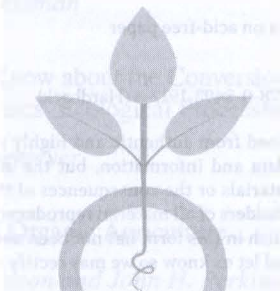
The Conversion to Sustainable Agriculture

Principles, Processes, and Practices



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10 Cuba

A National-Level Experiment in Conversion

Fernando R. Funes-Monzote

CONTENTS

10.1 INTRODUCTION

Cuba has a long tradition as an exporter of agricultural crops produced under conditions of monoculture and natural resource extraction (Le Riverend, 1970; Moreno Fraginals, 1978; Marrero, 1974-1984). Practiced over approximately four centuries, these agricultural patterns have generated a dependence on imported inputs and caused an enormous negative environmental impact on soils, biodiversity, and forest cover (CITMA, 1997; Funes-Monzote, 2004). During the last 15 years, however, agricultural development has been reoriented (Rosset and Benjamin, 1994; Funes et al., 2002; Wright, 2005). Today, agricultural production in Cuba is concerned, as never before, with food self-sufficiency and environmental protection. In 1994, the National Programme for Environment and Development (the Cuban adoption of the United Nations Division for Sustainable Development's Agenda 21) was instituted, and two years later the National Environmental Strategy was approved (CITMA, 1997; Urquiza and Gutiérrez, 2003). In 1997 the Cuban law of environment became the environmental protection policy of the state (*Gaceta Oficial*, 1997). Although environmental protection is still not practiced as fully as it might be, government support for preserving the environment has helped put Cuban agriculture on a more sustainable course.

A principal goal of the revolution of 1959 was to resolve what were perceived as long-standing problems of Cuban agriculture, mainly national and foreign (basically North American) ownership of large farms and lack of agricultural diversification (Anon, 1960; Valdés, 2003). However, the rapid industrialization of state-controlled agriculture based on conventional methods after the revolution tended to concentrate land in large state enterprises, and consequently resulted in environmental problems similar to those caused by the old *latifundios*. Although on one hand, this model successfully increased both levels of production and rural well-being owing to the social goals of the political system, on the other hand it produced negative economic, ecological, and social consequences that cannot be ignored.

The excessive application of externally produced agrochemical inputs (i.e., produced outside the country), the implementing of monocultural, large-scale production systems, the concentration of farmers in the cities or rural towns, and the dependence on few exports conferred a high vulnerability to the nationally established conventional agricultural model. This vulnerability became evident at the beginning of the 1990s with the disintegration of socialist Eastern Europe and the USSR, when the majority of the favorably priced inputs, both material and financial, disappeared. Cuban agriculture, along with the other branches of the national economy, entered into its greatest crisis in recent history; at the same time, however, these factors provided exceptional conditions for the construction of an alternative—and far more sustainable—agricultural model at a national scale.

The transformation that occurred in the Cuban countryside during the last decade of the twentieth century is an example of a large-scale agricultural conversion—from a highly specialized, conventional, industrialized agriculture, dependent on external inputs, to an alternative input substitution model based on principles of agroecology and organic agriculture (Altieri, 1993; Rosset and Benjamin, 1994; Funes et al., 2002). Numerous studies of this conversion attribute its success to both the form of social organization employed and the development of environmentally sound technologies (Rosset and Benjamin, 1994; Deere, 1997; Pérez Rojas et al., 1999; Sinclair and Thompson, 2001; Funes et al., 2002; Wright, 2005).

Unlike the isolated sustainable agriculture movements that have developed in most countries, Cuba developed a massive movement with wide, popular participation, where agrarian production was seen as key to food security for the population. Still in its early stages, the transformation of agricultural systems in Cuba has mainly consisted of the substitution of biological inputs for chemicals, and the more efficient use of local resources. Through these strategies, numerous objectives of agricultural sustainability have been serendipitously reached. The persistent shortage of external inputs and the surviving practices of diverse production systems have favored the proliferation of innovative agroecological practices throughout the country.

Under current conditions, however, with about 5,000 enterprises and cooperatives and nearly 400,000 individual producers (*Granma*, 2006b), neither the conventional model nor that of input substitution will be versatile enough to cover the technological demands of such a heterogeneous and diverse agriculture. Consequently, the author believes it is necessary to develop a more integrated, participatory, long-term agroecological focus and to more strongly combine the economic, ecological, and sociopolitical dimensions of agricultural production. A mixed farming systems approach is presented here as the next step toward sustainable agriculture, one that can address these needs at a national scale.

10.2 GEOGRAPHIC AND BIOPHYSICAL BACKGROUND

Cuba, the biggest of the Caribbean islands, is strategically located between the two Americas, allowing it to play an important role for the Spaniards in their conquest of the New World. Cuba is approximately three times the size of the Netherlands, and half the size of Minnesota, the 12th largest state in the United States. With a total area of 110,860 km^2, the country is dominated by expansive plains (occupying about 80% of the total) and three well-defined mountain ranges.

Cuba may even be considered a micro-continent, owing to the highly diverse nature of its natural biodiversity, soil types, geographic landscapes, geological ages, and microclimates (Rivero Glean, 2005). The country comprises 48 well-defined natural regions, each with specific characteristics of climate, vegetation, and landscape, ranging from rainforest to semidesert (Gutiérrez Domenech and Rivero Glean, 1999). Such heterogeneity favors a high natural biodiversity: the island supports 19,631 known plant and animal species, of which 42.7% are endemic (ONE, 2004).

TABLE 10.1
Demographic, Physiographic, and Climatic Features of Cuba

General Data		Climate	Season: Wet	Season: Dry
Length of country, km	1,250	Rainfall, mm	1,104	316
Area, km^2	110,860	Mean temperature, °C	26.9	23.2
Highest elevation, m	1,974			
Total population (millions)	11.3			

Source: ONE (2004).

Cuba is long (1,250 km) and thin (the average width is less than 100 km, with a maximum of 191 km and minimum of 31 km). This physiography facilitates sea transport. The most important cities, connected by some 5,700 km of railway, are located an average of less than 40 km from the coast, with its more than 200 bays and coves.

According to the climate classification system recognized by the Food and Agriculture Organization (FAO) (Koppen, 1907), Cuba's climate is tropical savannah. However, it is also considered to have a tropical oceanic climate (Alisov and Paltaraus, 1974). These and other general classification criteria have been adapted in various forms to heterogeneous Cuban conditions (Lecha et al., 1994). Except for some specific areas, the whole island is influenced by the ocean.

Near to the Tropic of Cancer and the Gulf Stream, the island receives the destructive effects of tropical storms and hurricanes (with winds of 150 to 200 km/hour and more) as well as severe droughts that directly affect agricultural activity and the infrastructure in general. The climate is characterized by a wet season, with high temperatures and heavy rains, between May and October (70% of the total annual rainfall) and a dry season from November to April with low rainfall and cooler temperatures (Table 10.1).

Although Havana is the main economic center, each of the country's 14 provinces is important agriculturally, culturally, and economically. Population density is higher in Cuba (101.7 inhabitants/km^2) than in Mexico (50), Central America (68), and South America (17), but lower than the average for the Caribbean region (139) (FAOSTAT, 2004). More importantly, Cuba has a high percentage of arable land, so that each arable hectare only needs to feed less than two people per year. Whereas agricultural land accounts for about 34% of the total land area in Latin America as a whole, in Cuba approximately 60% of the land is appropriate for agriculture (ONE, 2004; FAOSTAT, 2004). However, according to the last national census, currently less than 25% of the Cuban people live in rural settlements, only 11% work in the agricultural sector, and probably less than 6% are directly linked to farming activities (ONE, 2004).

Soils in Cuba are heterogeneous. Soil fertility, as based on available nutrients and classified as a percentage of the total arable land, is 15% high fertility, 24% fair fertility, 45% low fertility, and 14% very poor fertility (CITMA, 1998; ONE, 2004;

TABLE 10.2
Principal Limiting Factors of Cuban Soils

Factor	Affected Agricultural Area (million ha)	(percent of total)
Salinity and sodicity	1.0	14.9
Erosion (very strong to medium)	2.9	43.3
Poor drainage	2.7	40.3
Low fertility	3.0	44.8
Natural compaction	1.6	23.9
Acidity	2.1	31.8
Very low organic matter content	4.7	69.6
Low moisture retention	2.5	37.3
Stony and rocky areas	0.8	11.9

Source: CITMA (1998), ONE (2004).

Treto et al. 2002). According to these sources, Cuban soils are predominantly oxisols and ultisols (68%), and the remaining areas are mostly inceptisols and vertisols. The primary limiting factors of soils used for agricultural activities are low organic matter content, low fertility, erosion, and poor drainage (Table 10.2).

Despite these limitations, Cuba possesses an exceptional natural environment for agriculture. Due to its continuous growing season and diversity of plants and animals used for agricultural purposes, crop cultivation and raising animals in open air are possible throughout the year. The ample infrastructure of roads and railroads with access to the sea, the existence of high-water reservoir capacity for irrigation, electrification of the countryside, and high investment in agricultural facilities are all valuable preconditions for greater agricultural production in Cuba. In addition, the extensive network of scientific institutions is a considerable asset in carrying out agricultural changes. However, these resources are not being efficiently used for several reasons, including a lack of maintenance of the agricultural infrastructure, continued specialized organization of agriculture, a scarcity of agricultural labor, and the high cost (or lack of availability) of necessary inputs for production.

10.3 BRIEF HISTORY OF CUBAN AGRICULTURE

10.3.1 Migratory Aboriginal Groups

The first inhabitants of Cuba arrived about 10,000 years ago from North America through the Mississippi River watershed, via Florida and the Bahamas (Torres-Cuevas and Loyola, 2001). Called *Guanahatabeyes,* these groups were hunters, fishers, and gatherers. The second migratory stream came from South America about 4,500 years ago. Known as *Ciboneyes*, they were also fishers and gatherers, but introduced a variety of more advanced instruments for hunting and food processing. Some 1,500 years ago, a third group of people called *Taínos* came to the island. Part of the South American aboriginal family known as *Arawaks*, they were advanced hunters and fishers, but they also practiced agriculture (Le Riverend, 1970). They were the most numerous and dominant Native Americans when the Spanish arrived on the island in 1492. One of their most productive agricultural systems utilized raised beds, called *camellones*, which were planted mounds of earth and organic matter. These communities applied the system of small-scale slash and burn for the cultivation of crops, especially cassava and corn, and those used in their rituals, such as tobacco and cotton.

10.3.2 Spanish Colonization of Cuba

At the time of the Spanish arrival, an estimated 60 to 90% of Cuba was covered with forest (Del Risco, 1995). Initially the conquerors resettled indigenous people in *vecindades* or reserves. In these reserves, most inhabitants continued using traditional agricultural methods. As colonists, the Spanish became landholders, employing predominantly mixed crop–livestock systems called *estancias* with a high proportion of crops (Le Riverend, 1970). The transition from indigeous agriculture to the new form implemented by the Spanish may be considered the first major step in the process of conversion to European agricultural practices.

The small population of Spaniards focused on cattle raising as their principal economic activity. To this end, they distributed lands in extensive circular areas called *hatos* and *corrales*. At the same time, around their population centers they established less extensive areas of crop cultivation (Le Riverend, 1992). In the middle of the 1500s, increasing demand for wood for ship construction, swelling populations in the main villages of the island, and the growing external market for agricultural products led to an expansion in timber extraction and sugar and tobacco production and processing. These activities extended into the interior of the cattle ranches, transforming the original Spanish agrarian structure.

Beginning in the early 1600s, commercial agriculture experienced more rapid development with the advent of sugar cane and tobacco production in the *estancias* (Le Riverend, 1992; Marrero, 1974–1984; Funes-Monzote, 2004).

The outbreak of the Haitian slave revolt in 1791 gave Cuba the opening it needed to begin competing with the French colonies as the principal producer and exporter of sugar worldwide. The consequent establishment of sugar processing plants in the Cuban countryside meant a radical transformation in the structure of agriculture and a definitive jump in the economy of colonial Cuba. The great expanses of land dedicated to cattle ranching, interspersed with forest and grassland, were subdivided into smaller properties. The increased scale of production and the specialization in sugar cane accentuated the social and environmental impacts in the countryside that had accompanied the industry from the beginning. Early criticism of the system was based on damage to the natural resource base, specifically forest destruction and the abandonment of "tired," unproductive lands (De la Sagra, 1831; Reynoso, 1862).

10.3.3 Neocolonial Agricultural Patterns and Their Consequences

Concentration and centralization of sugar production continued into the 1900s. After Cuba achieved independence from Spain in 1898, North American capital flowed into the country, helping to establish giant sugar *latifundios* on the eastern half of the island, which until this time had been the area least affected by agriculture. During the first two decades of the twentieth century, the planting of sugar cane produced the most intense deforestation in Cuba's history. By around 1925, most of the extensive plains of Cuba had been planted with sugar cane. The largest ranches, both foreign and nationally owned, were predominantly sugar cane and cattle, and these occupied 70% of the agricultural land. A little more than 1% of the landowners owned 50% of the land, while 71% held only 11% (Valdés, 2003).

However, the lands managed by the *latifundios* were inefficient at producing food, and many of these large farms (around 40%) were gradually abandoned. Meanwhile, the *campesino* sector, which practiced a diversified agriculture with traditional mixed farming strategies, was having a considerable impact on the agrarian economy. According to the agricultural census of 1946, almost 90% of the farms were diversified. These 5 to 75 ha farms, with their mixed crop–livestock production and better organizational efficiency, generated about 50% of the country's total agricultural production but occupied only 25% of the total agricultural area (Censo Agrícola Nacional, 1951).

Despite the existence of many diversified small farms, the structure of land tenure and the export-oriented economic model combined to create an agriculture sector that as a whole specialized in only a few agricultural crops. Rural Cuba was characterized by an economic and political dependency on the United States, a scarcity of subsistence foods, social inequity, and a high rate of unemployment during the "dead period" (months where there was no sugar processing). This unstable situation greatly influenced the emergence of the Cuban Revolution of 1959, which was grassroots, agrarian-based and anti-imperialist. During the 46 years since the revolution, unprecedented events have taken place with arguable relevance to the future of world agriculture.

10.4 POSTREVOLUTION SCENARIO

10.4.1 Agrarian Reforms

The revolutionary government adopted two agrarian reform laws that passed ownership of rented lands to the peasants who had worked them. This considerably reduced farm size. First, in May 1959, the maximum land holding was reduced to about 400 ha. Later, in 1963, a Second Agrarian Reform established an upper limit of 67 ha in order to eliminate the landed social class and thus the exploitation of farmers (Anon, 1960; Valdés, 2003). In the first stage, 40% of arable land was expropiated from foreign companies and large landholders and passed into the hands of the state. In the second stage, another 30% of the land became state owned (Valdés, 2003).

At that point, there were four prioritized objectives for the transformation of Cuban agriculture: (1) to meet the growing food requirements of the population, (2) to generate monetary funds through the exportation of products, (3) to obtain raw materials for the food processing industry, and (4) to eradicate poverty from the countryside (Anon., 1960). A number of educational, cultural, and economic approaches were developed, including literacy campaigns, the development of planned rural communities to supply social and health care services to farmers, the building of thousands of kilometers of new roads, and the extension of electricity to rural areas (Anon., 1987). The government's will to change was reflected clearly in the first decree of the first law of agrarian reform: "The progress of Cuba is based on the growth and diversification of industry to take more efficient advantage of its natural and human resources, as well as the elimination of the deep dependency on monocultural agriculture that is a symptom of our inadequate economic development" (*Gaceta Oficial*, 1959).

10.4.2 The Conventional Agriculture Model

Although the government expressed its official desire for diversification, its actual on-the-ground administration of agriculture supported large-scale monoculture. The commitments to export primary materials such as sugar, citrus, coffee, tobacco, etc., to the countries of the Council for Mutual Economic Assistance (COMECON)—the economic block of the former socialist countries—forced Cuba to fulfill five-year plans at high environmental costs. Consequently, the dependency on processed food imported from Eastern Europe reached unprecedented levels (Espinosa, 1992).

The application of green revolution concepts was facilitated by Cuba's strong relationship with the socialist countries of Eastern Europe, particularly with the Soviet Union (USSR). As a national policy, Cuba adopted the world trend of substituting capital for labor in order to increase productivity. This method was characterized by the physical and agrochemical management of agricultural processes—specifically large-scale, mechanized production with a high application of external inputs to a monocultural crop. The application of the industrialized model of agriculture, along with the 10-fold increase in food imports over a 30-year period (1958–1988), was successful in achieving increases in per-capita calorie consumption from 2,552 kcal/day in 1965 to 2,845 kcal/day in 1989. Protein consumption per capita also increased in the same period from 66.4 g/day to 76.5 g/day. In spite of this progress, however, per-capita consumption rates still fell short of the calculated nutritional needs of 2,972 kcal/day for calories and 86.3 g/day for protein (Pérez Marín and Muñoz, 1991).

These improvements were achieved and sustained through a model that relied on high external inputs, a few export crops, and trade with the socialist countries of Eastern Europe. Throughout the 1980s, 87% of external trade was undertaken at favorable prices with socialist countries, and only 13% at world market prices with other countries (Lage, 1992). In 1988, Cuba sent 81.7% of its total exports to the socialist bloc of Eastern Europe, while 83.8% of its total imports came from those countries (Pérez Marín and Muñoz, 1991). The COMECON agreement allowed Cuba to sell its goods in the socialist market of Eastern Europe at high prices while imports were purchased from them at low cost.

Consequently, the dependency of the agricultural economy on a few export products was impressive, and the land dedicated to these crops was enormous. Three of the principal export crops—sugar, tobacco, and citrus—covered 50% of agricultural land. Importing energy (petroleum), machinery, and diverse raw materials in large amounts was favorable for Cuba in economic terms, but not for its food self-sufficiency. Under these conditions the country imported 57% of its protein requirements and more than 50% of its energy, edible oil, dairy products and meats, fertilizers, herbicides, and livestock feed concentrates (PNAN, 1994).

As early as the 1970s, Cuban scientific research institutions had become aware of the concepts of low external inputs and input substitution. Policies and research began to focus on the economic implications of substituting local raw materials for imported. Nevertheless, at the end of the 1980s, Cuban agriculture was characterized by a high concentration of state-owned land (80% of total land area was in the state sector), high levels of mechanization (one tractor for every 125 ha of farming land), crop specialization, and high input usage (13 million tons diesel, 1.3 million tons fertilizers, US$80 million in pesticides, and 1.6 million tons livestock feed concentrates applied per year) (Lage, 1992).

10.4.3 Consequences and Collapse

The continued application of this agricultural model resulted in several economic, ecological, and social consequences. Among the most important were soil salinization (1 million ha affected), an increased frequency of moderate to severe soil erosion, soil compaction with its resultant soil infertility, loss of biodiversity, and deforestation of agricultural land (CITMA, 1997). From 1956 to 1989, an accelerated rural population exodus to urban areas caused a drop in the rural population from 56% to 28%, and then to less than 20% by the mid-1990s (Funes et al., 2002).

As result of this situation, at the end of the 1980s crop and livestock yields and subsequent economic efficiency started to decrease (Pérez Marín and Muñoz, 1991). The conventional agricultural model, which had been applied for about 25 years, demanded higher amounts of chemical inputs and capital to keep yields stable. The depression of agricultural production provoked a shortage of goods in the agricultural markets. To counter this situation, an ambitious food program was initiated in order to recuperate the infrastructure and subsequent volume of production and cover internal demand (ANPP, 1991). This program essentially carried on the conventional high-input focus because it could count on abundant externally derived inputs. Even when the disintegration of Eastern European and Soviet socialism resulted in the loss of these inputs, the government decided "to continue developing the Food Program despite whatever difficult conditions might have to be faced" (ANPP, 1991, p. 7). Without the expected aid, however, it would be necessary to seriously adjust the technology and structure of production.

10.5 SITUATION AFTER THE COLLAPSE OF THE SOCIALIST BLOC

> Today Cuba faces the most difficult challenge in its history … in addition to the worsening blockade exercised for more than 30 years by the United States, it now has to resist the effects of a second blockade provoked by changes in the international order.
>
> **—Fidel Castro, 1992**

The unexpected collapse of the socialist countries of Eastern Europe and the USSR fully highlighted the contradictions and vulnerabilities of the agricultural model that Cuba had developed. The island lost the principal markets and guarantees that these countries had provided in the past. Foreign purchase capacity was drastically reduced from US$8,100 million in 1989 to US$1,700 million by 1993, a decrease of almost 80%. In that year, some US$750 million was required solely for the purchase of fuel for the national economy and US$440 million for basic foods (Lage, 1992; PNAN, 1994).

Cuba's reduced foreign exchange greatly affected its ability to obtain necessary agrochemical inputs, leading to a drastic reduction in production. This shortage.was most severely felt by the large state farm enterprises that were dependent on high inputs to maintain their monoculture systems. In fact, all farmers suffered under the difficult situation, but small- and medium-size farmers were less affected due to their more locally oriented agricultural strategies, the practice of a more diversified agriculture, greater control of farm management, and lower dependence on external inputs.

Although small- and medium-scale traditional farming exhibited higher resilience to the crisis, in 1989 this sector of agricultural production represented only 12% of the total agricultural land area. The remaining agricultural lands, which were being managed using high-input, industrialized, and large-scale methods, dramatically collapsed. This led to the drastic reduction of each citizen's food ration, which seriously affected food security. One of the first effects was caloric deficiency, and consequently, widespread weight loss among the population. In addition, many diseases started to appear as a result of low intake of certain nutrients (PAHO, 2002) (Table 10.3). For example, epidemic neuropathy, caused by vitamin B deficiency, affected the vision of more than 50,000 people (Arnaud et al., 2001). The consequences of the food security crisis would have been far more dramatic without the government's ration system, which ensured equitable food access and avoided famine (Rosset and Benjamin, 1994; PNAN, 1994; Wright 2005).

TABLE 10.3
Comparison of Nutritional Levels per Capita per Day in 1987 and 1993

		Percentage Satisfaction of Recognized Needs	
Nutrient	**Nutritional Needs[a]**	**1987**	**1993**
Calories	2,972 kcal	97.5	62.7
Protein	86.3 g	89.7	53.0
Fat	92.5 g	95.0	28.0
Iron	16 mg	112.0	68.8
Calcium	1,123 mg	77.4	62.9
Vitamin A	991 mg	100.9	28.8
Vitamin C	224.5 mg	52.2	25.8

Source: PNAN (1994), Pérez Marín and Muñoz (1991).

[a] The nutritional needs for the Cuban population (Porrata et al., 1996) were defined by the FAO standards (FAO/WHO/UNU, 1985).

Despite the economic difficulties, the government continued to reinforce social programs. For example, the infant mortality rate during the first year of life was reduced by almost half during this time—from 11.1 per 1,000 in 1989 to 6.4 at the close of 1999 (*Granma*, 2000). During the early 1990s, severe economic actions were necessary in order to maintain the main social guarantees while reconstructing the Cuban economy. This phase was officially called the "special period." In order to deal with the crisis, the Cuban government implemented measures of austerity and changed the strategies to reduce negative impacts on the national economy.

In response to the precarious food situation, the Cuban National Program of Action for Nutrition (PNAN) was instigated, as a result of commitments made by the International Nutrition Conference in Rome in 1992. Its overall objective was to buffer the consequences of the crisis using the following basic strategies (PNAN, 1994):

- Strengthen agrarian policy through widespread decentralization of land holdings and management, diversification of agricultural production, and the transformation of land tenure of state lands.
- Encourage the population to participate in agricultural activities for their own nutritional improvement.
- Encourage the creation of *autoconsumos* or on-site farms/gardens to supply the dining halls of residential and educational establishments.
- Promote sustainable development compatible with the environment.
- Reduce postharvest losses through improved methods, such as direct sales of food from producers to consumers in the cities (e.g., urban agriculture).
- Incorporate nutritional objectives in programs and plans of agricultural development.

Many of these measures taken by the state were key factors in the proliferation of a more sustainable Cuban agriculture. However, the success of these strategies has been muted by a variety of factors, including the difficulty of adapting specialized large-scale agriculture to new practices, a lack of monetary resources and materials to enact these solutions, and a small workforce in the countryside.

10.6 CHANGES IN AGRARIAN PRODUCTIVE STRUCTURES

In general, certain technical and organizational measures were taken to reduce the impact of the crisis on agriculture. Decentralization and reduction in the scale of big state enterprises was a necessity due to their inefficiency. In 1993, the government created Basic Units of Cooperative Production (UBPCs). This effective measure gave usufruct rights (land use free and for an "indefinite" time) to farmers who were previously workers of state farm enterprises. Other forms of land distribution were also developed that provided interested urban dwellers the opportunity to return to the countryside. Eventually, 10 distinct forms of organization in Cuban agriculture were created; these coexist within three sectors: the state sector, the nonstate sector, and the mixed sector (Table 10.4).

These changes in the agrarian structure of the country were characterized by transfers of land from the state to the other sectors. By January 1995 the state had

TABLE 10.4
Organization of Cuban Agriculture

State sector		State farms
		New-type state farms (GENT)
		Revolutionary Armed Forces (FAR) farms, including farms of the Young Workers' Army (EJT) and the Ministry of Interior (MININT)
		Self-provisioning farms at workplaces and public institutions
Nonstate sector	Collective production	Basic Unit of Cooperative Production (UBPC)
		Agricultural Production Cooperatives (CPA)
	Individual production	Credit and Service Cooperatives (CCS)
		Individual farmers, in usufruct
		Individual farmers, private property
Mixed sector		Joint ventures between the state and foreign capital

Source: Martín (2002).

granted usufruct rights to 58% of the arable land it had controlled at the beginning of 1990 (which had constituted, at that time, 83% of total arable land). This shift in land ownership is informally called the silent third Cuban agrarian reform. During a five-year period, about 150,000 workers were incorporated into the UBPCs (Pérez Rojas et al., 1999). A chronological analysis of the percentage of national agricultural area shows that the UBPCs quickly predominated (Table 10.5). The private, *campesino* sector also increased its land area in the distribution process, an acknowledgment of its management capacity and increasing role in food production. Compared to state enterprises, the UBPC is a more decentralized form of production (Villegas, 1999).

With the creation of the UBPCs, the state was able to both better manage production and save on scarce resources. The size of large mixed crop enterprises was reduced 10-fold, while the size of livestock enterprises was reduced on average 20-fold, reaching a size similar to that of the Agricultural Production Cooperatives

TABLE 10.5
Percentage of Arable Land in Cuba by Form of Land Ownership, 1989–2008

	1989–1992	1993	2000	2008
State	83	47.5	33.1	23.2
Other state sector organizations		9		
UBPC	—	26.5	40.6	39.8
CPA	12	7	26.3	37
Private		10		

Source: PNAN (1994), Pérez Rojas et al. (1999), ONE (2004, 2008).

TABLE 10.6
Average Size of State Enterprises, UBPCs, and CPAs

Principle Activity	State Enterprises (ha), 1989	Average Size UBPCs (ha), 1994	Average Size CPAs (ha), 1994
Various crops[a]	4,300	416	483
Citrus and fruit	17,400	101	577
Coffee	—	429	470
Tobacco	3,100	232	510
Rice	27,200	5,040	—
Cattle	28,000	1,597	631

Source: Data from PNAN (1994).

[a] Tubers, roots, vegetables, plantain, grains, and seeds (beans, corn, soybean, sunflower, sesame, etc.).

(CPAs) that had existed for more than 20 years with reasonable levels of production and efficiency (Table 10.6). The strategy of dividing land into smaller plots within the UBPCs was based on recognition of the greater efficiency of production at a smaller scale. (However, even with these reductions, the average sizes of UBPCs were still large for most of the principal agricultural activities, and the lack of resources made many of them almost unmanageable.)

Following the principle of linking people to the land (i.e., allowing farmers to live on the farm), thousands of families became based on the UBPCs, which had been previously uninhabited and controlled by state enterprises. For example, more than 50 families moved to the 1,000 ha that is now the UBPC "26 de Julio" in Bacuranao, Havana—a tract of land occupied some 15 years ago by only two families—after housing was created to attract people knowledgeable about working in agriculture. (Today this UBPC is highly self-sufficient in food production, generates extra production for commercialization, and achieves its commitment of milk production for sale to the state.) The repopulation of rural areas has been one of the major contributions of the UBPC.

As agricultural enterprises worked and managed by the people who live on them, UBPCs facilitated better natural resource management and local farmer decision making. The reduced scale of the UBPCs, along with their greater diversification and more rational use of inputs, machinery, and infrastructure, allowed increases in efficiency and productivity, and this helped mitigate the losses in external inputs and capital.

However, the UBPC model, as a new form of agriculture in Cuba, is still far from achieving its potential benefits. Many organizational methods employed in the state enterprises were replicated in the UBPCs (Pérez Rojas and Echevarria, 2000). The lack of a sense of ownership, the persistant dependency on external inputs, and limited decision making affect the functioning of UBPCs. In summary, even though the UBPCs in their essence have continued to form part of a structure that operates under the direction of the state enterprises, this form of production has created mechanisms favoring the transition to decentralized production that tends to imitate the values, efficiency, and potential of traditional *campesino* (small farmer) production.

10.7 CONTRIBUTION OF THE SMALL FARMER SECTOR

In Cuba, private farming (carried out by *campesinos* at mostly small and middle scales) can be undertaken individually or in groups under two types of cooperative production—CPA and CCS. The first type, the CPA, is composed of farmers who have given their land to the cooperative so that it can be transformed into social or collective property. The second type is composed of farmers who form a cooperative in which they continue to own land and equipment on an individual basis, buy inputs from the state, and receive credit and services (Alvarez, 2002). Both types of producers sell to the state based on agreements over their production potential, and also cultivate crops and raise animals for self-provisioning. They may also sell agricultural products directly in the local market or to middlemen.

Compared to state farms, private farmers have greater experience and a longer tradition with Cuban agriculture, and unsurprisingly, their agricultural systems proved to be more resilient in the face of the crisis. While the state agricultural enterprises were strongly impacted by the loss in inputs and funding, and delayed adapting to change, the *campesino* sector was able to buffer the scarcity of material resources. At the end of the 1980s, the private sector in Cuban agriculture accounted for 18% of the country's arable land; 10 years later it occupied 25% of the agricultural area and participated significantly in production for both internal consumption and export. The relatively high percentage contribution of *campesino* production to total sales in the national agricultural sector during the years of crisis (Table 10.7) demonstrates how efficient is its use of land. It also shows the capacity of small farmers' methods of production and organization to contribute to the national food balance, even with scarce external inputs.

Abolished at the end of the 1980s, the *Mercado libre campesino* (farmers' free market) was reopened at the beginning of 1994 as the *Mercado Agropecuario*

TABLE 10.7
Percentage Contribution of *Campesino* Production to Total Sales to the State for Various Products in Cuba

Product	Percent of Sales to the State	Product	Percent of Sales to the State
Roots, tubers, and vegetables	43	Milk	32
Sugar cane	18.4	Rice	17
Tobacco	85	Fruit	59
Coffee	55	Citrus	10
Cocoa	61	Pork	42.6
Beans	74	Fish	53
Corn	64	Honey	55

Source: Lugo Fonte (2000).

TABLE 10.8
Structure of Livestock Production in Cuba, 2006

Type of Production	Land Area (ha)	Percent of Land Area	Owners	Head ($\times 10^{3}$)	Percent of National Herd	Head/Owner
State enterprises[a]	1,221.6	48.3	4,569	1,082.5	27.3	236.9
UBPC	780.1	30.8	2,470	969.6	24.4	392.5
CPA	201.7	8.0	1,063	191.8	4.8	180.5
CCS + individuals	325.8	12.9	236,088[b]	1,728.4	43.5	7.3
Total	2,529.3	100		3,972.3	100	

Source: Adapted from MINAG statistic bulletins and González et al. (2004).

[a] Included are livestock and crop enterprises dedicated to livestock rearing.

[b] Included are individual owners or in CCS and farmers with or without land.

(agricultural market). Despite the new name, it was in essence the same institution. This agricultural market functioned under the law of supply and demand and became an important distribution channel for agricultural products. In 1996, some 70.7% of the total agricultural direct sales to the population were by individual or cooperative farmers (Martín, 2002).

The small farmer sector was particularly successful with livestock. From 1995 to 2000, the number of livestock animals under private sector management increased, as did the production of livestock products, while during the same period state and UBPC livestock production showed no signs of recovery (González et al., 2004). In 2006, the small farmer sector, with only 13% of the grazing land, owned more than 43% of Cuba's livestock (Table 10.8), a fact that demonstrates the efficiency of *campesino* management. Although cattle production at the national level has been depressed by the scarcity of imported feed and adverse climatic conditions, such as prolonged drought, hurricanes, and other natural events, *campesino* production has developed ways of working around these conditions. Consequently, the small farm sector has, for many, served as a model for restructuring Cuban agriculture (Álvarez, 2002).

The Cuban *campesino* is a key link in the preservation of traditional crop and livestock varieties, which are indispensible to genetic improvement and sustainable agriculture from a local perspective (Ríos, 2004; Wright, 2005). Within the National Association of Small Farmers (Asociación Nacional de Agricultores Pequeños, ANAP), the Agroecological Farmer to Farmer Movement (Movimiento Agroecológico Campesino a Campesino, MACAC) has systematized much traditional agricultural experience and reinforced sustainable principles in Cuban agriculture. This movement is represented in 155 municipalities (i.e., 85% of total) at the national level, and at the end of 2004 employed 3,052 facilitators and 9,211 promoters (Perera, 2004). In a parallel effort, more than 4,000 farmers are involved in the Local Agriculture Innovation Programme of the National Institute for Agricultural Sciences (INCA), which is based on participatory grassroots processes (Ríos, 2006).

However, the positive impact of the *campesino* sector in the transformation of Cuban agriculture has not yet been sufficiently addressed. Many *campesino* agroecological experiences throughout the country are still undocumented despite the fact that they are undoubtedly the main resource necessary for the implementation of a sustainable and agroecological approach at a national scale.

10.8 URBAN AGRICULTURE AND FOOD SECURITY

10.8.1 Foundation, Structure, and Objectives

A major new initiative for the promotion of food self-sufficiency has been urban agriculture. This form of agriculture was almost neglected in Cuba when food was affordable. However, urban gardening was the first reaction of the population to overcoming food shortages (Murphy, 1999). By growing within and around cities, people could make use of local resources and not have to pay transportation costs for either inputs or products (Cruz and Sánchez, 2001). At the beginning of the crisis, people organized themselves to cultivate vacant lots, backyards, and rooftops in the cities. Animals were even reared inside houses in order to ensure families' food supply. At first a matter of subsistence production, urban agriculture by the mid-1990s had been transformed into a practice that also included commercial activities and made a significant contribution to the country's food security.

As urban agriculture became more widespread, it also became more organized and began to receive government support. The "horticultural club" formed in the Havana suburb of Santa Fe in 1992–1993 was the first to organize urbanites for the purpose of providing them with technical assistance and creating a framework for urban production. This movement grew very fast in Havana city and subsequently spread around the whole country.

By 1995, there were already 1,613 organoponics (i.e., small plots of abandoned land in the cities where beds of soil and sources of organic matter are used to produce fresh vegetables), 429 intensive gardens, and 26,604 community gardens. In 1997, a network of municipal enterprises and state institutions (the National System of Urban Agriculture) was created to organize the people already involved in urban agriculture. Spatially, this system covers a radius of 10 km from the center of the capital city of each province, a radius of 5 km from the center of municipal capitals, a radius of 2 km around population centers of more than 10,000 residents, and local production for settlements of less than 1,000 people. The government still plays an important role in the promotion and support of this massive movement toward food security.

The principal objective of the Cuban urban agriculture movement is to increase the daily consumption of vegetables to 300 g per citizen, the amount recommended by UN FAO. The following basic principles of urban agriculture in Cuba define its objectives and organization (Companioni et al., 2002).

- A fresh supply of good quality products offered directly to the population, guaranteeing a balanced production of not less than 300 g of vegetables daily per capita and an adequate variety of animal protein.

- Uniform distribution throughout the country (i.e., in every area of the country with an urban population, urban agriculture should be developed).
- Local consumption by the urban population of local production in each region.
- Crop–animal integration with maximum synergy (i.e., internal cycling of nutrients) to boost production.
- Intensive use of organic matter to increase and conserve soil fertility.
- Use of biological pest controls.
- Use of all available land to produce food, guaranteeing intensive but not import-dependent high yields of crops and livestock.
- Multidisciplinary integration and intensive application of science and technology.
- Maximum use of food production potential, including available labor as well as wastes and by-products for plant nutrients and animal feed.

The urban agriculture program is composed of 28 subprograms, each related to a type or aspect of animal or plant production. These subprograms form the organizational and administrative base of the program (GNAU, 2004). They include, for example, management and conservation of soils, use of organic matter, seed production, vegetables and fresh herbs and spices, fruit trees, grassroots or *arroz popular* production of rice, grains, animal feed, apiculture, livestock, aquaculture, marketing, and small agroindustries (Companioni et al., 2002). Taken together, Cuban urban agriculture has the components to achieve a systems approach; however, each program is supervised separately, responding to its specific factors and providing specialized technical assistance.

10.8.2 *Arroz Popular*: Example of a Successful Subprogram

Central to the Cuban diet, rice is consumed together with beans, meat, vegetables, and even fruits. Its per-capita consumption exceeds 44 kg annually, or 265 g per day (Socorro et al., 2002). Rice production in Cuba was developed for many years in large state farms, and it was also one of the prioritized crops at the beginning of the special period, when it appeared "irrefutable" that conventional, high-input methods were the only possible way to supply enough rice to meet the populations' needs (León, 1996). However, even during the 1980s, when unlimited inputs were available, the national demand was not met and it was necessary to import 40% of the rice consumed. High-input rice production proved to be unsustainable at the onset of the crisis of the 1990s. The new "popular rice" program demonstrated that self-organized, low-input agriculture could have a positive impact on national food self-sufficiency (García, 2003).

The popular production of rice (*arroz popular*) was originally, like urban agriculture in general, a grassroots movement toward self-provisioning. People started to cultivate this cereal in abandoned areas, in small plots between sugar cane fields, in road ditches, etc. This movement grew rapidly and achieved unforeseen levels of production and efficiency. In 1997, while the severely affected Union of Rice Enterprises (Unión de Empresas del Arroz) produced 150,000 tons of rice, popular rice production achieved 140,600 tons, involving 73,500 small producers yielding, as a national average, 2.82 tons per hectare without the use of costly inputs (*Granma*, 1998a). This yield compared favorably to that of conventional rice production during 1980s, which achieved a national average yield of between 2 and 3 tons/ha (ANPP, 1991). In 2001, *arroz popular* was responsible for more than 50% of total domestic rice production (García, 2003).

10.8.3 Recent Success and the Future

In the year 2000, urban agriculture produced more than 1.64 million tons of vegetables and employed 201,000 workers. Two years later, 326,000 people were linked with the program of urban backyard production. In 2005 production was 4.1 million tons, and in 2006 it had risen to 4.2 million tons, employing 354,000 people (*Granma*, 2001, 2003a, 2006a) (Figure 10.1). The reported production of 20 kg/m^2 achieved by urban agriculture exceeded 300 g of vegetables per citizen per day.

The urban agriculture movement has also contributed to the establishment of a network of 1,270 points of sale of agricultural products in the cities and 932 agricultural markets (*Granma*, 2003b). The products distributed via this network significantly contribute to food security, although the prices are still high considering the average buying capacity of the population.

The quantity of people dedicated to agricultural labor in the city periphery continues to increase. However, Cruz and Sánchez (2001) consider that this type of agriculture, emerging as a solution to food scarcity and unemployment in the cities, ought to look for a more integrated approach that goes beyond a temporary solution to the crisis and toward goals other than food security—such as preservation of urban environments, the permanent management of resources in urban settings, avoidance of air and water pollution, and creating a culture of nature conservation.

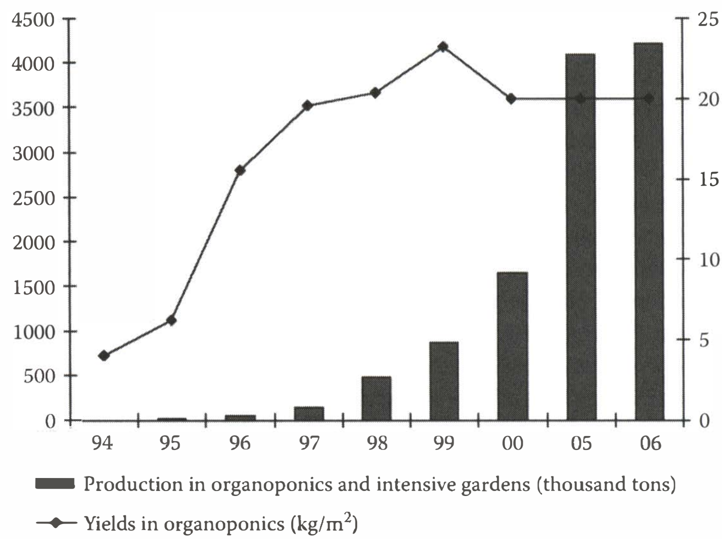

FIGURE 10.1 Vegetable production from organoponics and intensive gardens.

Although cities became productive in terms of food, urban agriculture still satisfied a small part of the country's overall needs. Thus, it was necessary to develop participatory, low-input rural food production at the onset of the 1990s. An alternative model to the prevailing conventional agriculture paradigm—that of input substitution—was established at a national level, not only in state enterprises and the UBPCs, but also in private individual and cooperative production.

10.9 THE INPUT SUBSTITUTION STRATEGY

Gliessman (2001, 2007) describes three levels or stages in the process of converting from conventional to sustainable agroecosystems. At level 1 farmers "increase the efficiency of conventional practices," and at level 2 they "substitute conventional inputs and practices with alternative practices." Input-substituted systems at the second level, though demonstrably more sustainable than conventional systems, may nevertheless have many of the same problems that occur in conventional systems (e.g., the use of monoculture). These problems will persist until changes in agroecosystem design (i.e., on the basis of a new set of ecological processes) take place at level 3. This conversion process has been widely analyzed by Altieri (1987), who attributes the main cause of ecological disorders in conventional agriculture to monocultural patterns.

During the 1980s, a certain amount of research in Cuba focused on aspects of input substitution—reducing the use of fertilizers, pesticides, and concentrated feed for livestock. These investigations were applied to the most economically important and largest-scale agricultural activities (Funes, 2002). Although the main objective was the reduction of production costs in commercial agriculture through the substitution of biological inputs for agrochemical, these studies—underpinned by ecological principles—formed the basis for scaling up the application of ecological practices when no alternatives were available. As a result, input substitution in Cuba reached a scale never previously attempted in any other country, and its effectiveness and positive impact were significant (Rosset and Benjamin, 1994; Funes et al., 2002).

10.9.1 Alternatives for the Ecological Management of Soil

Many microbiological preparations had first been developed for a range of crops as part of general research on nitrogen fixation and solubilization of phosphorus. In the search for input substitution, a wide range of these biofertilizers have been successfully developed and applied on a commercial, main-crop scale, substituting for a significant percentage of chemical fertilizers (Table 10.9).

Research results confirmed the effectivness of using green manures and cover crops in commercial crop production. These studies included the use of sesbania (*Sesbania rostrata*) in rice production (Cabello et al., 1989) and the use of crotalaria (*Crotalaria juncea*), jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*), and dolichos lablab bean (*Lablab purpureus*) in other commercial crops (García and Treto, 1997). The inclusion of these plants in local systems was found to fulfill most nutrient needs of the crops. These green manures were able to substitute for high levels of nitrogen fertilization (i.e., the equivalent of 67 to 255 kg/

TABLE 10.9
Principal Uses of Biofertilizers in Cuba

Biofertilizers	Crops	Substitution Achieved
Rhizobium	Beans, peanuts, and cowpeas	75–80% of the N fertilizer
Bradyrhizobium	Soybeans and forage legumes	80% of the N fertilizer
Azotobacter	Vegetables, cassava, sweet potato, maize, rice	15–50% of the N fertilizer
Azospirillum	Rice	25% of the N fertilizer
Phosphorus-solubilizing bacteria	Vegetables, cassava, sweet potato, citrus fruits, coffee nurseries	50–100% of the P fertilizer
Mycorrhizae	Coffee nurseries	30% of the N and K fertilizers

Source: Martínez Viera and Hernández (1995), Treto et al. (2002).

ha of N, 7 to 22 kg/ha of P, and 36 to 211 kg/ha of K) and to improve the physical characteristics of the soil (Treto et al., 2002). In commercial tobacco production, chemical applications were reduced through the use of green manures for soil fertility improvement. Other traditional farming practices were also recovered, including the use of oxen teams for cultivation, which avoided soil compaction, conserved physical soil conditions, and eliminated weeds by mechanical means rather than with herbicides.

Worm humus (or vermicompost) and compost production were applied on a large scale. Between 1994 and 1998, national production of these two organic fertilizers together was between 500,000 and 700,000 MT/year. Small-scale compost and worm humus production became popular, especially in urban agriculture, due to the high levels of organic fertilizers demanded by organoponic vegetable production in beds. At the industrial scale, the use of *cachaza* "filter cake" (impurities filtered from cane juice, a by-product from the sugar industry) allowed a considerable reduction or elimination of chemical fertilizer demand in most of the important commercial crops, especially sugar cane, one of the most fertilizer-demanding crops. With an application of 120 to 160 t/ha, this organic fertilizer completely replaced chemical fertilizers over three years in sandy soils, and the same result was achieved with application of 180 to 240 t/ha over five years in soils with a higher clay content (Treto et al., 2002).

10.9.2 Biological Control

After 1990, as a response to the scarcity of pesticides, biological control became a principal strategy for pest control in Cuba. The rapid implementation of this broad strategy at a national scale in the 1990s was possible because of long-term experience in biological control and the existence, beginning in 1960, of five laboratories for its study. Entomophagous and Entomopathogenous Reproduction Centres (CREEs) were created throughout the country for the production of biological control agents to manage the most important agricultural pests. Some 276 CREEs were widely distributed throughout the nation: 54 for sugar cane cultivation areas and 222 for lands producing vegetables, tubers, fruits, and other crops (Pérez and Vázquez, 2002). The actual production of these biocontrol agents (fungus, bacteria, nematodes, and beneficial insects) was small scale and decentralized, and the CREEs provided services to state farms, cooperatives, and private farmers (Fernández-Larrea, 1997). Their use was widespread, covering about 1 million ha in the nonsugar sector in 1999 (Pérez and Vázquez, 2002).

Although Cuba never halted pesticide imports, they were reduced to about one-third of what was previously purchased before the 1990s (Pérez and Vázquez, 2002). Integrated pest management (IPM) programs, combining biological and chemical pest control together with cultural management, were the most common strategy for confronting the pesticide shortage. The effectiveness of biological control stragetíes, however, has allowed a continuing decrease in the use of pesticides. Pesticide applications on cash crops were reduced 20-fold in a 15-year period, from 20,000 metric tons in 1989 to around 1,000 metric tons in 2004 (*Granma Internacional*, 2004). This indicates not only the effectiveness of the biological practices developed, but also the countrywide need to strengthen sustainable strategies and innovate for nonchemical pest control.

10.9.3 Animal Traction

At the end of the 1980s, the number of tractors in Cuba had reached almost 90,000, with imports of 5,000 per year. After 1989, the number of tractors in operation dropped dramatically due to a lack of spare parts, maintenance, and fuel to keep them working. The traditional practice of using oxen for cultivation and transport was revived. About 300,000 oxen teams were trained, conferring a lower fossil fuel dependency to the new production systems. In 1997, 78% of oxen teams were being used in the private sector, this covering only 15% of national agricultural acreage; later the use of oxen was extended to all agricultural sectors (Ríos and Aguerrebere, 1998).

Lowering fossil fuel use was not the only benefit of using oxen for cultivation. Oxen could offer effective mechanical control of weeds, and thus serve as a substitute for herbicides. Substitution of oxen teams for machine power was successful in achieving many agroecological goals; however, the use of oxen is appropriate for traditional small- to mid-size farming systems, less for large-scale monoculture. Thus, changes in land use patterns were necessary to allow the benefits of animal traction to reach their full potential.

The systematic use of oxen in cropping areas required an integration of land for pasture and animal feed production, i.e., mixed use. Many livestock farms that previously specialized in milk or meat production started using oxen to transport cut forages and to plow land that would grow crops for both subsistence and markets. Specialized crop and livestock farms had to adapt their designs to the new conditions. Similarly, many cooperatives previously dedicated to specialized crops such as potatoes, sweet potatoes, vegetables, etc., created "livestock modules" using dual-purpose cattle that produced milk and meat for farmers and could replace oxen teams over time as a source of traction.

10.9.4 Polycropping and Crop Rotation

Crop rotations and polycultures were developed in order to stimulate natural soil fertility, control pests, restore productive capacity, and to obtain higher land equivalency ratios (LERs).* The application of these alternatives—often practiced by traditional farmers—proved to be critical in supporting production levels, and subsequently was expanded through the country, especially in the cooperative sector (Wright, 2005). Both research results and actual production figures showed that polycropping and crop rotation made possible an increase in the yield of the majority of the economically important crops (Casanova et al., 2002). Experiments confirmed, for example, that the use of soybean (*Glycine max*) in rotation with sugar cane increased yields of the latter from 84.4 to 90.6 t/ha with an additional production of 1.7 t/ha of soybean (Leyva and Pohlan, 1995). Polyculture of cassava (*Manihot esculenta*) and beans (*Phaseolus vulgaris*) under different management cropping systems achieved a higher LER than monoculture of cassava or beans (Mojena and Bertolí, 1995). Polyculture of green manures and corn (*Zea mays*) in rotation with potatoes (*Solanum tuberosum*) also increased potato production (Crespo et al., 1997). All these polycropping arrangements made for more efficient land use as well as successful pest control.

10.9.5 Beyond the Input Substitution Strategy

The previous examples of input substitution strategies recognize the positive results of such approaches on national food self-sufficiency and the environment. This model of input substitution prevailed in Cuba during the years of crisis and is considered the first attempt to convert a conventional food system at a national scale (Rosset and Benjamin, 1994). However, these approaches arguably need to evolve if a higher level of agricultural sustainability is desired.

Many farmers in Cuba, lacking an agroecological framework, substitute inputs out of necessity but prefer the use of agrochemicals when they are available, even though they may recognize the negative effects of these inputs on health (Wright, 2005). Along the same lines, most policymakers in Cuba tend to consider the conventional approach as the most viable way to restore soil fertility, control pests, and increase productivity in agriculture. In fact, one present strategy from the state is the "potentiation" of production—increasing imported agrochemical, oil, and feed inputs for use in prioritized cropping or livestock activities. These conventional approaches are again becoming policy, and the lower-yielding systems still receive much less support from the administrative structures than is necessary. Such political trends in Cuban agriculture make it clear that the national input substitution strategy has not yet evolved to an agroecological stage.

* "The land equivalent ratio is calculated using the formula

$$LER = \sum \frac{Ypi}{Ymi}$$

where Y_p is the yield of each crop in the intercrop or polyculture, and Y_m is the yield of each crop in the sole crop or monoculture. For each crop (i) a ratio is calculated to determine the partial LER for that crop, then the partial LERs are summed to give the total LER for the intercrop" (Gliessman, 2001, p. 241).

The Cuban alternative model needs to be reinforced with a stronger focus on both a systems approach and an ecological foundation. Only by making more profound changes—considering alternative agricultural systems that are truly regenerative rather than merely input substituted—can long-term sustainability be achieved. The integration of crops and livestock within more diversified production systems—to create what can be called mixed farming systems (MFSs)—is one of these alternatives.

10.10 MIXED FARMING SYSTEMS: AN AGROECOLOGICAL APPROACH TO SUSTAINABILITY

The national input substitution strategy established both infrastructure for and basic knowledge about sustainable farming system management. However, it is necessary to recognize the technological limitations of input substitution to achieve a more integrated and ecologically sound approach. The still prevalent monoculture systems in agriculture, the continued dependence on external inputs, and the restricted degree of internal cycling in agroecosystems are some of these limitations.

10.10.1 Changes in the Structure of Land Use

The patterns of land use in present Cuban agriculture are of special relevance for more fundamental conversion to an agroecological model at the national scale. During the past 10 years, major structural changes in the agricultural sector have taken place in Cuba that create the preconditions for a nationwide application of a mixed farming strategy.

First, as mentioned previously, the effects of the crisis during the 1990s made necessary the decentralization of state enterprises and the promotion of cooperativization in order to keep the people on the land. Giving usufruct land rights, reducing the scale of production, and diversification were key factors in the agricultural changes.

Second, the deactivation of 110 sugar mills out of the existing 155 during the last five years means that half of the more than 1.4 million ha formerly devoted to the monoculture of sugar cane is available for other agricultural purposes, e.g., crop production, fruits, reforestation, and livestock. In the first stage of this structural change only 71 sugar mills remained working, with their lands covering an area of 700,000 ha. In the year 2002, the Ministry of Sugar (MINAZ) started a restructuring programme (named *Tarea "Alvaro Reynoso"*) in order to use the lands previously belonging to these sugar mills (Rosales del Toro, 2002). This led to further reductions in sugar production; today there are only 45 mills in operation.

Third, about 40% of the 2 million ha covered by pasture (some 900,000 ha) are now invaded by marabú (*Dichrostachys cinerea*) and aroma (*Acacia farnesiana*), two thorny, *fast-growing, woody* leguminous *species*. These plants are difficult to control by hand and expensive to control with machinery. The main causes of this tremendous invasion are the abandonment of areas and inappropriate land use.

The incorporation of mixed farming strategies might be an effective control practice for these weeds where conditions permit. Calculations made by García Trujillo

(1996) have shown that through mixed farming system strategies in the livestock sector, it is possible—even at very low levels of productivity—to fulfill the food requirement of the Cuban population with respect to animal protein and contribute to energy (carbohydrate) needs as well. Under this approach, extensive land use farming systems might be considered a valid strategy for the future of agriculture in Cuba.

Present ecological, economic, and social conditions favor the conversion to agroecological MFSs in the livestock sector. Because of the availability of animals, infrastructure, and long-standing pastureland, there can be immediate positive results when livestock units are converted to manure-fertilized crop and livestock systems (García-Trujillo and Monzote, 1995; Funes-Monzote and Monzote, 2001). In specialized commercial crop production, rotations with an animal component might allow better use of resources such as the fallow biomass, crop residues, or the by-products of food processing.

Although traditional farmers have commonly practiced the integration of crops and livestock at a small scale, the innovative approaches needed for medium-scale mixed farming systems should be researched, implemented, and disseminated. Moreover, strategies need to be developed for overcoming the major constraints to the development of mixed systems. These constraints include the systems' high need for labor in the context of a sparsely populated countryside, the lack of capital, and the priority still given to conventional agriculture and its specialized infrastructure.

Integration of crop and livestock production can be achieved at different scales in time and space. On a large scale (i.e., regional, national) it requires more capital and inputs than at a middle or small scale. For example, long-distance transportation of animal manure, with its high water content, is difficult and costly, and the available machinery makes it difficult to establish polycropping designs in larger areas. The increase in scale will bring decreases in production efficiency as well. In contrast, resource use efficiency is maximized at smaller scales, at the cooperative or farm level, because at these scales interrelationships (e.g., internal nutrient cycling) can be better facilitated. However, at any scale, the priorities, demands, and capacities of producers to carry out such alternatives are key factors in the successful implementation of the MFS model.

10.10.2 General Approach for Researching and Developing MFSs

Ultimately, MFSs integrate the specialized knowledge of plant and animal production with the benefits of crop and livestock diversity. Therefore, many individual approaches form part of a more holistic management program. One way to unite these specialized management concepts into a holistic system based on agroecological principles is to apply an approach called DIA systems, which stands for diversified, integrated, and self-sufficient (Monzote et al., 2002).

During the last decade, this approach has been developed and tested at the farm and cooperative levels; its principles seem to have potential application at the regional or national level. Each of the three components of DIA systems has its particular characteristics, but they share several basic principles, including (1) system biodiversification, (2) soil fertility conservation and management, (3) optimization of nutrient and energy cycles and processes, (4) optimal use of natural and local available resources, (5) maintenance of high levels of resilience in terms of systems sustainability and stability, and (6) use of renewable energy (Funes-Monzote and Monzote, 2002). The validity of this approach for the conversion of Cuban agriculture has been assessed by applying ECOFAS (Ecological Framework for the Assessment of Sustainability) methodology to evaluate the process of converting specialized dairy farming systems (DFSs) into MFSs.

ECOFAS consists of a comprehensive three-stage program for evaluating, monitoring, comparing, analyzing, and designing management strategies for converting specialized land use into mixed land use. Each stage is related to a different hierarchical level of analysis. Stage 1 is the experimental assessment of the conversion process. In stage 2, multivariate statistical methods are used to analyze different agroecological variables and indicators of sustainability in a broader array of systems. This second stage, as a scaling up of the results achieved in stage 1, serves as evidence for policymakers. In stage 3, participatory methods of research and action are used to diagnose and characterize farms and monitor their progress toward achieving multiple objectives using a set of agroecological, economic, and social indicators. The potential impact of the application of ECOFAS methodology for improving productivity and achieving the economic, agroecological, and social goals of sustainability is huge.

10.10.3 Study of the Conversion of Specialized Dairy Systems into Mixed Farms

Seven research teams throughout the country took part in the three stages of this project, designated Designs for Crop-Livestock Integration at Small and Medium Scale by the Ministry of Science, Technology and Environment (CITMA). Using the ECOFAS methodology, all the teams succeeded in identifying locally adapted strategies for mixed farming that have the potential to alleviate barriers to sustainable livestock production in Cuba.

10.10.3.1 Stage 1: The Experimental Scale

To study experimentally the effects of converting specialized "low external input" dairy systems into mixed farming systems, one specialized dairy operation was chosen as the control and two equivalent farms were converted to mixed farm systems with different percentages of their land put into crop production. Data collected over a six-year period demonstrated that productivity, energy efficiency, and economic profitability all improved on the mixed farms, and that these improvements occurred without a decrease in milk production per unit of farm area (Figure 10.2). Greater use of legumes, more intensive crop rotations, diversification of production, and the use of crop residues for animal feed allowed an increase in the stocking rate on the livestock area of mixed farms. The human labor demand was higher at the beginning of the establishment period on the mixed farms, but it decreased by one-third over the six-year period. Energy efficiency, calculated as a ratio of energy output per unit of energy input, was from two to six times higher in the mixed system and increased over time. In economic terms, the mixed farms reached three to five times the net

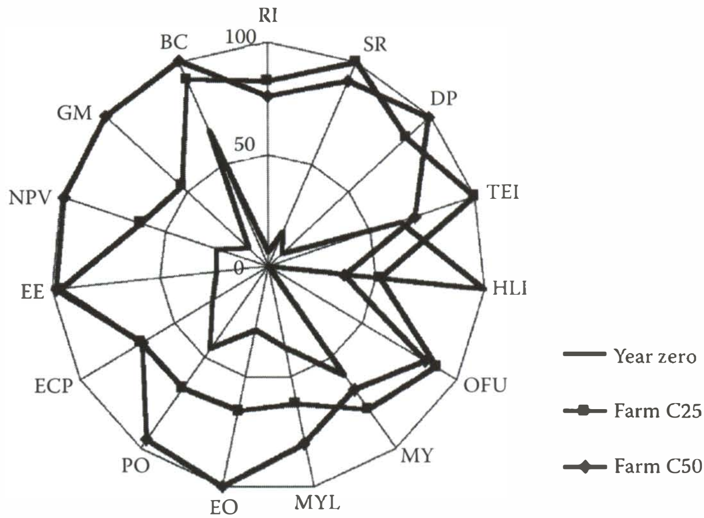

FIGURE 10.2 Agroecological and financial indicators (AEFIs) for the year 0 (specialized dairy farm) and the two experimental mixed farms averaged over the six-year period of the study. Farm C25 had 25% of its land in crop production, and Farm C50 had 50%. Target values for the assessment of each indicator are set at 100%. For Shannon and Margalef index calculation procedures see Gliessman (2007). Indicators: RI—Reforestation (Shannon index); SR—Species richness (Margalef index); DP—Diversity of production (Shannon index); TEI—Total energy inputs (GJ ha^{-1} $year^{-1}$); HLI—Human labor intensity (hours $ha^{-1}day^{-1}$); OFU—Organic fertilizers use (t ha^{-1} $year^{-1}$); MY—Milk yield (t ha^{-1} $year^{-1}$); MYL—Milk yield per livestock area (t ha^{-1} $year^{-1}$); EO—Energy output (kg ha^{-1} $year^{-1}$); PO—Protein output (kg ha^{-1} $year^{-1}$); ECP—Energy cost of protein production (MJ kg^{-1}); EE—Energy efficiency (GJ produced/GJ input); NPV—Net production value (CUP ha^{-1} $year^{-1}$); GM—Gross margin (CUP ha^{-1} $year^{-1}$); B/C—Benefit/cost ratio.

economic value of the original specialized dairy farm, mainly due to high market prices for crop products. In general, among the mixed farms studied, the one with 50% of land in crop proportion (C50) performed better for most of the agroecological and economic indicators than the one with 25% of land in crop proportion (C25). They both had much better performance than the original dairy system in year 0 of the conversion (Figure 10.2).

10.10.3.2 Stage 2: Scaling-Up Experimental Results

Experimental scale results were confirmed by a broader survey of 93 farms covering various soil and climatic conditions in the three main regions of Cuba. The farms under study were classified using multivariate canonical discriminant analysis. Diversity of production, species richness, energy efficiency, and human labor intensity were the primary factors influencing farming systems classification (Funes-Monzote et al., 2004). According to these indicators, integrated crop-livestock farms were more productive and more energy efficient than specialized systems.

In these studies, it was demonstrated that the inclusion of crops into livestock areas enhanced the energy and protein production capacity. This was possible due to the greater energy value of crops, the increase of milk yields achieved in the mixed farms, and the more efficient use of land, capital, and labor at the systems level. A nondetrimental or even positive effect on milk production, through the inclusion of crops in livestock areas, challenged the belief that milk production is reduced when crops are established in pasture-based areas.

10.10.3.3 Stage 3: Application and Conclusions

In stage 3 of the study, project teams characterized mixed and specialized farms in San Antonio de Los Baños municipality as study cases, analyzed their performance by comparing them using a participatorily designed set of agroecological, economic, and social indicators, and then discussed with farmers the possible impact of the results for improving productivity, economic feasibility, and agroecological sustainability of the farms. Application of participatory research methods considered farmers' perspectives in the definition of sustainability goals within strategies for the development of the MFS model at the regional level. The results of the comprehensive farm diagnoses, characterizations, and comparisons provide evidence of the advantages of mixed farming over specialized farming under low-input agriculture conditions.

In summary, implementing mixed crop–livestock designs might solve many problems—relating to adverse environmental effects, productivity, and efficiency—that predominate in specialized dairy systems (Monzote and Funes-Monzote, 1997). Much scientific and practical information demonstrates the advantages of the MFS model; however, more attention should be given to the development of adaptations under a variety of local conditions. A physical description of farming systems and quantification of their ecological flows are commonly found in the literature, but more integrated approaches that document agroecological, economic, and social dimensions are rare.

The application of agroecological approaches through the MFS model can be a further step toward sustainability in Cuban agriculture. Both the technological and practical advantages of MFSs have been scientifically confirmed, and the present economic and social structures of the agrarian sector in Cuba favor this process.

10.11 PRIMARY LESSONS OF THE CONVERSION PROCESS IN CUBAN AGRICULTURE

> The Cuban experiment is the largest attempt at conversion from conventional agriculture to organic or semi-organic farming in human history. We must watch alertly for the lessons we can learn from Cuban successes as well as from Cuban errors.
>
> **—Rosset and Benjamin (1994, p. 82)**

The recent history of Cuban agriculture demonstrates that agrarian reforms will not be effective in the long-term if adaptation to new political situations and ecological perspectives are not taken into account. Therefore, one of the main lessons of the national-scale conversion toward sustainable agriculture in Cuba in the 1990s is that it is necessary to change the prevailing world food production system so that stewardship of natural resources occupies a place as important as socioeconomic or political issues.

The elimination of the *latifundio* in 1959 by itself did not eradicate the many historical problems intrinsic to the Cuban agricultural system. Agrarian reform gave much of the land to those who worked it and reduced the sizes of farms, both of which had positive social impacts. However, the lack of an ecological focus and the concentration of lands by the state as never before in extensive monocultures reinforced the dependency characteristic of the inadequate agricultural development prevailing throughout Cuba's history. Although its intentions were to move toward a more socially just system, the new state agriculture, like that of the *latifundio*, created serious environmental and socioeconomic problems.

The enormous economic, ecological, and social crisis that was unleashed at the beginning of the 1990s was the result of the high level of dependency reached in Cuba's relationship with Eastern Europe and the USSR. Many studies demonstrate the depth of the crisis, and almost all agree with the conclusion that it would have been much worse had there not been the will to change to centralized planning of material resources and to work toward an equitable social structure. Government assistance, together with its encouragement of innovation, the high educational level of the population, and the exchange of resources and knowledge among the people, permitted the creation of a sustainable agriculture movement and its implementation at a national scale.

However, further steps—indeed, profound changes—are necessary in Cuban agriculture. Although innovation has been present in all branches of agriculture and the scientific institutions have tested environmentally sound technologies on a large scale, these efforts have tended to focus on the substitution of inputs, and there remains a disjunction between the biophysical and socioeconomic aspects of agricultural development. If this newest stage in Cuban agriculture, characterized by the emergence of diverse agroecological practices throughout the country, is to progress further, it must be recognized that neither the conventional pattern nor that of input substitution will be versatile enough to cover the technological demands and socioeconomic settings of the country's heterogeneous agriculture. Therefore, it is necessary to develop more integrated, innovative, and locally oriented solutions as opposed to solving specific problems from the top down. The MFS approach, based on agroecological perspectives and participatory methods of dissemination, might aid in reaching a higher stage in the transformation of Cuban agriculture as it moves toward sustainability.

10.12 FINAL REMARKS

Despite the acknowledged successes in the transition toward sustainable agriculture in Cuba, it appears that the impact in terms of national food self-sufficiency is still limited. The country at the moment imports about 50% of its food and only half of the suitable land is cultivated; thus, dependence on external food sources is high and food security is tenuous. Cuban agriculture is responding to this situation with emphases on diversification, decentralization, and greater food self-sufficiency. However, these developments must be systematically supported by science and policy if they are to overcome the food security challenge and allow the agricultural sector to contribute to a viable economy. If the need for economic recovery is used as an argument to return to intensive, industrialized agriculture, sustainability and resource conservation will be threatened. Changes in Cuban agriculture, once driven by the dire necessity for input substitution, must now be guided by more conscientious and scientifically driven policies that aim at development of an agricultural sector that combines production and conservation objectives.

The soaring prices of oil and food on the world market during the last few years emphasize the need for an agricultural reorientation that makes the substitution of food imports with homegrown food products a national priority (Castro, 2008; MINAG, 2008). Mixed crop–livestock farming systems have much to contribute to this goal and to the development of a sustainable agricultural model for Cuba. It is a positive sign that multistakeholder platforms of farmers, scientists, and policymakers have been involved, at various locations in the country, in the design and implementation of these systems in the period since the early 1990s. Rural development strategies are being identified at the local level, technologies adapted to location-specific conditions, and traditional and scientific knowledge integrated to arrive at more sustainable agricultural practices and best uses of available resources.

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