Indicators of Agricultural Sustainability at the National Level:

A Case Study of Venezuela

José L. Berroterán* and J. Alfred Zinck**

*Universidad Central de Venezuela, Facultad de Ciencias, Instituto de Zoologia Tropical, Caracas, Venezuela.
**International Institute for Aerospace Survey and Earth Sciences (ITC), Soil Science Division, Enschede, The Netherlands.

1. Abstract

The objective of this study is to evaluate selected criteria and indicators of agricultural sustainability at the national level. Venezuela is a developing country, located in the north of South America, between 1-12º N and 59-73º W. Criteria and indicators were selected according to data availability, data sensitivity to temporal change, and the capacity of the data to quantify the behavior of the national agricultural systems. The following four criteria were taken into consideration: agrodiversity, agrosystem efficiency, the use of the land resource base and food security. Each criterion was assessed by means of several indicators, quantified as partial indexes. The latter were combined in a sustainability index, after computing the average values with maximum probability and defining sustainability ranges such as: no sustainable, slightly sustainable and highly sustainable (maximum sustainability≤1). The agrodiversity was evaluated using the crop surface index and the regional agrodiversity factor, showing values of 0.06 and 0.24 respectively. Yields of the main crops have increased by 1.25 to 1.5 times in the last 30 years, although the gap between experimental and farmer yields remains high (0.43 to 0.6). The cost-benefit ratio shows an efficiency of 10% to 28% and the export/import ratio is 0.19. The cereal productivity index per capita decreases with population increase. Although land availability for food production is 2.4 times the required surface, the land used for annual crops is about 15.000 km^2 short in relation to the demand. The proportion of the agricultural population to the total population is 0.09, with a tendency to diminish. The ratio of cultivated to deforested land is less than 1. A low proportion of cultivated land (24%) is not degraded, and only 0.009% of the national surface is irrigated. The sustainability index suggests that Venezuelan agriculture is only slightly sustainable with a tendency to deteriorate with time. It is suggested to increase agrodiversity and the cultivated area-inhabitant ratio to mitigate soil degradation. This would decrease the loss of native ecosystems and improve the export-import ratio and the agrosystem efficiency.

2. Introduction

Agriculture is a complex of processes taking place within biophysical, socio-economic and political constraints, which control the sustainability of the farming activities (Yunlong and Smit, 1994). The concept of sustainable agriculture combines characteristics such as long-term maintenance of natural systems, optimal production with minimum input, adequate income per farming unit, fulfillment of basic food needs, and provision for the demands and necessities of rural families and communities (Brown et al., 1987). All definitions of sustainable agriculture promote environmental, economic and social harmony in an effort to attain the meaning of sustainability. The most relevant issue today is to design suitable technologies, as well as compatible strategies from the social, economic and ecological viewpoints that will bring about the necessary behavioral changes to achieve the objectives of sustainable agriculture.

Sustainability is a concept and cannot be measured directly. Appropriate indicators must be selected to determine levels and duration of sustainability (Zinck and Farshad, 1995). An indicator of sustainability is a variable that allows to describe and monitor the processes, states and tendencies of systems at the farm, regional, national or worldwide levels. An indicator of sustainability must be sensitive to temporal and spatial changes, predictable, measurable and interactive (Liverman et al.,1988). Glave and Escobal (1995) proposed a set of verifiable and replicable indicators to assess the natural resources, the ecological and economic structure, and the ecological, economic and social benefits in the Andes. Munasinghe and McNeely (1995) reported as important indicators the index of biophysical sustainability, soil and water conservation, efficiency of fertilizer use, efficiency of energy use, and productive permanence of the forest. Ramakrishnan (1995) included management practices, biodiversity and nutrient cycle. Harrington et al. (1995) distinguished between quantitative and qualitative indicators, with attention to processes, states or tendencies associated with sustainability. According to Smyth and Dumanski (1993), good indicators are measurable and quantifiable environmental statistics that measure or reflect environmental status or change in condition. In the present study, the concept of indicator was extended to system statistics that measure or reflect system status or change in condition, with emphasis on the national agricultural systems. Indicators are selected on the basis of diagnostic criteria that permit the discrimination of factors, causes and effects controlling a system. The definition of criteria may be broadened to standards or rules that govern judgments on system condition, instead of only environmental condition.

Agricultural systems can be analyzed at various hierarchical levels. For land evaluation and farming systems analysis, FAO (1992) distinguishes: cropping systems, farm systems, sub-regional systems, regional systems and national systems. Weterings and Opschoor (1994) consider geographical domains of sustainability and include continental and global levels. The objective of this study was to describe and assess criteria and indicators of agricultural sustainability at the national level, taking the case of Venezuela as example.

3. Method and Materials

3.1 Criteria and indicators of sustainability

Indicators to assess agricultural sustainability were selected according to data availability, data sensitivity to temporal change, and the capacity of the data to quantify the behavior of the national agricultural systems (Liverman et al., 1988; Smyth and Dumanski, 1993; Zinck and Farshad, 1995). The selected indicators belong to four families of criteria, referring to agrodiversity, agrosystem efficiency, use of the land resource base and food security (Table 1).

Table 1. Agricultural Sustainability Criteria and Indicators

CRITERIA	INDICATORS
Agrodiversity	Index of surface percentage of crops (ISPC)
	Crop agrodiversity factor(CAF)
	Genetic variability
	Surface variability (monoculture)
Agrosystem efficiency	Yield and yield gap
	Cost-benefit ratio
	Parity index
Use of the land resource base	Land availability/Land demand
	Land demand/Land used
	Cultivated land/Inhabitant
	Cultivated land /Deforested land
	Irrigated land/Irrigable land
	Degraded land
Food security	Per-capita production index
	Agricultural population/Total population
	Export/Import
	Food production/Food supply

To evaluate agrodiversity, the index of surface percentage of crops at the national level (ISPC) and the crop agrodiversity factor (CAF) were implemented. The first expresses the relation between the number of crops that represent 50% of the cultivated surface and the number of crops commercially cultivated. The crop agrodiversity factor (CAF) is given by the relation between the number of main crops in a region and the crops agroecologically adapted to the regional conditions and to the current management systems. The parity index of the cereals is based on the relationship between production income and total production costs for each crop, allocating a reference value of 1 to the year 1988. Parity indexes per specific crops were initially calculated by Abreu et al. (1993) until 1992 and adjusted for the following years in this paper. The relative indexes of per capita production of the principal cereals (corn and rice) were calculated taking 1965 as reference year. The different rates of increase/decrease were estimated in relation to previous periods of one and five years. The other indexes shown in Table 1 are self-explanatory.

The indicators that have been recorded for more than 20 years, corresponding to a long period according to Smyth and Dumanski (1993) and a medium period according to Lal et al. (1990), were used as partial indexes to generate an aggregated index. The latter is computed as the arithmetic mean of the partial indexes. Trends over time are highlighted by the adjustment of the annual indexes to regression models, considering maximum probability. For the estimation of the sustainability index, the variance of the partial indexes was normalized between 0 and 1.

3.2 Study area

Venezuela is located in northern South America, between 1-12° N and 59-73° W, with 912,050 km^2 of surface area representing 4.5% of Latin America (Figure 1). About 80% of the country lies below 400 m elevation, with temperatures above 25° C, and produces crops having high light requirements. Temperatures do not present significant seasonal changes but strong daily oscillations (about 10°C).North of the Orinoco river, the rainy season lasts 4 to 9 months in the lowlands, contrasting with severe aridity in the northwestern and northeastern edges of the country and with perhumid climates in the mountains. In the area south of the Orinoco river, representing about half of the country surface, rainfall is high during 9 to 11 months per year. Population is 22 millions, with an annual growth rate of 2.2%. About 85% of the gross national product (GNP) derives from oil exploitation and mining. Despite a high per capita income ($2,150 per month) resulting from the oil sales, Venezuela is considered a developing country, where critical poverty reaches 31%. Nine per cent of the population works in agricultural activities and generates 5.1% of the GNP (World Bank,1996). About half of the country is still covered by close and open forests, but the annual deforestation rate in the area north of the Orinoco river is 1.1%, close to the highest rates in Latin America, such as in Costa Rica and Mexico. Agriculture is based on high input and low efficiency in the use of fossil energy, with detrimental effects on the socioeconomic conditions of the peasant family (Gómez, 1996).

Figure 1. Geographic situation of Venezuela in South America

3.3 Data collection

Data collection information was collected at the national level. Physical, biological, economic and social factors were considered diagnostic criteria for determining partial indexes of sustainability. Data on crop yield, cultivated surface by crop, and import and export of products were taken from the Statistical Yearbook of the Ministry for Agriculture and Livestock of Venezuela (MAC, 1965-1995) and from AGROPLAN (1995). Crop production costs were obtained through interviews with farmers during 1995 and 1996. Land suitability for specific uses was derived from studies by MARNR (1983) and Marín (1990), using the FAO classification for rainfed agriculture (FAO, 1985) and the land capability classification (Klingebiel and Montgomery, 1961) modified by Comerma and Arias (1970). Food production in kilocalories was estimated from information in the FAO yearbooks (FAO, 1982, 1994) and from Abreu et al. (1993). Data on agricultural population and indexes of cereal production were obtained from the FAO yearbooks (FAO, 1982,1995). Parity indexes were established using field information and data from Abreu et al. (1993). Data were arranged and adjusted to a polynomial regression model to show trends in the partial indexes of sustainability.

4. Agrodiversity

Biodiversity includes the number of living organisms in three main dimensions: (1) genetic variation within species and populations, (2) number of species and subspecies, and (3) habitat variety and diversity at the ecosystem, landscape or bioma levels. Currently, biodiversity is one of the most studied ecological aspects worldwide, but it has been little used as an indicator of sustainability at the national level. In this respect, Weterings and Opschoor (1994) considered the numbers of species and populations of birds in the Netherlands as indicators of habitat loss and species diversity.

4.1 Indicators of agrodiveristy

The relation between biodiversity and agricultural sustainability has been intensively analyzed over the last five years (McLaughlin and Mineau, 1995; Burel and Baudry, 1995). Smith and Pucknett (1995) indicated that the genetic qualities of a crop, such as germoplasm banks, genetic variability, stress-induced resistance due to malnutrition or disease, are some of the most relevant indicators of agricultural sustainability. Deriving from the former, agrodiversity has been considered recently as an important criterion for estimating the sustainability of agricultural systems. Merrick (1990) pointed out that the stability and sustainability of the traditional agricultural production are based on crop diversity. Srivastava et al. (1996) included all important plants, animals and microorganisms of agrosystems in the definition of agrodiversity. For Ramakrishnan (1995) and Steenhuijsen (1995) agrodiversity is the result of interaction between population diversity and environmental variability in agroecosystems. Agrodiversity has an influence on the assimilative capacity, stability and adjustability of systems management (Niu et al.,1993), these characteristics being operational dimensions in the analysis of sustainable development.

In the present study, agrodiversity as a criterion of sustainability consists of crop diversity at the regional level, surface percentage of crops at the national level, genetic variability and management (Figure 2), which represent aspects of stability and balance of the national agricultural system under factors such as climatic changes, incidence of pests and diseases, and patterns of food consumption. Assessment was based on the following quantitative indicators : (1) the index of surface percentage of crops at the national level (ISPC), (2) the crop agrodiversity factor (CAF), (3) the genetic and surface variabilities of main crops during time. Also the variability of farming practices contributes to the heterogeneity of agrosystems.

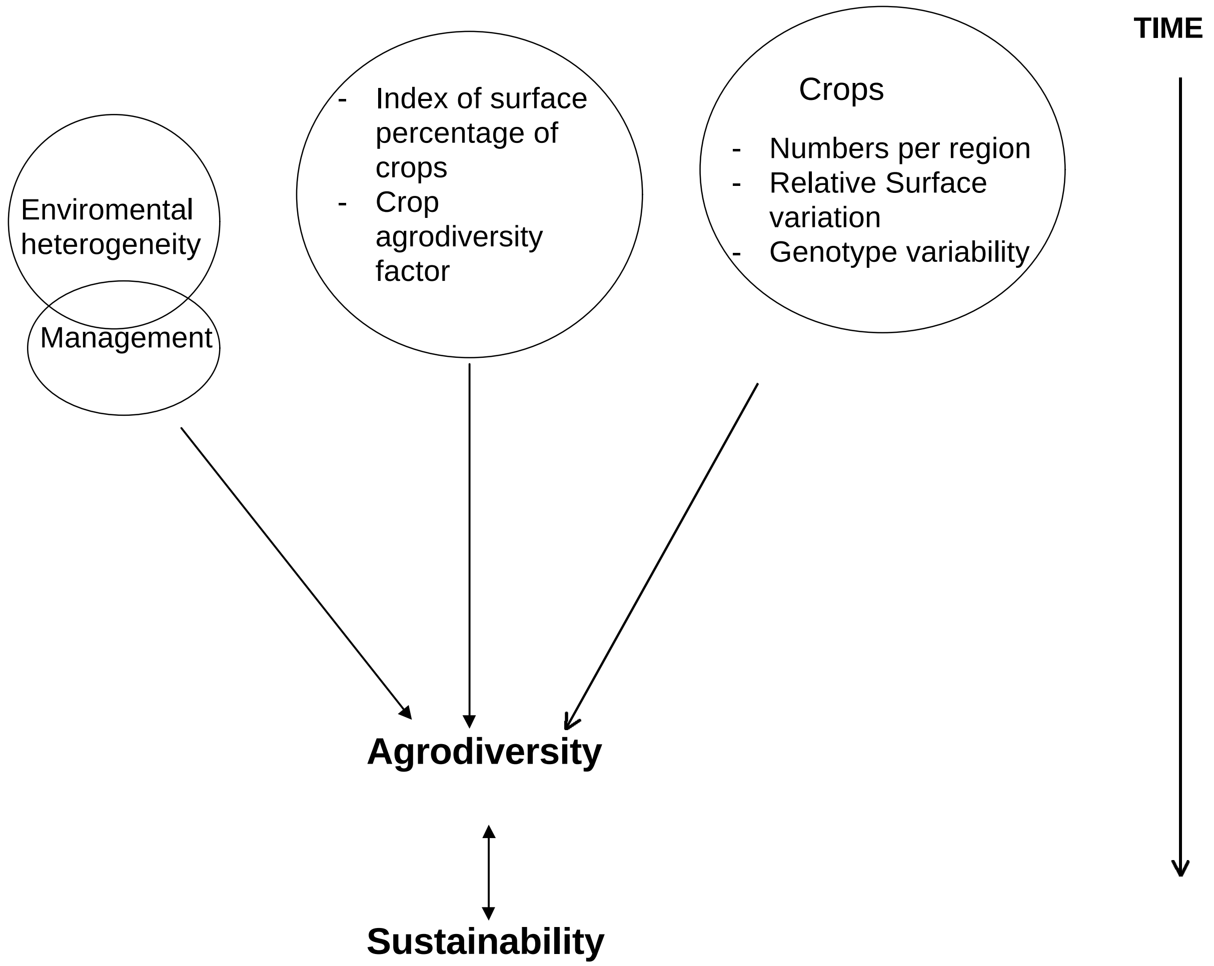


Figure 2. Agrodiversity components

4.2 The effects of monocultural land use

A total of 64 crops cover 98% of the national agricultural surface, which represents a low diversity of commercially cultivated species in a country with a high number of plant species (14,000-15,000 species) considered beneficial to humankind (Mazzani, 1995). The CAF is 0.24 for the ecoregions north of the Orinoco river, indicating that only one fourth of potentially useful species is exploited. Cereals such as corn (*Zea mayz*), sorghum (*Sorghum vulgare*) and rice (*Oriza sativa*) constitute together 45% of the agricultural surface (Figure 3). These crops are largely cultivated as monocultures, generating a very low ISPC (0.06). A similar pattern based on the predominance of a few crops, especially cereals, is observed in many countries with monocultural production systems, such as the United States of America, Iran, Denmark, among others (FAO, 1994, 1995).

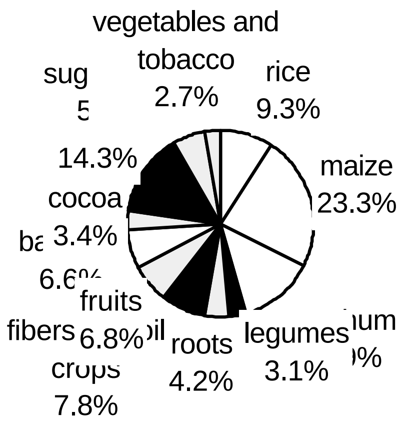
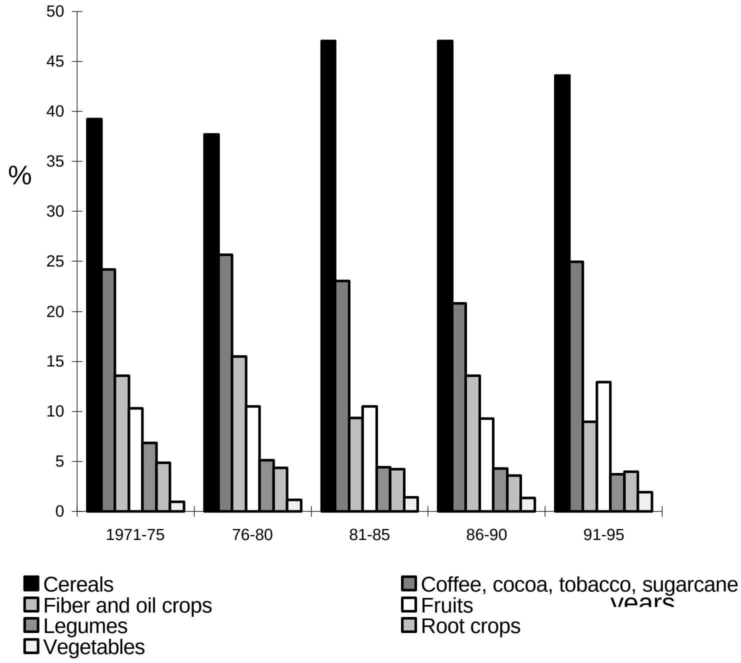


Figure 3. Crop area (%) in 1995

The order of importance of the main crop groups tends to hold over time (1971-1995): the relative national surface of cereals varies in 9.4% with an annual variation coefficient of 0.23, that of fibers and oil crops varies in 6.6% with an annual variation coefficient of 0.3, and that of the group including coffee, cocoa, tobacco and sugarcane varies in 4.9% with an annual variation coefficient of 0.24 (Figure 4). These levels of variation indicate stability of the main crop surfaces in time. Corn is the most extensive crop (23.3%) and its production is based on hybrids consisting of foreign genetic materials. Less than 10 hybrids have produced more than 80% of the corn in the last 20 years. FAO (1995) reports that, in Latin America, 46% of the corn surface is of hybrids or modern varieties, comparable to Africa (43%), but quite different from China (90%). Sorghum is an introduced crop in Venezuela, the cultivation of which started massively in the mid-1970s and the production of which is totally based on hybrids. Rice production uses highly productive varieties, more than 30 in the last 50 years, in general little resistant to pests and diseases and with low genetic plasticity. The case of Venezuela is similar to that of China where modern varieties cover 100% of the surface area (FAO, 1995). This tendency is opposite to the high genetic diversity of traditional systems. Merrick (1990), for example, reports that traditional agriculture uses 5 to 7 varieties of rice in Cambodia and some 4 strains of corn in Central America.

Figure 4. Percentage of main crops over time



Established pastures occupy a total of 28,000 km^2, represented by large areas of *Brachiaria* spp., *Andropogon gayanus*, *Hipharrenia ruffa*, *Echinocloa polystachia,* and another 10 species of lesser importance. The use of arboreal legumes is very low and agrosilvopastoral systems are practically absent, indicating a high biodiversity loss and low agrodiversity.

The low diversity of cultivated species at the national level and the poor genetic diversity of most cultivated species are aggravated by the type of predominant farming systems based on monocultures with high degree of mechanization and pesticide application, which hinder crop diversification in space and time (multiple crop system). This is perhaps one of the most alarming indicators of biodiversity loss, but the least considered in current research. In this sense, Srivastava et al. (1996) highlighted the severity with which modern agriculture homogenizes landscapes and accelerates habitat loss, causing considerable genetic erosion. Natural spatial diversity is reduced by deforestation, heavy mechanization, soil fertilization and monoculture establishment in diverse habitats managed the same manner, as shown by Berroterán (1994) for nutrient levels in savanna, shrub and forest soils used for corn production during a period of 8 years.

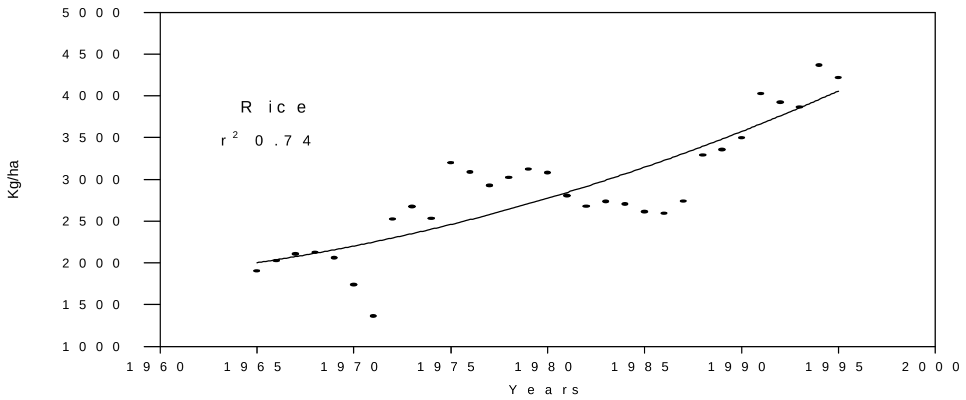
In summary, the ISPC is very low (0.06). The CAF may be considered low (0.24) and the variation of cultivated surface over time as intermediate (0.23-0.3). These indexes reflect poor agrodiversity, low resistance potential to pest and disease epidemics, low adaptability to environmental changes, and fewer strategies for adjusting the production to market fluctuations.

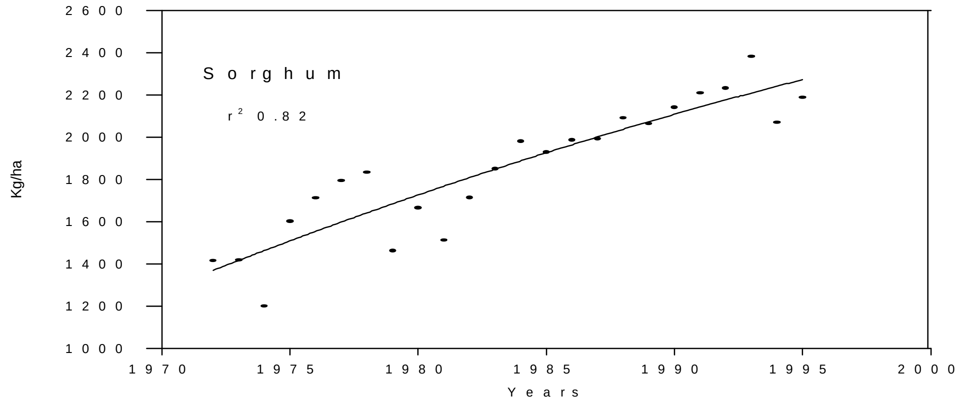
5. Agrosystem Efficiency

5.1 Crop yield and yield gap

Crop yield is an indicator of system efficiency, in regard to genetic potential, ecological conditions, management, capital investment and labor use. It denotes the production of biomass per time unit, e.g., years, months, days or production cycles. It is used as a biological parameter for the evaluation of system behavior and reflects its state at any given time. It is perhaps the best known functional characteristic of agrosystems and is mentioned by almost all authors as a criterion for the assessment of both the biological and the economic sustainability of agricultural systems. In this paper, it is used as a sustainability indicator, which not only quantifies the production/ha over time but also allows to identify gaps between experimental yield and farmer yield.

The yield of most crops increased substantially during the 1970-75 period, when the government encouraged the importation of more productive hybrids or varieties, which are nutrient-demanding and little resistant to pests and diseases generated in monocultural conditions. Sorghum had a 50% linear increment since 1970. Corn increased 50% and rice 25%, following a second-degree polynomial, with a marked increment beginning in the early 1980s (Figure 5). FAO (1995) reported similar increasing rates of corn and rice yields in developing countries since 1960, which are related to the arrival of highly productive but nutrient-demanding hybrids and varieties, and to intensive mechanization. The question remains if the yield increase trend will continue or a typical growth curve will appear, where yield stabilize with time. Decreasing use of fertilizers, little research in genetic improvement of crops and sprawling soil degradation do not guarantee persisting yield increase of cereals. Presently, yields in Venezuela are higher than those reported by FAO (1974,1982,1994) for rice (2,800 kg/ha), corn (1,800 kg/ha) and sorghum (1,000 kg/ha) in developing countries. However, they are actually low when compared with the high amount of input used. In the United States, for example, the average corn yield with similar input was 6,000 kg/ha in 1995 (NCGA, 1995), which is 2.5 times that of Venezuela.





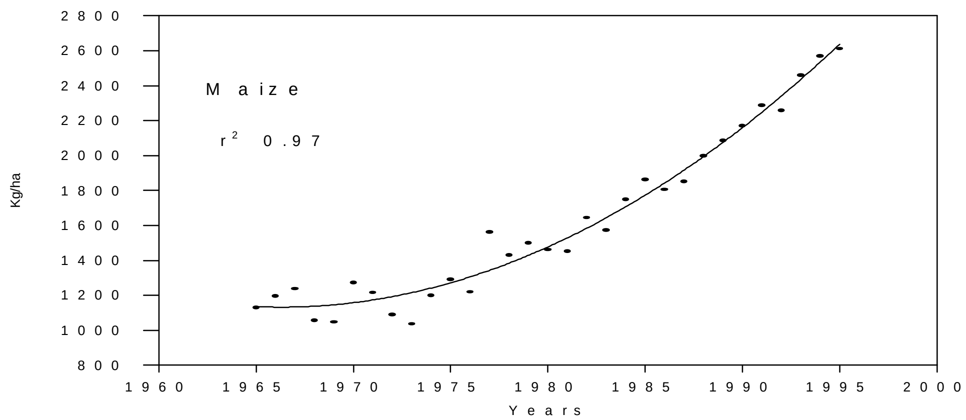


Figure 5. Yield of Main Cereals.

The present yield levels of rice (4,500 kg/ha), corn (2,600 kg/ha) and sorghum (2,300 kg/ha) are much lower than the potential yields of the hybrids used. For example, the experimental levels of low-irrigation corn production in Venezuela are above 4,500 kg/ha (Guillén,1982; Requena, 1982; FONAIAP, 1994). Thus the average farmer yield at national level is 43% lower. Smaller yield gaps between experimental and field productions are reported from Kenya (Wokabi, 1994) for rainfed corn (25-38%) and from USA (NCGA, 1995)for irrigated corn (33%). Experimental yields of rice and sorghum are 9,800 kg/ha and 4,400 kg/ha respectively (FONAIAP, 1997), generating yields gap of 54% and 52%.

The rate of yield increase of the main crops (25-50%) and the yield gaps (43-54%) are partial indexes of agricultural sustainability at national level, which must be complemented by indicators reflecting the economic efficiency of the production system.

5.2 Cost/benefit ratio and parity index

The cost-benefit relationship is an economic index used by Lynam and Herdt (1989) and Tisdell (1995) to evaluate crop sustainability at the level of farming units. It indicates the economic feasibility of the agricultural activity at the crop, farm, regional, national or continental level.

An evaluation of the costs and cereal production levels for the years 1995-96 in the region of the Venezuelan Llanos, which contributes by more than 80% to the national production of cereals, shows that human labor is very low with relative costs between 2.1% and 4.5% of the total(Table 2). In constrat, mechanized labor represents between 32% and 39% of the total, indicating that cereal production is based on a high participation of machinery and very little use of human labor. This follows the agricultural pattern of industrialized countries with limited agrodiversity and large use of fossil energy (Schroll, 1994).

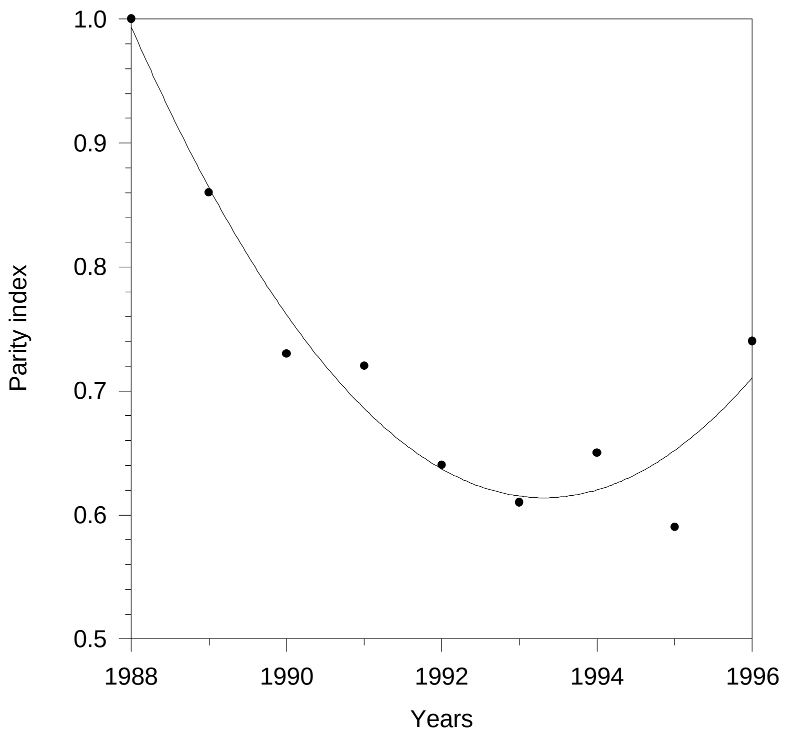
TABLE 2. Cost-benefit analysis for main cereals (1995-96); $

	MAIZE $	SORGHUM $	RICE $
INPUT/ha			
Tillage	76.60	76.60	113.40
Application of seeds, fertilizers, herbicides and insecticides	89.36	110.64	127.66
Mechanized harvest	42.55	34.04	85.11
Transport (input and output)	51.06	46.81	74.47
Seeds	37.45	35.32	53.19
Fertilizers(NPK)	67.66	67.66	85.11
Herbicides	31.49	31.49	63.83
Pesticides	17.45	17.45	74.47
Human labour	25.53	17.02	22.28
Land rent	12.77	12.77	21.28
Irrigation			85.11
Unexpected	45.19	44.98	81.49
Interest (30% annual)	74.57	74.21	134.45
Total	**571.67**	**568.98**	**1021.83**
OUTPUT/ha			
Seed-grain/crop	704.68	585.53	1249.47
Field residues	29.79	38.30	38.55
Total	**734.47**	**623.83**	**1288.02**
Output/input	**1.28**	**1.10**	**1.26**
Efficiency (%)	**28.48**	**9.64**	**26.05**

Income to cost ratios are 1.1 for sorghum, 1.26 for rice and 1.28 for corn (Table 2). Normally, a product productivity factor greater than 1 indicates that the system is sustainable (Lynam and Herdt, 1989). But in the case of Venezuela, an index between 1 and 1.3 actually reflects low sustainability, as the economic efficiency of the production systems is lower than the estimated rate of capital interest (30%).

The parity index of cereals was calculated from the relationship between production income and the total production cost for each crop (corn, sorghum, rice), allocating a reference value of 1 to the highest index observed in a given period of time (Abreu et al., 1993). A clear decline of the parity index of the cereals occurs between 1988 and 1995 (Figure 6), indicating that the increase in total production costs has not been compensated by an increment in product prices and/or production levels. This reflects a deterioration of the farm rentability and producer income and influences negatively the agricultural sustainability at the national level.

Figure 6. Parity index of cereals



6. Use Of The Land Resource Base

6.1 Land availability, demand and use

Current land classifications (Klingebiel and Mongomery, 1960; FAO, 1976, 1983, 1985) consider the sustainability of land use as a basic assumption of the assessment system, but it is only recently that land suitability and land use have been implemented as criteria for evaluating the sustainability of agricultural systems (Smyth and Dumanski, 1993). At national level, the ratios of land availability/land demand, land demand/used land and cultivated land/deforested land may be used as indexes of sustainability. When these indexes become lower than 1, they indicate limitations to the national agricultural sustainability.

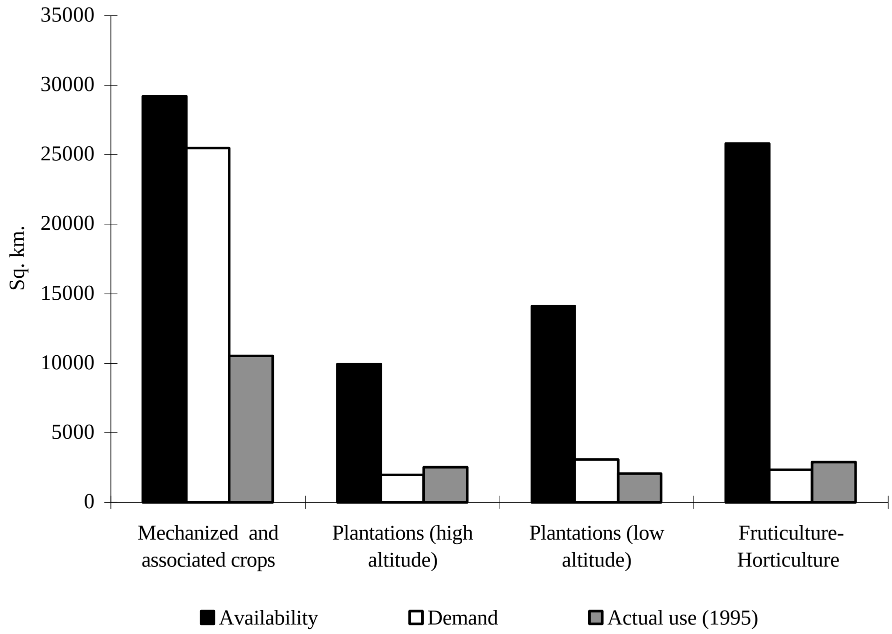


Figure 7. Availability, Demand and Use of Land.

For the purpose of evaluating the general adaptability of specific land uses, crops were grouped into comprehensive classes such as annual mechanized and associated crops (cereals, legumes, oil crops, and roots and tubers), high altitude plantations (coffee), low altitude plantations (cocoa, sugarcane, coconut, African palm, pineapple, banana), fruits and vegetables. For each crop group the current land availability is larger than that necessary to supply the demand of the 1992 population (Figure 7). Land availability for food and fiber crop production (79,092 km^2) is 2.4 times the surface needed (32,872 km^2) to satisfy the demand of the population (MARNR, 1984; Marín, 1990). This reveals that land quality at the national level allows for the use of crops adapted to given ecological conditions without damage to the environment and with acceptable levels of productivity. Similarly, the production surface of coffee, fruits and vegetables guarantees the supply of the national demand and allows even for exports. In contrast, the land used for mechanized and associated crops is deficient in 14,931 km^2 and that of permanent low-altitude plantations such as sugarcane and cocoa is short in 1,004 km^2. It is thus indispensable to increase the national agricultural surface of mechanized crops and plantations to meet the food demand.

The cultivated surface per inhabitant has decreased form 0.16 to 0.08 ha between 1970 and 1994 (Figure 8). The latter figure is comparable to the world's lowest ratios, as is the case of Rwanda, and is somewhat lower than that of Colombia, Dominican Republic, El Salvador, Kenya and Indonesia (FAO, 1995). This indicates high pressure on the land being used and scant possibilities to supply the demand with the low yield levels previously reported. The cultivated surface at the national level is 22% of the total available land for crop production and the available surface per inhabitant is 0.36 ha.

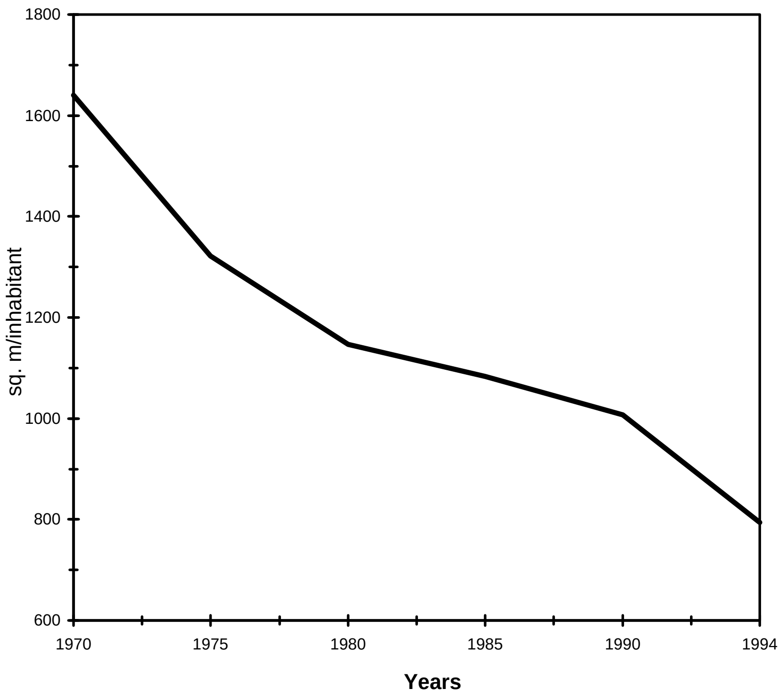
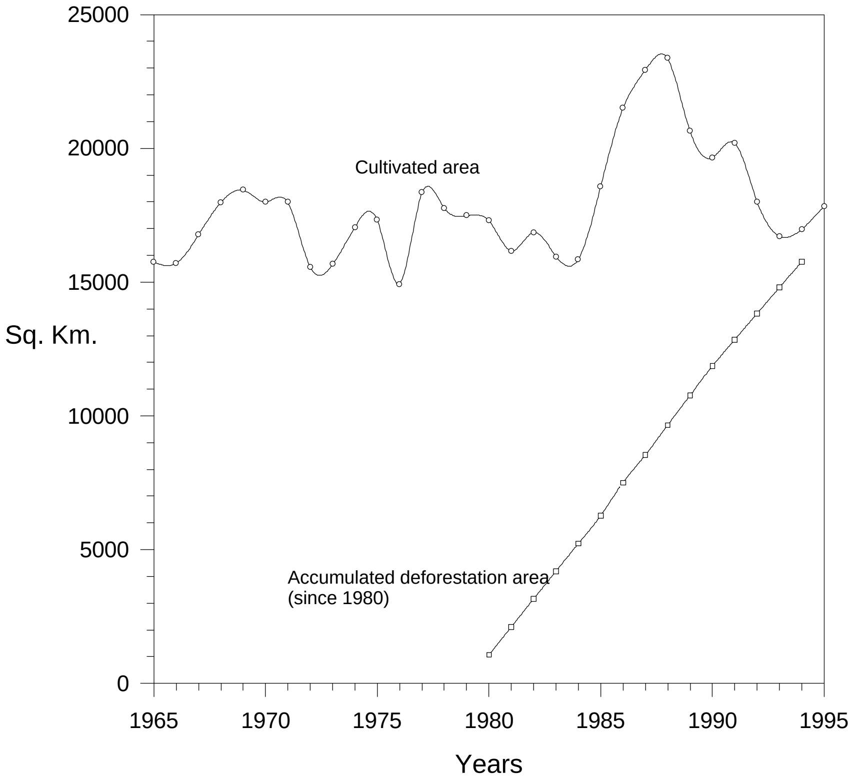


Figure 8. Cultivaded Area per Inhabitant.

Despite the insufficiency of the cultivated land for meeting the food demand, the national crop surface has not consistently grown (Figure 9). The curve representing the variations of the cultivated area tends to adjust to a polynomial (r^2=0.71), with maximum extent (19,652-23,371 km^2) between 1986 and 1988. In contrast, the deforested surface, estimated from the rates of deforestation calculated by Rivero (1994) and Berroterán (1994) for the north of Venezuela, increases systematically and reaches the extent of 15,760 km^2 in 1994. Thus the high rates of deforestation in the 1990s did not contribute to increase the crop surface. It is necessary to investigate more closely the unfavorable relationship between cultivated and deforested areas.

Figure 9. Cultivated and deforested areas



6.2 Soil degradation

Soil degradation is defined as the reduction in soil quality because of human use, including physical, biological and chemical degradation, such as reduction in fertility, decline of aggregate stability, erosion, salinity, acidity or alkalinity, toxicity from chemicals and pollutants, or excessive flooding (UNEP, 1982). Soil degradation is a widely used criterion of unsustainability and considered by Smyth and Dumanski (1993) as visual evidence of environmental degradation. In Costa Rica, soil depreciation is considered the principal problem for agriculture (WRI, 1991). In Chile, sustainability of peasant or farmer production systems is evaluated on the basis of soil erosion (Ramírez and Martínez, 1995). In Latin America, it is estimated that more than two thirds of the area occupied by annual and permanent crops have lost more than 25% of their productive capacity (Pla, 1993).

In Venezuela, agricultural land use is limited by one o more of the following factors: 44% topography, 32% fertility, 18% drainage, 4% aridity; only 2% present no limitations (Comerma and Paredes, 1978). Main problem - soils and areas affected are described hereafter.
3,500 km^2 of soils have fertility limitations. Acid soils have been reclaimed using lime and high applications of fertilizers. There has been excessive use of machinery causing loss of structure along with compaction and sealing.

4,200 km^2 of land are highly susceptible to water erosion. The soils are currently exposed to accelerated erosion because of intensive agricultural mechanization without conservation practices.

Soils under irrigated agriculture (900 km^2) in arid zones present problems of salinity and sometimes sodicity; the latter also occurs in soils irrigated under subhumid climate.

Soils originally with little limitations for agricultural production (western Llanos), but that have been overmechanized, face now problems of structure degradation, compaction and sealing.

Acid sulfate soils in the Orinoco Delta have been drained, with an approximate surface area of 200 km^2 (MARNR, 1983). Peat soils have been destroyed by the burning of organic matter in the drained areas (Mogollón and Comerma, 1994).

The following is a short chronology of soil degradation in Venezuela:

Problems of soil degradation started in the period of 1950-1960 with the expansion of mechanization. Deep gullies and massive landslides occurred in the sloping areas of the Andes (>1000 m. asl), which were cultivated mainly with cereals because of population pressure. Today, erosion is no longer a main issue in these areas because eroded land has been abandoned and conservation practices have been introduced for intensive vegetable and fruit crop production, with irrigation by aspersion or dripping. During the same period, salinity problems emerged in irrigated arid areas.

In the decade of the 1970s, problems of degradation began to show up in the low- lying and relatively flat lands of the western Llanos and in the acid soils of the eastern Llanos. The deterioration of the soil structure led to soil sealing and compaction (Pla, 1988). In this decade, chemical degradation of the soils in the Orinoco Delta and erosion in the piedmonts of the Andes and the Cordillera de la Costa started.

In the decade of the 1980s, water erosion appeared in lands with slight to moderate slopes (4-10%) in the northern part of the central and mideastern Llanos, where the rainfed production of cereals (sorghum and corn) concentrated in the last 20 years. The combination of highly erodible soils, severe rainfall erosivity and inappropriate farming practices has led to accelerated soil loss. Similar problems of accelerated water erosion appeared in hillside soils used for rainfed corn production in the midwestern region of the country (Yaracuy State) (Pla, 1988).

Briefly, main problems of soil degradation are due to water erosion, sealing, compaction, salinization, alkalinization and fertility depletion, all of them generally accompanied by biological degradation. According to Pla (1990), taking 1988 as a reference date, only 24% of the cultivated soils were not affected by degradation; the rest was exposed to incipient or advanced erosion (26%), incipient compaction (30%), advanced compaction (10%), high sodium content (6%), and salinity (4.5%). Thus soil degradation is a severe limiting factor for agricultural sustainability in Venezuela. Degradation is rapidly increasing in areas under production during the last 30-40 years and will delay the development of sustainable farming systems in semiarid and subhumid climates, if the present management practices are not improved.

6.3 Water use and conservation in agriculture

Water use and conservation is an indicator for measuring the conservation and efficiency of use of the natural resources at the national level. For example, WRI (1989) used it in Costa Rica to evaluate the stage of degradation of the country resources.

In Venezuela, because of dry climate, water deficit and low crop production, irrigation has been recommended for annual crops, plantations, fruits and vegetables. More than 70% of the agriculture is established in the life zone of the tropical dry forest, characterized by erratic precipitation of short duration and high intensity, although the mean annual rainfall might be as high as 1,000-1,400 mm. Most crops are cultivated without irrigation, with a high risk of water deficit in the period of greater water demand. Water conservation is not or little practiced. However, 75% of the corn production in the central Llanos is limited by low water availability in the subsurface horizons and by low rainfall frequency (Berroterán, 1994. The possibility of obtaining a good corn production in this zone is reduced to 45% due to restricted water availability (Brito and Gilarbert, 1985).
The availability of irrigable land, based on the convergence of suitable soils and viable surficial and underground water reserves, reached 14,504 km^2 in 1980 (López and Zerpa, 1984). However, only 2,118 km^2 were irrigated in 1961 and some 3,875 km^2 in 1980 (López et al., 1984). According to the World Bank (1995), this surface area remained the same during the 1990s. As a result, the ratio of irrigated land to irrigable land is very low (0.22). Currently, only 0.7% of the national land surface is irrigated (World Bank, 1995), representing a low proportion when compared to an average of 9.3% in Latin America. The reservoirs built by the state and fully operational in 1982 had an actual capacity to irrigate 1,043 km^2; however, only 48% of that surface was irrigated (López et al., 1984). There were also reservoirs serving partially equipped irrigation systems, in which 686 km^2 land remained idle. This points to the under-utilization of the existing irrigation infrastructure, further aggravated by the priority given to urban water supply.

Additionally, about 100,000 km^2 of land have poor drainage, of which only about 4,000 km^2 have been drained. Flooding of low-lying and flat areas, usually accompanied by sediment deposition from the higher catchment areas, effects urban and agricultural projects. Sediments also produce indirect damage when they reduce the lifespan of water reservoirs, built in the middle and lower basin areas to regulate the river discharges and supply water for irrigation, urban and industrial consumption, or hydroelectric energy generation.

7. Food Security

7.1 Indexes of per capita production of cereals and agricultural population

Indexes of per capita production of crops have been considered by FAO (1982, 1994) as an indicator of the global production of the farming systems per year, which is useful for monitoring the relative evolution of the food supply. Verheye (1997) used it to compare the tendency of the agricultural production in several parts of the world. In this study, the relative indexes of per capita production were calculated for the principal cereals (corn and rice), taking 1965 as reference year (FAO, 1974,1982,1994).

In Venezuela, the growth rate of the population (2.3%) is not compensated by an increment in the indexes of per capita production of the principal cereals at the national level (Figure 10). The relative index of corn production has decreased to less than 80 in the last few years, which is lower than that of cereals (85-108) in South America (FAO, 1994). In the case of rice, the index remained higher than 120 since 1991, which is considered a high figure in comparison with the values reported by FAO (1994) for developing countries. The variation coefficient is 0.31 for rice and 0.3 for corn. The highest relative indexes of corn were obtained in the late 1960s and late 1980s, respectively, coinciding with an increase of the national agricultural surface. The decline of the rice index during the same periods is explained by the competition with corn and sorghum. The variation of the relative indexes indicates instability of the production process and their decrease to levels inferior to 100 for intermittent periods expresses low security in product supply at the national level.

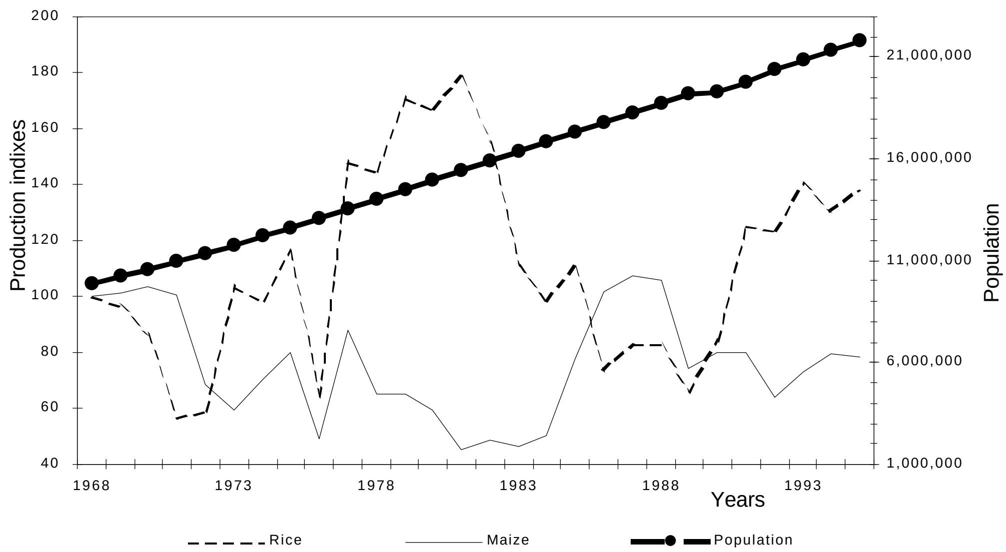
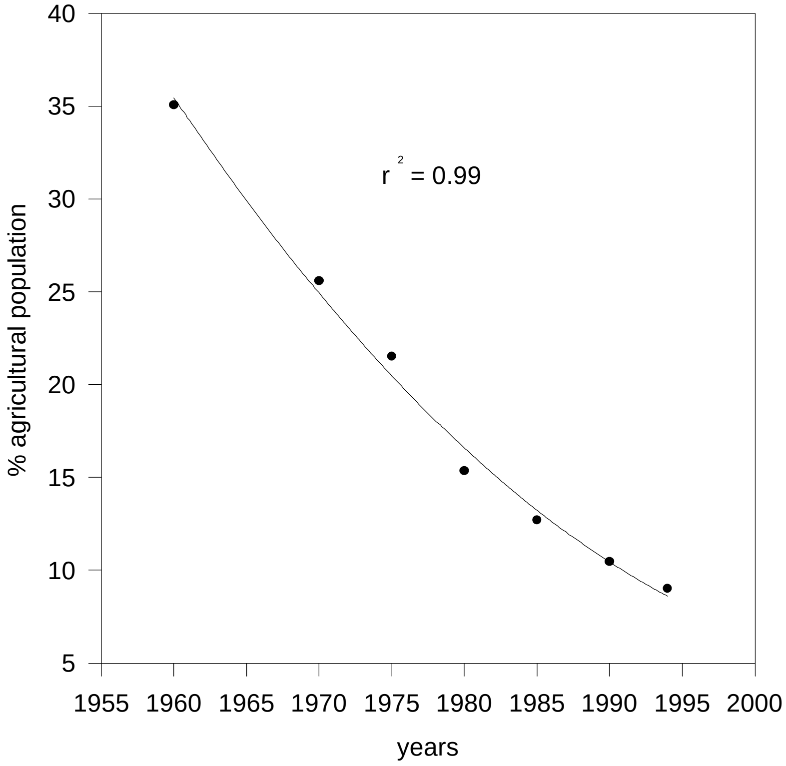


Figure 10. Population and indexes per capita production of main cereals in Venezuela

The percentage of agricultural population in relation to the total population has decreased substantially from 35% in 1960 to 9% in 1994 (Figure 11). People massively migrate to cities, because of extreme poverty in rural areas and little official support to farming activity (Gómez, 1996). The proportion of agricultural population in Venezuela is very close to that of developed countries, such as Sweden, Austria and Germany (7-9 %), and quite below that of developing countries, such as Mexico (28%), Colombia (33%), Ecuador (33%), Syria (36%), Iran (39%), Gabon (53%) and Indonesia (55%) (FAO, 1995). This situation limits the labor force for agricultural activities, promotes greater dependency on mechanization and use of fossil energy, and favors monoculture expansion.

Figure 11. Agricultural population

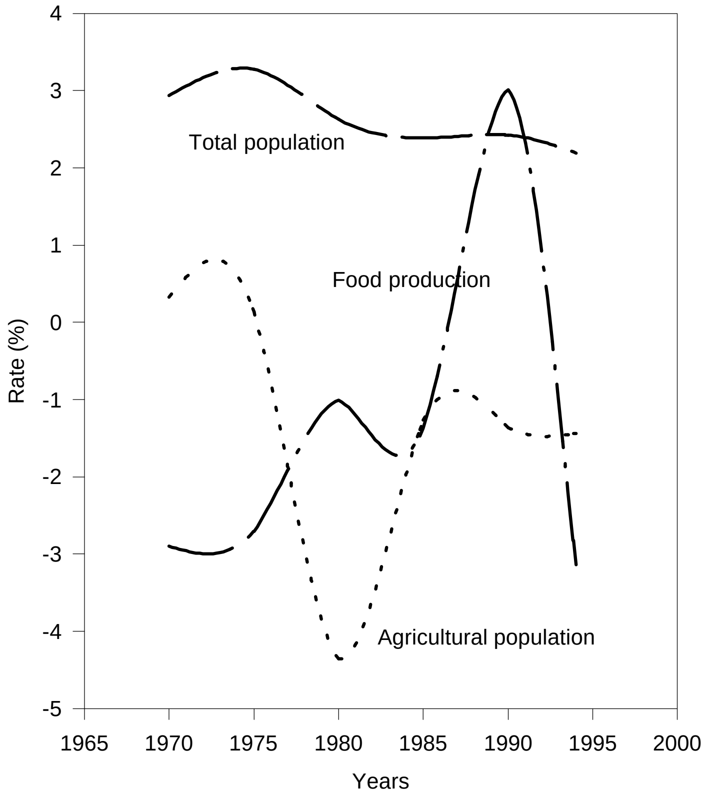


The growth rate of the agricultural population became negative as from 1975-1980, but the negative tendency has since stabilized (Figure 12). This contrasts with the rate of sustained growth of the national population (2.2-2.6) during the last 25 years, which is above the average of developing countries (1.7-1.9) and only slightly lower than that of Africa (2.6-3.3) and of some Asian countries. The population growth is becoming critical for autonomous food supply, because the growth rate of the national food production is negative (except around 1990). This strongly differs from food production rates of 2.3-3.4 reported for 93 developing countries in the period 1970-1995 (FAO, 1995).

7.2 Food supply of the agricultural sector

The possibility of obtaining foreign exchange currencies from exports and the dependence on imported goods for the functioning of the food supply system are measures of sustainability at the national level. A relationship favorable to imports produces an exchange currency deficit and instability in the food security of a nation, delays the application of techniques promoting sustainable farming systems and, in the case of developing countries, causes competition with more efficient systems of production. The relationship between production and supply of agricultural products at the national level indicates dependency and need of importation, highlights the level of food security of the country and signals the risk of failure. The ratios of export/import and supply/production of agricultural products are indexes of the dependency, stability and buffering capacity of the national agricultural system against external factors. Risk mitigation policies and supply capacity are indicators of sustainability. A ratio significantly lower than 1 is considered unfavorable to the agricultural development in developing countries which have sufficient potential of agricultural land, as is the case of Venezuela.

Figure 12. Growht rate of food production and population



In Venezuela, imports of agricultural products have increased in the last few years and, in 1995, reached a maximum of 586 million dollars, with an export/import ratio of 0.19 (Figure 13). The trend of importing more than exporting agricultural goods has prevailed over the last decades (ratios 0.19 and 0.29).

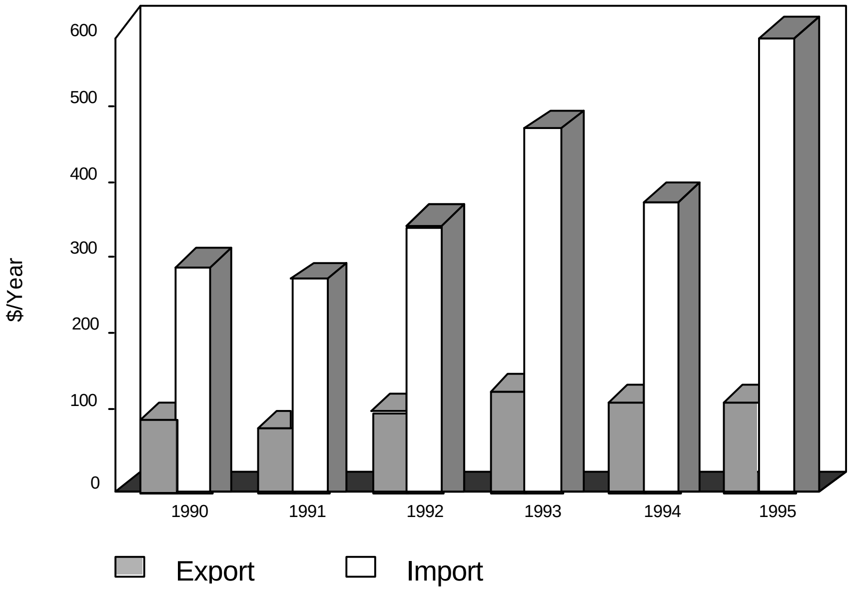
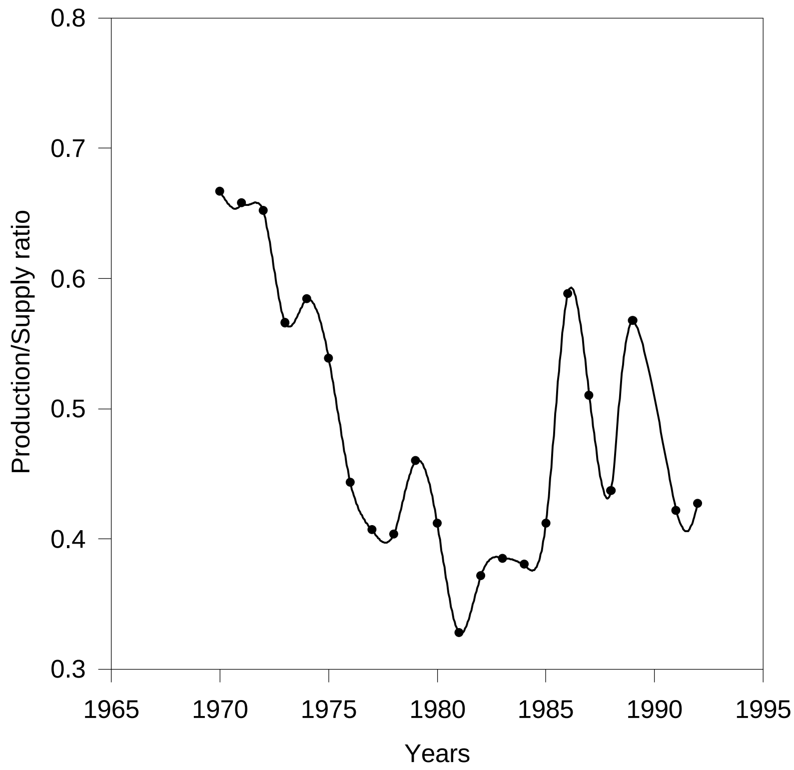


Figure 13. Export and import of agricultural products (millions US $)

The food supply is expressed by the sum of two components, the first consisting of the national production minus exports and the second component being imports. It can be expressed by the ratio of production/supply. This paper used the information available in Abreu et al. (1993), taking 1970 as the reference year. A ratio lower than 0.5 after 1976 indicates a high dependency on imports to accomplish the national supplies (Figure 14). The approximation to a seventh-degree polynomial (r^2=0.67) is evidence of interannual variability in the production/supply relation, and is better explained by the variation in import levels than by the variation of the national production (Abreu et al., 1993). There is an unfavorable tendency in the national food supply capacity, particularly for cereals, legumes, and fiber and oil crops, which have import/production ratios of 2, 3.2 and 0.75, respectively. According to Gómez (1996), it is necessary to import 2 calories for each calorie produced in the country, in order to reach a consumption level of 2,400 cal/day/person. Thus the food production by the country itself does not cover the food requirements of the population.

Figure 14. Production and supply food



8. Sustainability Index

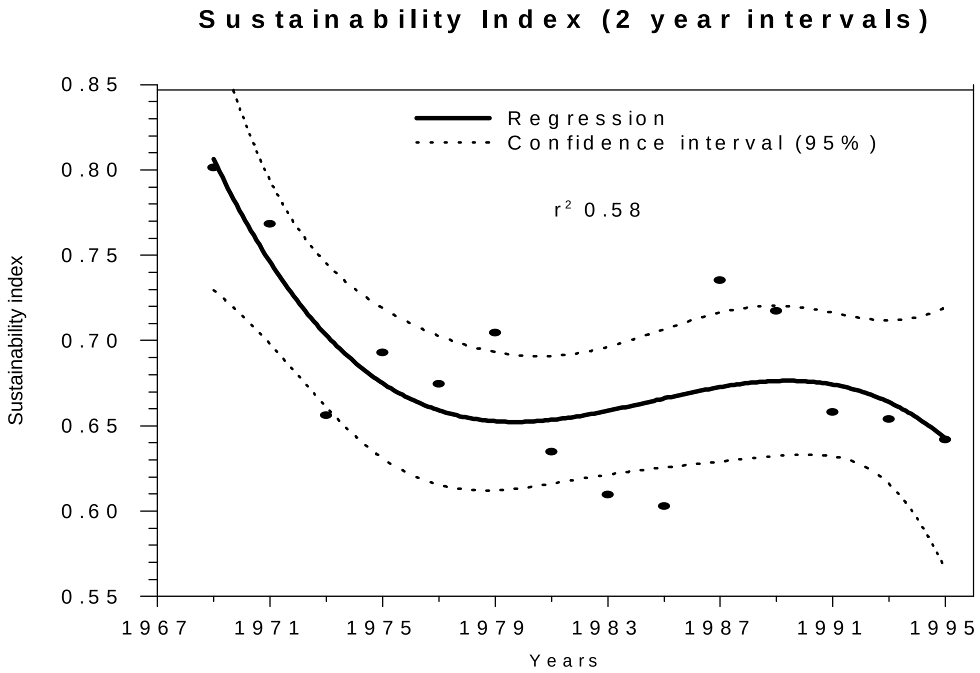
On the basis of the indicators analyzed above, the Venezuelan agriculture tends towards unsustainability: low crop percentage index (0.06), low crop agrodiversity factor (0.24), moderate variation of crop groups over time (0.23-0.30), increased yield/ha of the principal crops (0.25-0.5) but low relative yield in relation to potential productivity (0.43), low crop production income/cost ratio (1.1-1.28) and decreasing parity indexes, high available land/land demand ratio (2.4), deficient land use for provision of food demand, low cultivated surface per inhabitant (0.08 ha), unfavorable cultivated land/deforested land ratio, low irrigated land/irrigable land ratio (0.22), high degradation of soils under cultivation (0.76), insufficient food production in relation to demand (<0.5) with negative growth rates, low export/import ratio (0.19), low stability of the indexes of per capita production of cereals, low proportion of agricultural population (0.09) and negative growth rate (Table 3).

Table 3. Quantified Sustainability Indicators

INDICATORS	VALUE	ASSESSMENT
Index of surface percentage of crops (ISPC)	0.06	Low
Crop agrodiversity factor (CAF)	0.24	Low
Variation of crop groups in time	0.23-0.3	Medium
Increase of cereal yield in time	0.25-0.5	Increasing
Actual yield/Potential yield	0.43	Low
Output-Input ratio	1.1-1.28	Low
Parity index	0.6-0.75	Low
Available land/ Land demand	2.4	High
Land demand/Land used	0.5-0.6	Deficient
Cultivated area (ha) per inhabitant	0.08	Low
Cultivated area/Deforested area		Unfavorable
Irrigated land/Irrigable land	0.22	Low
Degradation of soils under cultivation	0.76	Severe
Food production/Food supply	< 0.5	Insufficient
Export/Import	0.19	Low
Index of per capita production	85-130	Medium
Stability index of per capita production		Low
Proportion of agricultural population	0.09	Low

In an attempt to quantify the level of sustainability/unsustainability reached by the Venezuelan agriculture at any time over the last two to three decades, selected indicators provided with time series of data larger than 20 years were taken into account. The following six indicators satisfy this requirement: percentage of agricultural population, relative index of per capita production of cereals, cereal yield, total food production, agricultural surface, and agricultural surface per inhabitant. The partial indexes describing these indicators were normalized between 0 and 1 relative to their maximal values. An aggregated index of sustainability was generated by averaging the partial indexes, following the approach implemented by Hansen and Jones (1996) for farming systems. The values of the sustainability index, calculated for consecutive years, were represented graphically to highlight the evolution of sustainability over time (Figure 15).

The sustainability indexes revealed similar trends for intervals of 2 and 5 years. The adjustment of the indexes fitted a third-degree polynomial, which shows an exponential reduction in the 1970s, then varies with no tendency to increase in the long-run, and presents now a negative slope. The high variability in two-year intervals limits the reliability of the data for the regression model at the confidence level of 95% and makes it necessary to increase the level to 99% to include all the available information in the confidence interval. Such a high variability of the indexes over time reflects a low stability of the national agricultural system, which in turn limits its sustainability. When the index is analyzed for intervals of 5 years, less variability is observed in time. It is thus suggested to consider a minimum of 5 years to evaluate the tendency of sustainability for long periods (>25 years) and improve its estimation for future years, without omitting the analysis of interannual variability.



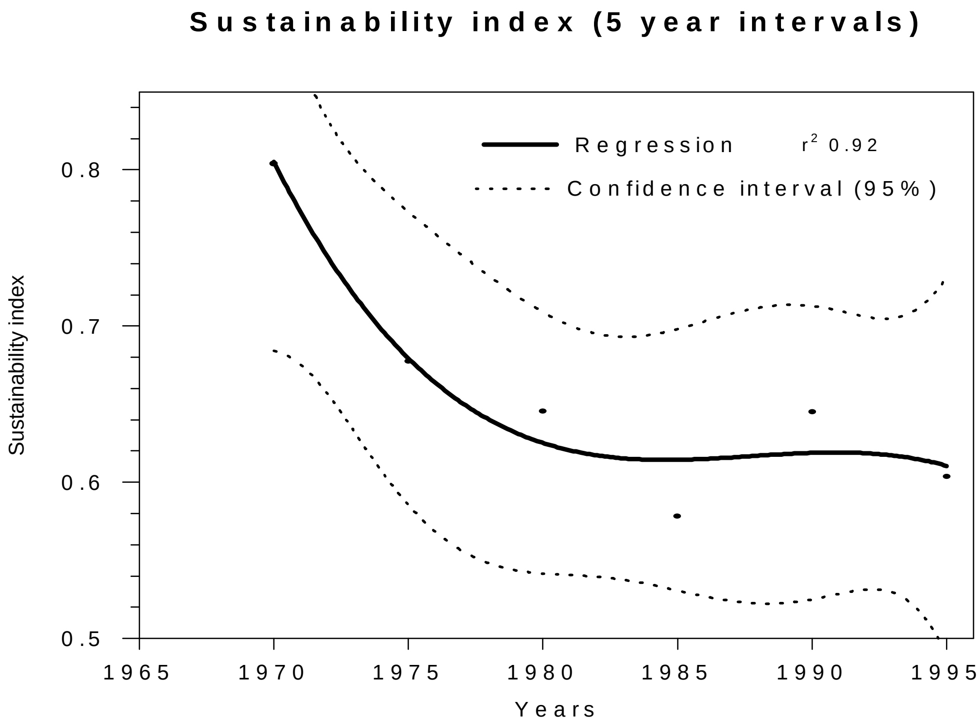


Figure 15. Sustainability index

According to Niu et al. (1993), the degree of sustainable development may be expressed in terms of probability classes such as strongly sustainable (>0.70), weakly sustainable (0.59-0.70), and not sustainable (<0.59). According to this criterion, agricultural sustainability in Venezuela was strong until the mid-1970s and weak afterwards, with a tendency to decrease over time if the following conditions do not change: the technological pattern of monoculture, the abandonment of deforested land because of soil degradation, low economic efficiency, and low levels of production in relation to crop potential despite high farming input.

9. Conclusion And Recommendations

To increase the sustainability of the national agricultural system, the following strategies and measures are suggested: Increasing the surface of annual crops, such as cereals, fibers and oil crops, with larger agrodiversity in farming systems. To do this, it is necessary to increase the agricultural population and the agricultural surface per inhabitant, with conservation plans for native ecosystems.

Increasing the economic efficiency and parity indexes, with a reduction in the use of fossil energy compensated by labor force, without soil degradation and with water conservation. Less input should be used for the present levels of production and production could increase without high input. Multiple crop systems and the use of hybrids or varieties suitable for minimal input practices are necessary.

Making use of the available irrigation capacity at the national level and of poorly drained land with adapted systems of crop (rice) and animal production. Adoption of water conservation policies are recommended.

Quantifying soil degradation, evaluating the practices of soil management and making mandatory soil conservation in farming systems.

Providing or supporting technical assistance and research to promote commercial production and avoid favoring imports at the expense of the national production.

When a country, referring to Venezuela in this case, imports more than half of the agricultural goods internally consumed, but is endowed with plenty of land suitable for farming, although soils are increasingly degraded by inappropriate management, political will must be promoted and political measures must be implemented to change the current structure of the agricultural sector and compensate for the unfavorable conjunctural conditions created by the national and international market terms.

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