apple, peach, olive, alfalfa, cotton, wheat and other field crops (Altieri et al., 1989).

The main successes in classical biological control programs in the region include the citrus blackfly (*Aleurocanthus woglumi*) in Mexico and Central America; the sugarcane borer (*Diatraea saccharalis*) in Cuba, Peru, Brazil and the Caribbean; the cottony cushion scale (*Icerya purchasi*) in Chile; the woolly apple aphid (*Eriosoma lanigerum*) in Uruguay, Chile and Argentina; black scale (*Saissetia oleae*) controlled by *Metaphycus lounsburyi* in Chile and Peru, and several species of mealybugs and scale insects in various countries (Gonzalez, 1976).

A particularly successful biological control effort is the control of sugarcane borer (*D. saccharalis*) in Colombia's Cauca Valley. In 1971, a biological control program was implemented which featured importation, mass rearing, and the periodic release of tachinid and braconid natural enemies. By 1975, damage due to the borer was virtually eliminated (less than 3% damaged internodes), resulting in savings of $3.4 million year^{-1}. At present, no insecticides are used on sugarcane in the Cauca Valley and the sugarcane borer control program remains as a model of effective biological control (Altieri et al., 1989). The yield of sugarcane in Colombia increased from 52 307 kg ha^{-1} in 1975 to 76 104 kg ha^{-1} in 1986.

Another successful case is the biological control of cereal aphids in Chile and Brazil. In 1972, populations of two aphid species (*Sitobium avenae* and *Metopolophium dirhodum*) were detected in cereal fields in Chile. Despite the presence of resident natural enemies, these aphids reached outbreak proportions which led to the aerial application of insecticides over 120 000 ha of wheat. In 1975, the aphids and the Barley yellow dwarf virus virus they transmit caused a loss of about 20% of the natural wheat production (Zuñiga, 1986). In 1976, the Chilean government's agricultural research center Instituto Nacional de Investigaciones Agropecuarias, in conjunction with the FAO, initiated a pest management program. As part of the strategy, several aphidophagous insects and parasitoids were introduced against *Metopolophium dirhodum* and *Sitobium avenae*. Five species of predators were introduced from South Africa, Canada and Israel, and nine species of parasitoids of the families Aphidiidae and Aphelinidae were brought from Europe, California, Israel and Iran (Zuñiga, 1986). In 1975, more than 300 000 Coccinellidae were mass-reared and released, and from 1976 to 1981 more than 4×10^6 parasitoids were distributed throughout the cereal areas of the country. Today, aphid populations are maintained below the economic threshold level by the action of biological control agents (Zuñiga, 1986).

The success in Chile prompted Brazilian researchers to introduce 14 species of hymenopterous parasites and two Coccinellidae in 1978. About 3.8×10^6 parasites were released throughout the wheat-producing regions of Rio Grande do Sul, Parana and Santa Catarina. *Aphidius uzbekistanicus* became established and efficiently adapted against *Sitobium avenae* and *Rhopalosiphum maidis*, whereas *Praon volucre* impacted *Sitobium avenae* and *M. dirhodum* (Gassen, 1983).

IMPROVING SMALL FARM PRODUCTIVITY

After 20 years of technological innovations in agriculture, rural poverty and low land and labor productivity persist in Latin America (Lacroix, 1985; Scott, 1987). Moreover, the distribution of benefits has been extremely uneven, favoring primarily larger, better-off farmers who control optimum lands. In certain areas, this has resulted in increased concentration of land ownership, peasant differentiation and more landless peasants (Brockett, 1986).

The reason that the new technologies have been distributed so unevenly is because they are biased towards modern, high-input farming. They are also channeled through institutions whose policies perpetuate conditions of land tenure, credit, technical assistance, infrastructure, etc. which mostly favor large-scale farmers. These technologies are not made available to small farmers on favorable terms and often are not suited to the agroecological conditions of small-scale farmers (Ortega, 1986).

There is a need to build new research and extension capabilities that translate into specific actions which actually improve the livelihoods of the poor.

In the past 10–15 years in Latin America, a number of non-government organizations (NGO) have become important new actors in rural development, focusing greater attention on neglected small farmers, their crops and land. The approach of many NGO has been to search for technologically unconventional systems of agricultural development and resource management that, based on local participation, skills and resources, enhance productivity while conserving the resource base (Altieri and Anderson, 1986). Local farmers' knowledge about plants, soils and ecological processes regain unprecedented significance within this new 'agroecological' paradigm (Toledo et al., 1985). This new agroecological development approach is more sensitive to the complexities of local agricultures, emphasizing properties of sustainability, food security, biological stability, resource conservation and equity, along with the goal of increased production (Table 2).

Promoted agroecological techniques are culturally compatible since they do not question peasants' rationale, but actually build on traditional farming knowledge, combining it with the elements of modern agricultural science. Also, the techniques are ecologically sound since they do not attempt to radi-

TABLE 2

A comparison of some features of the green revolution and agroecological technologies in the context of Latin American agriculture (modified after Kenny and Buttel (1985))

Characteristic	Green revolution	Agroecology
Crops affected	Wheat, rice, maize and few others	All crops
Areas affected	Flat lands, irrigated areas	All areas, especially marginal areas (rainfed, steep slopes)
Dominant cropping systems	Monocultures, genetically uniform	Polycultures, genetically heterogeneous
Dominant inputs	Agrochemicals, machinery, high dependency on external inputs	Nitrogen fixation, biological pest control, organic amendments, high reliance on on-farm resources
Environmental impacts	Medium–high (chemical pollution, erosion, salinization, pesticide resistance, etc.)	Low–medium (nutrient leaching from manure, etc.)
Crops displaced	Mostly traditional varieties and land races	None
Technology development and dissemination	Quasi-public sector, private companies	Largely public, NGO involvement
Capital costs of research	Relatively high	Relatively low
Research skills needed	Conventional plant breeding and other disciplinary agricultural sciences	Ecology and multidisciplinary expertise
Proprietary considerations	Varieties and products patentable and protectable by private interests	Varieties and technologies under farmers' control

cally modify or transform the peasant ecosystem, but rather to optimize it and conserve the resource base. Costs of production are minimized by enhancing the use efficiency of locally available resources (Altieri and Hecht, 1990).

In practical terms, the application of agroecological principles by NGO has translated into programs that emphasize: (a) improving the production of basic foods, including the valuation of traditional food crops (*Amaranthus*, quinoa, lupine, etc.) and the conservation of native crop germplasm; (b) rescuing and re-evaluating peasants' knowledge and technologies; (c) promoting the efficient use of local resources (i.e. land, labor, agricultural sub-products, etc.); (d) increasing crop and animal diversity to minimize risks; (e) improving the natural resource base through water and soil conservation and regeneration practices; (f) reducing the use of external chemical inputs, testing and implementing organic farming and other low-input techniques.

The various examples of grassroots rural development programs currently functioning in Latin America suggest that the process of agricultural betterment must: (a) utilize and promote autochthonous knowledge and resource-efficient technologies; (b) emphasize the use of local agricultural diversity, including indigenous crop germplasm as well as essentials like firewood resources and medicinal plants; (c) be a self-contained, village-based effort with the active participation of peasants. The evaluation of projects in Chile, Peru, Bolivia, the Dominican Republic and Honduras suggests that promoted methods represent important alternatives for better water-use efficiency, environmentally sound pest control, effective soil conservation and fertility management that subsistence farmers can afford (Altieri and Andersen, 1986; Altieri and Hecht, 1990).

REDIRECTING AGRICULTURAL POLICY

In Latin America, sustainable development implies the search for new socioeconomic strategies that take into account environmental concerns and the needs of the vast majority of the population, especially the poor (Leonard, 1986). So far, the elements of this strategy are not very clear, other than it must deal with the problems of poverty, foreign debt, inequity in resource distribution and the development of environmentally, energy-saving and socially compatible technologies. An important first step will be to promote research and discussion on the following questions.

(a) The objectives of sustainable rural development (SRD): what does it mean in view of the need for active economic growth as well as conservation imperatives?

(b) Research and policy priorities in SRD: which are the key issues, what are the information gaps, which are the policy constraints and opportunities?

(c) What are the lessons from past development efforts? What conditions led to success or failure?

(d) What are the requirements and prerequisites of SRD? What kinds of structural changes are needed to reduce environmental costs during development? Which strategies are needed to effectively combat rural poverty?

(e) How is SRD achieved? What are the methodological guidelines and the institutional mechanisms to harmonize economic growth and natural resource conservation? How is SRD operationalized?

(f) When is SRD achieved? How is sustainability measured? What are the new indicators of development?

Overall, economic policies in the region have tended to favor large-scale commercial agriculture and have been biased against small-farm agriculture. A case in point is the extensive process of grain substitution in production and trade occurring in Latin America. Land dedicated to maize, the common human cereal for most of the continent, is in relative decline compared to other crops. For Latin America as a whole, maize acreage has declined from 56 to 51% of the total cultivated cropland.

Sorghum for animal feed is the major grain displacing maize. Sorghum cultivation is highly mechanized and, therefore, benefits from governmental policies aimed at modernizing agriculture through subsidies and/or credits for tractors, improved seeds, fertilizers and other inputs. Individual producers, small and large scale alike, also see benefits in planting sorghum, which is much less labor intensive than maize (Barkin, 1990).

There are many policy obstacles that prevent peasants from having fair competition in the market, thus limiting the chances for any agroecological strategy to be assumed at the household level (Conway and Barbier, 1990). The removal of policy constraints must occur in at least three areas (see also Table 3): (a) elimination of anti-peasant institutional biases in access to credit, research and technical assistance; (b) elimination of the perennial social underinvestment in peasant communities in education, health and infrastructure; (c) elimination of subsidies to capital-intensive and agrochemical agriculture.

In addition, it will be important to create the right policy climate that improves the terms of trade for peasant production by providing competition to local monopolistic intermediaries, and that allows peasants to capture the externalities that a peasant sustainable agriculture might produce. This will require the definition of adequate tax policies to charge 'free riders' taking advantage of peasants' efforts. This kind of economic policy could help create subsidies to encourage peasants to assume sustainable agricultural practices (de Janvry et al., 1987).

Defining Latin America's own sustainable rural development agenda will ultimately depend on the analysis of the economic, social, political and institutional conditions determining poverty and environmental degradation in the area, and on the types of structural changes that will be promoted to affect such conditions (BID, 1990). Several tasks lie ahead: (a) determining ways

TABLE 3

Policy constraints and opportunities to promote sustainable rural development in Latin America (after Barry (1987))

Obstacles	Possible solutions
Domestic	
Land concentration	Agrarian reform
Government neglect of small farm sector	Government recognition of importance of small-farm sector for national food security and economic development; extension of credit and technical assistance through NGO
Lack of campesino organization and participation in decision making	Government support for rural organizing and for grassroots decision making
Lack of infrastructure for basic foods production and marketing	Increased government support for national food system that emphasizes food security
Lack of appropriate technologies	Promote agroecological research, training and information-exchange programs
Rural poverty	Promote income generation rural activities, provide poor with access to productive resources
International	
Low and fluctuating prices for agricultural commodities	International commodity agreements and formation of associations of exporting nations
Dependence on only a few cash crops for foreign exchange	More agroindustrial development and diversification
Increasing external debt	Renegotiation and cancellation of debt burden
Transnational corporations' (TNC) control of world agribusiness	Regulation of TNC investment in agricultural production and local food-processing industries, state marketing of exports, commodity agreements and cartels of exporting nations
Protectionist measures of economically powerful larger nations	Diversification of trade, regional alliances and association with other non-aligned nations

in which agricultural and environmental national/international policies can be changed to promote SRD in the region; (b) fostering research on specific policy change that removes biases against SRD, and to assess the impacts of such changes on socioeconomic and environmental parameters within a natural resource accounting, as well as a social welfare framework; (c) defining the elements of an appropriate agricultural strategy that enhances local development and the viability of non-conventional land-use strategies; (d) reorienting and redesigning university curricula to more effectively address the problems of agricultural development, environmental degradation and rural poverty, their connections and viable solutions.

Recognizing that each Latin American country is unique ecologically, culturally, politically and socioeconomically, it will be important to identify and discuss common themes and challenges related to economic growth and resource management at the regional level, and to derive common principles of SRD of wide applicability.

CONCLUSIONS

Given the economic crises and the degree of environmental degradation in Latin America, governments should expand the efforts in sustainable agriculture (i.e. biological control, organic soil management, crop diversification, etc.) and tailor specific programs to reduce input use in the large capitalized holdings, and promote agroecological approaches that fit the needs of the peasants who lack resources and capital. However, the mapping of a sustainable agricultural development for the agroindustrial export-oriented sector will be different than that for the peasant sector. In the first case, the challenge is to maintain high levels of production to foster the generation of foreign exchange to be used in implementing equitable social services, while ameliorating the consequences of a technology-induced environmental degradation brought about by the indiscriminate use of monoculture agriculture and its associated chemical technology.

A true reduction and/or elimination of pesticide use in the agroexport sector will require major political reforms that deal with the main forces that push farmers to use chemicals: government pesticide subsidies, corporate control of agricultural enterprises, research serving the needs of the private sector rather than the public sector, internationally set unrealistic cosmetic standards, etc. The many successful examples of biological pest control implemented in Latin America (i.e. sugarcane pests in Colombia and Brazil, wheat aphids in the American southern cone, etc.) show the environmental soundness, cost effectiveness and permanent effect of this approach. However, biological control has not been widely adopted because its benefits cannot be captured by profit-oriented agricultural service companies, leaving its promotion to mostly ill-funded, technically unskilled and bureaucratic government agencies. Thus, although biological control is novel by bringing an environmentally sound and long-term solution to pest problems, its promotion suffers from 'technological determinism' which has prevented scientists and environmentalists from understanding and addressing the structural factors that encourage the overuse of pesticides and reduce the economic incentives to use alternatives.

The progression of large-scale agriculture typically evolves from a phase of intensification of production, through mechanization and increased agrochemical inputs, to a phase of crisis due to the failure of chemical pest control and disaster when production becomes uneconomical. In many areas of Latin America, production systems are still in the stage of intensification, while the familiar signs of imminent disaster (economic and ecological) loom on the horizon. A major challenge to research and development agencies is to first develop alternative production tactics and then to provide incentives to growers to implement them, even during the period when intensive chemical control is profitable, i.e. before the crisis stage.

In the case of peasant agriculture, the challenge is to develop appropriate low-input agricultural techniques adapted to the needs and circumstances of a vast population of resource-poor farmers. Agroecologists must determine ways, based on low-input approaches, to increase agricultural productivity that benefit the rural poor under marginal agricultural conditions, while conserving and regenerating the resource base. Obviously, improving the access of peasants to land, water and other natural resources, as well as to equitable credit, markets and appropriate technical assistance, will be crucial.

Groups involved in the implementation of agroecological proposals are faced with the need to promote productive alternatives that are not only ecologically sound, but also economically profitable.

This is very difficult in an environment where land ownership is very skewed, where peasants have little access to political and economic resources, and in which institutional biases against peasant production prevail.

There is no doubt that the current economic and social juncture in the region calls for more low-input approaches to agriculture. Agroecology can provide important methodological guidelines to direct the conversion of agriculture into a more sustainable one. As a new agricultural development approach, agroecology is more sensitive to the complexities of local agricultures, by broadening its performance criteria to include properties of sustainability, food security, biological stability, resource conservation and equity, along with the goal of increased production (Altieri, 1987).

However, the macro-perspectives for a more sustainable agriculture in the region are uncertain. On the one hand, it is possible to observe that high real exchange rates push for a more local resource-oriented agriculture, since labor costs have gone down and imports have become more expensive. On the other, the strength of export-oriented economic approaches, dominated by large multinational companies, are preventing the emergence of a technological option based on the regional resource endowment.

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