Towards sustainable agriculture in Cuba

Fernando Funes-Monzote

P.O. Box 4029, PC 10400, Havana, Cuba

e-mail: mgahona@enet.cu

Chapter outline

1. Introduction

Cuba has a long agricultural tradition as an exporter of 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 caused an enormous negative environmental impact on soils, biodiversity, and forest cover (Funes-Monzote, 2004). However, during the last decade agricultural development has been reoriented (Rosset and Benjamin, 1994; Funes et al., 2002; Wright, 2005). Undoubtedly, today agricultural production in Cuba is more self-sufficient and concerned, as never before, with environmental protection. In 1994, the National Programme for Environment and Development (The Cuban adoption of the Agenda 21) was designed, and two years later the National Environmental Strategy approved (CITMA, 1997; Urquiza and Gutiérrez, 2003). In 1997 "The Cuban Law of Environment", become the environmental protection policy of the State (Gaceta Oficial, 1997). Although environmental protection is still low in practice, legal support for preserving environment is very useful for present and future agriculture sustainable strategies.

A principal goal of the Cuban revolution of 1959 was to resolve the long-standing problems of agriculture. One of the primary measures taken by the revolutionary government was the First Agrarian Reform Law, which eliminated both national and foreign (basically North American) ownership of large farms, called *latifundios*, and turned over the land to peasants (*campesinos*) to work. Additionally, it promoted agricultural diversification (Anon, 1960; Valdés, 2003). This action generated great conflict with both the old *latifundio* interests and the United States government. In 1963 a much more radical Second Agrarian Reform Law decreased the maximum landholding limit to 67 ha for individuals.

As a consequence of these laws, the rapid industrialization of agriculture based on conventional methods again tended to concentrate land in large state enterprises, and consequently resulted in similar environmental problems as 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 was strongly noted at the beginning of the 1990s with the disintegration of the 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, but at the same time, these factors provided exceptional conditions for the construction of an alternative agricultural model at a national scale.

The transformation that occurred in the Cuban countryside during the last decade of the 20th century is an example of agricultural conversion at a national scale --from a highly-specialized, conventional industrialized agriculture, dependent on external inputs-- to an alternative model based on some of the principles of agroecology and organic agriculture (Altieri, 1993; Rosset and Benjamin, 1994; Funes et al., 2002). Numerous studies of this conversion attribute its successful advances both to the form of social organization 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).

Different from sustainable agriculture movements developed in isolated fashion 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. At this early stage, the agricultural systems most commonly employed consisted of the substitution of biological inputs for chemical, and the more efficient use of local resources, by which numerous objectives of agricultural sustainability were serendipitously also reached. Nevertheless, the author believes it is necessary to develop a more integrated, long term agroecological focus and to more strongly combine the economic, ecological and social dimensions. On one hand, the persistent shortage of external inputs and, for other, the diverse production systems in the Cuban agriculture, has favored the proliferation of agroecological practices through the country. In the present scenario (with about 5 000 enterprises and cooperatives and nearly 400 000 individual producers) neither the conventional pattern nor that of input substitution will be versatile enough to cover the technological demands of such a heterogeneous and diverse agriculture (Granma, 2006a).

Cuba has already accumulated significant experiences in the transition towards a more sustainable agriculture. However, this effort could be thwarted by changing economic conditions if sustainable agriculture is viewed as a temporary solution to overcome the consequences of the crisis. It will only continue if is perceived as a vital necessity for the future of the country. This chapter will present the context of Cuban agriculture, pointing out relevant elements of the national level experiment towards sustainable agriculture which has been taking place during the 1990s. A mixed farming systems approach is presented here as the next step toward an agroecological model at national scale.

2. Background information

Cuba, the biggest of the Caribbean islands, is strategically located between the two Americas, consequently playing 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 that of the Minessota State, which is 12th largest in the US. With a total area of 110,860 km^2, the country is dominated by expansive plains (occupying two-thirds of the total) and three well-defined mountain ranges (Figure 1).

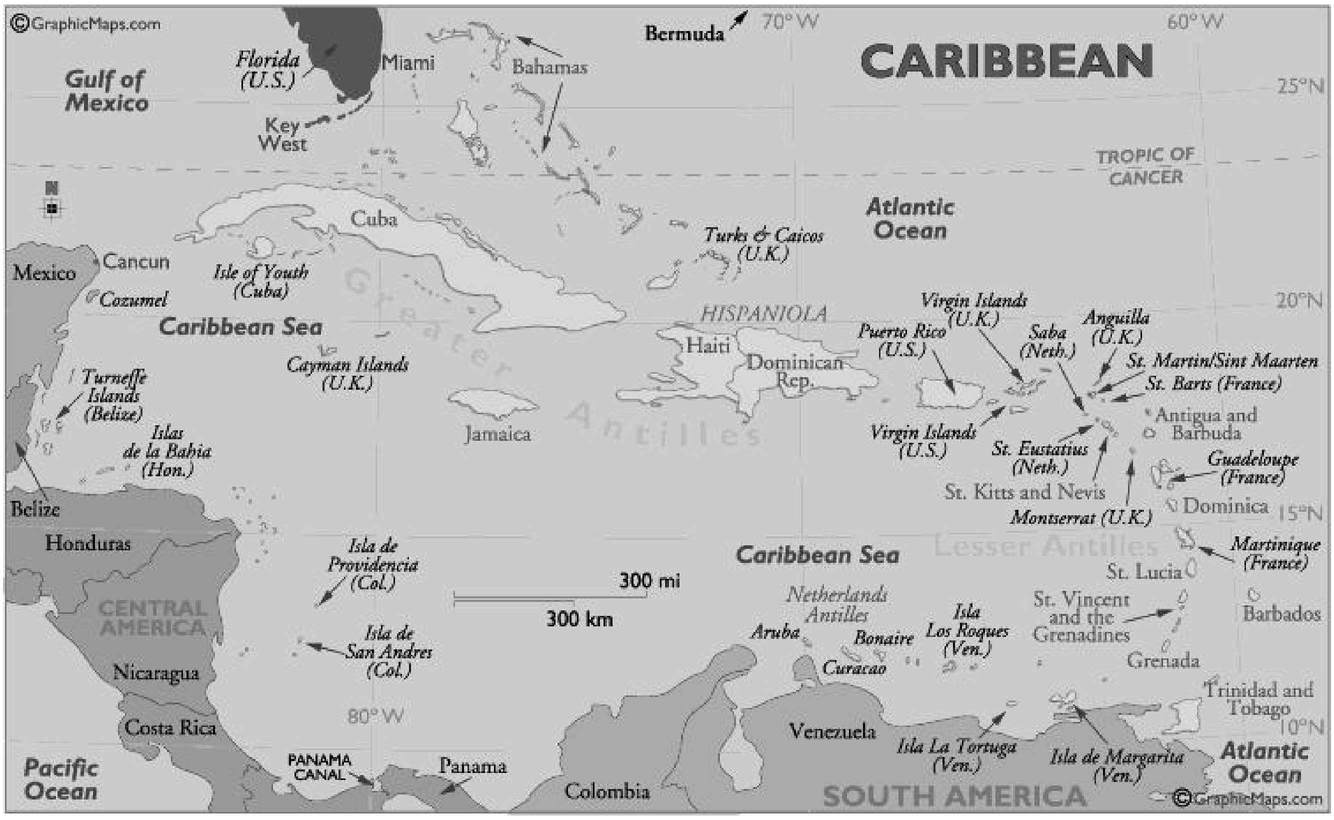

Figure 1. Cuba in the Caribbean region.

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 of 48 well defined natural regions, each with specific characteristics of climate, vegetation, and landscape from rainforest to semi-desert (Gutiérrez Domenech and Rivero Glean, 1999). Such heterogeneity in the Cuban landscape favors its high natural biodiversity, with 19,631 known plant and animal species of which 42.7% are endemic (ONE, 2004).

The physiography of the island facilitates sea transport, being 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). Some 5,700 km of railway connects the most important cities and their distance from the coast with more than 200 bays and coves, is as average less than 40 km.

Although Havana is the main economic center, each of its 14 provinces is important agriculturally, culturally and economically. Population density is higher in Cuba (98 inhabitants/sq. km) than Mexico (50), Central America (68), and South America (17), but lower than average in 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. While in Latin America as a whole the agricultural area is about 34% of total land, in Cuba approximately 60% of its land is appropriate for agriculture (ONE, 2004; FAOSTAT, 2004). However, currently less than 25% of the population lives in rural settlements and of that figure, only 11% work directly in agricultural activities (ONE, 2004).

According to the most widely used climate classification system (Köppen, 1907) recognized by the Food and Agriculture Organization (FAO), Cuba's climate is a *tropical savannah* type (Aw). However, it is also considered as a *tropical oceanic* climate (Alisov and Paltaraus, 1974). These and other general classification criterias 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 1).

Table 1. General data and climate conditions in Cuba.

General data		Climate		
			Season	
Length of country, km	1 250		Wet	Dry
Area, km^2	110 860			
Highest peak, metres.above.sea.level.	1974	Rainfall, mm	1104	316
Total population, million inhabitants	11.3	Mean temperature, ^0C	26.9	23.2

Source: ONE, 2004

Soils in Cuba are heterogeneous. Soil fertility, 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 the remaining 14% very poor fertility (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 2).

Table 2. Principal limiting factors of Cuban soils.

Factor	Affected agricultural area	
	million ha	%
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

Despite the limitations mentioned, Cuba possesses an exceptional natural environment for agriculture. Due to its continuous growing conditions and great diversity of plants and animals used for agricultural purposes, crop cultivation and open air animal raising is possible throughout the year. The ample infrastructure of roads, railroads with access to the sea, the existence of high reservoir capacity for irrigation, countryside electrification and high-investment in agricultural facilities, are valuable pre-conditions for greater agricultural production in Cuba. In addition, the extensive network of scientific institutions is a considerable strength to carry out agricultural changes. However, these resources are not being efficiently used for several reasons: the lack of maintenance of agrarian infrastructure, the continued specialised organisation of agriculture, the scarcity of agricultural labor, the costly or inaccessible primary materials, among others.

3. Brief history of Cuban agriculture

3.1. Migratory aboriginal groups

The first inhabitants of Cuba arrived about 10,000 years ago from North America through the Mississippi watershed, to 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. This more advanced group introduced a variety of instruments for hunting and food processing. Some 1,500 years ago, a more evolved people called *Taínos* occupied the island. These were the most numerous and dominant Native Americans encountered by the Spanish at their arrival to the island in 1492. Part of the South American aboriginal family known as *Arawaks*, they were advanced hunters and fishers but they also practiced agriculture. One of their most productive agricultural systems was called raised beds *or 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.

3.2. Colonization of Cuban territory

At the period of the Spanish arrival, the landscape was predominantly forest and estimated to cover from 60 to 90% of the national territory (Del Risco, 1995). Initially the conquerors resettled indigenous people in *vecindades* or reserves. In these reserves they predominantly 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 implanted by the Spanish may be considered a precedent in the process of agricultural conversion to European practices.

The small Spanish population focused on cattle 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, timber extraction, as well as sugar and tobacco production and processing, extended into the interior of the cattle ranches and transformed the original Spanish agrarian structure. This was mainly due to economic reasons such as the demand for wood for ship construction, the increasing population in the main villages of the island, and the growing external market for agricultural products. From the beginning of the 1600s, commercial agriculture rapidly developed with the advent of sugar cane and tobacco production in the *estancias* (Le Riverend, 1992; Marrero, 1974-1984; Funes-Monzote, 2004).

At the outbreak of the Haitian slave revolt in 1791, French colonies were the principal producers and exporters 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 extensions of land dedicated to cattle ranching and 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 “fatigued”, unproductive lands (De la Sagra, 1831; Reynoso, 1862).

3.3. Agricultural patterns in neocolonial times and their consequences

The process of concentration and centralization of sugar production continued until the 1900s. However, after the triumph of Cubans in the liberation war against Spanish colony in 1898 and the initiation of the so-called neo-colonial times in 1902 favored large investments of North American capital to establish giant sugar *latifundios* on the eastern half of the island, which until this time was the area least affected by agriculture. During the first two decades of the 19^{th} 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* throughout the country were inefficient in producing food, and many of these large farms were gradually abandoned (around 40%). Meanwhile, the campesino sector

that 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 farms, from 5 to 75 ha in size, occupied only 25% of the total agricultural area (Censo Agrícola Nacional, 1951), but the mixed crop-livestock production and the better organization efficiency generated about 50% of total country agricultural production.

The combination of the structure of land tenure along with an export-oriented economic model meant a dependency on only a few agricultural crops. The Cuban countryside was characterised 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 agrarian-based of the people and anti-imperialist. During the 46 years since the Revolution, unprecedented events have taken place with arguably relevance to the future of world agriculture.

4. Post-revolution scenario

4.1. Agrarian reforms

With the success of the Cuban Revolution on January 1st, 1959, the government adopted two Agrarian Reform Laws, passing ownership to the peasants who had worked rented lands. This considerably reduced farm size. Firstly, in May 1959 the maximum land holdings were reduced to about 400 hectares. 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, and another 30% in the second stage (Valdés, 2003).

At that point, the four prioritized objectives for the transformation of Cuban agriculture were: 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, 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).

4.2. The conventional agriculture model

Although the official desire of the government for diversification was expressed above, the on-the-ground administration of State supported a 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 Assitstance (COMECON) –the economic block of the former socialist countries– forced Cuba to fulfill five-year plans at high environmental costs. It is also important to mention that the dependency on processed food imported from Eastern Europe reached unprecedented levels (Espinosa, 1992).

The application of Green Revolution concepts was made possible owing to 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 chemical management of agricultural processes, and 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. However, this still did not reach the calculated nutritional needs of the Cuban population of 2,972 kcal and 86.3 g respectively (Pérez-Marín and Muñoz, 1991).

These successes were achieved and sustained through a model of dependence which used high external inputs. 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 block of Eastern Europe while 83.8% of its total imports came from those countries (Pérez Marín and Muñoz, 1991). The COMECON agreement allowed selling national goods in the socialist market of Eastern Europe at high prices while imports were purchased from them at low cost.

Meanwhile, 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 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 implication of local substitutions for imported raw materials. Nevertheless, at the end of the 1980s, Cuban agriculture was characterized by a high concentration of state-owned land (of total land area, 80% was in the state sector, 8% cooperatives, and 12% small farmers), high levels of mechanization with one tractor for every 125 ha of farming land, crop specialization, and high input usage (13 million tons diesel, 1.3 million tons fertilizers, USD$ 80 million pesticides, and 1.6 million tons livestock feed concentrates applied per year) (Lage, 1992).

4.3. Consequences and collapse

Continuing to apply this agricultural model resulted in several economic, ecological, and social consequences. Among the most important were one million hectares of salinized soils, the increased frequency of moderate to severe soil erosion, soil compaction with its resultant soil infertility, loss of biodiversity and deforestation of agricultural land. 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 1990's) (Funes et al., 2002).

As result of this situation, at the end of the 1980's 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 to cover internal demand (ANPP, 1991). This program essentially continued the conventional high-input focus because it could count on abundant externally-derived inputs from abroad.

The disintegration of Eastern European and Soviet socialism frustrated these plans initially; however, the government decided "*to continue developing the Food Program despite whatever difficult conditions might have to be faced*" (ANPP, 1991). Without the expected aid, it would be necessary to seriously adjust the technology and structure of production.

5. Situation after the collapse of the socialist block

"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…"

(Castro, 1992).

The unexpected collapse of the socialist countries of Eastern Europe and the USSR fully highlighted the inconsistencies of the agricultural model that Cuba had developed. The island lost the principal markets and guarantees provided by these countries 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 system. 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 amongst the population. In addition, many diseases started to appear (PNAN, 1994); one of the most virulent epidemics called optical neuritis affected the vision of over 50,000 people as result of the low intake of certain nutrients (Table 3). However, the consequences of such a food security crisis would have been far more dramatic without the government's ration system that assured equitable food access and avoided famine (Rosset and Benjamin, 1994; PNAN, 1994; Wright 2005).

Table 3. Comparison of nutritional levels per capita per day in 1987 and 1993 vs. recognized nutritional needs for the Cuban population.

Nutrient	Units	Nutritional needs*	Percentage satisfaction of recognized needs	
			1987	1993
Calories	Kcal	2,972	97.5	62.7
Protein	gr	86.3	89.7	53
Fat	gr	92.5	95	28
Iron	mg	16	112	68.8
Calcium	mg	1,123	77.4	62.9
Vitamin A	mg	991	100.9	28.8
Vitamin C	mg	224.5	52.2	25.8

Source: PNAN, 1994; Pérez-Marín and Muñoz, 1991.

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

Despite the economic difficulties confronted, the government continued to reinforce social programs. For example, the infant mortality rate during the first year of life was reduced by almost half-- from 11.1 per 1000 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 changes and strategies to reduce negative impacts on the national economy.

In response to 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):

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

Many of these measures taken by the State were key factors in the proliferation of sustainable Cuban agriculture. However, the difficulties of adaptation by specialized large-scale agriculture, the lack of monetary resources and materials to enact these solutions, the small work force in the countryside, amongst other reasons, has impeded the obtaintion of all expected results.

6. Changes in agrarian productive structures

In general, certain technical and organisational 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 the impossibility of maintaining them under reasonable levels of efficiency and production. In 1993, the creation of Basic Units of Cooperative Production (UBPC) was an effective measure that gave *usufruct* rights (land use free and for "indefinite" time) to farmers who were previously workers of State farm enterprises. Other forms of land distribution were also developed, which provided interested urban dwellers the opportunity to return to the countryside. Currently, ten distinct forms of organization in Cuban agriculture coexist, which can be grouped into three sectors: the State, non-State and mixed sectors (Table 4).

Table 4. Organization of Cuban agriculture (Martín, 2002).

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

Non-state 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

These changes in the agrarian structure of the country tended both towards cooperatives in the State sector and to permitting *usufruct* land use. Consequently, although at the beginning of 1990 the State controlled 83% of arable land, by January 1995 the State had allowed *usufruct* rights to 58% of this area. Such process 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 5). The private, campesino sector also increased its land area in the distribution process, which acknowledges its management capacity and increasing role in food production.

Table 5. Percentage of the area according to the form of land ownership in Cuba (1989-2000).

	1989-92	1993	2000
State	83	47.5	33.1
Other State organizations		9	
UBPC	-	26.5	40.6
CPA	12	7	26.3
Private		10	

Sources: PNAN, 1994; Pérez Rojas et al., 1999; ONE, 2004.

In fact, compared to State enterprises, the UBPC is a more socialized (i.e. decentralized) form of production (Villegas, 1999). The primary characteristics of the UBCP include: *usufruct* rights to land for an indefinite time; workers' can decide the manner to sell their products at local markets or to the State regulated markets; payment for technical advice from the State; the possibility to have a bank account and the ability of cooperativists to obtain agricultural inputs on credit as well as the collective determination of their management, maintain their accounts and comply with financial obligations such as taxes.

With the creation of the UBPCs, the State was able to both better manage production and save on scarce resources. The large mixed crop enterprises reduced their scale 10-fold, while the livestock enterprises reduced their size on average 20-fold until they reached a size similar to those of the Agricultural Production Cooperatives (CPAs) that already existed for more than 20 years with reasonable levels of production and efficiency (Table 6). However, the resulting average sizes of UBPCs were still large for most of principal agricultural activities, while the lack of resources had made many of them almost unmanageable. Thus, the strategy of dividing land into smaller plots within the UBPCs further recognized the greater efficiency of production at smaller scale. Following the principle of "*vincular*" (linking of) people to the land (i.e. granting the possibility to farmers living on the farm), thousands of families became based on the UBPCs area, which had been previously uninhabited and controlled by State enterprises. For example, some 15 years ago only two families populated an extension of about 1000 ha occupied today by the UBPC "26 de Julio" in Bacuranao, Havana. After the foundation of this UBPC, housing conditions were created to attract people aware of working in agriculture. Today more than 50 families live there, sustain their own consumption, generate extra production for commercialization and accomplish commitments of milk production for sales to the State. These conditions boosted the re-population of rural areas.

Table 6. Average size of State enterprises, UBPCs and CPAs for the principal crops and cattle (PNAN, 1994).

Principle activity	State enterprises (ha) 1989	Average size UBPC (ha) 1994	Average size CPA (ha) 1994
Various crops*	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

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

Within the UBPCs, people lived closer to land while facilitating better natural resource management and local farmer decision-making. Increases in efficiency and productivity were caused by the reduction in scale, greater diversification and more rational use of inputs, machinery and infrastructure. In this way, the losses in external inputs and capital were mitigated. However, the UBPC model, as a new form of agriculture in Cuba, is still far from achieving their potential benefits. Many organizational methods employed in the State enterprises were replicated in UBPCs (Pérez Rojas and Echavarría, 2000). The lack of a sense of ownership, the persistant dependency on external inputs, and limited decision-making affect the functioning of UBPCs (Granma, 1997). In summary, the UBPCs in their essence have continued to form part of a structure that operates under the direction of the State enterprises. Nevertheless, since its foundation, 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.

7. The contribution of small farmers in alleviating the impacts of the crisis

In Cuba, private farming 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 gave their land to the cooperative, and this individual property is transformed into social or collective property. A CPA is the voluntary association of small farm holders who combine their interests and material resources to create a common holding that is administrated by all, and is worked for the benefit and development of the entire society (Alvarez, 2002). The second type is composed of farmers who form a cooperative in which they continue to own land and equipment on an individual basis. They buy inputs and receive credit and services. Both of these types 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 at the local market or to middlemen.

Compared to State farms, private farmers hold the greater experience and tradition in Cuban agriculture and unsurprisingly, their agricultural systems proved to be more resilient. While the State agricultural enterprises were strongly impacted by the crisis 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 occupied 18% of the country's arable land. Ten years later, and with 25% of the agricultural area, the small farmers participated significantly to 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 7), demonstrates their efficient land use. It also acknowledges the capacity of small farmer's methods of production and organization to contribute to the national food balance, even with scarce external inputs.

Table 7. Percentage contribution of *campesino* production to total sales for various products in Cuba.

Product	% of sales to the State	Product	% 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.

Abolished at the end of the 1980s, the "*Mercado libre campesino*" (farmer's free market), was re-opened at the beginning of 1994 as the "*Mercado Agropecuario*" (agricultural market), a new name but in essence with similar characteristics. This agricultural market functioned under the law of supply and demand and became an important distribution channel of agricultural products. In 1996, some 70.7% of the total agricultural sales to consumers were by individual or cooperative farmers (Martin, 2002). From 1995 to 2000, the national herd, and subsequent livestock products, under private sector management also increased (García, 2003). During the same period, State and UBPC livestock production had shown no signs of recuperation. Factors that have contributed to the depression in cattle production at the national level are the scarcity of imported feed and adverse climatic conditions such as prolonged drought, hurricanes and other natural events. However, *campesino* production has encountered short term solutions to these factors, resulting in a minimizing of their negative impact and consequently has 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 indispensible to genetic improvement for sustainable agriculture from a local perspective (Ríos, 2004; Wright, 2005). The Local Agriculture Innovation Programme of the National Institute for Agricutlural Sciences (INCA) with more than 4,000 farmers involved (Ríos, 2006) and the Agroecological Farmer to Farmer Movement (Movimiento Agroecológico Campesino a Campesino, MACAC) of the National Association of Small Farmers (Asociación Nacional de Agricultores Pequeños, ANAP) 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).

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

8. Urban agriculture: A massive organizational initiative towards food security

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). At the beginning of the crisis, people organized themselves to cultivate vacant lots, backyards and rooftops in the cities. Even animals were reared inside the houses in order to assure the families' food supply.

From the middle of the 1990s, urban agriculture was transformed from subsistence production to a practice that also included commercial activities. It was based in the use of local resources and minimum transportation costs of both inputs and products (Cruz and Sánchez, 2001). 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 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. The government still plays an important promotion and support role in this massive movement towards food security.
The principal objective of the Cuban urban agriculture movement is to increase the daily consumption of vegetables to 300 grams per citizen, the amount recommended by UN FAO. Spatially, it covers a radius of 10 km from the center of the capital city of each province; 5 km from the center of municipal capitals; 2 km around population centers of more than 10,000 residents, and local production for settlements of less than 1,000 people. The following basic principles of urban agriculture in Cuba define its objectives and organization (Companioni et al., 2002).

- 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
- Employment 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
- A fresh supply of good quality products offered directly to the population, guaranteeing a balanced production of not less than 300g of vegetables daily per capita and an adequate variety of animal protein
- Maximum use of the food production potential, such as the available labor force and the recycling of wastes and by-products for plant nutrients and animal feed

The organizational and administrative base of the urban agriculture program is the 28 sub-programs related to all aspects of animal and plant production found in the country (GNAU, 2004). These subprograms include, for example, management and conservation of soils, use of organic matter, seed production, vegetables and fresh herbs and spices, fruit trees, popular production of rice, grains, animal feed, apiculture, livestock, aquaculture, marketing, small agro-industries (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.

8.2. Popular production of rice: example of a successful sub-program

Rice is the basic food in Cuba. Consumed together with beans, meat, vegetables and even fruits, is the essential plate of daily ration for Cubans. Its per capita consumption exceeds 44 kg, i.e. 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 1980s, when unlimited inputs were available, the national demand was not met and therefore it was necessary to import 40% of rice consumed, and national high-input rice production showed to be unsustainable at the onset of the crisis of the 1990s. The new "*Popular Rice*" program demonstrated that, even without high initial expectations,

this form of self-organization and low-input agriculture had a positive impact on national food self-sufficiency (García, 2003).

The "popular" production of rice (*arroz popular*) was originally a grassroots movement towards 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, "popular rice" production achieved 140,600 tons, involving 73,500 small producers. The yields obtained by such ways were 2.82 tons per hectare as a national average, without the use of costly inputs (Granma, 1998), while conventional rice production during 1980s achieved a national average of between 2 and 3 tons per hectare (ANPP, 1991). In 2001, popular rice comprised more than 50% of total domestic rice production (García, 2003).

8.3. Success and the future of urban agriculture

In the year 2000, urban agriculture produced more than 1.64 million tons of vegetables and employed 201,000 workers (Granma, 2001). Two years later, 326,000 people were linked with the program of urban backyard production, benefiting some 75% of the population (Granma, 2003). In 2005 the production was 4.1 million tons and employed 354,000 people (Granma, 2006).

The reported production of 20 kg per square meter achieved by urban agriculture, allowed exceeding 300 grams of vegetables per citizen per day. This 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, 2003a). 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 a more holistic concept than just food security. They suggest a concept which emphasizes the preservation of urban environment and the permanent management of resources in the urban settings, avoiding pollution of air and water as well as creating a culture of nature conservation.

Although cities became productive in terms of food, this still comprised a small part of the country's overall needs. Thus, the development of participatory, low-input "rural food production" was crucial at the onset of the 1990s. An alternative model to the prevailing conventional agriculture paradigm was established at national level, not only in State Enterprises and the UBPCs, but also in private individual and cooperative production. The input substitution strategy was a second step for the conversion towards a more sustainable agriculture in Cuba.

9. The input substitution strategy

During the 1980s, a certain amount of research focused on reducing the use of fertilizers, pesticides, and concentrated feed for livestock. These investigations focused on the most economically important and large scale agricultural activities (Funes, 2002). Although the ecological underpinning of these researches was implicit, the main objectives were the substitution of biological inputs for agrochemical and thus the reduction of production costs in commercial agriculture. Nevertheless, these studies formed the basis for a nationwide application of more ecological practices when no alternatives were available. The effectiveness and positive impact of such alternatives was proven in Cuba at a scale never previously attempted in any other country (Rosset and Benjamin, 1994, Funes et al., 2002).

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 solubilisation of phosphorus. In the search for input substitution, a wide range of these bio-fertilisers have been successfully developed and applied on a commercial, main crop scale, with a significant percentage of substitution of chemical fertilizers achieved (Table 8).

Table 8. 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-sulubilizing bacteria	Vegetables, cassava, sweet potato, citrus fruits, coffee nurseries	50-100 of the P fertilizer
Micorrhizae	Coffee nurseries	30% of the N and K fertilizers

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

Advanced research results confirmed the effectivness of green manures and cover crops in commercial crop production such as the use of sesbania (*Sesbania rostrata*) in rice production (Cabello et al., 1989) and crotalaria (*Crotalaria juncea*), jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*), dolichos lablab bean (*Lablab purpureus*) in other commercial crops (García and Treto, 1997). The inclusion of these plants, which are adapted to the Cuban soils and cropping conditions, into local systems were found to fulfill most of nutrient needs of the crops. These green manures were able to substitute for high levels of nitrogen fertilization (i.e. the equivalent to 67-255 kg/ha of N; 7-22 kg/ha of P; and 36 to 211 kg/ha of K), and improved the physical characteristics of the soil (Treto et al., 2002). In commercial tobacco production, chemical applications were also reduced through the use of green manures for soil fertility improvement and other traditional farming practices were recovered, such as the use of oxen teams for cultivation to avoid soil compaction, conservation of physical soil conditions and the elimination of weeds by mechanical means to avoid the use of 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/yr. Small scale compost and worm humus became popular, especially in urban agriculture due to the high levels of organic fertilizers demanded by organoponic vegetable production in beds. At 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 which is 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 application of 180-240 t/ha over five years in soils with a higher clay content (Treto, 2002).

9.2. Biological control

Long-term experience in biological control and the existence since 1960 of five laboratories for biological pest control, made possible the rapid implementation of this broad strategy at a national scale. After 1990 as a response to the scarcity of pesticides, biological control became a principal strategy for pest control in Cuba. 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 bio-control 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). Direct impact of such biocontrol agents covered about one million hectares in the non-sugar sector in 1999, making clear how widespread was their use (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). The development of integrated pest management (IPM) programs combining biological and chemical pest control, together with cultural management, were the most common strategy to confront this shortage. However, the use of pesticides continues to decrease. Pesticide applications on cash crops were reduced twenty times in a 15-year period, from 20,000 metric tons in 1989 to around 1,000 metric tons in 2004 according to Granma Internacional (2004). This indicates not only the effectiveness of the biological practices developed, but also the countrywide need to strengthening sustainable strategies and innovation for pest control without the use of chemicals.

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. The amount of tractors dropped dramatically post 1989, due to a lack of spare parts, maintenance, and fuel to keep them working. This stimulated the revival of the traditional practice of using oxen for cultivation and transport. About 300,000 oxen teams were trained, conferring a lower fuel dependency to the new production systems.

The use of oxen in agriculture at such a large scale served as a substitute for herbicides due to better soil preparation and therefore effective mechanical control of weeds. In 1997, 78% of oxen teams were being used in the private sector, this covering only 15% of national agricultural acreage. After this date, the use of oxen was extended to all agricultural sectors (Ríos and Aguerrebere, 1998). Substitution of oxen teams for machine power was successful in achieving many agroecological goals; however, the use of oxen is appropriate for a traditional small to middle scale farming system. These systems differ from large scale monoculture farming strategies. Thus, changes in land use patterns were necessary to make animal traction sustainable.

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 plough 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 to produce milk for farmers and their families, as well as to replace oxen teams over time.

9.4. Polycropping and crop rotation

Crop rotations and polycultures were developed in order to stimulate natural soil fertility, to control pests, to restore the productive capacity, and to obtain higher Land Equivalency Ratios (LER[1]). 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 an increase in the yield of the majority of the economically important crops because of this (Casanova et al., 2002). Experiments confirmed 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). Polycrops of cassava (*Manihot sculenta*) and beans (*Phaseolus vulgaris*) under different management cropping systems achieved a higher LER when compared to monocrops of cassava or beans (Mojena and Bertolí, 1995).

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[1] “The land equivalent ratio is calculated using the formula $LER = \sum \frac{Ypi}{Ymi}$ wereYp is the yield of each crop in the intercrop or polyculture, and Ym is the yield of each crop in the sole crop or monoculture. For each crop (i) a ratio is calculated to determine the partuial LER for that crop, then the partial LERs are summed to give the total LER for the itercrop” (Gliessman, 2001).

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 better land use and were successful pest control practices as well.

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 as the first country-wide attempt for converting a conventional food system at a national scale (Rosset and Benjamin, 1994). However, these approaches arguably need to evolve if a higher level of sustainable agriculture is desired.

In a three-stage conversion model towards sustainable agriculture, Gliessman (2001) describes stage 2 as "substitute conventional inputs and practices with alternative practices". At such a level, input substitution systems may 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 in stage 3. This conversion process has been widely analyzed by Altieri (1993a), who attributes the main cause of ecological disorders in conventional agriculture to monocultural patterns.

Many farmers substituting inputs without an agroecological approach prefer the use of agrochemicals while available, even though they recognized the negative effect on health (Wright, 2005). In the same line, most policy makers in Cuba tend to consider that the conventional approach as the most viable solution for soil fertility, pest control and increasing productivity in agriculture. In fact, one present strategy is the "potentiation" of production, i.e. the increase of input use in prioritized cropping or livestock activities. These conventional approaches are again becoming policy, and the low yielding systems receive much less support by the administrative structures. Such political trend in Cuban agriculture makes clear that the national input substitution strategy has not evolved to an agroecological stage.

It is therefore necessary to reinforce the Cuban alternative model with a stronger focus on system approache and with greater ecological foundations. Only by making more profound changes considering regenerative alternatives of agricultural systems rather than the mere substitution of inputs can long term sustainability be achieved. The integration of crops and livestock within more diversified production systems is one of these alternatives.

10. Mixed Farming Systems: An agroecological approach towards sustainability

The national input-substitution strategy established infrastructure and basic knowledge about sustainable farming system management. However, it is necessary to recognize its technological limitations to achieve a more integrated and ecologically sound approach. The still prevailing monoculture in agriculture, the continued dependence on biological inputs and the low boost of internal cycles at systems level, among others are some of these limitations. The patterns of land use in present Cuban agriculture are of special relevance for future MFS strategies and the conversion towards an agroecological model at national scale.

10.1. Changes in the structure of land cultivation

During the past ten years in Cuba, many structural changes in the agricultural sector have taken place that favors a nationwide application of a mixed farming strategy. 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 and reducing the scale of production and diversification, were key factors in the agricultural changes.

In 1985, Cuba had 2.2 million ha of pastures and forages, 1.8 million ha devoted to sugar cane, some 1.9 MMha of cash crops and fruits, 2.8 million ha under forest and 0.9 million ha in other uses. This

proportion did not considerably change up to the year 2000. However, during the last five years, the deactivation of 110 sugar mills out of the existing 155 over the country meant that half of more than 1.4 million ha devoted to the monoculture of sugar cane was 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, 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).

Present ecological, economic and social conditions favor the conversion to agroecological mixed farming systems (MFS) in Cuba. The availability of animals, infrastructure, and long-standing pasture land provides 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). About 40% of the two million hectares covered by pasture (some 900,000 ha) are now invaded by "marabú" (*Dichrostachys cinerea*) and "aroma" (*Acacia farnesiana*), two thorny, leguminous fast-growing woody species, which are difficult and expensive to control. The main cause of this tremendous invasion is the abandonment of areas or 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 make a great contribution to energy supply. Under this approach, extensive land use farming systems might be considered a valid strategy for the future of agriculture in Cuba.

In specialized commercial crop production, rotations with an animal component might allow better use of resources like the fallow biomass, crop residues or by-products of food processing. Although the integration of crops and livestock has been commonly used by traditional farmers at small scale, these new innovative approaches should be researched, implemented, and disseminated. Nevertheless, major constraints for the development of mixed systems, commonly with high demand of labor, are the low population in the countryside and the specialized infrastructure still prevalent in Cuban agriculture.

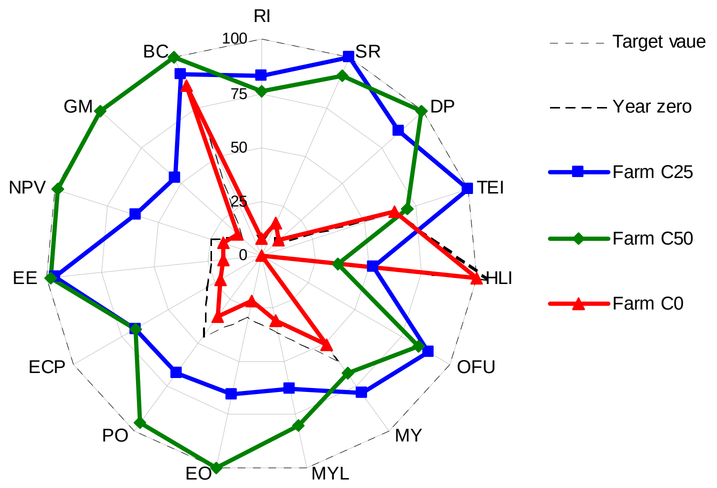
Integration of crop and livestock production can be achieved at different scales in time and space. At large scale (i.e. regional, national) will require more capital and inputs than at middle or small scale. The increase in scale will bring decreases in production efficiency. On the contrary, resource use efficiency would be maximized when interrelationships (e.g. internal nutrient cycling) are facilitated at smaller scales, at the cooperative or farm level. For example, animal manure has high water content, thus long distance transportation is difficult and costly. However, at any scale, the priorities, demands, and capacities of producers to carry out such alternatives are key factors in the successful implementation of MFS.

10.2. General approach for research and development of MFS

Ultimately, MFS integrates the specialised knowledge of plant and animal production with the benefits of diversity. Therefore many individual approaches form part of a more holistic management. An effort for uniting specialized management concepts into a new approach based on agroecological principles is "DIA systems" (i.e. *Diversified, Integrated and Self-sufficient*) (Monzote et al., 2002). During a decade, this approach has been developed and tested at farm and cooperative levels; its principles seem to have potential application at regional or national levels. Each of the three components of DIA systems have their particular characteristics, however, they have common strategies acting under the principles of mixed crop-livestock farming systems. These strategies comprise: a) system biodiversification, b) soil fertility conservation and management, c) optimization of nutrient and energy cycles and processes, d) optimal use of natural and local available resources, e) maintenance of high levels of resilience in terms of systems sustainability and stability and f) 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 methodology, an Ecological Framework for the Assessment of Sustainability in the process of conversion from specialised dairy farming systems (DFS) intoMFS.
ECOFAS consists of a comprehensive approach of three stages for evaluating, monitoring, comparing, analysing and designing management strategies for converting specialized land use into mixed land use. Each stage is related to different hierarchy level of analysis. Stage 1 is the experimental assessment of the conversion process. Stage 2 deals with agroecological classification indicators by using multivariate statistical methods, where different variables are considered. This second stage, as a scaling-up of the results achieved in Stage 1, serves as evidence for policy makers. Stage 3 is about the multi-objective assessment of farms by using participatory methods of research and action. This last stage considers farms diagnosis, characterization and monitoring by using a set of agroecological, economic, and social indicators.
The potential impact of the application of ECOFAS methodology for improving productivity, achieving economic feasibility, with agroecological sustainability, and social acceptability is huge. Seven research teams throughout the country took part in the three stages of this methodological construction and its validation under the project 0800058 "Designs for crop-livestock integration at small and medium scale" of the Ministry of Science, Technology and Environment (CITMA). All the teams accomplished the ultimate goal of ECOFAS: the identification of potential integrated local strategies of mixed farming to alleviate barriers for sustainable livestock production in Cuba.

10.3. Stage 1: Comparing specialized and mixed farms at experimental scale
A study comparing MFS and DFS over a six-year period, demonstrated that productivity, energy efficiency, and economic profitability were all better on the mixed farms, without decreasing milk production per unit of farm area (Figure 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. The energy efficiency calculated as a ratio of energy output per unit energy input was from two to six times higher and increased over time. In economic terms, mixed farms reached 3 to 5 times the net economic value of the control, mainly due to high market prices for crop products. In general, among the mixed farms studied, the one with 50% of crop proportion (C50) performed better for most of agroecological and economic indicators than the one with 25% of crop proportion (C25). They both had much better performance than that without crops (C0), which was similar in characteristics of year zero in the other designs, and far from target values for most of the indicators monitored (Figure 2).



RI - Reforestation index (Shannon index)
SR - Species richness (Margalef index)
DP - Diversity of production (Shannon index)
TEI - Total energy inputs (GJ ha^{-1} $year^{-1}$)
HLI - Human labour intensity (hours $ha^{-1}day^{-1}$)
OFU - Organic fertilisers 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

Figure 2. Agroecological and Economic Indicators (AEEIs) performance in the specialized farm without crops (C0) and the two mixed farms with 25% and 50% of crop land (C25 and C50) averaged over the six-year period compared to the start of the experiment. Target values for the assessment of each indicator are set at 100%. For calculation procedures of Shannon and Margalef indexes see Gliessman (2001).

10.4. 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 labour intensity were the primary factors influencing farming systems classification (Funes-Monzote et al., 2004). According to these indicators, the integration of crops into livestock farms was more productive and more energy efficient than specialized systems.

Implementing mixed crop-livestock designs might solve many problems affecting the environment, productivity and efficiency that predominate in specialised dairy systems. In these studies, it was demonstrated that the inclusion of crops into livestock areas enhanced the energy and protein production capacity (Table 11). 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 land use, capital and labor at systems level. A non-detrimental or even positive effect on milk production, through the inclusion of crops into livestock areas, challenged the belief that milk production is reduced when crops are established in pasture-based areas.

10.5. Stage 3: Application

Stage 3 of ECOFAS includes: a) the characterization of mixed and specialized pilot farms as study cases; b) the analysis of their performance by comparing them using a participatorily designed set of agroecological, economic and social indicators; and c) the discussion of the possible impact of results for improving productivity, economic feasibility and agroecological sustainability of DFS. The results of comprehensive farm diagnosis, characterisations and comparisons, provide evidence of the advantages of mixed farming over the specialised farming under low input agriculture conditions (Table 9). Application of participatory research methods allowed considering farmers' perspectives in the definition of sustainability goals in strategies for the development of MFS approach at regional level.

Table 9. Performance of agroecological and productivity indicators in the two mixed farms (at small and middle scale) and the specialised farm at middle scale under commercial conditions.

Indicators	Farm system			SE	
	A – Mixed Small scale	B – Mixed Middle scale	C – Specialised Middle scale		
Reforestation index, RI (Shannon index)	1.8 [a]	1.6 [a]	1.4 [b]	0.06	***
Species richness, SR (Margalef index)	6.5 [a]	7.5 [a]	2.7 [b]	0.60	***
Diversity of production, DP (Shannon index)	2.4 [a]	2.3 [a]	0.3 [b]	0.29	***
Total energy input, TEI (GJ ha^{-1} $year^{-1}$)	10.8	6.1	8.0	0.81	
Human labour intensity, HLI (hr $ha^{-1}day^{-1}$)	3.0 [a]	1.1 [b]	1.3 [b]	0.26	***
Organic fertiliser use, OFU (t ha^{-1})	4.5	2.5	0.0	0.58	
Milk yield, MY (t ha^{-1} $year^{-1}$)	1.7	1.3	1.4	0.11	
Milk yield per livestock area, MYL (t ha^{-1} $year^{-1}$)	2.2	2.0	1.4	0.16	
Energy output, EO (GJ ha^{-1} $year^{-1}$)	22.8 [a]	12.1 [b]	4.3 [c]	2.35	***
Protein output, PO (kg ha^{-1} $year^{-1}$)	273.0 [a]	102.0 [b]	52.0 [b]	29.47	***
Energy cost of protein production, ECP (MJ kg^{-1})	40.0 [a]	60.0 [a]	154.0 [b]	16.70	**
Energy efficiency, EE (GJ output GJ $input^{-1}$)	2.1 [a]	2.0 [a]	0.5 [b]	0.23	**

Means with different letters (a, b, and c) in superscript differ significantly between farm systems (Tukey-HSD; ** = P<0.01, *** = P<0.001). For calculation procedures of Shannon and Margalef indexes see Gliessman (2001).

In summary, much scientific and practical information demonstrates the advantages of the MFS; 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 combine agroecological, economic and social dimensions are rare.
The application of agroecological approaches through MFS can be a further step toward sustainability in Cuban agriculture. Both the technological and practical advantages of MFS have been scientifically confirmed, and the present economic and social structure of the agrarian sector might favour this process.

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)

The recent history of Cuban agriculture demonstrates that agrarian reforms will not be effective 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 towards sustainable agriculture in Cuba in the 1990s is the necessity to change the prevailing world foundation of food production systems, so that natural resources occupy a place as important as socio-economic or political issues.
The elimination of the *latifundio* in 1959 in Cuba by itself did not eradicate the many historical problems intrinsic to the national agricultural system. The agrarian reform gave part of the land to those that worked it and reduced the size of the farm, which had a positive social impact. However, the lack of an ecological focus and the concentration of lands by the State as never before in extensive monocultures, reinforced the spiral of 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, equal to that of the *latifundio*, invoked serious environmental and socioeconomic problems.
The enormous economic, ecological and social crisis that was unleashed at the beginning of the 1990s was in the first place 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 both a centralized planning of material resources and an equitable social structure. The explicit help of the government together with the encouragement of innovation, the educational level of the population, as well as resource and knowledge exchange, permitted the creation of a sustainable agriculture movement and its implementation at a national scale.
Further steps are necessary. Although innovation has been present in all branches of agriculture and the scientific institutions have tested environmentally-sound technologies on a large scale, these have tended toward the focus of the substitution of inputs. The input substitution model has not evolved fast enough and there is at present a need for profound changes in Cuban agriculture. At the outset of the new scenario in Cuban agriculture, characterized by the the emergence of diverse agroecological practices through the country, neither the conventional pattern nor that of input substitution will be versatile enough to cover the technological demands of such a heterogeneous agriculture.Therefore it is necessary to develop more integrated, innovative and locally oriented solutions as opposed to solving specific problems from top to down as they emerge from practice. The MFS approach based on agroecological perspectives, might aid in reaching a higher stage in the transformation of Cuban agriculture as it moves toward sustainability.

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