ASSESSMENT OF SUSTAINABLE LAND SYSTEMS RESEARCH IN SOUTH AMERICA

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INTRODUCTION

The South American Region covered in this assessment includes the following countries: Argentina, Uruguay, Paraguay, Brazil, Chile, Bolivia, Peru, Ecuador, Colombia, Guyana, Venezuela and Surinam. The 1990 population is estimated to be of 296 million people, of which 70 million live in rural areas (FAO, 1989).

The characteristics of the biophysical environment vary widely, as it includes from coastal deserts to perennial rain tropical forests. The region comprises almost all of the 103 Life Zones identified by Holdrige for the totality of the world, and Per alone contains 84 of them (FAO, 1988). There are over 25 soil units of major importance, including Acrisols, Ferralsols, Lithosols, Gleysols, Luvisols, Arenosols, Fluvisols, Histosols and Planosols (FAO-UNESCO, 1971).

There is also a wide range of agricultural policies, although all countries in the region have shared during the 1980's a context of generalized economic crisis. Average inflation rate was over 1000 % in 1989, and the mean per capita gross product is now at the same level as in 1977-78 (CEPAL, 1989). As a consequence of the region's foreign debt, Latin America transferred US$ 25 billion in 1989 to the industrialized countries (CEPAL, 1989).

In the past ten years, agricultural policies have been marked by the structural adjustment programs dictated by such international financial centers as the World Bank and the International Monetary Fund. Thus, agricultural policies now tend to provide for a relatively larger role for the private sector and free market mechanisms. However, most countries still maintain price-control systems, as well as several subsidized programs (credit, marketing, technical assistance, etc.).

It is a paradox that Latin American countries have had to significantly expand their agricultural output and their exports in order to maintain the same level of income. Much of the present problem of agricultural sustainability has to do with this fact.

Between 1974-76 and 1983, fertilizer consumption increased 47%; tractors, 40%; agricultural production, 25%, livestock production, 28%; and total food production, 27% In the decade between 1970 and 1981, the irrigated area grew by 4 million ha, from 10 million. Between the 1960's and the 1980's, cereal yields increased on the average by 66% in the South American countries. In 1969 the region consumed 77

million tons of pesticides, while ten years later it used 136 million tons (Redclift, 1989).

Despite of this impressive adoption of the tools and tenets of the Green Revolution, the region's food production per capita grew only 4% between 1974-76 and 1983. During this period, Bolivia, Chile, Ecuador, Per and Venezuela all had diminished per capita food production (Redclift, 1989).

It is important to emphasize that in several countries (in particular, Brazil, Colombia and Chile) for-export agriculture has expanded tremendously, marking major socioeconomic and technological transformations; it is expected that this trend will tend to continue and involve new countries in the future.

Traditional agriculture is still a major component of the agrarian picture in South America. It is carried out in more than 16 million small-scale farms, five million of which have less than 2 ha. Peasant agriculture controls close to 160 million hectares (ECLAC-FAO, 1986).

Given the significant variations in socioeconomic and biophysical determinants, it is to be expected that there are many different farming system types throughout the region, and even in each country in particular. These include highly modernized, capital-intensive enterprises many of them dedicated to for-export agriculture (for example, temperate-zone fruits in Chile, coffee and flowers in Colombia, soybeans in Brazil, sugarcane and cotton in Paraguay and a very wide variety of tropical and semi-tropical products in the coastal plains of Per and Ecuador); extensive capitalist enterprises (for example, wheat and meat production in the Argentinean humid and dry pampas); mixed crop/livestock farms in newly colonized tropical areas (for example, in the Amazonian areas of Brazil and Paraguay); and mixed crop/livestock systems in most areas dominated by traditional peasant agriculture of all countries, which include tropical, semi-tropical, temperate and dryland conditions, some of which have a history of many centuries (such as Andean agriculture in the highlands of Per , Bolivia, Ecuador and Colombia).

The predominant land use systems in South America are:

(a) Andean agriculture[1]

Andean agriculture is organized around very complex farming systems, where the elements or spatial organization (ecological niches along a gradient of altitude) and socio-cultural traditions play a very significant role. This land use system is characteristic of the agriculture that is practiced in the Andean mountain range in the Northwestern countries of South America (Per , Bolivia, Colombia, Ecuador and Northern Chile).

It is present between 2000 and 4800 masl. Mean annual temperatures range from 5 C ,to 12 C; mean minimum temperatures range from -11 C to -6 C, and; mean maximum temperatures vary between 12 C and 25 C. There is a negative correlation between altitude and temperature. Mean annual rainfall is of approximately 400 to 600 mm in the lower areas and of 900 to 1000 mm in the high puna; however, rainfall is highly irregular and annual precipitation can vary 200 to 400% from year to year, this being a greater problem at the lower altitudes.

Natural resource characteristics vary to such an extent that five ecological niches have been recognized by Holdridge (1967). In the most benign of these (dry mountain tropical forests, or Sierra), an intensive, diversified form of agriculture is practiced, while in the High Puna (wet alpine tropical tundra) only pastoral activities are present.

Farming systems in this land use system include: (a) community-based, subsistence traditional agriculture, that combines a diversity of crop and livestock enterprises, some of which have prehispanic origins. (b) Relatively well-to-do peasant farming systems that operate less diverse small-farms and that do not hire labor on a permanent basis, typically found in the lower inter-andean valleys, where environmental conditions are much more benign than those found at higher altitudes. Many of these valleys are at least partially irrigated. Vegetables, maize, improved pastures, fruit trees and milk are common activities in these farms. (c) A third type of farming system in the Andean land use system is that of fully commercial, capital intensive agriculture in the inter-andean valleys. Irrigated fundos tend to be continuous, while those holdings that are rainfed usually are composed of plots of land which are

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1. Greslou and Ney (1986); Mayer (1981); Mann (1966); Pecora (1969); Posada (1969); Pons (1969); Rossi (1969); Gligo (1986); Agreda et.al. (1988); Quijandr a et.al. (1990); Feige (1989); Larrea (1988); Carrizosa (1987); Felipe-Morales (1987); Masson (1987).

dispersed throughout the areas surrounding the major local towns. Fertilizers, pesticides, improved varieties, agricultural machinery and hired labor are key components of these farms, to such an extent that traditional crops (characteristic of the peasant **comunidades**) such as potatoes can be produced with a profit.

(b) Agriculture of the Pampas[2]

The **Pampas** (an indian word meaning flatland) comprise a vast area of over 700,000 km , located in Eastern Argentina. While showing within-system heterogeneity, the agriculture of the **Pampas** is a distinct entity that can be treated as a land use system. Similar formations can be found in Uruguay and Southern Brazil (Rio Grande do Sul). The area is inhabited by 15 million people (50% of the country's population). The region was colonized through the La Plata ruver, with the incoming population settling the communication routes between the La Plata river and the rich Spanish colony of Per . The native indian populations did not practice agriculture.

The climate of the **pampas** ranges from temperate warm to subtropical. The typical climatic regime of this region has been compared to the steppes of North America and the USSR. Annual temperature variation is limited and the winter is mild. Rainfall increases from West to East, going from 500mm to 1400mm. The natural vegetation is that of permanent grasses, the dominant genera being **Stipa and Poa.** The "loess" (Chernozen) soils are highly fertile. The carrying capacity of these pastures is more than 10 heads of cattle/ha.

The western portion of the **pampas** is much drier (300 to 500mm annual rainfall), giving origin to stepparian open forests of **Prosopia spp.** Animal breeding (cattle and sheep) predominates in the farming systems of this sector. Moving NE, rainfall increases (to 650mm) and climatic variation decreases, and mixed crop/cattle farming systems predominate, which are characterized by the very low costs of production given the favourable climatic and vegetational conditions. Still further East, rainfall becomes more abundant (700-900mm) and soils tend to be heavier and richer in organic matter, so that cereal and oilseed crops become the most important components of the farming systems.

For many decades the **pampa** has been one the prime agricultural areas of the world. It is heavily oriented

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2. Viglizzo and Roberto (1889); Viglizzo (1986, 1983); Muscolo, 1969; FAO-UNESCO (1971)

towards the world markets of cereals and wheat, while also providing abundant food for the national population.

(c) Extensive sheep breeding in the Patagonia[3]

The **Patagonia** is a very large arid steppe in SE Argentina. Rainfall ranges from 100 to 200 mm/year, while mean temperatures steadily decrease from North to South. Strong winds (specially during Spring) are a characteristic of the **Patagonia**.

The vegetation is highly uniform and is formed by stepparian spiny shrubs (**Larrea spp.**) and grasses (**Stipa** and **Festuca**).

Extensive sheep production characterizes the farming systems of the **Patagonia** and most of the product (wool and meat) is destined to overseas markets. Crops are grown under irrigation in a few small valleys. Plans are underway to increase oil production in this area.

A similar land use system, also with sheep breeding farming systems, can be found North of the **Patagonia**.

(d) **Caatinga of Brazil**[4]

This well-defined area in NE Brazil has a semiarid tropical climate. Annual precipitation is in the range of 300 to 800mm and mean annual temperatures vary between 20 and 24 C. The predominant forms of vegetation are cacti (landmarks of the area are **Cereus jamacaru** and **C. squamosus**) and spiny shrubs (**Caesalpinia, Cavanillesia, Mimosa, Acacia**, etc).

Extensive goat breeding is combined with honey-bee culture and such crops as cotton and manioc (**Manihot esculenta**). However, the agricultural landscape of this area is changing rapidly, due to the expansion of irrigated, for-export fruitculture (grapes, mango and guava) and horticulture (tomatoes, onions, peppers, melons and asparagus) in such places as the San Francisco river valley.

A nearby agricultural formation, which for some purposes could be treated as part of the same land use system, is the **Agreste**. It is much more humid (800-1200mm of

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3. FAO-UNESCO, 1971; Muscolo, 1969; Biggs, 1969.

4. FAO-UNESCO, 1971.

annual rainfall) than the **caatinga**. It is a narrow strip between the **caatinga** and the seasonal forest areas of eastern Brazil. Small-scale mixed farming systems are predominant, dedicated to such crops as pineapple, tobacco and vegetables and to extensive animal breeding.

(e) Capital-intensive soybean production in the Brazilian **Campos Cerrados**

This vast savanna of Central Brazil covers a series of flat plateaus that reach maximum heights of 1000 to 1800 m. The warm tropical climate is characterized by rainy summers and dry, windy winters. The typical vegetation is a mixture of high grasses (**Paspalum**, **Panicum** and others) with short (4-8 m), twisted trees (**Kielmeyera**, **Salvertia**, **Caryocar** and others), intermingled with dwarf palmtrees with subterranean shots (**Diplothemium littorale**). The soils present unfavorable chemical properties and are old and depleted.

In the last several years this area has experienced a major transformation due to the introduction and notable expansion of the soybean crop, in capital-intensive, highly mechanized farming systems that have made of Brazil a major exporter of this legume. Livestock production is also important in this area.

Moving west, the **Cerrados** give way to the **Pantanal** (area of marshes), where rice production is predominant.

(f) Shifting agriculture in the savannas of the Amazonian basin[5]

This form of agriculture takes place in "islands" of **Campos Cerrados** that are located within the Amazonian basin, in Northern Brazil (Mato Grosso, Roraima). The climatic and vegetational characteristics of these islands are very similar to those found in the typical **Campos Cerrados** described above. However, the low topography of these areas causes significant drainage problems during the rainy season.

Mixed crop/livestock farming systems are found in this area. Land is cleared by means of fire. In those sectors controlled by small farmers that practice subsistence agriculture, the system appears to be highly stable.

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5. FAO-UNESCO, 1971.

(g) Deforestation-based agriculture in the Brazilian Amazon[6]

The climate of this enormous region is wet semicalid. Annual rainfall is above 2900mm and there is no dry season. The perennial wet tropical forest of this area are formed by numerous woody species.

In the area of the states of Acre, Rondonia and Para, of Northern Brazil, these forests grow in marshy flatland.

Two basic forms of farming systems are found within this land use system: rubber tappers (extractive agriculture) and settlers (livestock farming on deforested lands). Tappers base their living on rubber extraction, collection of Brazil-nuts and fish-ing. Low-soil fertility and poor water management lead to very rapid degradation of clear lands in the settlers' system.

(h) Plantations and fruitculture in Southeastern Brazil[7]

This is another area of Brazil that in the past few years has experienced great changes, leading to new land use systems. This is also one of the most densely-populated parts of the country and demographic pressure on the land is high.

The climate ranges from tropical upland to subtropical; annual rainfall is 800 to 1000mm; and mean annual temperatures vary between 18 and 22 C.

There are several different types of farming systems in this area, although they all tend to be of the plantation type and highly mechanized and capital-intensive. One of these farming system types is the sugarcane plantations for the manufacturing of alcohol as a gasoline replacement. Citrus farming is also highly important, as the region produces 70% of the world's output of these fruits. Coffee plantations are a third major type of farming system.

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6. FAO-UNESCO, 1971.

7. FAO-UNESCO, 1971.

(i) Extensive livestock and mixed crop/livestock farming in the Gran Chaco[8]

This large system is located in the center of the South American continent. Although it is very heterogeneous within itself, it is widely recognized as a peculiar form of agriculture in South America. It covers parts of Northern Argentina, Western Paraguay and parts of Southern Bolivia.

The climate is warm semitropical, ranging from semiarid in the central part of the **Gran Chaco** to dry and humid (monsoon-type) both to the West and to the East. The semiarid portion has an annual rainfall of 540mm and evapotranspiration of 2160mm, with no humid months. The dry and humid part has an annual rainfall of 1300mm and evapotranspiration of 1520mm, with a wet season between October and July; large tracts of land become flooded during the rainy season.

There is a great diversity of farming systems within this large expansion of land. In Northern Argentina it is possible to find forestry-based systems (wood and charcoal). Agroforestry systems are important in Northcentral Paraguay.

Further east in Argentina and in the Eastern and Riverine regions of Paraguay, there are both commercial and highly diversified small-scale peasant farms (tobacco, tea, mate tea, cotton and maize). Commercial, capital-intensive, monoculture farming systems have expanded in the Santa Cruz area of Bolivia and in the eastern hills of Paraguay. There are rainfed and irrigated forms of crop farming.

Livestock production, combined or not with crops, is important throughout the **Chaco**, based on low quality grasslands and native and Zebu breeds. Over 60% of the Bolivian territory (the **Llanos** and the **Oriente** regions) is under this type of farming systems. Extensive livestock production is the predominant type of farming system in the **Chaco**, and is also responsible for most of the negative environmental impact.

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8. FAO-UNESCO, 1971; Muscolo, 1969; Pccora, 1969; Giggs, 1969; Morello and Hortt (1987).

(j) Commercial plantations in the Coastal Deserts of Northwestern South America[9]

A very narrow (75 to 150 km) and long (over 2000 km) strip of land marks the Pacific Ocean coast of Per . The climate is classified as cold tropical desert. Annual rainfall is of less than 50mm, while evapotranspiration approaches 1000mm. It is very common to have zero rainfall years. However, the Humboldt current, that brings water from the Antarctic to the Equator, causes mean annual temperatures to be very low (15 to 20 C).

Large, capital-intensive commercial plantations produce cotton, rice, sugarcane, grain crops, potatoes and legumes, in a form of oasis-agriculture.

The for-export plantations of the Coastal provinces of Guayas and Manab , in Ecuador, can be said to belong to this major land use system, although the climatic regime (equatorial wet semicalid) is much more humid (200-400mm of annual rainfall) than that found in the coast of Per .

(k) Fruit production in Central Chile[10]

The area presents a Mediterranean climate, with a North to South decrease in temperature (20 to 12 C mean annual temperature) and increase in rainfall (400 to 2000 mm annual precipitation). Winters are rainy and summers are dry.

At the northern and central portions of this climatic zone, a new land use system has originated in the last 25 years, based on for-export fruits (table grapes, apples, peaches, pears and others). The commercial farming systems are highly capital-intensive. Small-scale peasant agriculture coexists producing basic food staples.

EXISTING RESEARCH STRATEGIES FOR IMPROVING LAND USE SUSTAINABILITY

For this Workshop, the organizers requested that the assessment be oriented to "... identify institutions that are doing systems-focused research that explicitly looks for

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9. FAO-UNESCO, 1971; Pons (1969); Rossi (1969).

10. FAO-UNESCO, 1971; Baraona and Saa (1969); Echenique and G mez (1988); GIA (1984)

strategies to enhance the sustainability of a particular land use (agricultural) systems."11

Table 1 summarizes the basic findings of this search.

PRESENT RESEARCH EMPHASES AND FUTURE PRIORITIES

(a) Definition of sustainability

The core of the definition of sustainability used in this paper is taken from Conway and Barbier (1988): "the ability to maintain productivity in the face of stress or shock."

However, a second dimension is suggested by the fact that, many times, this stress or shock is induced not by an external supra-system, but by the structure and function of the land use system itself. That is, present land use systems cause or facilitate the accumulation of ecological, social, cultural and/or economical imbalances that eventually can lead to decreasing productivity. In fact, it appears that many of the major sustainability problems confronting present land use systems, have originated in the structure and/or functioning of the system itself, and not only in the relationship between the system and a higher hierarchy.

Therefore, it seems appropriate to modify Conway and Barbier's definition as follows: land use sustainability is the ability of a system to maintain its productivity in the face of stress or shock and in the absence of additional inputs of energy.

This definition places this assessment closer to the proposition of Hart and Sands (1990) "to begin to develop land use systems that are both economically viable in the short-run yet not environmentally degrading in the long run. In short, the essence of sustainability is the maintenance of natural resource productivity."

However, in the case of the major South American land use systems, it is possible to find two essentially different cases of long run environmental degradation (Gallopin et al., 1989). On the one hand, there are those problems associated to the predominant productive and technological patterns of economic growth, in the areas of

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11. M. Sands, personal communication, 23 oct 89. Underlining by the authors.

expansion of capital-intensive agriculture (SE Brazil, coast of Per and Ecuador, central Chile, and others); colonization of new agricultural frontiers (in the Gran Chaco, in the Brazilian Cerrados and in the amazonian basin) constitute a special case of this general situation.

On the other hand, there are problems of environmental degradation associated with poverty, in the areas where peasant agriculture is still predominant (Andean agriculture, Amazonian basin, NE Brazil, Gran Chaco of Paraguay, Argentina and Bolivia, and others).

It is almost self-evident that these two cases demand different approaches and require particular answers. It is well documented (Sancholuz et al., 1985) that actions that under one condition would promote greater sustainability, are responsible for accelerating or being ineffectual under the other set of circumstances.

This confronts us with the problem of specifying the condition of short-term economic viability, so that it is compatible with the socioeconomic and cultural characteristics of the human population that manages the land use system.

(b) Conclusions of current situation of land use system sustainability

There are four main conclusions of this assessment:

i. Most of the agricultural systems surveyed in this assessment face important sustainability problems. In some cases (for example, community-based agriculture in the Andean highlands, livestock in the Amazonian basin, the mixed crop/livestock systems under semiarid, semitropical and tropical conditions) the problem is an urgent one, as it is now affecting the natural resource base to such an extent that agriculture may not be feasible within a few decades.

ii. Very few of the institutions identified in Table 1 are engaged in systems-focused research whose explicit objective is to enhance the sustainability of a land use system. There are no institutions that have accumulated experience with long-term, multi-hierarchy studies, of the kind that would be indispensable to design sustainable land use systems.

iii. There is a lack of contact and exchange between research programs that deal with different levels of a land use system, within and between institutions. The characteristic organization of the National Research Systems (NRS) separates research according to specific commodities

restauration of present-day agroecosystems and in the design of land use systems that avoid past and present mistakes in such areas of agricultural colonization as the amazonian basin (4 million km of uncultivated land) or the South American savannas (1.5 million km uncultivated).

v. From the point of view of their economic logic, the land use systems described above can be divided into four groups:

Group A: Land use systems dominated by capital-intensive agriculture

In this group, it is possible to include the following:

- Plantations in interandean temperate valleys (Per , Ecuador, Colombia).
- Plantations in coastal deserts of Per and coast of Ecuador (Guayas and Manab).
- Fruitculture in Central Chile. ,
- Fruitculture and horticulture in irrigated valleys of the Brazilian **Caatinga** and in the Southeast.
- Rainfed coffee, citrus, sugarcane and soybean farms in SE Brazil.

Group B: Land use systems dominated by extensive, commercial agriculture

In this group, it is possible to include the following:

- Extensive animal breeding in the South American **Gran Chaco**, the Brazilian **Cerrados** and **Pantanal**.
- Extensive cereal and livestock farming in the Argentinean **Pampas**.
- Extensive sheep breeding in the **Patagonia**.
- Extensive livestock farming in the Colombian and Venezuelan **Llanos**.

Group C: Land use systems in areas of expansion of the agricultural frontier

These land use systems share some characteristics with those in groups A, B or D. However, they are specific enough to merit separate consideration:

- Deforestation-based extensive livestock farming in the **Gran Chaco** and the amazonian tropical forests.

- Soybeans and rice farms in the **Cerrados** of Brazil.

- Cotton production in the South American **Gran Chaco**.

- Small-scale settler farming systems in the Amazonian perennial tropical forests.

Group D: Land use systems dominated by peasant agriculture

In this group it is possible to include the following:

- Community-based agriculture in the Andean highlands.

- Small-scale farming in the interandean highlands, including agroforestry systems.

- Mixed crop/livestock farms in Central and Central-Southern Chile, including **Mapuche** agriculture.

- Extractive agriculture in the Amazonian perennial tropical forests.

- Mixed crop/livestock farms in Southern Paraguay, NE Argentina and Central-South Bolivia, in the Brazilian semiarid tropics and South and Southeast regions, and in the warm tropical savannas.

(c) Recommendations for future research priorities to enhance the sustainability of land use systems.

Recommendations for future research priorities can be ordered according to the five-step process suggested by Hart and Sands, 1990:

- Description:

  * Basic research of agricultural ecology and ecology of non-cultivated environments, especially tropical rain forests and savannas.

  * Identify and describe the different agroecological environments, to potential, restrictions and opportunities for development.

- Analysis:

  * Introduce dynamic systems analysis at a whole-farm, microregional and regional levels.

- Design:

  * Stimulate greater interdisciplinarity and inter-level exchange in research programs and institutions.

  * For capital-intensive land use systems, research should be supported that aims at reducing costs, enhancing quality of products and strengthening the link with agroindustry, as compared with more traditional research that emphasizes on yield increments.

  * For land use systems in areas of agricultural frontier, research should be supported that enhances soil-crop-livestock interactions and the relationships between diversity, stability and productivity.

  * Consolidated land use systems based on extensive livestock farming do not confront major sustainability problems, with the exception of increasing competition for space with capital-intensive crop farming.

  * Land use systems dominated by small-scale traditional farming require the design of appropriate and improved technologies and the strong support of their national societies to open up space and time opportunities for those alternatives to take hold.

- Evaluation:

  * Development of methodologies for **ex ante** and **ex post** evaluation of the efficiency of each land use system and of the impact of new components within a given system. Such methods must consider socioeconomic and agroecologic criteria.

  * Monitoring of present land use systems and spatial/temporal changes and assessment of the environmental impact of agriculture. Areas of agricultural frontier and of rapid technological change should be given priority. Incorporation of Remote Sensing, Geographic Information Systems and ecological impact modelling would greatly increase the efficiency of these research programs.

- Dissemination:

* Definition of biophysic and socioeconomic parameters that permit the early detection of environmental disturbances caused by errors in the preceding steps, by the effect of scale, or by unpredictable or new factors, in order to allow the fine-tunning or reorientation of land use systems before problems reach a critical stage.

* The very old and resilient problem of the link between research and extension, should continue to be a very critical priority.

Research related to Group A land use system should prioritize work that is conducive to replacing high environmental-impact technologies with new options that show a potential to be accommodated within the profit-motive of commercial, capital-intensive agriculture. Cost-saving and quality-enhancing research should be given a greater emphasis, as compared to yield-increasing research.

Research is also important to support the enhancement of what one author (Gligo, 1988) has called the "infrastructural complexity factor", i.e., the adequate availability of infrastructure for the circulation of energy and information into and out from the land use systems. Such factor should reduce the fluctuation of these fluxes and the internal variability of the agroecosystems.

Group B land use systems probably present the least sustainability problems, as compared with the other two groups. More sustainable agricultural systems could be designed if more research was conduced related to the following questions: diversification of agricultural activities, and, in particular, crop/livestock interactions; systems analysis of the relationship between productivity and sustainability; genetic improvement of pastures, crop varieties and breeds, from the point of view of their tolerance to stress environments (salinity, drought and water-lodging); soil-forage-animal interactions.

It is important to point out that a systems perspective is lacking in most research being conducted for this land use systems.

Finally, a number of policy-related research issues need to be given attention, since this land use system has suffered a relative technological stagnation over the past decades; several authors have argued in favour of technical and economic changes, in the face of the new realities of the world cereal and meat markets. Since these potential changes will inevitably have an impact on the natural

resources, it seems that research should be supported that deals with policy analysis and resource economics.

Group C land use systems contain the most pressing agricultural sustainability problems, and they demand a major commitment of research resources. There is a basic lack of knowledge on the ecology and economics of the major colonization ecosystems, which is reflected on the many blunders that characterize many of the colonization programs. Agroforestry is an area that should receive consideration. In addition, more resources should be devoted to understanding the basic elements of the extractive agriculture that has been practiced for many years without significant environmental impact. Water-systems equilibrium is a fundamental problem in watersheds of such great magnitude as those of the Amazons, the Orinoco and the La Plata rivers. Monitoring of the colonization projects need to be expanded, both on a regional level as well as through indepth case studies. In short, unless more solid basic scientific knowledge is gathered, it seems difficult to identify those technological components and farming system designs that are best fit to the particular conditions of the three main colonization areas: the Amazon, the Gran Chaco and the Brazilian Cerrados.

Group D land use systems face many pressing sustainability problems. Most of them originate in a vicious cycle of impoverishment of the agricultural societies that inhabit them and of overexploitation of the natural resource base to try to meet the most fundamental household needs. Research that is aimed at **preventing** increased damage to the environment and impoverishment of the societies is required, as compared to **curative** efforts that today are most prominent.

Although a systems approach is present in many ongoing research projects in Group D land use systems, there is still a need to link component technology efforts such as variety improvement to a whole-farm and whole-microregion (watershed, communities) perspective, given the great complexity of the present forms of agriculture that precludes isolated breakthroughs (Gligo, 1986).

Soil and water conservation and management will continue to be major research questions in Group D land use systems. Another area that requires support has to do with the development of new concepts and the design of new methods for the dissemination of technological improvements into the farming systems of the Andean land use system, particularly in the community-based systems of the highlands. Development of more sustainable land use and farming systems components should be combined with efforts

to open up space and time opportunities for those components to take hold and cause their expected effects.

Finally, there are three areas of research that need to be supported throughout the whole South American region:

First, there is a need for projects aimed at generating and disseminating high quality scientific information concerning the development of sustainable land use systems among policy-makers, researchers, extension agents and organizations of producers. This aspect appears to be necessary in order to stimulate new attitudes in those sectors concerning the environmental dimension of agricultural development, and its relation to the questions of productivity, efficiency, short-term economic goals and social equity. There are strong biases that make it difficult to obtain national support for the proposition of sustainable agriculture, including support for research.

Second, effective monitoring capabilities are lacking in most countries, even in those that have more than enough laws and regulations that would preclude (if enforced) at least the most harmful elements of some of the present agricultural systems.

Third, it is necessary to support research efforts aimed at developing new concepts, methods and tools that allow the scientific community to operationalize the notion of developing more sustainable land use systems. Even traditional analysis methods designed for fixed-structure and steady-state systems need to be revised in order to meet our new challenges (Gallopin et.al, 1989; Nicolis and Prigogine, 1977; Holling, 1986).

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