ANIMAL AGRICULTURE AND NATURAL RESOURCES IN CENTRAL AMERICA: STRATEGIES FOR SUSTAINABILITY

Proceedings of a Symposium/Workshop held in San José, Costa Rica

PREFACE

During the last decades, animal production has been frequently questioned as a an incompatible activity with natural resources conservation, mainly in fragile ecosystems in the tropics. The Tropical Agronomical Research and Higher Education Center (CATIE) and the Secretariat at the University Group for International Agriculture (UGIAAG, at Wisconsin University) carried out an expert activity to analyze the relationships between animal production and natural resources management. For this purpose, a Symposium/Workshop was organize to: a) promote communication between researchers, decision makers, technicians and producers to find alternatives for increasing animal production while protecting the natural resource base; b) identify key interrelationships between the natural resource base and animal production systems in Central America; and c) to make available, to key people who may have an impact on agricultural sustainability in the region, information on alternate production systems involving farming activities.

The Symposium/Workshop was carried out thanks to funding from the Convenio de Alcance Limitado (Limited Scope Agreement, Ref. 569-0159-023) between the Agency for International Development (USAID) and CATIE, through the Regional Office for Central American Programs (ROCAP, today G-CAP).

The Symposium/Workshop was held in San José, Costa Rica, October 07 to 12, 1991 as "Ganadería y Recursos Naturales en América Central: Estrategias para la Sostenibilidad" (Livestock and Natural Resources: Strategies for Sustainability"). Besides CATIE, the UGIAAF and the Local Support Committee, this activity was organized by the Ministry of Agriculture and Livestock, Costa Rica, the Cooperativa Matadero Nacional de Montecillos (COOPEMONTECILLOS), and the Escuela de la Región del Trópico Húmedo (EARTH, Costa Rica).

Experts participation in the Symposium/Workshop was as numerous as allowed by the available resources; thus, high quality papers were presented by regional and non-regional specialists based on experiences and previous analysis, such as USAID report on strategies "Environment Management and Natural Resources in Central America" published in 1989 and the documents on the USAID supported symposium "Livestock: Development Priorities towards the Year 2000" held in Washington, D.C. in 1989.

This publication, addressed to scientists interested on the topic and to readers in general, includes papers presented by symposium participants and the panelists comments on the workshop final discussion. It also includes the "Principles Declaration" prepared by a commission of expert participants in the Symposium/Workshop, coordinated by Dr. Thomas Yuill (University of Wisconsin) and Dr. Danilo Pezo (CATIE).

CATIE thanks those who made publication of these proceedings possible, and particularly to Dr. Thomas

Yuill from Wisconsin who provided his personal support to this task. I am sure that they will be an important contribution for the future of production systems sustainability, including the animal component, in fragile ecosystems in the American Tropics.

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DIRECTOR GENERAL
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July, 1994

PAPERS PRESENTED AT THE SYMPOSIUM

CURRENT STATUS AND TRENDS IN ANIMAL AGRICULTURE IN CENTRAL AMERICA

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1. INTRODUCTION

In Central America, human pressure on the use of land for animal agriculture activities has increased during the last decade. The growth of the population in the region, the economic difficulties and problems, the international financial situation, and the decrease in the *per capita* production of food have contributed to a great demand across all agricultural fields. The impact has been greater deforestation, greater use of agrochemicals, marginal production on the hillsides, greater erosion on the soil, deterioration of watersheds and water sources. Cattle production has been one of the most criticized activities associated with this destruction. Cortes (1990) argued that "the majority of the studies agree that the main cause for the deforestation in Latin America has been the establishment of cattle ranches.

The purpose of this symposium is to promote the discussion among scientists, agriculturists, and representatives of the industry about this problem, and the confrontation between the livestock production and natural resources in a search for working relations and collaboration between these groups. It is important to find solutions to this problem so that Central America can meet its productive and economic needs and, at the same time, maintain and protect its natural resources, since these are indeed the most important resources for productivity.

To begin this discussion, it is important to establish a common point of reference in discussing the trends in use and production of livestock products in the region. This information will give us a good understanding on the influences that currently affect the land use and operational practices. This is the departure point for any future improvement. The central focus of my discussion will be the natural resources-livestock relationship which is the focus of the symposium. That is not to say that the impacts of agricultural crop production are not important. On the contrary, banana plantations and other non-traditional crops in Costa Rica have now replaced livestock as the sacrificial goat of natural resource destruction.

2. DEMAND AND CONSUMPTION OF LIVESTOCK PRODUCTS

Let us start by discussing the demand and consumption of livestock products given that, at heart, this form of production is merely a business which responds to market influences.

2.1 Trends in Domestic Demand

Demand for livestock products is determined by consumer taste, income level, and population numbers. Any change in these factors over time would cause changes in the level of demand. If we assume that the domestic taste for a product does not change drastically over time[1], then only two factors will determine the trends in the domestic demand: the population growth and the changes in the national income level. Let us consider the trends of these factors during the last decade and the future expectations.

2.2 Population

In 1985, the Central American population was increasing at an average annual rate of 2.8%, compared with 2.3% for the rest of Latin America (Leonard, 1987). With this rate of growth, the Central American population will duplicate in 25 years, from 25.25 million in 1986 to 50.5 million in 2011. If income per individual is maintained at the same level, then the demand for agriculture and livestock products will also duplicate during this time.

2.3 Income

What are the expectations for income, and what impact would it have on the demand in the future? Table 1 shows the trend for *per capita* gross national product in each country of the region, from 1960 to 1984. The gross national product has fallen from 1960 to 1980. Due to the socio-political and economic problems of the region during the last decade, population growth has been greater than income growth. However, since the beginning of the 1990s the economies of the region are on the way to improvement and the opening of world markets benefit the region's economic development. Based on these factors, we can predict that the tendency during the next decade will be a gradual growth in individual income.

Table 1. Individual gross national product (1982 US$)

Country	1960	1970	1980	1984	% change 1980-84
Guatemala	841	1083	1413	1193	-15.0
Belize	ND	ND	1009	1004	- 0.5
El Salvador	610	785	855	708	-17.0
Honduras	536	640	746	663	-11.0
Nicaragua	806	1238	1942	874	-55.0
Costa Rica	957	1313	1756	1565	-11.0
Panama	884	1547	2089	2022	- 3.0

Source: Leonard (1987).

If the individual income in the region grows, what kind of impact will it have on the demand for livestock products? To determine all of this, economists use a measurement called income elasticity. This index simply shows the percentage change in the demand for a product for each percentage increase in family income. Table 2 shows the estimated elasticity in demand for some livestock products in Central America. For example, an elasticity of one implies that for each percentage increase in family income, the amount the family is willing to spend on such a product will increase by an equal amount. The elasticity for meat is, in general, high in Central America, indicating that when family income increases in this region, there will be a substantial increase in consumption of livestock products.

[1]Countries by culture and custom tend to be consumers of certain types of product. In Central America the consumption of meat, poultry, beans, corn and plantain is a part of the culture and any change will occur slowly.

Table 2. Estimated income elasticity in the demand for beef, pork, poultry, and milk

Country	Beef	Pork	Poultry	Milk
Guatemala	0.7	0.6	1.0	0.3
El Salvador	0.8	0.5	1.0	1.0
Honduras	0.8	0.5	1.0	1.0
Nicaragua	0.8	0.5	1.0	0.3
Costa Rica	0.7	0.5	1.0	0.8
Panama	0.7	0.5	1.0	1.0

Source: Jarvis (1986).

During the 1970s, there was a tremendous increase in the demand for livestock products, due to the growth in population and in income. Table 3 shows the trends in demand for fresh milk and beef due to the annual population and *per capita* income growth during the period 1970 to 1981. The increase in demand for these products in the region was estimated to be between 4.0% and 4.2% annually.

Table 3. Annual percentage growth rate in domestic demand of fresh milk and beef: 1970-1981

Country	Milk[1]	Beef[1]
Costa Rica	3.6	4.8
El Salvador	4.1	3.9
Guatemala	2.6	5.2
Honduras	3.6	3.6
Nicaragua	5.6	1.6
Panama	3.7	3.5
Regional total	4.2	4.0

[1] Demand estimated as a function of annual population growth and income.
Source: Jarvis (1986).

In conclusion, it is believed that the trend in domestic demand for livestock products in Central America will continue to increase during the next decade. The continued population growth and the expected increases in *per capita* income, will increase the domestic demand for these products, and will put pressure on the markets that supply them. The demand will have to be met from domestic or from imported sources. An increase in the domestic demand of the 4.0% *per* year, experienced during the period 1970-1981, presents serious implications for the domestic livestock sector and the natural resources if the intent is to meet the demand without importation.

2.4 Status of Consumption of Central American Livestock Products

Meat, particularly beef, is an important product in the Central American diet. The amount of meat consumed *per capita* varies quite a bit between countries, as shown in table 4.

The Honduran does not consume as much meat as the Panamanian. In terms of the kind of meat, beef predominates in all countries. Less than 50% of the total meat consumed is beef in El Salvador, while in Costa Rica more than 70% is beef. These differences reflect differences in income distribution among countries, the comparative value of the meats, the availability of domestic meat and, to a lesser extent, differences in tastes.

The data imply that, unless there are changes in the preference for beef by the consumers or relative price changes for meat, any other increase in the demand for meat in the region, will have serious implications on the consumption and production of beef. This is of great importance since it is beef production that has been implicated in environmental destruction.

Table 4. Distribution of total meat consumption by species: 1975-1977 (percentage)

Country	Consumption[1]	Beef	Pork	Poultry	Fish
Costa Rica	26.6	70.7	12.4	6.0	10.9
El Salvador	13.7	43.1	19.7	16.1	12.4
Guatemala	13.4	63.4	10.4	17.2	4.5
Honduras	12.8	57.0	13.3	25.8	3.9
Nicaragua	35.1	63.2	14.0	8.3	12.3
Panama	42.1	66.7	8.6	13.5	10.5

[1] kg *per capita*.

Source: Jarvis (1986).

3. THE FUTURE OF MEAT EXPORTATION

With the exception of El Salvador and Panama, the Central American countries have been beef exporters, while everyone but Costa Rica are milk importers (Jarvis, 1986). The low consumption of beef in El Salvador and the low production for exportation indicates the shortage of land to support an extensive cattle industry. Beef production in Panama is not enough to meet the high demand and *per capita* consumption, and therefore, there is little surplus for export.

The beef export industry has been an important source of hard currency. The importance of beef exports from the Central American market is presented in table 5. Meat production increased from 1961 to 1980, but has since stabilized. Exportation also increased in the period 1961-1980, but has decreased. This reflects the impact that the social and political problems of the 80's had on the industry. The most recent trend is a reduction in the production of meat for export.

In general, agriculture is the main source for currency exchange in the Central American economy, and beef exportation is one of the most important activities in this respect. Table 6 contains the total percentage of revenues from the exportation of different livestock products for each country in the region (except Belize) for 1982. We note that beef was of great importance to Honduras, Nicaragua and Costa Rica. However, in comparison with coffee, cotton and banana, its importance has decreased. If we compare the change in percentage of revenue from beef exports from 1972 to 1982, it has gradually decreased in some of the countries while remaining stable in others (Table 7). Considering that the volume of exported meat has decreased in the region since 1982, and other agricultural activities have increased in importance in the exportation markets (non-traditional exports), we can conclude that the production of beef for export makes a very limited contribution to the generation of currency.

Table 5. Production and exports of meat in Central America: 1960-1984 (thousands of metric tons)

Years	Total production	Exports	% exported
1961-65	153	34	22
1966-70	198	75	38
1971-75	287	119	41
1976-80	363	138	38
1981	355	101	28
1982	353	91	26
1983	336	79	24
1984	341	80	23

Source: Leonard (1987).

Table 6. Percentage income from exports of agricultural commodities in 1982

Commodity	Guatem.	El Salvador	Honduras	Nicarag.	Costa Rica	Panama
Meat	2.8	0.5	5.2	7.7	6.7	1.2
Bananas	3.7	—	35.0	7.5	23.4	17.7
Sugar	1.5	2.1	3.8	3.5	1.7	6.4
Coffee	30.8	57.7	23.5	30.3	27.2	3.3
Cotton	6.6	6.4	1.0	20.6	—	—
Total	45.5	66.7	68.8	69.6	59.8	28.6

Source: Leonard (1987).

Table 7. Percentage of income from meat exports

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
1972-76	3.4	0.9	6.7	9.3	7.7	1.2
1977-81	2.3	0.6	6.6	10.5	7.1	0.8
1982	2.8	0.5	5.2	7.7	6.7	1.2

Source: Leonard (1987).

If the sociopolitic conditions for exportation were to change in favor of beef production, what would it be its economic potential as generator of currency? A measurement of this potential, of importance for decisions on the use of the natural resources, is the amount of currency exchange generated per unit of land dedicated to livestock production in comparison with other agricultural activities. Table 8 shows the amount of land dedicated to different export generating activities in 1980, in different countries of the region. It is notable that the amount of land used for animal production considerably exceeds that used for other activities.

Table 8. **Land area used for agricultural exports in 1980 (km^2)**

	Guatemala	Honduras	Nicaragua	Costa Rica
Meat	8,700	34,000	34,200	15,580
Sugar	740	750	410	480
Cotton	1,220	130	1,740	—
Coffee	2,480	1,300	850	810
Bananas	NA[1]	NA	NA	280

[1] NA = not available

Source: Leonard (1987).

Table 9 shows the foreign exchange generated by the exportation of different products per square kilometer dedicated to each activity. The foreign exchange generated by the exportation of bananas, coffee, cotton, and even sugar, contrasts with the low offtake from beef production. We conclude that extensive beef production as a generator of foreign exchange is an inefficient user of land. Cattle production cannot be justified if there is an alternative land use of greater value, which is the case in most of Central America (Leonard, 1987).

Table 9. **Exportation income *per* square kilometer dedicated to different agricultural products in 1980 (millions of US$)**

	Guatemala	Honduras	Nicaragua	Costa Rica
Meat	47	17	19	41
Sugar	722	NA	478	770
Cotton	1,577	NA	850	—
Coffee	1,745	1,514	2,348	3,111
Banana	NA	NA	NA	6,035

[1] NA = not available Source: Leonard (1987)

In conclusion, beef production for the export market is decreasing in importance. In comparison with other agricultural activities, beef production is an inefficient form of land use for hard currency generation. For this reason, beef production for export should not receive political support in the future, thus reducing the pressure to open more land to increase livestock production.

4. TRENDS IN THE PRODUCTION OF MEAT AND MILK

We have noted that the demand for animal products will tend to increase in the future, as population grows and *per capita* income increases. We must now evaluate the capacity of the Central American countries to respond to this demand.

The total production of meat and milk depends on the total number of animals dedicated to this activity as well as on the productivity per animal. In other words, the number of hectares in pasture, the stocking rate (number of animals per hectare) and the productivity of the animals. Each one of these factors influences the possibilities of producing milk or meat. In order to determine the potential of the Central American livestock industry to respond to growth in domestic demand, each of these factors must be evaluated.

4.1 Animal Population

Livestock population for 1965 and 1984 is shown in table 10. In this period the number of animals increased by 164 percent. This increase was observed in all the countries of the region, except in El Salvador.

Table 11 contains the number of milk and meat producing livestock for the period 1979-81 and for 1986, 1987 and 1988. During the decade of the 80s the number of cattle has increased in all the countries of the region, except El Salvador and Nicaragua, countries that have been devastated by war. In Honduras there has been a remarkable increase, while Guatemala, Costa Rica and Panama have experienced little change. The changes are less marked for dairy cattle, except for the reduction in Nicaragua and El Salvador.

Table 10. Change in the livestock population in Central America (thousands of heads)

Country	1965	1984	% change
Costa Rica	1,216	2,605	114.0
El Salvador	1,158	908	-22.0
Guatemala	1,447	2,700	86.6
Honduras	1,672	2,000	19.6
Nicaragua	1,074	2,550	137.4
Panama	860	1,452	68.8
Regional total	7,427	12,215	

Source: Leonard (1987).

Table 11. Number of beef and dairy animals in Central America (thousands of heads)

	Country	1979-81	1986	1987	1989
Beef cattle	Guatemala	1886	2160	2151	2140
	El Salvador	1234	1050	1088	1144
	Honduras	1980	2803	2859	2824
	Nicaragua	2373	2100	1710	1700
	Costa Rica	2183	2329	2345	2190
	Panama	1425	1430	1410	1502
Dairy cattle	Guatemala	360	400	400	400
	El Salvador	289	240	254	258
	Honduras	416	324	333	333
	Nicaragua	283	200	200	180
	Costa Rica	298	291	300	310
	Panama	95	105	107	109

Source: FAO (1989).

The area dedicated to pastures changed little during 1966-1970 and 1976-1980 (Table 12). Except for an increase of 26% in Costa Rica and a reduction of 8.9% in Guatemala, there has been little change in the areas under permanent pasture. Although no data was found for the 1980's, we assume that the socio-political situation in the region, particularly the military activities in Nicaragua and El Salvador, have made it unlikely that the areas under pasture have increased in these countries; more likely they have decreased. Honduras may have been the only exception, given the sharp increase in beef cattle numbers.

Table 12. Area dedicated to permanent pastures (1966-1980)[1] and stocking rate (1980)[2]

	Thousands of hectares			Stocking
Country	1966-70	1976-80	% change	rate
Guatemala	1,239	1,558	26.0	1.90
El Salvador	610	610	0.0	2.36
Honduras	964	880	-8.9	0.65
Nicaragua	3,400	3,400	0.0	0.70
Costa Rica	3,384	3,394	0.2	1.40
Panama	1,018	1,101	2.0	1.31
Region	10,678	11,003	2.9	1.03

[1] Source: Jarvis (1986).

[2] Source: Leonard (1987)

4.2 Stocking Rate

Stocking rate is an index that indicates the number of animals that a hectare of pasture can support under the conditions of the region. The greater the number of animals a unit of land can support, the less hectares which must be dedicated to meet national demand. The stocking rate for each one of the countries in the region, during 1980, is also shown in Table 12. The average for the region is 1.03, which is very low. There is variation within the region which reflects the conditions in each one of the countries. The indices for Honduras and Nicaragua are very low, while El Salvador has the highest index, reflecting the limited availability of land in EL Salvador and the need to reach higher stocking rates to meet national demand. El Salvador cannot afford the luxury of extensive livestock production.

In general, the stocking rate has not changed much since 1980. This implies a great pressure for additional land and natural resources in order to meet demand. If the stocking rate cannot be increased, the only way to increase production is to dedicate more land to pasture or to raise the productivity per animal, or both.

4.3 Animal Productivity

Productivity per animal allows us to determine the technological level and the potential for increasing production. Table 13 shows the change in beef and milk production per animal from the period 1966-70 to 1981. In the case of beef, the production per head has increased in the region. Although positive, this represents an annual increase of less than 2%, far less than the increase in demand during the same period. In addition, in some countries there is no growth In the case of milk, the rate of growth of production per animal has varied considerable within the region, from a negative growth of 0.92% in Nicaragua to a positive growth of

2.35% in El Salvador. Once again, in the case of El Salvador this reflects the pressure on land in this country. In general, we can conclude that there has been little improvement in the production of milk per animal.

Table 13. Average production of meat and milk (kg/head) in 1966-1981

	Production *per* head Country	Rate of 1966-70	1981	change, %
Meat				
	Costa Rica	26.1	35.2	3.63
	El Salvador	15.8	23.0	2.80
	Guatemala	37.1	54.7	2.69
	Honduras	16.6	22.0	3.33
	Nicaragua	22.1	15.7	0.31
	Panama	28.0	25.4	-0.01
	Region	24.1	28.9	2.19
Milk				
	Costa Rica	947.3	1,047.4	0.90
	El Salvador	760.3	995.0	2.35
	Guatemala	907.3	897.6	-0.07
	Honduras	532.4	579.5	0.93
	Nicaragua	1,003.2	950.5	-0.92
	Panama	955.7	983.4	0.37
	Region	832.7	894.4	0.60

Source: Jarvis (1986).

Table 14 shows the change in milk production *per* animal during the decade of the eighties. In general, there has been an increase, with the exception of Nicaragua. Nevertheless the increases have not been significant except in the case of Honduras, which has made marked progress to attain the production levels of the rest of the region. Only Nicaragua remains significantly behind, with an index of milk production *per* animal of less than half that of Costa Rica.

Table 14. Average milk production *per* animal in Central America (kg/animal) in 1979-1988

Country	1979-81	1986	1987	1988
Guatemala	885	910	915	915
El Salvador	925	966	988	969
Honduras	652	801	886	889
Nicaragua	767	625	625	556
Costa Rica	1067	1424	1367	1339
Panama	988	1059	1078	1000

Source: FAO (1989).

In summary, there has been little growth in the number of animals in production in the region, little change in the area dedicated to pasture, a slight increase in the production of beef per animal, and little change in milk production per animal. The trends have serious implications for beef and milk production in the region. If there is not an improvement in the intensity of use of land and production per animal, the only way to increase production in the future will be to increase the area dedicated to pastures. In addition, this will be in competition with agricultural activities which potentially have a better profitability, so that small and marginal producers will have serious conflicts in the use of natural resources or forest.

5. ANIMAL PRODUCTION SYSTEMS IN CENTRAL AMERICA

There are three main cattle production systems in Central America: beef production, milk production and dual purpose. The tendency in distribution of animal numbers between these systems indicates the relative importance of each of the systems for the region and how their relative importance is changing. Table 15 shows some data from Costa Rica; it contains the distribution of female cattle between the three main production systems for the years 1982 and 1988, indicating that beef production predominates with more than 50% of the total in both years. When the total number of heads is considered, 64% of the cattle are beef animals, 22% dairy animals, and 14% dual purpose cattle (MAG, 1989). The data in table 15 also shows that the distribution between systems is changing over time, with an important shift from beef to dual purpose production.

Table 15. Distribution of female cattle in the main production systems in Costa Rica

	Beef		Milk		Dual purpose		Total
Year	No.	%	No.	%	No.	%	females
1982	1052.3	68.7	255.2	16.8	222.3	14.5	1529.8
1988	845.9	56.7	277.0	18.6	369.3	24.7	1492.2

Source: MAG (1989)

This situation, observed in Costa Rica, is probably not very different from the rest of the region. While the profitability and the markets for beef have decreased, so has the level of investment in this activity. Nevertheless, the beef production system still predominates with respect to the capital investment in animals.

5.1 Characteristics of the Beef Production Systems

There are fundamental differences in the size and management of the production systems throughout Latin America. Although there are small producers of beef cattle, the majority is characterized by the use of medium to large extensions of land. Leonard (1987) reports that the areas of land dedicated to beef production vary between 40 hectares and thousands of hectares. The management of beef production systems in Central America is, in general, extensive or semi-extensive.

Jarvis (1986) describes the production systems found in South America, in 1968, based on data collected by Von Oven. With the observation that the information is old, the descriptions still apply to the systems found today.

Beef production in Latin America is characterized by low technology. The stocking rate is on average one animal unit per hectare, similar to that found in Central America. Land itself represents at least 50% of the investment and the animals 40%. The use of various inputs is low; labor use is scarce and in general very little management is applied.

This is very similar to what Leonard (1987) reported for Central America. The main source of feed for the animals is pasture with very little supplementation; forage legumes are not grown in the region, in spite of research showing that productivity can be improved this way. In addition, in areas which have recently been in forest, there has been a tendency not to use improved pastures, but to leave the native grasses. This can explain the low stocking rates observed in Nicaragua and Honduras (0.65 and 0.70, respectively) in contrast with El Salvador (2.36).

In order to draw conclusions and make recommendations one has to analyze the factors which have influenced the decision to have extensive livestock with low technology. Various factors are surely important at explaining the situation. Distance from markets, lack of technologic information, and probably a lack of incentives to invest in improvement of the system are among the most important ones.

In this system, the return on investment is low, especially when compared with other agricultural activities. Jarvis (1986) reports a real rate of return of 3-4% for 1968. This is above the rate of inflation. For Belize, Leonard (1987) reports an annual rate of return on investment of between 3% and 4%, before adjustment for inflation, during the 70s and 80s.

In general, we can conclude that the management of extensive livestock systems is one of low productivity in the region. It is necessary to intensify the system, increase the investment in alternative feed sources and increase the managerial level. This will allow an increase in production to meet national needs, without an increase in the total area dedicated to pasture. In addition, such changes could have a positive impact on the economic development of the region. Intensification of the production system requires a greater input of labor and of agricultural commodities. Increasing the demand for these production components would spur local economies.

5.2 Characteristics of Milk Production Systems in Costa Rica

Dairy production systems of Central America have relatively uniform characteristics. Given the lack of information on other systems, we will comment only on the Costa Rican situation. Table 16 shows the distribution by size of dairy farms in 1984. In contrast to beef, most operations are small (less than 20 hectares), and only 6.7% exceed 100 hectares.

Table 16. Size of dairy farms in Costa Rica in 1984

Farm size	Number of farms	%
Less than 20 hectares	10,136	70.2
20-50 hectares	2,276	15.8
50-100 hectares	1,053	7.3
100-200 hectares	560	3.9
Over 200 hectares	407	2.8
Total farms	14,432	

Source: MAG (1984).

Specialized milk production in Costa Rica is done in essentially two regions: highlands and lowlands. In the highlands dairying is done around the volcanic central mountains of the country, generally over 1130 meters above sea level. It is characterized by highly technified operations, using breeds such as Holstein and Jersey. Average production is between 3,500 and 6,000 kg per lactation. The animals are fed on improved pastures and supplemented with concentrates. The producers are specialized in milk production and obtain between 90 and 95% of their income from this activity.

Milk production in the lowlands is carried out between 130 and 900 meters above sea level. The technological level is less than that used in the highlands. The animals used are mostly improved and have a production of between 1,900 and 2,500 kg per lactation. Improved pastures are used but with a lesser degree of supplementation. The producers, although specialists in dairy production, have other activities and obtain 70-85% of their income from milk.

5.3 Characteristics of the Dual Purpose System in Costa Rica

Table 17 shows the distribution of dual purpose farms according to size.

Table 17. Size of dual purpose farms in Costa Rica in 1984

Farm size	Number of farms	%
Less than 20 hectares	12,079	64.4
20-50 hectares	3,784	20.2
50-100 hectares	1,585	8.4
100-200 hectares	737	3.9
Over 200 hectares	583	3.1
Total farms	18,768	

Source: MAG (1984).

As in the case of the specialized dairy producers, the majority of dual purpose producers have small land areas. The dual purpose system is characterized by a technology level midway between the dairy producers and the extensive and semi-extensive beef producers. Production takes place in the lowlands, below 900 meters. Animals used are crossbreds of zebu and specialized dairy breeds (Holstein or Brown Swiss). Average milk production is low, between 420 and 1,200 kg per lactation. Improved pastures are used as well as native pastures, but there is no supplementation. Although some income is received from milk production, between 45% and 55 % of the total income is derived from he sale of animals. The dual purpose system is one of low technology in milk production, but the beef component generates good family income. It is a special system, well adapted to the lowlands, but located far from milk collection centers.

6. CONCLUSIONS

Livestock production in Central America is undergoing change and restructuring. Domestic demand for products continues to rise due to population growth and the promise of improvements in the economy. While the countries are net importers of milk, in general they continue to export beef, although this industry is decreasing in importance.

In order to meet the needs of the population, the region will have to increase its production. There are two ways of achieving this: increasing the land area under pasture or increasing the productivity of the land already under pasture. The first approach will cause conflict with other land uses, particularly crop agriculture and forests. There are various factors and arguments against this option; first, the increase in profitability of agricultural activities such as banana and the cultivation of non traditional crops has increased the demand for land most suited to these activities. Much of this land is currently under pastures.

Another factor is the pressure that comes from the concern for adequate use of natural resources. On one hand there is significant pressure from ecological groups, both inside and outside the region, to stop the deforestation produced by livestock production (or by agricultural activities such as banana). On the other hand, the increasing demand for forest products and the continued increase in deforestation at the world level leads us to predict an increased profitability of these products. The competition from alternative land uses will lead to an increase in the value of land which has alternative uses. The land value should reflect the difference in potential profitability.

For these reasons the increase in livestock production in Central America will tend to come in the form of increases in productivity. There will have to be an increase in the intensification of beef production, with a shift to improved feeding to make feed conversion and weight gain more efficient. This can be done using improved pastures, fertilizers, legume forages and supplements. This will allow an increase in stocking rate and in productivity per animal. Included in the sustainable options is the use of tree legumes and silvopastoral techniques.

Livestock activity in the region will have to change and improve if it is to survive the coming changes. The liberation of markets and the emphasis on comparative advantages by the leaders of the region, mean that the Central American livestock industry will find itself totally displaced if it does not increase its productivity and profitability.

Acknowledgments

I would like to thank the following persons for their valuable contribution and support in the collection of data for this document: Ing. Luis Villegas, Dairy Development Program Director, MAG, Costa Rica; Ing. Jorge Celso Rodriguez, Dr. Carlos Burgos and Ing. Carlos Murillo, Professors at Escuela de Agricultura de la Regi¢n Tropical H£meda (EARTH). I also would like to thank Dr. Richard Taylor of EARTH, for his valuable comments and revision of the final document.

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CURRENT STATUS AND TRENDS IN THE UTILIZATION OF NATURAL RESOURCES IN CENTRAL AMERICA

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1. INTRODUCTION

Some of the topics which will be discussed in this presentation may seem repetitive of the presentation by Dr. James French; some of the tables I will present will contain similar information. Nevertheless, I am going to analyze them from a different perspective: that of the demands made on natural resources and the impact they have on degradation.

2. DEMOGRAPHIC FACTORS AND THE USE OF LAND RESOURCES

The rate of growth of the Central American population (Table 1) is one of the highest in the world. Nevertheless, it is interesting to note that these rates are higher in those countries of the region which have the greatest concentration of population. This means that the demands on the natural resource base are not only high, but are also going to increase as a consequence of this population growth. When this is related to the land resources (a fixed resource, as we cannot create land) we can translate this into population density (Table 2). The figures for Central America are dramatic; the number of inhabitants per square kilometer of cultivated land are as high as those observed in the European countries, that have an extremely high population density but higher levels of agricultural productivity. In contrast, in the case of Central America, we have obviously a very different situation; a very low productive capacity of the soils. This is further complicated when we analyze the distribution of the lands in Central America in terms of tenure. In Central America we note three categories or types of property: multifamily farms, family, and subfamily farms. This follows the characterization made by organizations such as CEPAL, which defines the family unit as that which has the capacity to produce sufficient to meet the nutritional requirements of one family; the multifamily unit is the one that has larger capacity, and permits the sale or commercialization, and even export, of products from the agriculture unit. Obviously, the subfamily units are those which cannot supply food security for even one family.

Table 1. Demographic profile in Central America

Country/ Region	Population 1986 (miles)	Natural annual growth, %	Years to duplicate population[1]	Projected population to year 2000 (1000s)	Projected population to year 2020 (1000s)[2]	Percentage of pop. under 15/ above 64 year
Guatemala	8600	3.1	22	13100	19700	45/3
Belize[3]	159	2.5	28	220	370	44/4
El Salvador	5100	2.4	29	7500	12400	45/3
Honduras	4600	3.2	22	6800	12200	48/3
Nicaragua	3300	3.4	20	5200	7800	48/3
Costa Rica	2700	2.6	27	3600	4800	35/3
Panama	2200	2.1	33	2900	3500	39.4
Central America	26659	2.8[4]	26	39320	60770	44/3[4]
Latin America	419000	2.3	30	563000	752000	38/4
Developing countries	3762000	2.0	34	4893000	6409000	39/4
World total	4942000	1.7	41	6157000	7760000	35/

[1] At the present rate of growth.

[2] From the 1985 world population information sheet prepared by Population Reference Bureau.

[3] Estimations for Belize for 1986, 2000 and 2020 come from the Belize Government.

[4] Calculated from the Population Reference Bureau's 1985 world population information sheet.

Source: Population Reference Bureau (1986).

Table 2. Population and land in Central America

Country	Surface[1] km^2	Population in 1986 (miles)	Population per km^2	Cultivated land[2] km^2	Cultivated land %	Population per km^2 of cultivated land
Guatemala	108430	8600	79	18340	17	469
Belize	22800	159	7	520	3	306
El Salvador	20720	5100	246	7250	35	703
Honduras	111890	4600	41	17570	16	262
Nicaragua	118750	3300	28	15160	13	218
Costa Rica	50660	2700	53	4900	10	551
Panama	75990	2200	29	5740	8	383

[1] Does not include large lakes or continental rivers.

[2] Land presently under cultivation on an annual basis, under fallow or perennial crops. It does not include grasslands.

Sources: Land figures come from FAO; population figures come from Population Reference Bureau.

Table 3 shows the distribution of land in multifamily and subfamily units within the different countries of the Central American region. The first ones represent 10.6% of the population of farms, covering 71% of the area. On the other hand, the subfamily farms represent 69.2% of the total number of farms but make up only 11.8% of the area. This is evidence of the high concentration in land tenure.

Table 3. Structure of land tenure in Central America[1]

	Agricultural units					
	Multifamily		Family		Sub-family	
	% farms	% area	% farms	% area	% farms	% area
Guatemala	2	72	10	14	88	14
El Salvador	2	50	6	23	92	27
Honduras	5	60	26	28	69	12
Nicaragua	22	85	27	11	51	4
Costa Rica	22	88	32	10	46	2

Source: Lassen (1980).

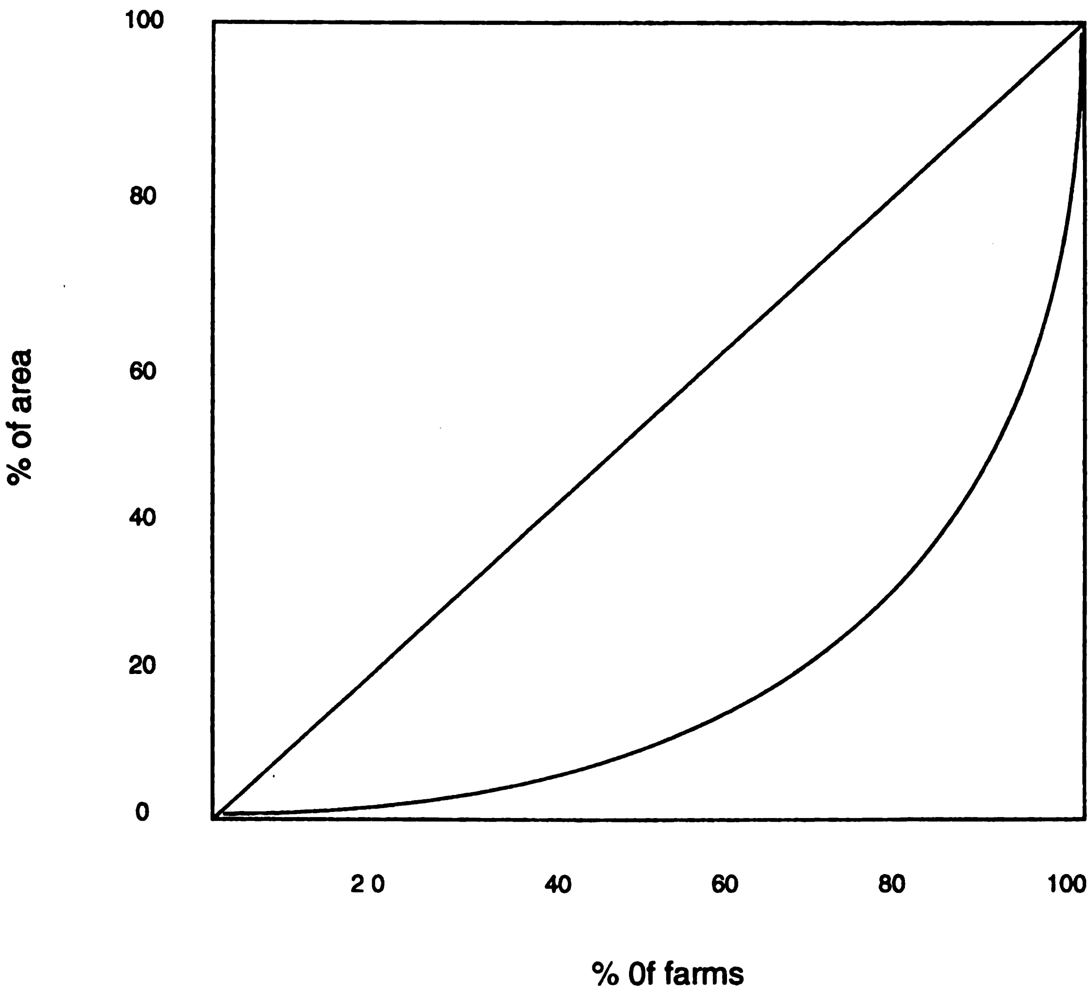
Another way of viewing this is through the use of indicators of concentration, such as the GINI index shown in figure 1, in which the x-axis presents the percentage of farms and the y-axis the percentage of area covered. To interpret this index one must consider whether it approximates zero, which indicates minimum concentration, or whether it is closer to 1, which indicates maximum concentration. In the case of Central America in 1963, and with few differences in the 1970s, the GINI index was approximately 0.8, indicating an enormous concentration in land tenure.

3. LIVESTOCK PRODUCTION AND THE USE OF LAND RESOURCES

The production of beef cattle is a very important activity in the Central American region. In the period between 1964 and 1973, there was a great upsurge in world prices for export beef, particularly in the case of Central America; this favored an important increase in this activity in the region (Table 4). This upsurge was coincident with a number of financial, credit, and subsidy incentives, and a series of conditions given by the governments of Central America to the activity during this period. Livestock agriculture became very important for the generation of hard currency in the region.

One aspect which must be analyzed is how much the value of the land represents relative to the total investment in the livestock activity. Table 5, shows the specific case of Honduras, although we can consider that the variations between production systems are relatively minor within Central America. We note that land value

Fig. 1 Land distribution among farms: Central America



(Must range betwen 0 y 1. The closer tozero, the more equitable the sitribution. The closer to one, the more concentrated the distribution).

Table 4. Beef: Actual export actual prices for Central America and Argentina, and Australian domestic prices. 1954-1984

Year	Central America	— Argentina — Series A	Series B	Australia
1954	269.1	187.8	NA	143.1
1955	250.8	182.9	NA	125.4
1956	221.7	155.4	NA	117.1
1957	228.6	159.9	NA	121.9
1958	229.9	150.7	NA	135.6
1959	267.4	163.3	NA	176.7
1960	267.0	154.4	165.7	183.3
1961	245.3	149.6	148.2	157.6
1962	260.6	121.5	146.6	140.9
1963	242.6	129.8	146.0	157.1
1964	298.2	202.1	211.6	170.9
1965	310.6	256.3	229.1	190.1
1966	340.7	220.7	189.7	201.0
1967	342.4	190.5	174.5	207.6
1968	380.7	179.0	210.9	228.4
1969	424.7	161.4	193.4	228.8
1970	422.7	177.6	229.7	223.7
1971	391.3	233.7	261.7	216.3
1972	392.6	275.3	287.2	218.8
1973	446.9	315.8	358.5	266.9
1974	280.5	262.8	351.2	137.9
1975	207.0	122.5	128.2	68.1
1976	242.1	125.7	138.4	95.1
1977	213.3	134.6	168.0	80.3
1978	257.6	115.3	140.1	93.4
1979	308.1	192.7	213.7	180.4
1980	276.0	219.2	201.3	168.5
1981	258.4	196.4	221.3	148.0
1982	254.0	158.8	NA	128.0
1983	267.3	158.4	NA	171.0
1984	264.5	193.0	NA	184.0

NA = Not available.

Source: Jarvis (1986).

constitutes 49.2% of the investment, the fixed capital is 8.4%, and the operating capital is 34.6%, while the labor force makes up less than 8% of the investment in the livestock enterprise as an average over the different strata. Nevertheless, the key question is what importance does this have with respect to natural resources. The response is simple; with the upsurge in livestock throughout Central America, there was an increase in the areas under pasture.

Table 5. Distribution of investment (% of total) in livestock farms of different sizes

Strata (heads)	Zone	Land value	Fixed capital	Operational capital	Labor force
10-29	I	52.4	16.4	26.4	4.9
	II	53.6	15.8	25.5	5.1
	III	46.0	20.9	26.7	6.4
	IV	40.4	23.7	28.6	7.3
	V	41.7	21.3	30.3	6.7
Average		47.7	19.1	27.3	5.9
30-99	I	53.1	9.6	31.1	6.2
	II	50.7	10.6	31.4	7.3
	III	48.4	11.4	32.0	8.1
	IV	43.5	13.4	34.0	9.2
	V	35.0	12.7	41.9	10.4
Average		47.3	11.3	33.5	8.0
100-299	I	45.1	9.6	37.7	7.6
	II	48.5	7.2	36.7	7.6
	III	54.5	7.3	30.8	7.4
	IV	50.5	8.7	32.5	8.3
	V	46.4	9.5	35.4	8.7
Average		49.2	8.4	34.6	7.9

On the other hand, given the structure of land tenure previously noted, combined with the value of the low cost of labor within extensive livestock productions systems, it follows that the presence of extensive cattle enterprises in the lowlands has displaced the human population to the hillsides, where indeed we see the greatest concentration of population in Central America. This displacement of the labor force for ranching is a consequence of the low demand that the activity has for labor, compared to other agricultural activities (Table 6).

When we analyze the trends in land use, we note that in the period of the 1960-80s the forested areas have diminished by 32%. If we compare this with the total area of forests in Central America destroyed since the discovery of the Americas, we note that the last forty years have seen the deforestation of two-thirds of Central America. Coincidentally, in the period 1960-1980 there have been more significant increases in pasture areas (49%) than in the area dedicated to crops (18%), as shown in table 7.

Table 6. Labor employment in different agricultural activities during the 70s

Activities	Man-days/ha/yr
Tobacco	482.6
Bananas (technified)	390.0
Coffee	202.0
Sugar cane	99.0
Plantain	83.2
Cotton	76.7
Corn	73.1
Common beans	63.1
Sorghum	61.7
Sesame	43.0
Rice	22.9
Cattle	6.3

Source: Adapted from Aguilar *et al.* (1980).

Table 7. Main changes in land use in Central America: 1960-1970-1980

		1960			1970			1980		
		Forest	Grassland	Crops[1]	Forest	Grassland	Crops	Forest	Grassland	Crops
Guatemala	km^2	84000	10390	15000	51000	9380	15430	45500	8700	18340
	%	77	10	4	47	9	14	42	8	17
Belize	km^2	NA	NA	NA	10470	370	450	10120	440	520
	%	NA	NA	NA	46	1	2	44	2	3
El Salvad.	km^2	2300	6060	6300	1800	6100	6340	1400	6100	7250
	%	1	29	32	9	29	31	7	29	35
Honduras	km^2	71000	20265	14500	48800	34000	15380	40600	34000	17570
	%	63	18	13	44	30	14	36	30	16
Nicaragua	km^2	64320	17100	13000	56200	33840	14350	44800	34200	15160
	%	54	14	10	47	28	12	38	29	13
Costa Rica	km^2	28480	9690	4800	25670	13510	4930	18300	15580	4900
	%	56	19	9	51	27	10	36	31	10
Panama	km^2	44000	8990	5250	44700	11380	5440	41700	11610	5740
	%	59	12	7	59	15	7	55	15	8
Total	km^2	294100	74295	58850	238640	108580	62320	202420	110630	69480
	%	61	15	11	47	21	12	40	22	13

NA = Not available

1 Estimated

Source: FAO

4. PROBLEMS OF THE STEEP SLOPES OF CENTRAL AMERICA

The steep hillside areas occupy the majority of the Central American territory (Table 8), and support the majority of the population of the region. But if one considers the capacity of use of these soils, one notes that 66% of the area has hillside soils which can be characterized as poor and/or superficial (Table 9). This obviously indicates that the productivity is low. Therefore, it is no surprise to see the majority of the rural population living in poverty. Those who have land, which is not necessarily the majority of the population in Central America, do have some options for production, but their options for food security are few.

Table 8. Percentage of steep hillside areas in Central America

Country	Total area km^2	Steep hillsides and highlands, km^2	Percent of total area
Guatemala	108889	89433	82
Belize	22965	7423	32
El Salvador	20877	19758	95
Honduras	112088	92450	82
Nicaragua	140746	105756	75
Costa Rica	50700	37233	73
Panama	77060	58565	76

Source: Posner *et al.* (1984); figures for Belize were estimated from information contained in Belize II, Table IV-5

Table 9. Soil fertility of hillside lands in Central America

		— Percent of soils —		
Country	Area as hillsides, km^2	good and deep	poor and deep	superficial
Nicaragua	105756	20	56	24
Honduras	92450	31	21	48
Guatemala	89433	35	14	51
Panama	58565	37	51	12
Costa Rica	37233	50	21	29
El Salvador	19758	76	12	12
Belize	7423	31	7	62
Total region	410618	34	32	34

Source: Posner *et al.* (1984); figures for Belize were estimated from information contained in Belize II, Table IV-5

5. LAND USE CAPACITY

According to land use capacity, a large proportion of Central America should be under forest cover (Table 10); the proportion of land with a capability for use in intensive annual crops is small, and only a slightly greater percentage is apt for limited annual cropping, perennial crops or pasture, or for associated perennials and forest plantations.

Table 10. Land use capacity in Central America[1]

	Agriculture[2]				
	IAC	LAC, PC, P	APC, FP	Production forests	Conservation forests
Guatemala	4	22	21	37	14
Belize	16	23	15	27	19
El Salvador	24	8	30	28	28
Honduras	11	9	13	66	66
Nicaragua	4	9	35	52	52
Costa Rica	19	9	16	32	24
Panama	9	20	6	43	18

[1] Percent of land; total may not add up to 100 per cent.

[2] IAC = intensive annual crops; LAC = limited annual crops; PC = perennial crops; P = pastures; APC = associated perennial crops; FP = forest plantations.

Source: Individual Country Profiles.

It is not simple to change traditional agricultural systems and culture of the region, unless changes are first made to policies, incentives and subsidies, to favor the creation of sustainable production systems based on the use of crops and/or livestock associated with trees. Otherwise it is not possible to significantly increase food security in a sustainable manner for our rural population.

6. PRODUCTIVITY OF AGRICULTURAL SYSTEMS

The trends in productivity of agricultural production systems are a function of the year taken as the baseline. For example, in Dr. French's presentation, we noted a small upsurge in productivity in recent years, but I believe that the baseline year he used was the early 1960s; if we use 1974-1976 as the baseline the period, as shown in figure 2, there has been a significant decrease in average production throughout the region. If one analyzes the statistics for the latter part of the 1980s, we can see that there has been a small increase which is basically due to the increase in intensive cropping under irrigation, particularly non-traditional crops. These have acquired great importance for the Central American countries, but most of all in Guatemala, Honduras and Costa Rica.

This small increase arises from increased cultivation of soils which are not necessarily the most suitable for this purpose. By way of example, we can consider the production of melons in Choluteca (Honduras), where the high intensity of use of agrochemicals, both fertilizers and pesticides, as well as the inefficient use of irrigation is resulting in environmental problems such as salinization of the land and the contamination of the mangroves in the Gulf of Fonseca. Therefore, increases in productivity are not necessarily synonymous of improvement in production, if we also add the adjective "sustainable", although there may be a temporary increase in production.

7. THE DESTRUCTION OF NATURAL RESOURCES

The low fertility and superficiality of a high proportion of the soils of the region result in problems of low productivity in the agricultural systems; therefore, it is not surprising that the percentage of the rural population living in poverty is so significant. The country with least rural poverty is Costa Rica (Table 11), where it is estimated that 40% of the rural population is in absolute poverty. The highest value (77%) is in Honduras.

Table 11. Labor productivity and poverty in the agricultural sector

Country	Relative productivity index of agricultural labor force (average for the economy = 100) 1960	1980	Percentage of the rural population under absolute poverty
Guatemala	45	45	60
Belize	NA	NA	NA
El Salvador	52	54	70
Honduras	53	49	77
Nicaragua	39	53	57
Costa Rica	51	59	40
Panama	45	37	55

[1] Includes crops, livestock, forestry and fishery activities.

NA = Not available.

Source: AID Brief v.1, Table 18. Estimations on rural poverty were supplied by the Center for Food and Development Policy.

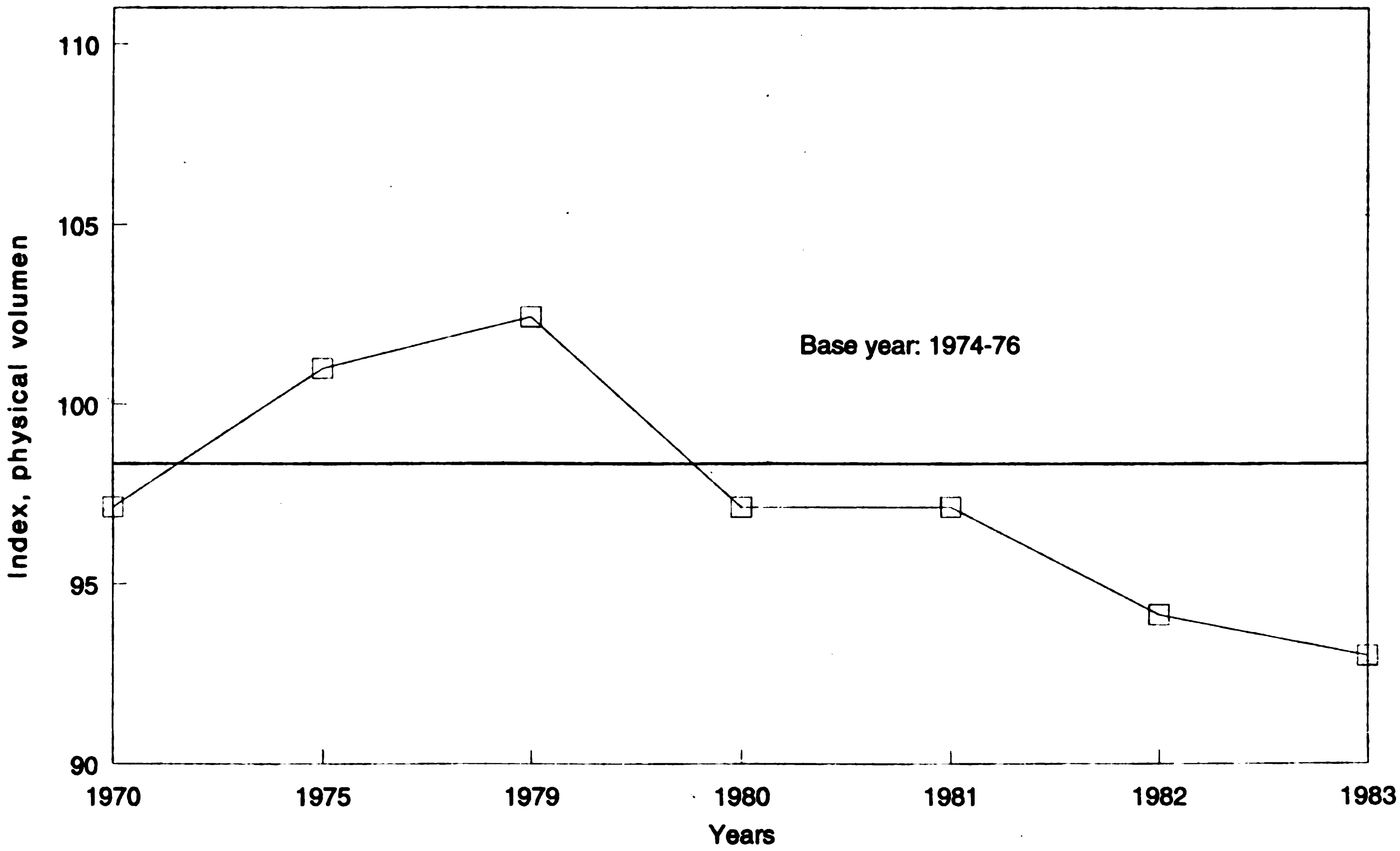


Fig. 2 Per capita food production in Centroamérica.

Source: Gallardo, M.E.; López, J.R. Centroamérica, la Crisis en Cifras. IICA, FLASCO. 1986.

Combined with the facts that a great majority of the population is found in areas of hillside, that the majority does not have access to land, and that a proportion of those with land barely achieve subsistence, it is obvious that just for survival they are forced to destroy the very base of the natural resources. This paints a dangerous picture, for if no action is taken to resolve the problem of natural resources destruction, not only will there be enormous social problems but also the options for development in the future will be reduced day by day.

The rate of erosion is increasing. For example, in the watershed of the Aceguate River, El Salvador, it is estimated that the annual loss of soil is more than two hundred tons per hectare per year, a figure not uncommonly found in other countries. What is more, the options for current development are starting to disappear. Take the following case in Western Honduras: 55 million dollars were invested in a dam, which was expected to have a useful life expectancy and return on investment of 25 years; this dam was only in production for three years due to the total silting of the reservoir, resulting from the natural resource loss in the upper parts of the watershed.

Statistics in table 12 show the size of the problem of erosion in the soils of the region, which is attributed to poor management of areas under pasture and annual crops, and to a lesser degree under perennial crops. Hence, it is important that this symposium yields specific recommendations for the improvement of the sustainability of the soil resources in different schemes of livestock production in Central America; and not only this, but that there be discussion of some incentives, policies and aspects of the legal framework which will permit the reversion of this process.

Table 12. Percentage of lands severely eroded[1] or degraded[2] in Central America

Country	Percentage	Year
El Salvador	45	1972
Guatemala	25-35	Estimated
Panama	17	1980
Costa Rica	17	1981
Honduras	7	1977
Nicaragua	5-10	Estimated
Belize	1	Estimated

[1] severely eroded: mountainous lands with small gullies and furrows, with occasional land-slides, limiting its use for pastures and crops.

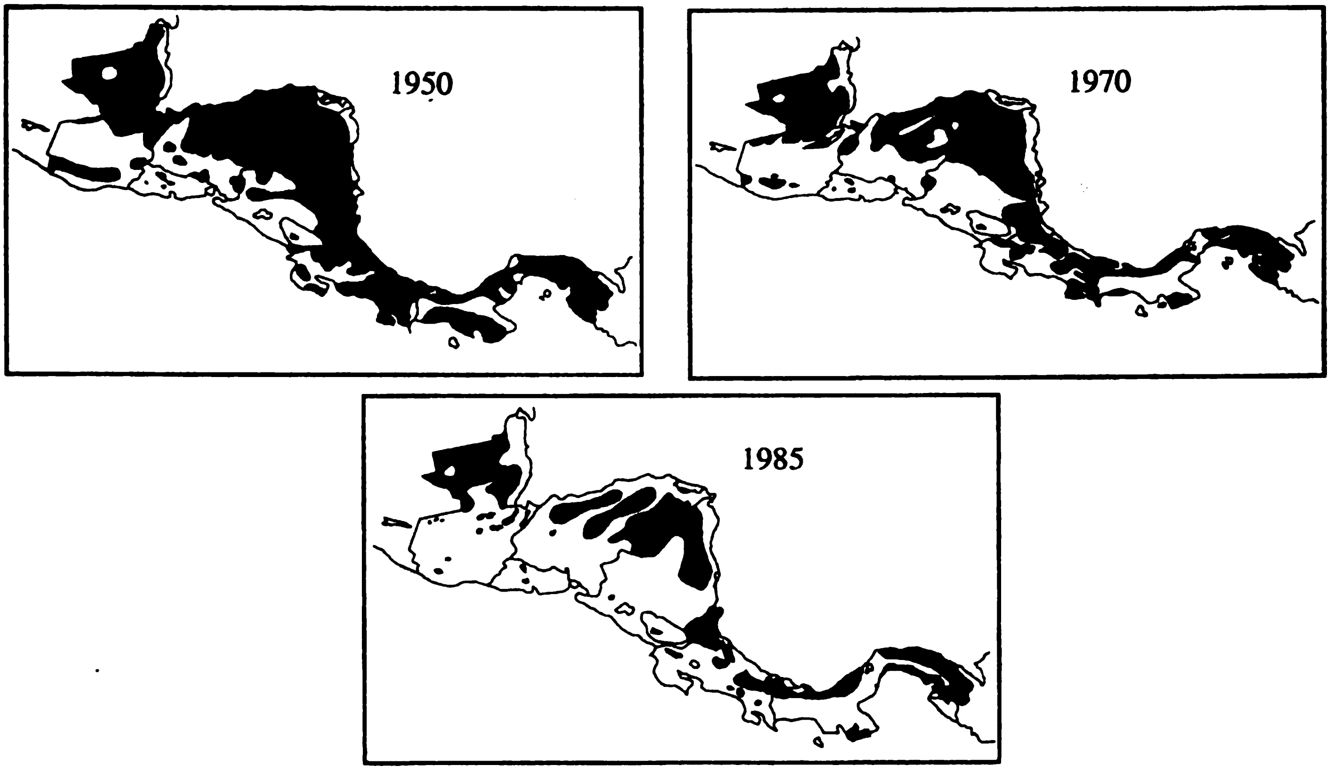
[2] degraded: soils abandoned due to loss of fertility or destroyed by abundant gullies, subsoil exposition, and large land-slides.

Figure 3 shows a map which illustrates the history of the forests in Central America. If we analyze what has happened between 1950 and 1985, we can see that a great proportion of the natural vegetation has been destroyed in this period, with the consequent destruction of the natural resources base in Central America. On the other hand, figure 4 shows the great environmental destruction that has occurred in Central America and its impact on the deterioration of the watersheds. Also, the destruction of natural resources is intimately linked to the options for development for the region, as in none of the Central American countries there is energy produced from fossil fuels, at least at an economically viable level. Thus, it is not surprising that a large proportion of the energy consumed among these countries comes from wood (thus the forest), while the majority of the energy used in the urban centers and for industrial development is derived from hydroelectric power. As a consequence, destruction of the natural resources in watersheds and its impact on the erosion process not only influences rural poverty in Central American countries, but also impacts their development options and economies.

As we analyze the different sectors of the economies of each country, including the livestock sector, we assume that natural resources, which form the base for all this production, are unlimited and undergo no depreciation; that they are a resource that we can use and reuse without limits, and will always support production. There is no greater falsehood than this. The figures shown in this presentation are evidence of the lack of validity of this supposition. In this respect, a group of economists associated with ecological sciences and the environment have been analyzing the concepts of discount of the resource capital, which depreciates with use. In table 13 we show the values for depreciation in 1984, by hectares, and for the different forms of land use (annual crops, perennial crops, and pasture), taking as criteria the depreciation, the rates of erosion of the soils, and the losses in productivity. Here we see that the biggest losses are associated with annual crops, followed by pasture and finally perennial crops. For 1989 the total loss is equivalent to 2500 colones per hectare.

On the other hand, if soil loss is discounted from the gross product, we then have the net agricultural product (Table 14). This depreciation as a percentage of the gross product has varied over the last 20 years between 6.5 and 13.3%. On the other hand, if we accept that the soil loss corresponds to a loss of fertility or to an actual loss of soil, we can anticipate a reduction in future gross production, with the same area producing less. In addition, soils with less production will have less vegetation coverage; the possibility of erosion is increased and hence the depreciation of the soil resource is also greater, causing a significant decrease in the net agricultural product. This a clear example of how the use of the soil is not sustainable.

Fig. 3 Deforestation in Central America 1950-1985



Dense forest (does not include mangrores nor open savanna forests)
Source: USAID Country Env ironmental Profiles; Heckadon and Espinoza 1985; Nations and Komer, 1983

Fig. 4 Environmental Destruction in Central America

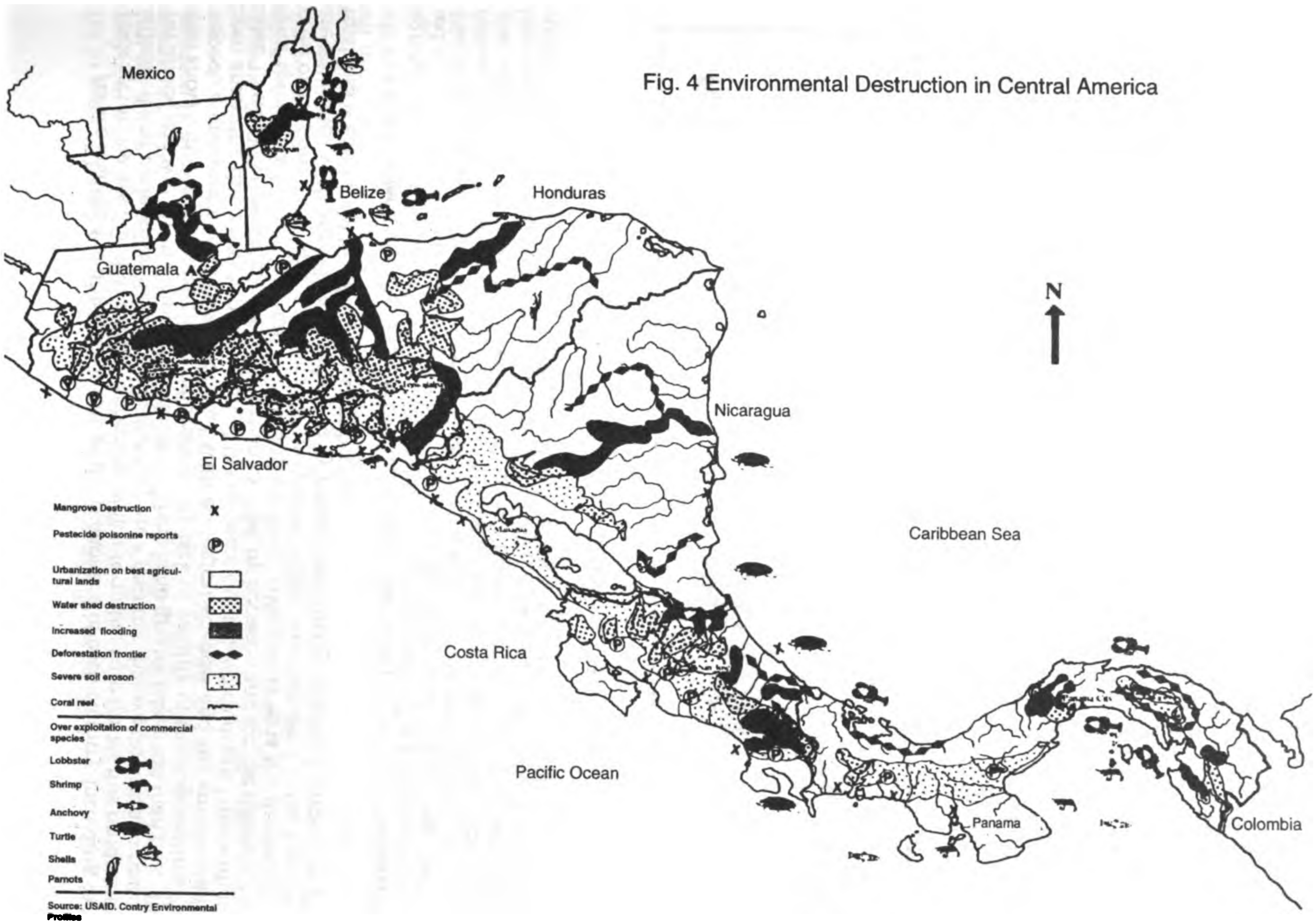
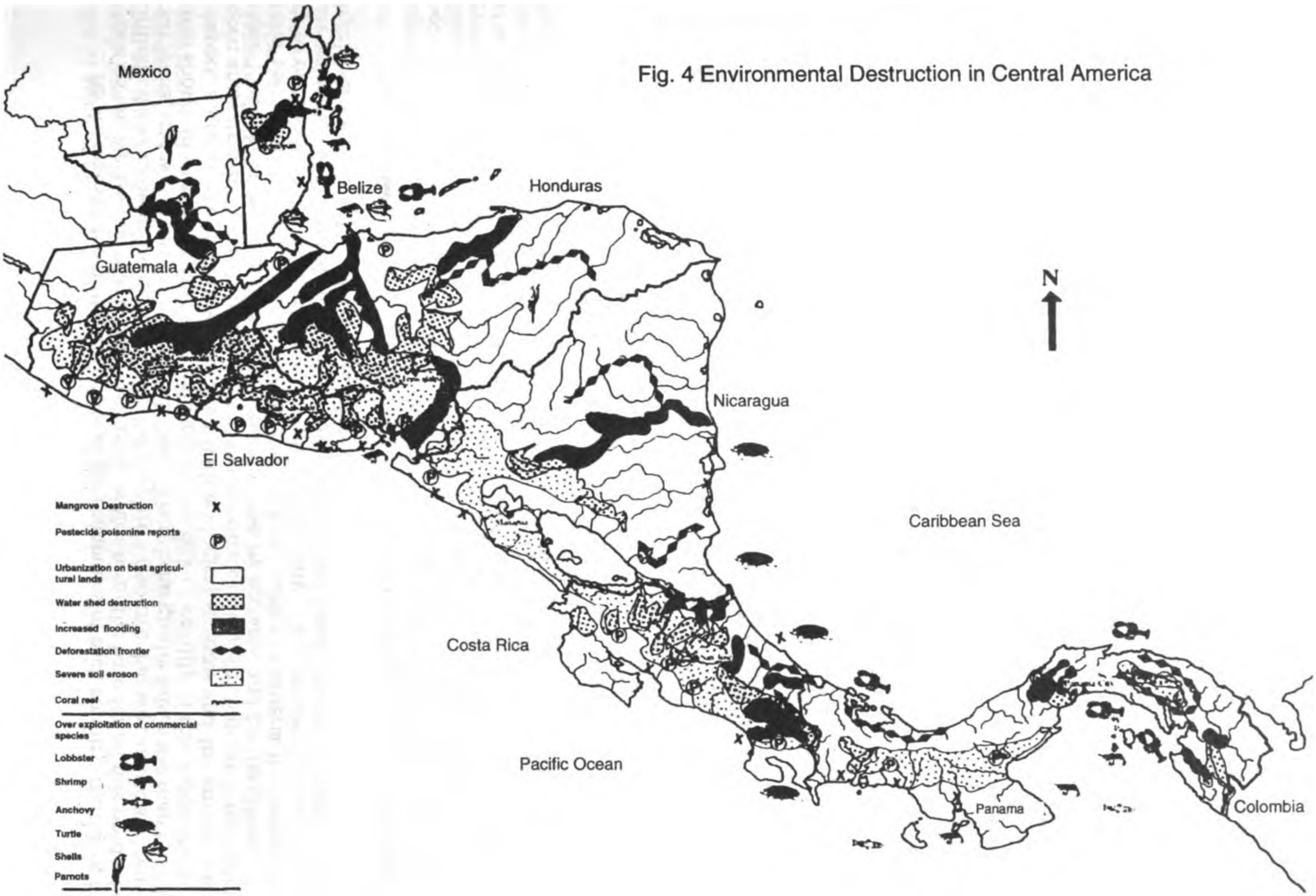


Fig. 4 Environmental Destruction in Central America

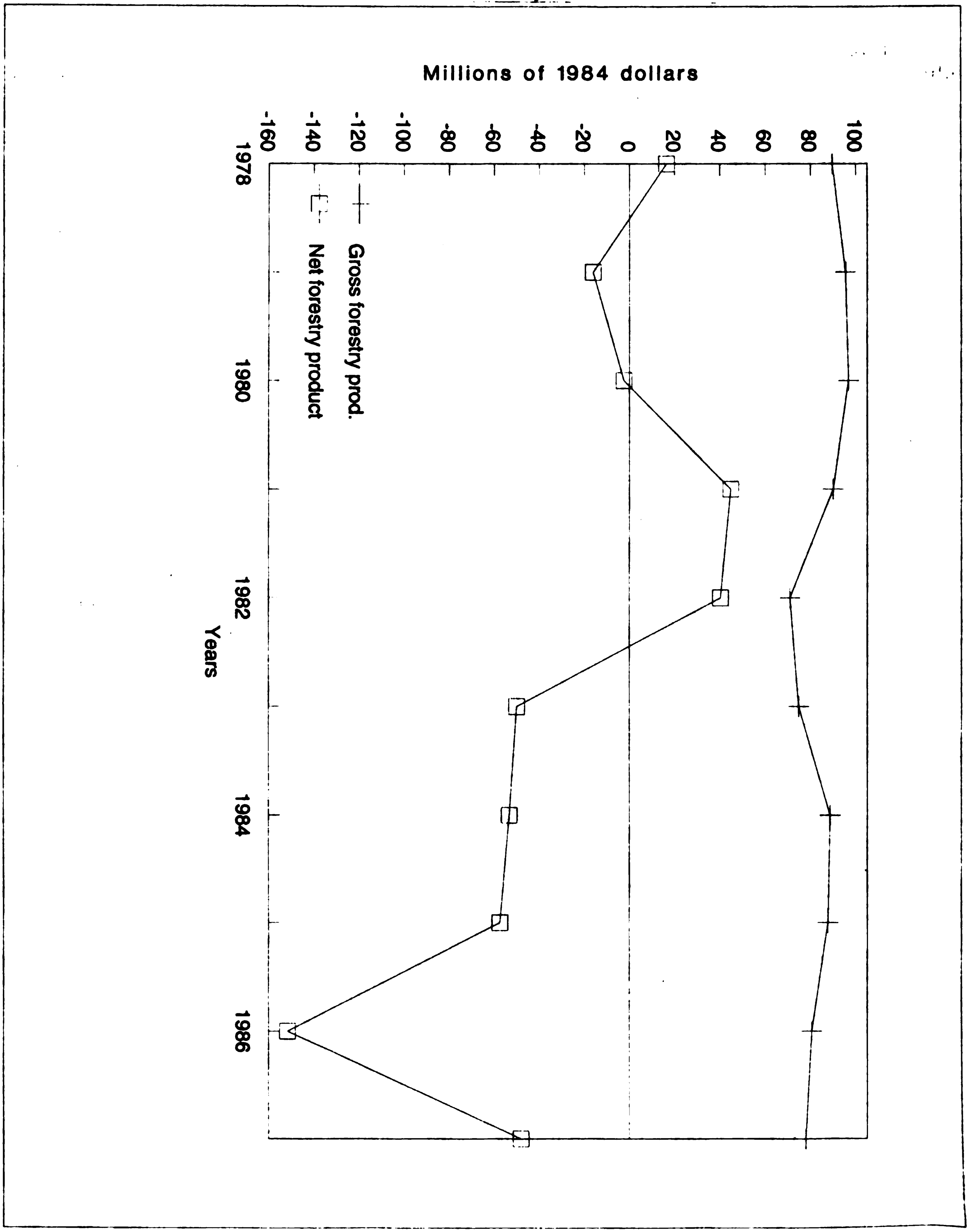


Source: USAID. Contry Environmental Profiles ing timber and loss of management potential due to misuse, *versus* appreciation due to management of secondary forest, we obtain a net forest product. This analysis for the case of Costa Rica shows that for most years the balance is negative, and it has been consistently negative in recent years. This means that there is a management problem for the existing resources, which are disappearing nowadays. This is not to be interpreted as saying that the forest resources should not be used, or that there should not be industry, but rather that this must be rational and avoid the loss of potential of the resource through sustainable management. Finally in figure 5 we see the depreciation of the net forest product which, in the case of Costa Rica, has been negative especially over the last decade.

Table 15. Depreciation of forest resources in Costa Rica and net forestry product

Year	Depreciation: Loss of standing timber	Depreciation: Loss of management potential	Total	Appreciation of secondary forest	Forest product	Net forest product
1970	2997	238	3235	169		
1971	4195	489	4684	147		
1972	3279	286	3565	128		
1973	4003	425	4428	110		
1974	4091	587	4678	84		
1975	3871	519	4390	61		
1976	3212	349	3562	40		
1977	3313	370	3683	21		
1978	3407	391	3798	4	4006	212
1979	4835	761	5596	-12	4239	-1368
1980	4356	642	4998	-26	4317	-707
1981	2430	192	2622	-38	3997	1337
1982	1854	79	1933	-49	3154	1171
1983	5395	909	6304	-59	3343	-3020
1984	6010	1082	7092	-68	3994	-3167
1985	6193	1201	7394	35	3917	-3442
1986	9224	2162	11385	128	3616	-7641
1987	6463	335	6798	212	3506	-3080
1988	14175	1249	15424	288		
1989	14326	1300	15626	355		

Fig. 5 Gross forestry product and net forestry product from the depreciation of forestry resources.



8. CHALLENGES FOR THE FUTURE

At the end of this symposium we expect some interesting options to emerge for sustainability of animal production systems, which permit sustainability of the natural resources. Nevertheless, with a challenge of this magnitude, the solutions will depend on the collective forces of the developing countries in the tropics, working together with the developed countries of the temperate region.

The challenges are intimately related, they are global, they are for the whole planet, not just for Central America. The consequences for not finding solutions will be serious. These challenges involve every economic sector and every region in their origins and consequences, and thus cannot be faced in isolation by any one region. They cannot be confronted with modest means when we face a duplication of our population over the next 20 years and a five-fold increase in agricultural activity in the life span of our children. Against this backdrop, what the human population does in the decades of the nineties will be of critical importance. From this symposium we must generate options for the rest of the decade, and these must be presented to political decision-makers and bring about real changes.

One of the important changes is that within the theme of this symposium. These changes are interdependent and a positive change in one area might strengthen positive changes in another. The World Resources Institute sums-up these changes as:

a) A demographic transition towards a more stable population in each nation at the regional and global levels, before the world population duplicates again;

b) A technological transition (technology today is resource-intensive, with a tendency to produce waste and contamination) towards a more environmentally benign technology;

c) An economic transition towards a world economy based on income from nature and not on the exhaustion of its capital;

d) A social transition towards a more equalitarian participation in the environmental and economic benefits in society;

e) A transition towards a deeper understanding of what global sustainability and harmony with nature are;

f) An institutional transition towards new agreements between governments and people to assure environmental and food security.

For the political leaders of this region and, in fact, for the political leaders of the world, the challenge will be that of how to conceive a system of international co-responsibility. The challenge of diplomacy, as we have seen in the last few months, is to move from furthering conflict to moving towards a common goal.

PEOPLE, CATTLE AND NATURAL RESOURCES IN THE LANDSCAPE OF THE CENTRAL AMERICAN ISTHMUS

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1. BACKGROUND

The relationship of people, cattle, and natural resources arose with the Spanish colonization. With the Spanish settlers came the cattle and a new relationship with natural resources, and the incorporation of those into production increased drastically with the use of animal traction for agricultural work and transport, and in allowing extensive use of areas of pasture lands. From this perspective, it is the history of the expansion of livestock into human activities and into the space of the Central American Isthmus. It is a heterogeneous history at the national level; some stages were not experienced at all, or were experienced at different times, with vestiges of earlier centuries coming through in practices and in the variety of animals. There are instances of dramatic leaps which failed to make use of the potential of staged lived too fast. The links between agriculture and livestock are a rich source of teaching for the future of our countries.

My purpose in calling up this broader historic background is to make evident that the present livestock expansion is a process with very deep roots, and that modificating the relationship between people, cattle, and natural resources represents a change in national culture and not simply a modification in the management techniques.

Our purpose in this symposium is much more limited and short-term. I want to focus my analysis on the transformation of production demanded by the crisis of the 1980s and its sequels, and to relate it to the period immediately prior to this (1960-1990), and to the prospects for the next three decades.

In volume of production, stock in hand, and occupation of space, the expansion of livestock production between 1960 and 1990 is unprecedented in the Central American history. Also, unprecedented have been the growth of population, urbanization, and the change in educational and occupational characteristics. Both processes have had a profound role in bringing about a change in the national landscape, with the reduction of forest coverage being only the most visible symptom. How much of the positive and how much of the negative effects in this relationship of people, cattle, and natural resources has been an obligatory product of the expansion of the livestock production? To what degree it is linked to land speculation and to the control of groups with reduced access to credit and fiscal concessions of lands? How much of the productive expansion and its growth in area was linked to the rate of urbanization and its coincidence with the dynamics of external demand?

The answers to these and other questions will serve as a basis for exploring the future possibilities for the countries of the Isthmus. For example, the population projections and the availability of natural resources indicate that the challenge to Central America has a precedent in Asia; it will be the development of livestock in densely populated spaces. The change in size, structure, and levels of income of the population appear playing the role previously played by urbanization and the push to export. Environmental dimensions, in all their many facets, are winning a dominant place in the use of natural resources and in the allocation of funding. These brief comments indicate the imagination that will be required in finding solutions.

Finally, we will analyze the political viability of some of the solutions presently in use, or suggested in the context of the productive transformation, and the achievement of sustainable development.

2. LESSONS FROM THE EXPERIENCE OF 1960-1990

Far beyond the heterogeneity of the relationships of people, cattle, and natural resources in the countries of the Isthmus, the development of the exports of meat in the 60s and their subsequent stagnation and decline in the 80s gave rise to change and, equally importantly, to the different national realities. It is these factors and modalities which we will now analyze as we work through this presentation.

3. THE MULTIPLICATION AND CHANGING CHARACTERISTICS OF THE PEOPLE

In the last three decades the population of the Isthmus had a growth ratio (235%) greater than any previous one, or anticipated to have in a similar time period (CELADE 1990). Guatemala and Costa Rica together had, in 1990, more than 12 million inhabitants, the same as the region had as a whole in 1960. With an area a little more than one-sixth of Argentina, the Isthmus has a population of close to the 32 million of this Southern ranching giant (Table 2 of the Statistical Annex). The rapid growth in the population density accompanied the livestock expansion.

At the same time, the inhabitants of the Isthmus today are predominantly urban. Their consumption habits are increasingly molded on the model of an emerging middle class, despite the fact that more than half of them live in poverty and indigence. These medium income groups, together with the modest income *per capita* of the 1960s and 1970s, explain the increase in consumption and the unsatisfied pressure for products of animal origin. The combined effect of the population growth, the change of patterns of consumption, and the improvement in incomes have resulted in an increase in consumption of animal products greater than the population figures would suggest.

Added to the internal pressure, overcoming it for part of the 1960-1989 period, was that of the external market, the North American market in particular. The lower rate of population growth in the North American population, combined with the trend towards lower consumption of red meats and animal fat from the 1970s, led to a transformation in the dynamics of markets, of leading increasingly to production for the internal market even during the crisis of the 80s.

Meat was the support to the trade balances of the Isthmus in the 1960s and 1970s, representing more than twice the expenses for the importation of dairy products and fats. However, during the crisis of the 80s it became a headache for the economic authorities because of its incidence on internal inflation. The changes in exports caused livestock producers to depend more and more on the conditions and dynamics of the national population.

4. CITIES AND PRODUCTIVE SPACE

The growth of the urban population, and that of the one or two main cities (Tables 3 and 4 of the Statistical Annex) led to a concentration of markets, particularly for livestock products, in the capital or the two principal cities. This resulted in a spatial organization of livestock production as a function of service to these cities similar, and eventually greater, than that which arose to meet the requirements of exports. This led, especially in the case of meat and milk production, not only to competition with crop lands for other products, but also to the localization of these relative to the market. At the same time, it became necessary to move away from the areas of urban growth in search of cheaper lands for production.

The urbanization of the population and of the market, expressed in a higher increment of the commercial demand than that of total demand, makes spatial organization of production a key issue in small countries with high and rapidly growing populations. This is an essential point which is often overlooked. There are many who still think that the only factor to determine land use is its aptitude and its limitations as a natural resource. This explains the recurrent criticism of the utilization by livestock of soils appropriate for cultivation.

5. ROADS, SETTLEMENT AND SPATIAL ORGANIZATION

Since the 1950s, the economic development in the countries of the Isthmus was identified with the total incorporation of the territory into the production process. Technicians and government officials emphasized the importance of the road infrastructure (Williams, 1985). In the 60s the Alliance for Progress stimulated the huge highway plan which opened up extensive areas for agriculture, livestock and forestry activities, before or at the time that the studies of natural resources indicated their potential and their management requirements. We were living in an era when we still did not talk about the limits to economic growth, and we continue living this way long after having read the papers of the Club of Rome. Many people shared this error, including the livestock producers, who were motivated by the highway plans and the financial credits provided by international organizations, and who were favored by the increment of prices for meat between 1960 and 1980.

The point at which all of the highways converged was the export industries and the principal cities, within the context of national plans and the Central American highway integration. At the same time, the new spaces open to production, or the old ones with access to markets, were much vaster than the financial resources from public and private sources. This caused that the spatial organization of production responded to the tension between a tendency towards concentration originated in the markets and the credit programs oriented to increasing productivity per hectare and per animal unit, and the tendency to dispersion stimulated by the desire to incorporate maximum area of natural resources with the limited resources available.

6. ACCESS TO PROPERTY AND THE USE OF NATURAL RESOURCES

The decades of the 60s and 70s were particularly contradictory in terms of land tenure policies, combining threats and promises of agrarian reform with the greatest liberalization that we have known in land concessions and permissiveness of illegal occupation. We do not need to recall the extreme cases of Nicaragua and Honduras to demonstrate the vast process of privatization of national lands; figure 1 shows this in Costa Rica, where supposedly there was no more agricultural frontier in 1960.

Privatization of national lands *per se* does not necessarily lead to management causing the degradation of renewable natural resources, the worsening balance of social inequity, and the inefficient administration of production. This association of undesirable results was stimulated through a complex of factors operating at national level or in certain zones of the country. Foremost among them were:

a. Access nonrenewable resources whose potential and limitations for incorporation into productive agriculture were still poorly understood by the public authorities and by the users.

b. The demand for incorporation of the land into production as a requisite for title to the same. Included amongst the criteria for incorporation into production was the destruction of part of the resources (cutting of forest).

c. The facilitation *per se* of the incorporation of the resource regardless of the potential for sustainability of its use, including access (highways, roads), subsidized credit, and support for marketing of the products.

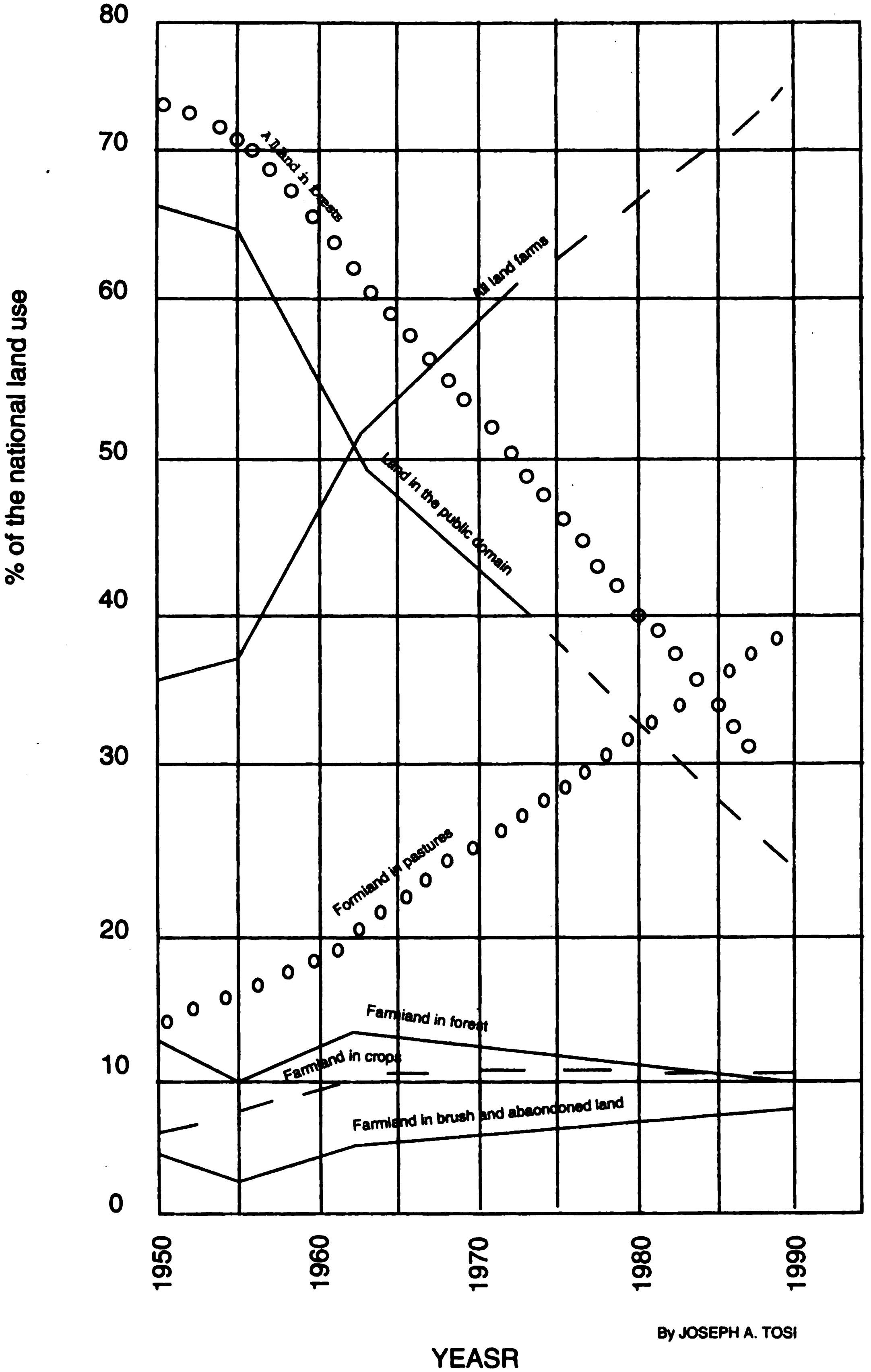
d. A tax system which favored extensive use of renewable natural resources.

e. The distribution of natural resources in areas of the agricultural frontier in a more unequitable way than was the case in zones of existing production.

f. The sustained increase over the medium and long-term of the price of land, and the use of renewable natural resources in general.

When this combination of factors exists in a country or a region of a country, land speculation becomes the most profitable use of this resource, and extensive livestock production the least costly way of demonstrating incorporation of the resources into production. From this extreme to that of efficient, equitable, and sustainable use of the resource, there is a wide range of situations which result from partial combinations of the above mentioned factors. In other words, livestock production in the countries of the Isthmus has been an efficient enterprise in social and private terms, but also served in many cases as a pretext for land speculation. Figure 1

Fig. 1 National Land Use for the years 1950-1990



By JOSEPH A. TOSI

7. THE PEOPLE AND THE DETERIORATION OF THE RESOURCES

In the range of scenarios of the relationship among people, livestock, and resources that we mentioned earlier, there is a whole complex of factors which we have left in the shade. Among these are the common tendency to identify the poor "campesinos" expelled from his "minifundio" or from areas incorporated into mechanized agriculture, as the agent who invades the virgin land and destroys the forest using slash and burn. He is identified as the initiator and accelerator of erosion through his cultivation on steep slopes, and final sale of his clearings to the livestock producer. Do not forget his wife and children, continually carrying firewood like a column of ants who destroy the forest. And finally these poor people as a group on land open for production, who destroy the habitat animals and plants, and misuse tropical biodiversity, through their own precarious nourishment and undervalued sale.

We only have to fly over the Isthmus in the season prior to sowing to see the numerous fires throughout the land. For this reason the association of rural poverty and destruction of resources is a permanent concern raised in meetings of technicians, scientists and government authorities in the region.

In my understanding this reality is no other than that of the migrant agriculturists. Its part in the process is generally little understood and overblown. In terms of impact, the amount of the natural resources which the "campesino" controls, and the capacity for their destruction that his technology permits, are so low that we cannot attribute more than a small proportion of the damage to him, and often we cannot associate that participation to a given moment in the cycle of deterioration of the resources.

The role of the migrant agriculturist has undergone a dramatic change in the era of the highway compared to his ancestors. He no longer is an element isolated from other faces or from the rest of the national territory. The migrant agriculturists does not travel unless the way is opened by the state, the lumber industry, the investor interested in gaining possession of resources to support his land concession or title, or the businessman needing occasional or seasonal labor, etc. The migrant agriculturists is no longer disinterested in his children's education, in the availability of health services for his family, or other services. These are precisely the issues which make him prefer a fixed residence in a village with services, to life in the middle of the forest.

In summary, the campesino is part of a system of nonsustainable development at the heart of which his relatively minor capacity for destruction of resources is potentiated and converted to other, more advanced or irreversible, forms of degradation. At the same time, it is him and his family who are the first to desire a change in the life style that makes possible his destructive action.

8. PEOPLE AND NATURAL RESOURCES: CENTRAL AMERICAN SPECIFICS

In analyzing the relationship of people, livestock, and renewable natural resources in the Central American Isthmus, whether in the last or next 30 years, clear differences in the expectations based on general theories are evident. There is a combination of causes: the accelerated urbanization, the availability of natural resources, the index of concentration of land titles, and the sectorial behavior of employment (Table 10 od the Statistical Annex).

In the context of rapid urbanization in countries with an agricultural frontier, the pressure arising from the population growth is transferred either to the city or to the frontier zones. At the same time, the control of land and the access to financial resources by a small group of people transfers to them the control of employment. The generation of jobs occurs outside of agriculture, either producing inputs and machinery for agriculture, or in activities generated in part by the income obtained by agricultural producers and workers. It is this combination of factors which explains why in Brazil and Mexico between 1960 and 1990 (Table 10) the people actively employed in agriculture decreased from almost 50% to 25%. In these cases the employment generated was paid in part by the deterioration in the natural capital of the agricultural frontier, and by the increase of employment in the informal urban sector; in other words, the expansion of urban poverty. We find the inverse situation in Asian countries such as India and Nepal, densely populated and with no or almost no agricultural frontier. The intermediate situation appears in the countries of the Isthmus with an agricultural frontier (Guatemala) and without an agricultural frontier (El Salvador). This indicates a combination of increasing numbers of "minifundistas" alongside the deterioration of the scarce natural capital of the poor campesino, the expansion of employment in commercial and itinerant agriculture in the frontier zones, and the increase in informal urban employment at rates below those of Mexico and Brazil.

9. DEMOGRAPHIC TRANSITION AND SUSTAINABLE DEVELOPMENT

Since the 60s, all of the countries of Latin America and the Caribbean, having reduced rapidly the rate of mortality of their population in earlier decades, started or accelerated their transition to a lower fecundity. This process explains the lower rates of growth in Latin America and the Caribbean from the middle of the 1960s, and is known as the demographic transition. As a product of this process, the experts expect that before the middle of the next century the countries of the Isthmus will have a stable population.

The importance of the demographic transition can be seen in the change in the population structure, and its effect on the dependency relationship and the requirements of the population (Tables 1, 5-9 of the Statistical Annex). In the initial stage of the process, as experienced between 1950 and 1990 by the countries of the Isthmus except Belize, Costa Rica and Panama, each worker had a large number of dependents, and the high birth rate which coincides with the importance of the maternal and infant, and educational programs. The acceleration of the urbanization of the countries also brought increasing costs per person (sewage, water, road infrastructure...). In the subsequent stage, already experienced by Belize, Costa Rica, and Panama, the cost of development increased further with the need to create more jobs for the growing population, and also with the costs of urbanization.

A few figures can help us understand the situation of the Isthmus in aggregate form. In the last thirty years the annual number of births passed from 650,000 to 1,120,000 and that of required jobs passed from 135,000 to 265,000. In other words, the greatest cost of development has been that of the population growth, its feeding, health, and education. On the other hand, in the next 30 years, even though the number of annual births may increase to 1,400,000 a greater effort will be needed create jobs, whose number will approach 600,000 *per annum* by the end of this time period.

The changes noted show that the countries of the Isthmus, by increasing their cost of development, have been -and will be- more likely to submit to the temptation of spending part of their natural capital in order to remain solvent. At the same time, activities like livestock production, which yesterday provided food and income, will be less important tomorrow because of their lesser capacity for creation of employment per investment unit, and for the loss of dynamism of the export markets.

10. FUTURE SCENARIOS (1990-2020)

In the next thirty years the countries of the Isthmus must confront a greater cost of development and an extraordinary effort in terms of creation of employment in the context of a greater population density. Actually, with the duplication of population in this period, the average density in the Isthmus will be close to that in the Dominican Republic (1.2 to 1.4 inhabitants per hectare). This situation is even more worrying in relation to the area in agricultural use, which will not change rapidly in favor of the forest. This means that there will be an almost doubling of population pressure per hectare.

In this analysis it is important to notice the consensus in the countries of the Isthmus for a strategy of development combining productive transformation with equity, sustained by a strong growth of exports, in particular of products generated using renewable natural resources (CEPAL, 1991). This export effort depends in large part on the agricultural activity and the agroindustries, with an increasing emphasis on industrial activity using intensive labor with imported raw materials.

To respond to these challenges, an increase in employment and the total generated and exportable value for each agricultural hectare must be achieved simultaneously. It will not be sufficient to increase the yields of traditional products. The transformation will demand incorporation of other products into agriculture, and different uses of the agricultural products by the rest of the sectors. The magnitude of this effort will be appreciated when we realize that it represents roughly a duplication in the number of work days per agricultural hectare.

An important part of this future effort must come from the achievement of satisfactory levels of sustainability in agriculture, including minimizing the negative effects of urban growth and industrialization on renewable natural resources. The spatial relocation of some products and the technological change to satisfy the requirements of sustainability, will not always be in harmony with the increase in employment and exportable products.

11. THE CHALLENGE TO LIVESTOCK PRODUCTION

It is easy to conclude that within a context like the one described, the development of livestock production will demand action on all fronts: by changing its composition (i.e. red and white meats), in the use of inputs (i.e. land, capital and labor), and in its relationship with other sectors (i.e. industrial) and subsectors (i.e. crops). The scenarios for the Isthmus will be diverse. Included without doubt will be some reduction in the size of the areas used, and also of the components of production.

In one of the images most commonly painted for these latitudes in the development of sustainable livestock production, it is supposed that livestock will overcome the conflict with the forest. However, the indications are that in the future it is the conflict with man in the management of the food chain that must be dealt with. It is in these terms that the ecologists invite us to consider the relationship of people, livestock, and natural resources in the context of a high population density.

The intensification of urbanization, to which the high priority of creating employment, and the growing proportion of non-agricultural labor will contribute, points to a more important role of the urban market and its concentration in a few cities: the spatial organization of the agricultural production. How will livestock production compete in this scenario? Will it achieve harmony or will it conflict with agricultural production?

The changes in the current and anticipated external markets, given their linkage with dietary habits and low yields of those crops capable of complementing livestock feeding, do not offer a very inviting panorama for livestock based exports. Any increase in production will be triggered by the internal demand, population growth, urbanization of dietary habits, and the increasing incomes of the households. Depending on the demand in labor-intensive activities and modest salary levels, livestock production will have to do miracles, in terms of business profitability, in order to compete with export products for soils and for capital.

These considerations are valid for the period at large, but they acquire a very special connotation in the present period of transition from the strategy of productive transformation with equity and sustainability. The great temptation, especially amongst the extensive livestock producers will be to stand aside from changes, accentuating land speculation given the scarcity and increasing value of the land. At the same time, public policy leaders may assume an attitude of marginalization towards livestock activities because of their limited capacity for generating employment and increasing exports. These possibilities point to the middle class urban consumer and to the livestock enterprises -modern or in process of modernization- as the basic nucleus upon which livestock development production will depend.

If we accept this as the basic nucleus, it is clear that it may be affected, and in fact has been affected, by the policies of adjustment and stabilization, which have impacted negatively the consumption of products and the stock in hand in livestock enterprises. In general, the producers in the Isthmus have not reacted to these circumstances with an effort to increase efficiency in the management of livestock production or investment. To do this would signify on the part of the producers, and on the part of the authorities, a recognition of the viability of the economic programs and progressive expansion of that sector of the population with buying power, and the adaptive capacity of the national livestock production.

12. STRUCTURAL REFORM AND LAND SPECULATION

The package of structural reforms introduce through current programs has tried to achieve macroeconomic stability and international competitivity, including stability of internal production relative to importation. Scarce attention has been given to adopting tax measures, regulating systems for land and forest resources concessions, and to increasing and spreading knowledge on the potential use of renewable natural resources, and other measures intended to restrain the process of land speculation. In some cases, the greater yield of other taxes and the urgency for elimination or reducing of the fiscal deficit explains the postponement. In others, the fear of creating insecurity on the private businessman has inhibited reform of the concession system. Also, the preconceived ideas of the enormous potential of the renewable natural resources explains the marginal importance given to understanding them better.

In scenarios such as the above, the interest in eliminating the cancer of speculation, which is attacking our sustainable development, has been left to recently created ambientalist organizations, to specialized departments (forestry, for example) of ministries which are relatively marginal to economic planning. At the most, the interest to have access to environmental funds ("green money") has moved some economic authorities to become interested in "debts for nature" swaps, and to present projects to obtain loans and donations from international organizations. However promising the future of this process of investment in activities favoring sustainability, it cannot replace the adoption of the reforms and more global measures indicated above.

13. NOTES ON POLITICAL VIABILITY

The era of livestock expansion in the countries of the Isthmus coincided, with a few exceptions, with military regimes with conservative, reformist, or socialist orientations. The diversity in ideology was not an obstacle to collaboration by these regimes in channeling international support to expansion. It seemed there was competition to see which country could be the most liberal in land and forest concessions. Under the shadow of these regimes there was born and developed a livestock elite, whose capabilities as a pressure group skilled in obtaining favors from the democratic state has been demonstrated in the Costa Rican experience. The electoral systems within our representative democracies favored these groups who, although small, are distributed throughout the territory and especially in the poorly populated areas. This explains the high level of representation of the livestock groups in the congresses elected during the 1980s, and their role in the legislative process. This presence, in addition, increases the ability to apply pressure to economic activities, and explains the special concessions which they have obtained periodically on credit and taxes.

The ability of the livestock producers to win and exercise their political power, contrasts with the ease with which they have generated antagonism amongst the emerging conservationists and sustainable development groups. The image of the livestock producer is being increasingly depicted, inside and outside the Isthmus, by the spokesmen for these groups as the enemy of the forest and the destroyer of natural resources. This conflict tends to identify -in some circles- the struggle for sustainable development with an anti-livestock stand.

It is possible that the circumstantial power of the livestock producers will decrease with electoral reforms, which tend to perfect democracy, and that their conflict with the "greens" will lose its sharp edges when the basis and process of sustainable development in Central America is better understood. Nevertheless, this is the reality and will be for the next few years, while the viability of livestock development in these countries will be on the table. Taking advantage of that power and overcoming this conflict are, in my understanding, a prerequisite in developing a sustainable livestock development strategy.

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STATISTICAL ANNEX

Table 1. Global fecundity rate (GFR), mortality gross rate (MGR) and natural growth rate (NGR) for five country groups

		1950-55	1970-75	1990-95	2010-15	2020
GROUP 1						
Argentina GFR	3.15	3.15	2.79	2.35	2.24	
	MGR	9.16	9.01	8.62	8.68	8.91
	NGR	16.23	14.37	11.67	9.10	7.47
Uruguay GFR	2.73	3.00	2.33	2.12	2.09	
	MGR	10.52	9.90	10.30	10.38	10.33
	NGR	10.71	11.15	6.78	4.85	4.18
GROUP 2						
Barbados GFR	4.69	2.75	2.04	2.08	2.08	
	MGR	13.20	8.70	8.00	6.70	7.50
	NGR	19.60	12.10	10.10	8.00	6.30
Chile	GFR	5.10	3.63	2.66	2.35	2.25
	MGR	14.33	8.89	6.41	7.22	8.07
	NGR	22.87	18.67	16.12	10.75	8.58
Cuba	GFR	4.10	3.55	1.87	2.10	2.10
	MGR	11.45	6.54	6.70	8.12	9.70
	NGR	18.65	5.15	10.74	5.73	3.68
Jamaica GFR	4.22	5.41	2.45	2.08	2.08	
	MGR	11.50	7.40	5.10	4.50	5.00
	NGR	26.90	25.10	17.60	12.10	9.80
Trinidad GFR	5.30	3.47	2.47	2.10	2.10	
	MGR	11.30	7.20	6.10	5.90	6.70
	NGR	26.90	19.40	15.30	10.60	8.40
GROUP 3						
Brazil GFR	6.15	4.70	3.16	2.43	2.28	
	MGR	15.13	9.74	7.48	7.11	7.60
	NGR	29.51	23.91	18.66	12.61	10.00
Colombia GFR	6.76	4.67	2.92	2.41	2.28	
	MGR	16.68	8.71	5.91	5.82	6.52
	NGR	30.59	25.78	19.90	13.69	10.98
Costa Rica	GFR	6.72	4.34	3.02	2.36	2.21
	MGR	12.64	5.83	4.02	5.10	6.15
	NGR	34.69	25.68	21.50	13.90	10.67
Guyana GFR	6.68	4.55	2.42	2.09	2.09	
	MGR	13.50	7.60	5.20	5.30	6.20
	NGR	34.60	24.90	16.40	11.30	8.60

Table 1. Continuation

		1950-55	1970-75	1990-95	2010-15	2020-25
Mexico GFR	6.75	6.37	3.11	2.39	2.33	
	MGR	16.06	8.91	5.43	5.39	6.18
	NGR	30.50	33.68	21.22	14.15	11.57
Panama GFR	5.68	4.94	2.87	2.24	2.12	
	MGR	13.18	7.32	5.15	6.01	7.07
	NGR	27.12	28.41	19.78	12.01	9.06
Peru	GFR	6.85	6.00	3.57	2.47	2.23
	MGR	21.58	12.75	7.62	6.19	6.69
	NGR	25.50	25.70	21.40	14.10	10.94
Dominic. Rep.	GFR	7.40	5.63	3.34	2.38	2.19
	MGR	20.32	9.82	6.20	5.80	6.50
	NGR	30.20	28.99	22.10	13.67	10.29
Suriname GFR	6.56	5.29	2.56	2.09	2.09	
	MGR	12.60	7.50	5.60	5.50	5.80
	NGR	31.20	27.10	17.60	11.70	9.60
Venezuela	GFR	6.46	4.97	3.47	2.80	2.60
	MGR	12.38	6.52	5.35	5.74	6.31
	NGR	34.65	29.54	22.90	16.78	13.78
GROUP 4						
Bolivia GFR	6.75	6.50	5.81	4.31	3.50	
	MGR	24.03	18.91	12.14	7.07	6.23
	NGR	23.11	26.50	29.20	26.07	22.29
Ecuador GFR	6.90	6.05	3.87	2.68	2.35	
	MGR	18.87	11.15	6.94	6.03	6.31
	NGR	27.89	30.08	23.92	15.97	12.60
Guatemala	TGP	7.09	6.45	5.36	3.56	2.92
	MGR	22.38	13.38	7.63	5.31	5.25
	NGR	28.89	31.17	31.03	23.38	18.97
Honduras GFR	7.05	7.38	4.94	3.08	2.69	
	MGR	22.31	13.62	7.16	5.11	4.97
	NGR	29.07	35.05	29.90	20.54	17.27
Nicaragua GFR	7.33	6.71	5.01	3.20	2.68	
	MGR	22.60	12.61	6.65	4.84	5.09
	NGR	31.53	34.18	32.05	22.34	17.77

Table 1. Continuation

		1950-55	1970-75	1990-95	2010-15	2020-25
Paraguay GFR	6.80	5.65	4.34	3.45	3.10	
	MGR	9.26	7.15	6.38	6.24	6.62
	NGR	38.05	29.44	26.66	20.23	17.25
GRUPO 5						
El Salvador	GFR	6.46	6.10	4.51	3.24	2.80
	MGR	19.89	10.79	6.81	5.33	5.38
	NGR	17.34	32.02	29.23	21.86	18.31
Haiti	GFR	6.15	5.76	4.42	3.27	2.87
	MGR	26.33	17.04	11.55	8.44	7.87
	NGR	17.34	22.41	21.55	17.28	15.05

GFR in number of children per woman; MGR in 0/00; NGR in 0/00

Sources: CELADE. 1990. Boletín Demográfico, Año XXIII, No. 45.
UNITED NATIONS. 1989. World Population Prospects 1988. New York, UN. Population Studies No. 106.

Table 2. **Total surface (TS) population density (PD) in 1989, percentage of cropping land (PCL) in 1985-87, increase in percentage of cropping land (IPCL) since 1975-77 to 1989 and annual deforestation (AD) during the 80's**

	TS[1]	PD 1989	PCL 1985-87	IPCL 1975-89	AD 80's
GROUP 1					
Argentina	273669	0.117	3.14	3.2	—
Uruguay	17481	0.178	8.26	0.0	—
GROUP 2					
Barbados	43	6.023	6.74	0.0	—
Chile	74880	0.173	7.42	4.0	50
Cuba	11086	0.923	29.81	5.9	2
Jamaica	1083	2.293	24.84	5.2	2
Trinidad	513	2.462	23.30	3.2	1
GROUP 3					
Brazil	845651	0.174	9.07	22.7	9050
Colombia	103870	0.300	5.10	3.2	890
Costa Rica	5106	0.576	10.28	6.1	124
Guyana	19685	0.052	2.51	21.3	3
Mexico	190869	0.454	12.94	3.0	615
Panama	7599	0.312	7.53	4.5	36
Peru	128000	0.170	2.90	12.8	270
Dominic. Rep.	4838	1.451	30.45	13.2	4
Suriname	16147	0.025	0.40	49.2	3
Venezuela	88205	0.218	4.33	6.0	245
GROUP 4					
Bolivia	108439	0.066	3.13	3.0	117
Ecuador	27684	0.379	9.37	1.4	340
Guatemala	10843	0.824	17.04	10.2	90
Honduras	11189	0.445	15.94	5.9	90
Nicaragua	11875	0.315	10.68	3.1	121
Paraguay	39730	0.105	5.48	71.2	212
GRUPO 5					
El Salvador	2072	2.478	35.38	8.9	5
Haiti	2756	2.316	32.84	4.4	2

1 TS = total surface (thousands of ha.); PD = population density in 1989 (Inhabitants/1000 ha.); PCL = percentage of cropping lands; IPCL = increase in percentage of cropping land; AD = annual deforestation (thousands of ha.).

Source: WORLD RESOURCES INSTITUTE. 1990. World Resources 1990-91. New York, Oxford University Press.

Table 3. Percentage of urban population

	1950	1970	1990	2010	2020
GROUP 1					
Argentina	65.3	78.4	86.2	90.6	92.0
Uruguay	78.0	82.1	85.5	89.2	90.9
GROUP 2					
Barbados	33.9	37.1	44.7	58.3	64.8
Chile	58.4	75.2	85.6	90.5	92.0
Cuba	49.4	60.2	74.9	83.3	86.0
Jamaica	26.8	41.5	52.3	64.8	70.3
Trinidad	22.9	38.8	69.1	79.0	82.4
GROUP 3					
Brazil	36.0	55.8	76.9	85.8	88.0
Colombia	37.1	57.2	70.3	79.1	82.5
Costa Rica	33.5	39.7	53.6	67.0	72.3
Guyana	28.0	29.4	34.6	49.7	57.1
Mexico	42.7	59.0	72.6	81.0	84.0
Panama	35.8	47.6	54.8	66.6	71.9
Peru	35.5	57.4	70.2	79.2	82.5
Dominic. Rep.	23.7	40.3	60.4	73.5	77.8
Suriname	46.9	45.9	47.5	61.0	67.1
Venezuela	53.2	72.4	90.5	94.9	95.7
GROUP 4					
Bolivia	37.8	40.8	51.4	64.9	70.5
Ecuador	28.3	39.5	56.9	70.7	75.4
Guatemala	30.5	35.7	42.0	54.6	61.4
Honduras	17.6	28.9	43.6	58.7	65.1
Nicaragua	34.9	47.0	59.8	71.3	75.9
Paraguay	34.6	37.1	47.5	60.8	66.9
GROUP 5					
El Salvador	36.5	39.4	44.4	56.3	63.0
Haiti	12.2	19.8	30.3	45.1	52.8

Source: UNITED NATIONS. 1988. Prospects of World Urbanization. New York, UN. Population Studies No. 112.

Table 4. Percentage of urban population living in the main city

City	1950	1970	1990	2000	
GROUP 1					
Argentina	Buenos Aires	45.81	44.23	41.59	40.57
Uruguay	Montevideo	65.45	50.63	44.85	42.45
GROUP 2					
Chile	Santiago	37.48	39.67	41.65	41.23
Cuba	La Habana	39.65	33.81	27.05	25.77
Jamaica	Kingston	89.70	67.82	48.68	44.67
GROUP 3					
Brazil	Sao Paulo	14.31	15.07	15.92	15.91
Colombia	Bogota	15.72	19.93	24.99	24.32
Costa Rica	San Jose	63.39	63.75	64.15	64.97
Mexico Cd.	Mexico	24.13	28.06	30.13	29.46
Panama	Panama	38.74	47.88	34.65	32.72
Peru	Lima-Callao	37.34	37.43	41.46	41.76
Domin. Rep.	Sto. Domingo	39.19	47.04	50.89	51.42
Venezuela	Caracas	25.36	26.65	22.15	20.71
GROUP 4					
Bolivia	La Paz	25.40	29.29	35.01	35.64
Ecuador	Quito	22.04	20.97	20.26	20.56
Guatemala	Guatemala City	45.63	35.88	43.22	44.06
Honduras	Tegucigalpa	56.28	35.18	23.33	21.42
Nicaragua	Managua	28.65	39.16	43.75	44.03
Paraguay	Asuncion	42.97	50.64	62.46	63.98
GRUPO 5					
El Salvador	San Salvador	22.92	23.14	25.43	24.60
Haiti	Port-au-Prince	35.36	51.68	23.20	18.96

Source: UNITED NATIONS. 1989. Prospects of World Population Studies. New York, UN. p. 78-20442-43

Table 5. Percentage of population from 0 to 14 years old

	1950	1970	1990	2010	2020
GROUP 1					
Argentina	30.53	29.36	29.92	26.02	24.41
Uruguay	27.88	27.91	25.78	22.99	21.81
GROUP 2					
Barbados	33.20	37.00	25.60	22.20	20.30
Chile	36.71	39.10	30.62	26.32	24.52
Cuba	35.81	36.98	22.73	20.63	19.62
Jamaica	36.10	46.90	34.40	25.00	21.50
Trinidad	40.40	42.10	32.00	24.30	22.70
GROUP 3					
Brazil	42.03	42.25	35.23	28.18	25.70
Colombia	42.67	45.99	36.06	28.83	25.94
Costa Rica	43.33	46.05	36.17	28.17	25.46
Guyana	41.00	47.60	34.60	24.30	22.50
Mexico	43.69	46.93	37.20	28.73	25.89
Panama	41.00	44.20	35.00	27.50	24.30
Peru	41.57	44.01	37.63	29.75	25.93
Dominic. Rep.	44.52	47.33	37.89	28.90	25.48
Suriname	40.00	48.30	34.40	25.40	23.30
Venezuela	43.61	45.67	38.26	31.25	29.00
GROUP 4					
Bolivia	42.03	42.96	43.91	41.82	38.59
Ecuador	41.89	45.34	39.53	31.82	27.99
Guatemala	44.09	45.90	45.43	39.30	34.83
Honduras	44.73	47.23	44.58	36.14	31.73
Nicaragua	44.57	48.34	45.83	37.96	33.29
Paraguay	42.93	46.43	40.38	34.99	32.45
GROUP 5					
El Salvador	42.76	46.49	44.44	38.51	33.87
Haiti	36.83	40.91	40.19	38.26	36.49

Sources: CELADE. 1990. Boletín Demográfico, Año XXIII, No. 45.

UNITED NATIONS. 1989. World Population Prospects 1988. New York, UN. Population Studies No. 106.

Table 6. Activity rate of total population

	1950	1970	1990	2010	2020
GROUP 1					
Argentina	41.45	38.95	35.10	37.80	38.45
Uruguay	41.55	39.55	38.90	41.30	41.95
GROUP 2					
Barbados	47.75	37.90	52.55	56.85	55.05
Chile	35.45	31.25	36.60	38.00	37.65
Cuba	35.35	30.75	42.30	43.50	42.90
Jamaica	45.20	38.00	49.45	58.85	58.80
Trinidad	36.40	33.20	39.05	43.50	42.85
GROUP 3					
Brazil	33.45	32.90	36.60	39.40	39.80
Colombia	34.20	29.95	32.65	36.15	37.00
Costa Rica	34.25	30.65	34.85	37.95	38.40
Guyana	32.95	28.20	36.85	42.95	41.80
Mexico	32.20	28.30	34.25	39.80	41.35
Panama	35.25	33.65	36.10	40.40	41.45
Peru	33.85	29.30	31.95	36.15	38.40
Dominic. Rep.	32.65	26.95	31.40	37.10	39.00
Suriname	33.25	26.95	33.45	40.75	41.10
Venezuela	33.40	29.00	34.75	38.70	39.40
GROUP 4					
Bolivia	36.60	32.70	31.20	30.90	32.85
Ecuador	34.80	31.00	30.50	32.65	34.10
Guatemala	33.55	30.25	28.60	32.55	36.10
Honduras	33.35	29.95	30.85	34.70	38.45
Nicaragua	33.40	30.15	31.10	35.85	38.50
Paraguay	35.55	32.40	33.35	35.60	36.30
GROUP 5					
El Salvador	35.30	33.00	33.25	35.40	37.05
Haiti	59.50	50.85	41.70	38.65	38.60

Source: OFICINA INTERNACIONAL DEL TRABAJO. 1986. Población Económicamente Activa 1950-2025. Volumen III, América Latina. Third Edition.

Table 7. Activity rate of female population

	1950	1970	1990	2010	2020
GROUP 1					
Argentina	16.85	19.50	19.55	22.10	22.65
Uruguay	19.00	20.70	23.80	26.95	27.60
GROUP 2					
Barbados	37.65	28.55	47.55	51.90	49.80
Chile	14.05	13.85	20.65	21.95	21.70
Cuba	9.15	11.70	27.30	30.00	29.45
Jamaica	32.05	31.55	44.95	54.75	54.15
Trinidad	18.80	19.40	23.40	26.05	23.35
GROUP 3					
Brazil	10.20	14.35	20.00	23.60	24.30
Colombia	12.55	12.70	14.35	16.85	17.70
Costa Rica	10.25	11.15	15.30	18.05	18.55
Guyana	11.75	11.60	18.50	22.95	22.25
Mexico	8.35	10.10	18.60	22.85	24.35
Panama	13.90	17.35	20.00	24.60	25.85
Peru	14.25	11.95	15.55	18.50	20.20
Dominic. Rep.	6.20	6.00	9.45	15.55	18.85
Suriname	13.60	13.40	19.60	24.80	24.80
Venezuela	12.10	12.20	19.40	22.75	23.30
GROUP 4					
Bolivia	14.20	13.85	15.85	16.10	18.00
Ecuador	11.60	10.10	11.85	13.60	14.85
Guatemala	8.70	80.5	9.45	15.15	19.70
Honduras	7.75	8.55	11.65	18.60	23.95
Nicaragua	9.05	11.90	15.70	21.35	23.80
Paraguay	14.90	13.65	13.80	14.90	15.20
GROUP 5					
El Salvador	11.55	13.55	16.80	18.05	18.95
Haiti	56.55	46.40	34.35	28.40	26.90

Source: OFICINA INTERNACIONAL DEL TRABAJO. 1986. Población Económicamente Activa, Volumen III, América Latina. Third Edition. Ginebra, OIT.

Table 8. Annual births: 1950-2025 (thousands)

	1950 1955	1960 1965	1970 1975	1980 1985	1990 1995	2000 2005	2010 2015	2020 2025
GROUP 1								
Argentina	458	98	585	674	675	722	731	731
Uruguay	49	57	60	54	54	54	53	53
GROUP 2								
Barbados	7	7	5	4	5	5	5	5
Chile	239	298	274	281	309	305	317	323
Cuba	182	258	238	158	189	168	170	172
Jamaica	51	67	64	63	59	55	55	54
Trinidad	26	33	26	29	29	27	28	28
GROUP 3								
Brazil	2589	3301	3430	3929	4123	4144	4225	4222
Colombia	607	762	782	829	893	911	920	925
Costa Rica	45	62	58	74	82	83	86	86
Guyana	22	25	24	26	23	22	23	23
Mexico	1307	1883	2443	2371	2486	2492	2530	2594
Panama	36	49	57	58	63	63	62	61
Peru	384	495	574	627	659	668	653	641
Dominic. Rep.	129	174	184	203	213	203	198	188
Surinam	10	14	13	11	10	9	9	9
Venezuela	262	364	420	533	592	647	706	737
GROUP 4								
Bolivia	138	167	209	263	325	393	454	495
Ecuador	166	218	270	308	348	366	369	365
Guatemala	164	204	251	318	383	443	482	501
Honduras	78	108	139	170	206	223	234	245
Nicaragua	64	82	104	134	163	183	196	202
Paraguay	69	81	92	122	151	172	193	210
GROUP 5								
El Salvador	100	133	164	176	202	232	243	256
Haiti	141	167	187	200	226	241	249	256

Sources: CELADE. 1990. Boletín Demográfico, Año XXIII, No. 45.

UNITED NATIONS. 1989. World Population Prospects 1988. New York, UN. Population Studies No. 106.

Table 9. Annual growth of active population: 1950-2020 (thousands)

	1950 1960	1960 1970	1970 1980	1980 1990	1990 2000	2000 2010	2010 2020
GROUP 1							
Argentina	100.4	122.9	96.5	124.4	198.1	215.8	183.5
Uruguay	9.9	8.2	2.3	8.2	12.7	13.6	10.7
GROUP 2							
Barbados	-1.0	0.0	2.7	1.9	2.0	1.9	0.7
Chile	34.8	44.9	80.9	98.8	78.2	67.9	46.3
Cuba	31.7	24.8	93.1	89.4	63.8	37.6	23.7
Jamaica	3.1	4.6	23.5	30.0	30.8	33.4	19.3
Trinidad	5.0	3.6	8.0	10.4	11.0	10.7	6.3
GROUP 3							
Brazil	546.5	820.5	1269.6	1078.6	1283.6	1383.6	1138.2
Colombia	80.2	146.0	176.4	240.2	259.5	286.7	235.9
Costa Rica	8.5	15.2	24.6	24.6	27.4	31.1	24.9
Guyana	2.3	3.8	9.0	9.3	10.4	9.3	4.7
Mexico	224.6	343.3	775.9	823.9	995.5	1057.2	934.4
Panama	6.8	13.3	14.2	21.6	23.8	23.3	19.0
Peru	59.4	68.7	150.9	176.4	222.5	274.2	273.4
Domin. Rep.	14.6	22.4	41.4	61.6	68.8	81.6	77.8
Suriname	1.0	1.8	0.5	3.1	3.9	4.4	2.9
Venezuela	65.2	75.1	187.2	191.3	226.1	248.9	233.8
GROUP 4							
Bolivia	17.2	22.9	32.6	54.4	66.9	101.1	142.2
Ecuador	29.4	43.1	56.3	84.8	105.9	133.3	150.0
Guatemala	24.7	34.4	38.0	66.1	103.7	148.7	196.0
Honduras	15.1	17.2	28.9	49.7	72.3	96.2	134.0
Nicaragua	10.1	15.1	20.6	37.9	57.0	67.3	80.3
Paraguay	9.7	15.7	30.6	36.2	44.3	51.7	50.9
GROUP 5							
El Salvador	15.7	34.2	40.3	56.9	80.9	99.7	114.3
Haiti	21.2	28.6	21.6	57.3	78.3	106.0	136.9

Source: OFICINA INTERNACIONAL DEL TRABAJO. 1986. Población Económicamente Activa, Volumen III, América Latina. Third Edition. Ginebra, OIT.

Table 10a. Population/environment

	Growth rate of population					
	Total		Urban		Dif U/R	
	25-30 years ago	1988	25-30 years ago	1988	25-30 years ago	1988
AFRICA						
Argelia	2.5	3.0	6.4	4.3	6.2	2.1
Liberia	2.7	3.3	6.1	6.0	4.3	4.6
Kenya	3.2	4.1	6.5	8.7	3.6	5.8
Madagascar	2.4	3.2	5.2	6.7	3.3	5.8
Zambia	2.7	3.7	8.1	6.7	6.9	6.2
Zairel	.8	3.1	4.9	5.0	4.2	3.2
LATIN AMERICA AND THE CARIBBEAN						
Argentina	1.4	1.2	2.1	1.7	2.7	3.2
Brazil	2.8	2.1	5.0	3.5	4.4	5.5
Colombia	3.3	1.8	5.3	2.9	4.3	3.4
El Salvador	3.8	2.0	4.1	2.9	0.4	1.7
Guatemala	2.8	2.9	3.6	2.9	1.1	0.0
Jamaica	1.0	1.2	3.1	2.8	3.3	2.9
Mexico	3.2	2.1	4.7	3.1	3.3	3.6
ASIA						
Philippines	3.5	2.1	4.3	4.0	1.2	2.9
India	2.3	2.0	3.2	4.4	1.0	3.2
Indonesia	2.2	2.0	3.8	5.3	1.8	4.5
Nepal	1.6	2.6	4.0	8.3	2.4	6.1
Pakistan	2.8	3.1	4.0	4.9	1.5	2.6
Thailand	3.1	1.6	3.7	5.1	0.7	4.2
Sri Lanka	2.5	1.2	4.5	1.9	2.5	0.4

Source: WORLD BANK. 1989. Social Indicators of Development. Baltimore, Johns Hopkins University Press.

Table 10b. Population/environment

	Rate of participation in work force (%)		Active population (%) Agriculture		Industrial	
	25-30 years ago	1988	25-30 years ago	1988	25-30 years ago	1988
AFRICA						
Argelia 24.4	22.6	57.0	25.7	16.7	15.3	
Liberia 41.5	36.0	78.6	74.2	10.0	9.4	
Kenya44.6	39.9	86.1	81.0	5.1	6.8	
Madagascar	50.1	44.0	85.1	80.9	4.3	6.0
Zambia 35.6	33.5	78.7	37.9	8.0	7.8	
Zaire46.2	38.1	82.0	71.5	9.2	12.9	
LATIN AMERICA AND THE CARIBBEAN						
Argentina	39.1	35.3	18.3	13.0	34.2	33.8
Brazil 32.1	36.6	48.5	25.2	20.2	15.8	
Colombia	28.9	32.4	44.7	31.3	21.4	21.1
El Salvador	32.6	33.1	58.7	43.2	15.9	19.4
Guatemala	30.7	28.5	64.0	49.8	15.2	12.3
Jamaica 39.9	48.4	37.2	25.3	19.9	11.5	
Mexico 28.9	33.8	49.6	25.8	21.9	14.1	
ASIA						
Philippines	37.1	36.7	58.8	43.4	15.8	9.7
India41.8	38.9	72.9	62.6	11.9	10.8	
Indonesia	38.3	38.8	70.5	53.5	9.0	9.7
Nepal46.8	41.8	94.0	93.0	1.7	0.6	
Pakistan	30.2	29.9	59.8	48.7	18.3	13.3
Thailand	49.5	52.5	81.7	72.4	5.2	5.9
Sri Lanka	35.3	36.5	56.0	42.4	13.9	12.0

Source: WORLD BANK. 1989. Social Indicators of Development. Baltimore, Johns Hopkins University Press.

PNUD. 1991. Desarrollo Humano. Informe 1990. Bogota, Colombia, Tercer Mundo Editores (for the agriculture and industrial active population in 1988

Table 10c. Population/environment

	Population density inhab./km²		Agricultural land Inhab/km²		Index of concentr. of land property	Forest km² (000)	
	25-30 years ago	1988	25-30 years ago	1988		25-30 years ago	1988
AFRICA							
Argelia	5	10	27	60	0.72	32	44
Liberia	11	21	194	380	0.73	39	38
Kenya	17	38	168	359	0.77	43	37
Madagascar	10	19	17	29	0.80	180	149
Zambia	5	10	9	18	—	313	293
Zaire	7	14	118	205	—	1824	1756
LATIN AMERICA AND THE CARIBBEAN							
Argentina	8	11	13	17	0.87	609	596
Brazil	10	17	47	58	0.86	6007	5602
Colombia	16	26	47	65	0.86	650	482
El Salvador	143	236	236	369	0.81	2	1
Guatemala	42	77	170	261	0.85	53	41
Jamaica	160	218	361	517	0.82	210	189
Mexico	23	42	46	83	0.94	565	446
ASIA							
Philippines	106	195	410	640	—	170	113
India1	48	243	275	441	0.62	612	673
Indonesia	55	90	351	519	0.62	1238	1215
Nepal	73	125	293	406	0.60	24	23
Pakistan	66	129	217	398	0.54	21	33
Thailand	60	104	237	258	—	261	150
Sri Lanka	170	249	518	703	0.62	33	24

Sources: WORLD BANK. 1989. Social Indicators of Development. Baltimore, Johns Hopkins University Press.

IICA. 1990. América Latina y el Caribe: Pobreza Rural Persistente. Serie Documentos de Programas. (for concentration of land property).

DRIVING FORCES: ECONOMICS OF ANIMAL AGRICULTURE IN RELATION TO NATURAL RESOURCES

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The problem addressed by this workshop is to analyze the interactions between sustainable animal agriculture and natural resource management, in light of the challenge for the Central American countries to design and implement alternatives which will enhance sustainable agricultural productivity, while encouraging rehabilitation of degraded lands. As an economist, my interpretation of this objective is:

1. Explain why animal productivity parameters are apparently low in Central America.

2. Explain the economic rationality and driving forces in animal production which result in these productivity parameters.

3. Suggest strategies in response to demands for "sustainable agriculture".

1. WHAT IS ECONOMICS?

Economists operate at the micro or farm level, and the macro or national and international levels. At the farm level, studies are carried out on costs and returns of production, farm management and feasibility of introducing new management practices. Economists are therefore in a key position to help develop livestock related sustainability analyses, because a major question usually involves determination of whether a practice will be accepted. For example, if pollution from dairy or pig run-off is considered a problem, the economist can help determine the impact on producer profits of alternative control mechanisms. At the national level economists work on project analyses and determination of the regional impact of changes in laws and their social impacts. They also develop projections of food consumption, animal inventories, and trade.

There are many definitions of economics, but two stand out in relation to the sustainability issue. One, by Alfred Marshall a century ago in his book Principles of Economics, published in 1890, is: "Economics is a study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of well-being".

Another, more recent, definition by Tibor Scitovsky in his book Welfare and Competition: The Economics of a Fully Employeed Economy, published in 1951, is: "The task of economics is to study economic organization, to appraise its efficiency and equity, and to suggest ways and means whereby its imperfections can be lessened or eliminated".

Notable in both of these definitions is that economics is a discipline quite concerned with human welfare, and agricultural sustainability certainly falls in that category. The objective of production is to meet the needs and desires of a country's population and to assist in improving humankind's welfare. In brief, domestic animals are raised to meet perceived needs subject to social mores.

2. DEMAND FORCES

2.1 Animal Inventories

Producers in Central America keep animals in response to demand, whether it be for farm use or for sale to consumers. Demand is the driving force in animal agriculture. For example, the number of animals, at least on a human *per capita* basis, kept for work purposes has declined in importance because the demand for them has declined due to mechanization. The number of asses, for instance, declined from 54 thousand in 1961-63 to 48 thousand in the late 1980s. This represents a decline from 2.76 per person to 1.78 (Table 1). Horse numbers have increased slightly, from 847 thousand to 910 thousand head over that period, which is to be expected given the importance of ranching. The number of mules, a good barometer of work animals, declined from 237 thousand head in 1961-63 to 188 thousand head in 1987-89. They declined from 12.09 per 1000 people to 7.04 head.

2.2 Demand for Livestock Products

Central Americans, like people in most parts of the world, enjoy eating meat and drinking milk. They well realize the dietary benefits and value of these and other livestock products. Although there is a rising consciousness of vegetarianism and concern about animal welfare, which will have some mitigating influence on tastes and preferences for livestock products, it is safe to say that as incomes increase, the demand curve for livestock products will shift out. In other words, demand will grow. That translates to an expansion in *per capita* consumption of these products.

Table 1. Ass, horse and mule inventory in Central America

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
Asses								
Inventory, HD								
1961-63	0	3727	1977	6733	35224	6575	0	54236
1974-76	0	5400	1852	7833	22228	7175	0	44488
1986-89	0	6900	2233	8667	21900	7967	0	47667
Human population, 1000s								
1961-63	99	1332	2733	4200	2079	1531	1215	13249
1974-76	140	1965	4145	6243	3095	2322	1721	19631
1986-88	171	2791	4934	8434	4680	3501	2274	26785
Animals per 1000 people								
1961-63	0	1.90	0.48	1.08	11.38	2.83	0	2.76
1974-76	0	2.75	0.45	1.25	7.18	3.09	0	2.27
1986-88	0	2.47	0.45	1.03	4.68	2.28	0	1.78
Horses								
Inventory, HD								
1961-63	2500	98715	73667	163633	179000	169256	160689	847460
1974-76	6037	107333	83315	105367	161269	250000	164000	877321
1986-89	5000	114000	92500	107333	170000	255000	170333	914166
Human population, 1000s								

1961-63	99	1332	2733	4200	2079	1591	1215	13249
1974-76	140	1965	4145	6243	3095	2322	1721	19631
1986-88	171	2791	4934	8434	4680	3501	2274	26785
Animals per 1000 people								
1961-63	17.86	50.24	17.77	26.21	57.84	72.89	93.37	43.17
1974-76	43.12	54.62	20.10	16.88	52.11	107.67	95.29	44.69
1986-88	29.24	40.85	18.75	12.73	36.32	72.84	74.90	34.13
Mules								
Inventory, HD								
1961-63	2067	7067	28333	54167	98983	41876	4942	237434
1974-76	4067	5333	21863	43967	70028	42542	5000	192799
1986-89	4400	5000	22900	37533	68434	45167	5000	188435
Human population, 1000s								
1961-63	99	1332	2733	4200	2079	1591	1215	13249
1974-76	140	1965	4145	6243	3095	2322	1721	19631
1986-88	171	2791	4934	8434	4680	3501	2274	26785
Animals per 1000 people								
1961-63	14.76	3.60	6.84	8.68	31.98	18.03	2.87	12.09
1974-76	29.05	2.71	5.27	7.04	22.63	18.32	2.91	9.82
1986-88	25.73	1.79	4.64	4.45	14.62	12.90	2.20	7.04

Statistical data reveal that *per capita* consumption of many livestock products in Central America has declined, whereas incomes in most Central American countries have either increased or remained constant. Careful analysis indicates that in countries like Costa Rica, where *per capita* income has increased and population growth rate has been fairly low, *per capita* consumption has increased. There have been declines in other countries, not because there has been a shift backward in taste and preferences, but rather because the principal population growth has taken place among the lower income groups, those unable economically to satisfy their desire for livestock products due to economic reasons. In effect, the great increase in human population, from 13 million people in 1961-63 to 27 million in 1986-88, apart from internal political instability, has been the major factor in the decline of average well-being.

2.3 Small Ruminants

Per capita consumption of goat meat in Central America, which is very small at 0.03 kg per person, has remained about constant over the past decade (Table 2). Consumption of sheep meat *per capita*, also very low at 0.13 kg, has also remained constant (Table 3). Experience in other countries indicates that, in all likelihood, as urbanization increases, these *per capita* figures will drop because goat and sheep meat are relatively high-priced, and due to a poor image of goats by urbanites. Small ruminants are popular among rural residents in Central America because they are small, so storage of meat has not been a problem, thus leading to more consumption. As a greater proportion of the rural population enters the market economy, and as countries urbanize, there will be a shift to other meats. There is virtually no trade by Central American countries in these meats.

2.4 Cattle

Cattle meat consumption *per capita* in Central America has declined from an average of 10.7 kg to 8.7 kg over the past decade (Table 4). Apart from population growth, mainly occurring among lower income groups, it appears that the real price of beef has increased in relation to incomes. Slight decreases in *per capita* consumption for Central America will likely continue to take place due to the demographics of population growth. The data show that net beef exports, as a percent of production, have declined from 30 to 20 percent, despite all of these countries having access to the United States market.

Table 2. Goats and goat meat production, trade and consumption in Central America

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT4	14	59	400	148	30	0	655	
Inventory, HD 902	4000	11103	76000	22448	6133	5900	126486	
Slaughter, HD 360	1200	3967	26000	9890	1883	0	43300	
Carcass weight, kg	11.1	11.7	14.9	15.0	15.0	15.9	0	0
Offtake, %	40	30	36	34	44	31	0	34
Imports, MT0 0	0	0	0	0	0	0		
Exports, MT0 0	0	0	0	0	0	0		
Net exports (NE), MT	0	0	0	0	0	0	0	0
Total consumption, MT	4	14	59	400	148	30	0	655
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	0.03	0.01	0.06	0.05	0.05	0.01	0	0.03
NE, % of production	0	0	0	0	0	0	0	0
1986-88								
Production, MT6	35	86	433	190	31	0	781	
Inventory, HD 1200	9833	14567	75500	27328	6433	7000	141861	
Slaughter, HD 480	2950	5747	29400	12752	1933	0	53262	
Carcass weight, kg	12.5	11.9	15	15	15	16	0	0
Offtake, %	40	30	39	39	47	30	0	38
Imports, MT0 0	0	0	0	0	0	0		
Exports, MT0 0	0	0	0	0	0	0		
Net exports (NE), MT	0	0	0	0	0	0	0	0
Total consumption, MT	9	35	86	433	190	31	0	781
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	0.04	0.01	0.02	0.05	0.04	0.01	0	0.03
NE, % of production	0	0	0	0	0	0	0	0

Source: Calculated from data on FAO data tapes.

Table 3. Sheep and sheep meat production, trade and consumption in Central America: 1974-76 and 1986-88

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT8	16	20	2700	38	11	0	2793	
Inventory, HD 2803	3600	4051	517533	5000	2017	0	535004	
Slaughter, HD 560	1080	1317	180000	2500	900	0	186357	
Carcass weight, kg	14.3	14.8	15.2	15.0	15.0	12.2	0	0

Offtake, %	20	30	33	35	50	45	0	35
Imports, MT5 0	0	0	0	0	13	18		
Exports, MT0 0	0	0	0	0	0	0		
Net exports (NE), MT	-5	0	0	0	0	0	-13	-18
Total consumption, MT	13	16	20	2700	38	11	13	2811
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	0.09	0.01	0	0.43	0.01	0	0.01	0.14
NE, % of production	-0.63	0	0	0	0	0	0	-0.01
1986-88								
Production, MT10	27	31	3267	52	16	0	3402	
Inventory, HD 3500	6000	4600	666000	6972	3400	0	690472	
Slaughter, HD 700	1797	2047	218333	3534	1337	0	227749	
Carcass weight, kg	14.3	15.0	15.1	15.0	14.8	12.0	0	0
Offtake, %	20	30	45	33	51	39	0	33
Imports, MT10 0	0	0	0	0	4	14		
Exports, MT0 0	0	0	0	0	0	0		
Net exports (NE), MT	-10	0	0	0	0	0	-4	-14
Total consumption, MT	20	27	31	3267	52	16	4	3416
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	0.12	0.01	0.01	0.39	0.01	0	0	0.13
NE, % of production	0	0	0	0	0	0	0	0

Source: Calculated from data on FAO data tapes.

Table 4. Cattle and cattle meat production, trade and consumption in Central America: 1974-76 and 1986-88

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT876	66445	29675	59567	39834	61554	44540	301672	
Inventory, HD 46866	1790898	1059197	1515367	1816934	2560097	1347300	10136659	
Slaughter, HD 3623	515311	190268	339067	268814	305167	223365	1647814	
Carcass weight, kg	150	211	156	176	145	202	199	0
Offtake, %	12	18	18	22	15	12	17	16
Prod/HD of inventory, kg	18.7	37.1	28.0	39.3	21.5	24.0	33.1	29.8
Imports, MT495	1191	3159	400	1566	2020	5881	14712	
Exports, MT21930603	3702	22967	21141	24905	1840	105377		
Net exports (NE), MT	-276	29412	543	22567	19576	22885	-4041	90666
Total consumption, MT	1152	37031	29135	37000	19459	38649	48581	211007
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	8.2	18.8	7.0	5.9	6.3	16.6	28.2	10.7
NE, % of production	-32	44	2	38	50	37	-9	30
1986-88								
Production, MT1112	91669	20932	45000	39445	39404	56210	293772	
Inventory, HD 49500	1773000	1094267	2012000	2795354	1883333	1420733	11028167	
Slaughter, HD 7136	456586	140104	260433	260559	276767	280114	1681699	
Carcass weight, kg	156	201	149	173	151	142	201	0
Offtake, %	14	26	13	13	9	15	20	15
Prod/HD of inventory, kg	22.5	51.7	19.1	22.4	14.1	20.9	39.6	26.6
Imports, MT1239	3722	3319	433	2310	0	5	11029	
Exports, MT32629102	787	19933	13369	6845	107	70469		

Net exports (NE), MT	-913	25380	-2532	19500	11059	6845	102	59441
Total consumption, MT	2025	66289	23464	25500	28386	32559	56108	234331
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	11.8	23.8	4.8	3.0	6.1	9.3	24.7	8.7
NE, % of production	-82	28	-12	43	28	17	0	20

Source: Calculated from data on FAO data tapes.

Notable in Table 4 is that Belize's net imports of beef, as a percent of production, grew from 32 to 82 percent. Costa Rica's net exports declined from 44 to 20 percent. Both countries have been characterized by political stability and economic growth. On the other hand, international beef prices were relatively low in the mid 1980s. Costa Rica and Belize are the only two countries in which *per capita* consumption increased. Total beef production in El Salvador, Guatemala, and Nicaragua has decreased, probably due to political instability.

2.5 Pigs

Demand side forces are understood further by evaluation of pig meat consumption, which declined slightly from 3.6 kg average for all Central America in 1974-76, to 3.2 kg in 1986-88 (Table 5). Although technological change has made this product cheaper relative to other red meats, Central America continues to be a net importer of pork. About two thirds of it is by Panama.

Table 5. Pig and pig meat production, trade and consumption in Central America: 1974-76 and 1986-88

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT840	8220	13451	12900	8752	17724	5286	4773	
Inventory, HD 18066	220000	441667	609133	514452	640000	173367	2616685	
Imports, MT949	153	310	200	238	117	2832	4799	
Exports, MT14 44	9	233	0	427	2	729		
Net exports (NE), MT	-935	-109	-301	33	-238	310	-2830	-4070
Total consumption, MT	1775	8329	13752	12867	8990	17414	8116	71242
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	12.7	4.2	3.3	2.1	2.9	7.5	4.7	3.6
NE, % of production	-111	-1	-2	0	-3	2	-54	-6
1986-88								
Production, MT1272	10115	14907	15867	10900	14420	13419	80900	
Inventory, HD 25167	227667	423544	844000	576590	732987	229933	3059888	
Imports, MT1000	20	272	233	379	12	3294	5211	
Exports, MT32 183	0	0	3	0	0	218		
Net exports (NE), MT	-968	163	-272	-233	-376	-12	-3294	-4992
Total consumption, MT	2240	9952	15179	16100	11276	14432	16713	85892
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	13.1	3.6	3.1	1.9	2.4	4.1	7.3	3.2
NE, % of production	-76	2	-2	-1	-3	0	-25	-6

Source: Calculated from data on FAO data tapes.

2.6 Poultry

Poultry meat consumption has more than doubled since 1974-76, from 2.6 kg to 5.7 kg (Table 6).

Table 6. Poultry and poultry meat production, trade and consumption in Central America: 1974-76 and 1986-88

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT1273	3290	6177	14400	5886	9987	9371	50984	
Imports, M	86	8	309	67	0	414	84	986
Exports, MT17351	116	533	17	0	2	853		
Net exports (NE), MT	87	43	-193	467	17	-414	-82	-75
Total consumption, MT	1186	3847	6370	13933	5869	10401	9453	51059
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	8.5	2.0	1.5	2.2	1.9	4.5	5.5	2.6
NE, % of production	7	1	-3	3	0	-4	-1	0
1986-88								
Production, MT4085	5300	28404	52400	17831	10799	33814	152633	
Imports, MT55 0	298	33	86	0	325	798		
Exports, MT0 11	23	0	0	0	0	34		
Net exports (NE), MT	-55	11	-275	-33	-86	0	-325	-764
Total consumption, MT	4140	5289	28679	52433	17917	10799	34139	153397
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	24.2	1.9	5.8	6.2	3.8	3.1	15.0	5.7
NE, % of production	-1	0	-1	0	0	0	-1	-1

Source: Calculated from data on FAO data tapes.

Vast technological advances in production and marketing have led to the increase, a trend that will likely continue especially if government policy is appropriate to allow production or imports of needed production inputs, feedstuffs, and veterinary products, in addition to providing a climate which encourages expansion of medium and large scale enterprises. The same analysis holds for eggs. These two commodities are illustrative of the need to intensify production if demand is to be met. This conclusion is reinforced by evaluation of demographic changes.

3. URBANIZATION

Urbanization is one of the major driving forces of animal agriculture. Although it is difficult to make a case that economic development is caused by urbanization, analysis of world data clearly demonstrates a strong relationship between urbanization and *per capita* income. The reason is that when a country is heavily oriented toward agriculture, and particularly toward subsistence agriculture, there is a relatively weak interplay with a market economy. As urbanization takes place, greater industrialization leads to more manufacturing, which has a higher multiplier effect that agriculture, especially a subsistence oriented one. That multiplier effect is crucial for economic development.

Clearly, wide debate can be generated on the optimal speed of urbanization. But the message is clear: if a country's goal is economic development, migration from agriculture is to be encouraged. It should hastily be pointed out that urbanization need not mean growth of megalopolises. Rather, it can mean, as has happened in China, creation of industry in rural areas and expansion of smaller towns and cites. The definition of urbanization varies between countries and regions.

Projections by United Nation's demographers indicate that in Central and South America (including the Caribbean and Mexico) urbanization grew from 49 percent in 1961-63, to 61 percent in 1974-75 and 72 percent in 1986-88 (United Nations, 1989). The projection is for 77 percent in 2000 and 85 percent in 2025. In contrast, Europe was 85 percent urbanized in 1986-88. The world average was 41 percent in that period.

Central America's human population was 20 million in 1974-76. It jumped to 27 million in 1986-88 and is forecast at 38 million in 2000 (Table 7). The medium variant projection for 2025 by the United Nations is an astounding 63 million. Urbanization was 40 percent in 1974-76, 47 percent in 1986-88 and will grow to 54, 60 and 68 percent in 2000, 2010 and 2025, respectively. Most interesting for animal and crop agricultural strategy development is that while rural population increased from 12 million in 1974-76 to 14 million in 1986-88, it will only grow slightly to 18 million in 2000 and will then remain at about 19 million in 2010 and 2025. In other words, very little population growth will take place in rural Central America from now on.

Table 7. Total human population, urban and rural population and percent urbanization by country, 1974-76 to 2025

Country	1974-76	1986-88	Year 2000	2010	2025
			Total human population, 1000s		
Belize	140	171	221	259	315
Costa Rica 1965	2791	3711	4366	5250	
El Salvador 4145	4934	6739	8491	11299	
Guatemala6243	8434	12221	15827	21668	
Honduras	2322	3501	5261	6824	9219
Panama	1721	2274	2893	3324	3862
Total	19631	26785	37892	47759	63123
			Percent urbanization		
Belize	49.4	56.1	57.8	64.3	72.4
Costa Rica 42.2	53.6	60.8	67.0	74.6	
El Salvador 40.4	44.4	49.5	56.3	66.0	
Guatemala37.1	42.0	47.5	54.6	64.5	
Honduras	32.3	43.6	51.5	58.7	67.9
Nicaragua50.3	59.8	65.9	71.3	77.9	
Panama	49.1	54.8	60.4	66.6	74.3
Weighted avg.	40.3	47.4	53.5	60.1	68.8
			Total urban population, 1000s		
Belize	69	96	128	167	228
Costa Rica 829	1496	2256	2925	3916	
El Salvador 1675	2191	3336	4780	7457	

Guatemala	2316	3542	5805	8642	13976
Honduras	1000	2040	3526	5088	7815
Nicaragua	1168	2094	3467	4866	7182
Panama	845	1246	1747	2214	2869
Total	7902	12705	20265	28681	43444
			Total rural population, 1000s		
Belize	71	75	93	92	87
Costa Rica	1136	1295	1455	1441	1334
El Salvador	2470	2743	3403	3711	3842
Guatemala	3927	4892	6416	7185	7692
Honduras	2095	2640	3320	3580	3695
Nicaragua	1154	1407	1794	1958	2037
Panama	876	1028	1146	1110	993
Total	11729	14080	17627	19078	19679

The demographic data are of great importance for the sustainability issue, as they herald unprecedented opportunities to institute sustainable practices. One reason is that an urbanized population is more likely than a rural population to demand ecologically sound practices. Another is that both crop and animal agriculturalists will have to be increasingly efficient in order to feed, not only their own families, but also a growing number of other people. That means they will have to intensify, a concept that is measured by productivity. One implication is that limited development funds will increasingly have to be directed toward market oriented producers. Another is that an enormous increase will take place in the demand for grain and other feedstuffs. Taken together -population growth and urbanization- this pair of data underscore the demand which will be placed on the Region's resources. It is indeed unfortunate that Central Americans will not recognize the population problem and do something about it.

4. SUPPLY FORCES: PRODUCTIVITY AND EFFICIENCY

Productivity and efficiency are central factors in the sustainability issue. As productivity is enhanced, fewer resources are often used, due to greater efficiency and synergism. One example is the relation between feed use and body weight gain. As Conrad and van Es (1983) pointed out, 265 grams of crude protein (CP) and 34 mega Joules (MJ) of metabolizable energy (ME) are required daily just for the maintenance of body weight in a 300 kg bovine. When the animal is gaining 0.5 kg daily, it requires 370 grams of CP and 48 MJ of ME (Table 8). At this rate of gain, only 28% of the CP and 29% of the ME are used for body weight gain. In contrast, the 300 kg animal gaining 1.0 kg daily utilizes one half its CP and ME for gain and one half for maintenance.

Table 8. Influence of daily gain on efficiency of protein and energy utilization of 300 kg cattle

	Total protein		Metabolizable energy	
Daily gain kg	Daily requirement grams	Efficiency for gain %	Daily requirement MJ	Efficiency for gain %
0.00	265	0	34	0
0.25	315	16	40	15
0.50	370	28	48	29
0.75	435	39	56	39
1.00	520	49	67	49
1.25	620	57	80	57
1.50	755	65	97	65

Source: Conrad and van Es (1983), based on ARC data.

At zero level of performance, 100 percent of CP and ME are required for maintenance. The authors also point out that this relationship of maintenance and gain is one of the basic and fundamental explanations for the often poor feed conversions associated with livestock in developing countries.

The relationship of feed for maintenance is well illustrated by the case of dual purpose dairy cattle. Physiologically, high producing dairy cows can yield well in the subtropics, especially at higher elevations under appropriate management. But great efforts are spent on development and dissemination of crossbred dual purpose dairy cattle (Zebu and improved dairy breeds), which require an inordinately large proportion of feed for maintenance relative to purebred (or a high percentage) dairy cattle. The total quantity of feed consumed *per* kg of milk is quite high relative to purebreds or high crosses. These so called dual purpose cattle are not really dual purpose (beef/milk) but rather are a low level of production animal developed to survive under the stress of low nutrition and low management conditions.

Dairy farms in Latin America almost always have some proportion of Zebu in their herds. As management improves, there is generally more intensification of production, size typically increases and the proportion of Zebu breeding declines. The dual purpose animal has been propagated because government policy -and that of international development and lending agencies-
has been oriented toward small producers, ones who generally do not have resources or skills to manage high producing animals.

Milk is widely recognized as a nutritious product well suited to improvement of human condition, especially among children. But, evaluation of data for Central America reveals that net imports of milk products (on a fresh weight basis) doubled over the period 1974-76 to 1986-88. By the latter period, they accounted for 33% of consumption, compared with 14% in 1974-76 (Table 9).

While political unrest is a contributing factor, government policy stands out. Consideration of production practices in Panama, for example, indicate that milk can be produced in tropical and premontane areas with appropriate policies. The case of Costa Rica, which has focused on production by high yielding dairy cows, also stands out. In that country, net imports decreased from 20 thousand tons in 1974-76 to 5 thousand tons in 1986-88. Cheap food policies, which lead to subsidized milk powder imports at the expense of national production are a major variable in the productivity equation.

The development aid focuses on small producers, with equity as a primary rationale, has been a region-wide policy, whether it be articulated or passive. There was good reason until the past decade for it, because of Central America's relatively small population density, lower level of economic development and high proportion of rural population. But, given the large increases projected in urban population, very low growth forecast in rural population, demand for attention to ecological factors, and an implicit demand for increased productivity, the time has come to dialogue on equity priorities.

Table 9. Milk cows and milk production, trade and consumption in Central America: 1974-76 and 1986-88

Item	Belize	C.R.	El Sal.	Guat.	Hondu.	Nicar.	Pana.	Total
1974-76								
Production, MT3450	262368	243077	305333	232124	440243	70693	1558388	
Inventory, HD 3600	250800	253137	336667	357434	372072	74500	1648210	
Yield, kg	1014	1046	960	907	650	1185	949	946
Imports, MT33445	24996	71019	23100	36566	12492	80207	281825	
Exports, MT8442	5868	2646	4500	0	41652	1273	64381	
Net exports (NE), MT	-25003	-19128	-68373	-18600	-36566	29160	-78934	-217444
Total consumption, MT	28653	281496	311450	323933	268990	411683	149627	1775832
Human population, 1000s	140	1965	4145	6243	3095	2322	1721	19631
Consumption *per capita*, kg	204.7	143.3	75.1	51.9	86.9	117.3	86.9	90.5
NE, % of production	-685	-7	-28	-6	-16	7	-112	-14
1986-88								
Production, MT4333	412937	255510	420000	283503	127333	115644	1619260	
Inventory, HD 4217	300197	248567	430000	329866	207667	107000	1627514	
Slaughter, HD 1028	1376	1028	977	859	613	1081	955	
Imports, MT35929	9732	94617	135567	69369	145050	77781	568045	
Exports, MT6328	4342	15028	0	52	2870	7978	36618	
Net exports (NE), MT	-29601	-5390	-79589	-135567	-69317	-142180	-69783	-531427
Total consumption, MT	33934	418327	335099	555567	352821	269513	185427	2150687
Human population, 1000s	171	2791	4934	8434	4680	3501	2274	26785
Consumption *per capita*, kg	198.4	149.9	67.9	65.9	75.4	77.0	81.5	80.3
NE, % of production	-683	-1	-31	-32	-24	-112	-60	-33

Source: Calculated from data on FAO data tapes. Trade on fresh milk basis.

Emphasis from the sustainability viewpoint could best be placed on evaluation of the extent to which various livestock systems can effectively increase productivity, and public sector cost/benefit ratios of the development requirements. If, for example, one system will produce a certain product with a much greater productivity and fewer public and private resources, but requires much less labor and significantly fewer owner/operators, the tradeoffs should be discussed in a policy framework. Small producers will and should continue to be part of the Central America livestock production complex. The problem is to determine the speed at which non-commercial, non-market oriented producers shift to other employments.

Another reason why productivity in Central America's animal agriculture has not increased rapidly is that product prices are relatively low and input prices relatively high. The inevitable result is extensive production practices and low levels of technical inputs associated with low productivity. Product prices have been low because many governments have controlled them as part of a cheap food policy. Two other reasons are that incomes are low, and there is a relatively low demand for higher quality and greater processed products. Extensive production practices imply massive land clearing — the antithesis of sustainable agricultural goals today. The solution is to intensify production. In fact, there even exists the possibility of reversing the ecologically abused conditions through policies and investments in human migration from sensitive areas and intensification of other areas.

A few data, again employing milk production as an example, help place animal productivity in Central America in context and provide some ideas of how much improvement is technically possible. Sadly, milk production in Central America increased just 5 percent from 1974-76 to 1987-89, from 946 kg annually per cow in lactation to 995 kg (Table 10).

Table 10. Milk production per head (kg) of milk cows in lactation

Country or region	1974-76	1987-89	Percent change
Central America	946	995	5
France	2897	2896	0
United States 4769	6387	34	

Source: FAO Yearbooks.

In contrast, while government policy in France prevented any increase over that period, yield was thee times more than in Central America. The yield in the USA increased from 4,769 kg to 6,387 kg, a 34 percent increase in 13 years. Production per cow in the US is now six times greater than in Central America. Milk production per cow in Florida -a hot subtropical climate-increased 33 percent over the same time period, from 4,443 kg to 5,896 kg.

The high productivity in the USA is not without its drawbacks. There are ecological costs which the economist, animal scientist, and policy maker need to consider as Central America's sustainability issue is discussed. First, very high levels of concentrate feed are utilized in the United States. Second, intensive production practices imply much greater attention be given to pollution control mechanisms, and the fact that higher producing cows are associated with larger and more mechanized farms means less labor and fewer farms per kg of milk produced.

Another example will help demonstrate the importance of productivity as a driving force. Beef production per head of cattle and calves in Central America declined 10 percent from 1974-76 to 1987-89, from 28.9 kg to 26.6 kg (Table 11).

Table 11. Beef Production per head (kg) of cattle and calves.

Country or region	1974-76	1987-89	Percent change
Central America	29.7	26.6	-10
France	79.0	82.3	4
United States 87.7	107.7	23	

Source: FAO Yearbooks.

This very low level is reflective of the extensive type systems and a long time to reach market, associated with relatively low input use. For several countries it reflects the political unrest. As a contrast, beef production in Costa Rica grew from 37.1 kg to 51.7 kg and in Panama from 33.1 to 39.6 kg. Beef production in France only increased 4 percent over the same period, from 79.0 kg to 82.3 kg. In the United States, characterized by large feed yards for fattening cattle and improved production practices at the cow/calf level, beef production per head of cattle and calves increased from 87.7 kg to 107.7 kg, a 23 percent increase in that thirteen year period. Today, due to the application of technology and improved management practices, many calves go directly from cow/calf operations to feedlots, bypassing the traditional stocker phase due to large size, relatively cheap grain, and great efficiencies in feeding.

A summing up of the supply side begins by reiterating that demand is the driving force in animal production, just as in other aspects of agriculture. As Central America urbanizes, non-farm demand will become increasingly important. As *per capita* incomes increase, demand will grow for greater services such as improved quality, packaging, and sanitation. At that point, if governments do not otherwise intervene, product prices will rise, thus permitting more use of inputs and improved management. If social philosophy encourages greater commercial type production, productivity will increase. But, there is no free lunch.

United States cattle productivity, as shown by the data in table 12, is high because live weight gains from birth to market are nearly one kg per day. Furthermore, since emphasis is on improved production efficiency throughout the life cycle, fattened animals reach market weight at about 15-18 months of age, compared with 36-48 months in Central America. Short-term finishing on grain in American feedlots (4-6 months) is an important contributing factor. But demand conditions in Latin America are different from those in the United States, where consumers developed a taste for grain-fed beef — and the grading system reflects that bias. To a limited extent, in the U.S. at least, forage fed beef can be produced cheaper than grain fed beef, but it commands a much lower price due to low demand for that product.

Table 12. Productivity of cattle in the United Stated.

Item	1975	1989	Percent change
Number of feedlot marketings per year	2.0	2.4	20
Time on feed in feedlots, days	180-190	125-130	-31
Steer weaning weights, kg	207	238	15
Beef production per cow, kg	200	240	20

Source: National Cattlemans Association, 1990.

5. STRATEGY SUGGESTIONS

The following observations serve as both a summary of this paper and thoughts on what might be done to meet the goal of this workshop, which is to analyze the interactions between sustainable animal agriculture and natural resources management.

- The destruction of Central America's bio-diversity habitat, especially through widespread clearing of forests should not be tolerated. Neither should the myth that cattle are responsible be tolerated, for it is humankind which is the cause. More specifically, it is large human population increases rather than animals *per se*, or preferences for livestock products, which are responsible for the sustainability issue.

- Urban population in Central America will increase from 13 million people in 1986-88 to 20 million in 2000 and will double again over the next quarter century, according to United Nations projections. But rural population will only increase marginally according to these demographics. In effect, the development target probably will have to increasingly focus on intensified market oriented crop and livestock agriculture, as a means to feed a rapidly increasing urban population. This does not necessarily mean large-scale commercial operations but it does mean a re-orientation in development aid philosophy.

- A dialogue is needed on the question of who should produce and why. If the goal is economic development and radically improved standards of living for rural as well as urban dwellers, then promotion of commercial scale livestock operations should be encouraged. That means support for a policy which encourages urbanization, especially with a reduction of marginal and subsistence level producers. The concept of very small producers is a laudable one, but size as well as other constrains prevent substantial income improvements, thus leaving these producers as an ever alienated part of society.

- There should be recognition that society (i.e. policy makers) now need to set sustainability parameters rather than simply rely on market forces and belated public opinion. This could be accomplished by an interaction with agricultural specialists and economists to determine feasible targets and appropriate legislation. It must be recognized that producers are profit makers who operate within rules set by society. Development of regulations which stimulate productivity, yet provide guides of what society wants in terms of economic growth and an ecological vision, are part of the development process. Central America is at a critical juncture in which these policies and legislation should be articulated.

- The policy maker's role is a critical factor for, with equitable prices and reasonable profits, i.e. a producer oriented policy, there will be an adoption of technology which will lead to improved efficiency and increased efficiency per what Dr. Conrad has termed "natural resources unit". Again, the equity question is crucial for, in animal agriculture, much of the technology and management practices are of such complexity that application in an effective way is not realistic by smaller producers.

- Eggs and poultry meat output expansion and productivity can be handled by the private sector with relatively little technical help from the public sector. However, the private sector can only fulfill its task by legislation and policies which encourage investment, development and inexpensive feedstuffs. In effect, there is little that development agencies need to do related to poultry production from a sustainability and efficiency viewpoint, except assist in development of environmental regulations, help in creation of a good climate for investors, and fostering an atmosphere which rewards intensification and creation of economic size units.

- Pig production is quite similar to poultry in terms of strategy development. Rapid improvement in productivity and reduction in cost to consumers is possible from medium and larger scale commercial production units. A critical element, as with poultry products, is that investors require political stability and encouragement, issues on which it may be difficult to develop a consensus.

- Small ruminants merit some consideration from international agencies, from both a development and sustainability viewpoint. However, due to limited numbers and the relatively high cost of goat and sheep meat, the main emphasis will probably be on certain selected groups such as producers at the lower end of the economic spectrum, rather that as country or region-wide programs. Much has been learned over the past decade from the Small Ruminant CRSP.

- Beef cattle and dairy cattle, to a somewhat lesser extent than poultry and pigs, provide the major opportunities for development agencies and for national and regional development and research in Central America. It would seem that research should be very applied, particularly with much of it conducted on-farm by specialists with joint extension/research appointments. There is a missing link that is best filled by individuals who realize their mission is a developmental one — not one of basic research. Closing the dichotomy between extension and research has to be a top priority.

- There will be a tremendous demand for more feed grains and oilseed meals in Central America, primarily for poultry production and second for pork production. Without accelerated gains in farm productivity, rising demands due to both population increase and income growth will translate directly into environmental stress. A continuous flow of technology and associated intensification is critical to environmental sustainability.

- The key to reversing destruction to bio-diversity in Central America is resource management, which means improved economic efficiency, which in turn means more productive use of available resources. Perhaps the main point is that the systems must be economically viable to producers. They are the ones who do and will make the ultimate decisions.

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POLICIES RELATING TO LIVESTOCK AND NATURAL RESOURCES: INSTITUTIONAL FACTORS

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1. INTRODUCTION

Central America has an area of 533,325 square kilometers distributed among its seven countries. In 1989, it collectively had a population of 28.4 million inhabitants, with a growth rate of 2.8%. Its population is principally a mixture of colonists, indigenous, and blacks, the latter especially in the Atlantic regions. The total population of indigenous persons is less than 10% of the total in the seven countries, although some countries have twice, and some almost three times, the average for the region.

2. THE INSTITUTIONAL INFLUENCE IN THE DEVELOPMENT OF POLICIES IN CENTRAL AMERICA

Central America is a dynamic stage with many institutional actors. These include governments which develop their own policies, and multi-lateral organizations working at the macroeconomic level, such as the International Monetary Fund, the Interamerican Development Bank, and the Central American Economic Integration Bank. The latter has worked to date on natural resources, while its role in relation to livestock has been more passive. On the other hand there is a diversity of regional organizations, national organizations, and non-governmental organizations such as: AID/ROCAP, the EEC, the Netherlands Cooperation, the Neotropical Foundation, the Federation of Private Institutions of Central America, etc. In addition, in Costa Rica as well as in the rest of Central America, there are producers' organizations.

In spite of this diversity of actors in Central America there has not been any unified policy among them. On the contrary, each one has its individual policies, a fact which works against the concentration of efforts, and rather towards a dispersion of efforts. As a consequence, they work against a basic principle of physics which states that the greater the force applied to a point, the greater the result. Thus, we believe that an integration of efforts, such as this symposium is trying to achieve, is very important.

3. FACTORS INFLUENCING LIVESTOCK AND NATURAL RESOURCES IN CENTRAL AMERICA.

In Central America the recent political instability and adverse economic conditions have affected livestock production and its balance with natural resources. In this imbalance there exist factors of internal origin as well as of external origin. Among the internal factors we can point to the adverse economy of the countries of the region, and the political instability — although peace treaties now exist. Equally, in recent years the countries have elected governments through the democratic process.

The countries of Central America have a large fiscal deficit, a high inflation rate, and a major internal and external debt. For example, in Costa Rica the external debt exceeds 105,000 million colones and the internal debt has a relationship of almost 5:1 to the external debt. On the other hand, the unstable monetary policies, the high rates of interest, and -in some cases-unrealistic rates of exchange are a disincentive for those products which have a comparative and competitive advantage on the international market.

Among the external factors we find policies of protectionism which have isolated possible markets for the products of the region from efficient and effective international competition. Here we find a contradiction in that, on one hand, the countries of the region are asked to practice free trade, while on the other hand the major markets continue to be protected. At the same time there is a weak external demand for regional export products. Thus it is said that our capacity to export "desserts" (coffee, bananas, etc.), in terms of decreasing exchange, increasing offer of external credit, fluctuating rate of interest and development of structural adjustment programs, which have not assured a positive growth of gross internal product, result in the infeasibility of the region to reach its development potential in the present decade. In Central America there are few possibilities for reducing the external debt, given that the *per capita* income in the region has a rate of growth of 2.3%, well below the rate of 1965-1986 when it stood at 3.4%. In other words, there is a close relationship between economic conditions and the natural resources of the region, with direct impacts on forest resources.

Livestock production has also suffered part of this political and economic instability of the region. This is due in part to the basic fact that livestock are an input in their own production and that cattle production is intensive in its use of capital. The breeding herd is a fixed activity, whereas fattening and raising is a revolving activity. However, the breeding herd also becomes a revolving activity, moving to the slaughterhouse and to other countries when there are better prices. Also, in times of low prices the rate of slaughter increases, as it does too in times of political instability. It is notable that beef consumption in Costa Rica and Belize has increased in the last few years to 18-22 kilos *per capita,* whereas in Japan, a developed country with many resources, the consumption is only 4 kilos *per capita* of red meat. In Costa Rica domestic consumption accounts for 62 to 68% of the meat produced, which means that only 32-38% is exported.

4. THE BUSINESSMAN'S VIEW OF SUSTAINABLE DEVELOPMENT

Sustainable development is a process by which the demands of the current population are satisfied without putting at risk the capability to meet the needs of future generations. There is no doubt that this concept of sustainable development implies a difficult collaborative effort over the long term, worldwide. In considering the North-South relationship and its effect on achieving sustainability, there are factors which work both for and against the concept of sustainable development.

There are differing positions in regard to sustainable development and its implications for North-South relations. Those who oppose the concept state that sustainable development is an argument designed by the North as a straight-jacket for the South, and that it prevents the developing countries from expressing themselves freely and forces them to submit to Northern criteria. On the other side, those in favor of the concept see it as a totally new opportunity to reinforce the independence of the countries and to increase their negotiating power, above all when we consider that Latin America has 60% of the forest reserves.

For the businessman, an adequate definition and a constructive use of the concept of sustainable development makes a lot of sense. Sustainable development is reaching a state where natural resources assume a realistic price, from both an economic and ecologic point of view. This has two immediate and profound consequences for policies. Firstly, the business sector considers that all oversight and special advantages which tend to promote the use of natural resources should be eliminated. This measure alone should bring positive results, such as reducing by half the rate of deforestation. On the other hand, the agricultural products must maintain their price in the market, given that current subsidies and artificial price reductions tend to favor urban communities. This tends to contradict the principles of sustainable development, given that in this way the cities are supported at the expense of rural areas. In synthesis there has been a hidden slavery of the countryside by the cities.

There is also a close relationship with the model which the great majority of Latin American countries have followed in export substitution. The agricultural sector has produced dollars based on activities which have comparative and competitive advantages and these are then used for importations of raw materials for capital goods that the citizens of developing countries acquire at high cost, though not necessarily high quality, thanks to tariff protection. In summary, the model of CEPAL has had a high cost for the agricultural sector in Central America in particular, and Latin America in general. In some cases the regulatory policies and subsidies have permitted us to overlook the more rational uses of our natural resources.

For Central America, sustainable development implies better development with more efficient usage of natural resources. It also implies greater continuity, greater equality of opportunity and greater openness. The task of sustainable development is not only that of the State, nor only of the agricultural sector or the conservation groups, it is a task for all of them together. Nor is it a responsibility that the countries of Latin America assume alone, nor the other developing countries. In this respect the international organizations have an important role to play; in the short term the macroeconomic approach is of great importance in allowing sustainable development to become a reality, although we recognize it as a long term challenge, by providing financing and technical assistance for projects, and by assuring that within the projects sustainable development and the ecologic impact of said projects are taken into account. This task has already started with some efforts by the World Bank, the Interamerican Development Bank, and other organizations, but must be continued in a systematic way and with increasing and permanent emphasis.

A greater emphasis should be placed on conversion of the external debt in Latin America at market rates in favor of sustainable development; if we believe we need sustainable development, then we must support it. This must be conceived under three headings: a) the creditors must be willing to convert the debt at market rates; b) the debtors must pay attention to finding mechanisms which will have a minimum effect on inflation and c) the World Bank group, working with local banks where necessary (and we consider the Central American Economic Integration Bank should cease to play a passive role and become more active in the region) must provide the resources in local currency destined to specific activities related to sustainable development. This new mechanism, which has been successfully tested on a small scale in different countries in Latin America (such as Costa Rica and Bolivia), must be extended to those countries showing a clear commitment to sustainable development.

It is appropriate to place great emphasis on improving and raising the technical level by using this instrument. The World Bank group should assure the efficient use of these means, perhaps by encouraging a greater involvement of the private sector in the process of debt conversion. Sustainable development is possible when it is in the interest of the majority, when it represents an improvement in their lifestyle, but it must also be an activity supported equally by North and South.

ASPECTS OF MEAT MARKETING

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The market is where supply and demand meet; in a free market it is the point where the producer receives the result of his production. I must say that in the meat market there is no one who knows everything because usually predictions turn out to be mistaken. It is a market affected by multiple factors. These include not only supply and demand, but political negotiation, climatic factors, etc. What the producers need is the ability to plan their marketing strategies based on the information that they have available from the domestic supply of the country and the external environment. The meat market can be affected by a snowfall in the United States or by a drought in Queensland; in the latter case the result might be an acceleration of slaughter by the world's biggest meat exporter, Australia, to the United States market.

It is worthwhile to consider some of the background which has led to the situation that we have experienced in the decade of the eighties and early nineties in the meat market. The European Economic Community was an importer of meat, with a total of 422,000 tons of meat imported in 1970. The definition of the policies of the community as a block, with a high percentage of the gross domestic product directed to subsidies, meant that a decade later the EEC had 300,000 tons available for export. In other words, the subsidies generated an unexpected response, and one not based on comparative advantage, but rather a supply generated on the basis of subsidies to production. Once again, we face the inequality of having to open our markets to free trade with no subsidies for our production, but the market remains closed and they carry on subsidizing their producers.

The meat from this intervention was selling, in early 1991, in the Port of Veracruz between US$ 2,005 and US$ 2,010 *per* ton for forequarters, while last week we had prices for the same cut of meat of US$ 1,920 also in Veracruz. It is worthwhile mentioning that at present the EEC bids for 5,000 to 6,000 tons *per* month from countries not affected by foot and mouth disease. We could get quotations for brisket placed in Costa Rica or Central America of 57 cents U.S. *per* pound. But unfortunately, in many of the developing countries we have a taste for champagne although our wallet only serves for water, and our people do not like to eat frozen meat; they would rather go hungry or eat less meat than eat it frozen. In 1991 the big question all we ranchers in Central America had was if there would be a need to apply the U.S. Importation Law of 1979, known in the meat market circles in Latin America as the U.S. Anticyclical Law. The trigger level of the law was estimated to be 1318.5 millions of pounds of imported meat in 1991, with a mechanism for automatic initiation if the trigger level was reached. This year a system of voluntary quotas was implemented by the Government of the U.S. with Australia, which had reached import levels of 37,000 tons *per* month. Later I will comment on the agreement which they reached a few days ago - and as an example of just how volatile the meat market is, I can say that the situation changed significantly between the 1st and 7th of this month of October.

Australia, without doubt, is the biggest exporter of meat to the United States and it is an exporter which has a very significant impact on the world market. Its neighbor, New Zealand, is also a significant exporter of large volumes of meat, the second exporter to the United States and the biggest in the world after Australia. As I have said, in the meat market anything can happen and to illustrate this, let us go back to 1974 when we cattlemen were getting less than 50 cents *per* pound for meat on the international market. However, I would say that, at least in Costa Rica, the biggest difficulties cattlemen have had to face have not been the international markets, nor free trade, but rather the fixing of internal market prices.

The cycles in the meat market start very suddenly, the changes in offtake result from the fact that cattle, just as capital and other goods, is an important input in its own production. Thus an increase in slaughter can produce an abrupt negative effect and an increase in price fluctuation. We have to understand that the cattle industry is a classic case in economics and does not respond like the majority of goods that when the demand goes up stimulate an increased supply. Why not? Because of the basic role of breeding. When prices go up, the breeders immediately increase the number of animals going to slaughter, and thus the supply goes up a little or stays constant. Dr. Lovell Jarvis has studied this case for many years.

The periods of gestation and growth to the point of sale in cattle are relatively long, thus there is a considerable disphase between the application of resources and the resulting production. When the producer gets the information about the market at the moment, he tends to extrapolate good news into the future, and bad news likewise, and bases his decisions on this. If he sees the present as bad he will increase the present slaughter, if the present is good, less cattle are sent to slaughter by the breeder.

Storing meat for long periods of time is financially burdensome and the majority of people who have tried this have ended up in bankruptcy. Thus when prices fall those who have meat consigned to the major markets sell swiftly, and this tends to rapidly depress the price. On the other hand, the producers also have their financial commitments and have to sell a larger number of animals.

The problems of meat at the moment are closely related with the internal production in the United States, they produced 2.8 million units of meat in August and 1.9 million units in September of this year. The U.S. meat industry is producing more than ever before and this is due largely to the heavier weights of the animals at the moment of slaughter. For instance, animals which were supposed to go to the slaughterhouse at 1,200 pounds yesterday were arriving at Kansas at 1,506 pounds. One feedlot sent Holsteins at 1,750 pounds and another at 1,463 pounds, all of them animals destined originally to be sold at 1,200 pounds. The overall kill in the United States yesterday was 121,000 units, a week ago it was 127,000 and a year ago 127,000. In other words the U.S. is a meat producing machine and tends to bring the price down.

New Zealand had 87 million according to the news of domestic production and with these shipments to take place in the remaining two months and three weeks of 1991, anyone can guess that the prices are not going to be maintained at the levels at which they were on the Australian market most of last week and Monday this week.

The USDA informed that the projections were such that the imports of meat were not going to go beyond 1,318.5 million pounds, or 100,000 pounds less than the trigger level estimated for 1991. At the same time the USDA informed us that Australia had agreed to limit its exports to 743 million tons and New Zealand to 445. On the other hand, the Customs Service in the United States informed that on September 28, 1991, the importations from Australia had been 542.2 million tons and from New Zealand 357.6 million, making a total of 990,477 million tons of meat. This was not too bad for October 1st, but yesterday afternoon we were told that there was a clear downward trend and the prices could not be kept given the higher weight of animals going to slaughter, and cows which will be slaughtered before the winter; that the reduction of prices is due to domestic slaughtering within the U.S., which in one month was almost double the quota authorized for importation. This tells us that the animals being offered are 100-150 pounds heavier than last year, although they are the same age. In the case of Iowa, there have been reactions in the prices of 30 cents *per* pound for animals over 900 pounds; the feed lot cattlemen of Kansas and Texas have decided to stop animals going to slaughter; I personally think this will be temporary, but this is the information affecting the market; we all know that the available inventory and the amount of meat are elevated, which is going to push the price down, most of all the market of 7-45 days. We expect reductions in price down to levels of US$ 1.20 *per* pound of domestically produced meat in the United States, and for Central America to US$ 1.00 *per* pound for industrial meat. This tells us that the immediate future for the rest of 1991 does not have a very positive outlook, but I would say we have survived worse conditions and often these panoramas, which appear very negative in the short-term, turn around in two or three weeks. We must remember that this market is extremely volatile.

What is the future for the meat market? One possible scenario is Japan. Why Japan? Because it is a rich country at the moment and that is hopeful for the meat market. Japan has 126 million inhabitants, with a consumption of only 4 kilos *per capita*, way below that of the Central American countries, although it has a high consumption of fish and other foods. The big difference is that in Central America people do not have resources, whereas Japan, with its great tendency to savings and its income levels is, without doubt, a country with many resources or, in other words, a market potential. The reduction of tariffs over 1991 to only 70%, an anticipated reduction in the next year to 40%, and to 30% in 1993 is what makes us predict that Japan will be part of the future market, with changes that we hope to see one day in the EEC.

In 1992, greater importations from Japan would without a doubt mean greater prices, since if the Japanese eat two more kilos of meat *per* year, almost all the meat that Australia produces would be absorbed by the Japanese market. This will not happen because the Japanese tastes and preferences as far as meat are very similar to those of the Americans. What will happen is that the meat coming from feed lots of the same U.S. and the Australian meat produced with fodder (like Central American meat) will go to the Japanese market for a hamburger mix. This will cause a void in the American market favorable for the countries without hoof and mouth disease, as in the case of Costa Rica and the rest of Central America.

Although Costa Rica is very small, it is very dynamic; it increased its exports in the first semester of the present year by 47.88%. Costa Rica meets basically at one market; that of the U.S. where we are told the prices we are to receive for our industrial meat. For a more rapid definition we could say that 65% of the beef exported is industrial and the remaining 35% represents fine cuts. This 65% is worth half the value of the beef, while the other 35% is worth the other half.

In the case of Puerto Rico, we are the price fixers. For the great satisfaction of Costa Rican and Central American producers, in 1991 a market was opened which had been very protected and only had occasional imports (when there had been scarcity or attempts at high prices, the Mexican market, where we have entered significantly this year, with a substantial increase over 1990. At the present time you can see we have an increase of 3064% in exports to this market. This has helped us to raise the price of meat since the second month of this year, basically following a strategy of diversification, which is what we have followed in the export plan of the country. I would like to conclude saying that in the international market, the Central American countries have no saying in fixing the prices, the case of Puerto Rico is occasional or exceptional.

In the international meat market there exists, as I mentioned before, an excess of supply which is estimated at 200 - 300 thousand tons. We could construct some hypothetical scenarios of what could happen if Japan raises by only 2 kilos *per capita* its consumption of meat. What would happen if people in continental China increased their consumption of meat in half a pound more *per* year? I do not think it is too much to expect. The reaction will be quite significant and I am sure meat would occupy a higher level of return and in the high added value it has as a product produced with a comparative advantage. What would happen if the countries of the EEC and the U.S. tried to establish a line similar to PL-480 now that our Russian friends are demanding money or the means for more food? I think it would be an intelligent decision if, instead of giving them money, we gave them product and they paid us afterwards. We increase the prices in the international market, we reduce the excess of supply in the market, and we assure ourselves of maintaining adequate price levels for the producers of all the world. In addition, the Russian people would have better food.

From my perspective, the meat market will be positive in the future. I do not dare say what time period as that depends on the delays of the "Ronda de Uruguay"; it depends on the opening of the EEC, it depends on the percentage of internal gross product that the Community is inclined to continue applying to subsidize agricultural products. We must keep in mind that the great majority of producers are small or medium with farms of less than 500 hectares. Around 93% lack scale economies and require good third grade technologies to be efficient. Costa Rica is a country that has distributed more than 900000 hectares, which means that these theoretic formulas of more distribution cannot be generalized. I must say that the cattlemen here have paid 32% of the gross value in taxes, which includes what we call the tax over losses: instead of taxing for the profits we were charged according with the animals' change of category (when it passed one or two years); even if the business had losses it had to pay taxes. I must also mention that often the development and adoption of technology are limited by bad tax structures, like taxing the reinvestment of capital in the stock breeding business, as happened in Costa Rica with the Law 7064. I believe it is important that the tenancy tax be brought up to date, and its collection must be more efficient; this will help the country in making better use of its resources. I believe the future is positive for the meat market, but as I said at the beginning, in this business he who knows most knows nothing now that the situation is very variable.

ROLE OF ANIMALS IN RESOURCE CONVERSION AND CONSERVATION

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1. INTRODUCTION

Domesticated animals, particularly cattle, are becoming regarded as a destabilizing factor in land use and environmental degradation. Their role in low sustainability of land use centers on overgrazing, deforestation and competition with wildlife. Reality is, of course, more complex than this simple scenario implies. Deforestation is usually caused by economic subsidies that permit unsound and uneconomic use of land to become feasible; while overgrazing results from unsatisfactory land tenure policies. Because animals have visibility on the land they become a focus leading to low recognition that the basic cause of land abuse in the poorest countries centers on low levels of income, savings, and investment by rural population. Both small holders and pastoralists can easily be fixed into a pattern of land productivity, especially when land for tillable agriculture is scarce. Improvement in livestock production can be a crucial change through an increase in availability of funds to improve cropping practices (Brumby, 1988).

If reports of the media on abuses in animal welfare, land degradation, and atmospheric contamination (production of methane gas by ruminants), coupled with the association of cholesterol and heart disease, are taken literally, the use of animals to provide goods and services is approaching its darkest time (Durning and Brough, 1991). Yet, in many important ways, animal agriculture could be emerging into its brightest time (McDowell, 1991).

The Caribbean Basin can be quite an appropriate region for determining whether the use of animals could be entering its brightest time. The "basin", exclusive of Colombia, the U.S. and Venezuela, consists of 21 independent countries and 10 dependent territories. It is among the world's most densely populated (> 33 mil). Land area *per capita* is 1.68 hectares (ha), which is well below world average; available cropland is 0.18 ha, which is 15% less than India and 33% of that of Ethiopia; but in Total Livestock Units (TLU) per person the area is relatively low (0.27 *vs.* 0.62 on average globally). Annual yield or performance per TLU about equals world average, but overall is well above average in proportion of intensive production units for poultry, dairying, and pigs.

Land classed as permanent pasture (0.43 ha/cap) is above average but carrying capacity is low, requiring 4 to 7 ha to support one TLU of ruminants. The land resources are variable but in most countries land is a definite constraint. *Per capita* income is below world average, which is a constraint to both production and marketing. Additionally, much of the basin area has problems with periods of excess and deficient rainfall to support high crop yield. Generally, ambient temperature and threats of health problems exceed those desired for high animal performance. A number of countries have encouraged the private sector to invest in animal enterprises, e.g., poultry production in the Dominican Republic, Jamaica, Mexico, and Puerto Rico, but risks are high due to infrastructure and general economic conditions (McDowell, 1987).

Overall, the current outlook in the basin for food production and a rise in economic condition is frustrating. In seeking a "quick change", the tendency is to find fault with one or more facets of agriculture, with animals usually heading the list.

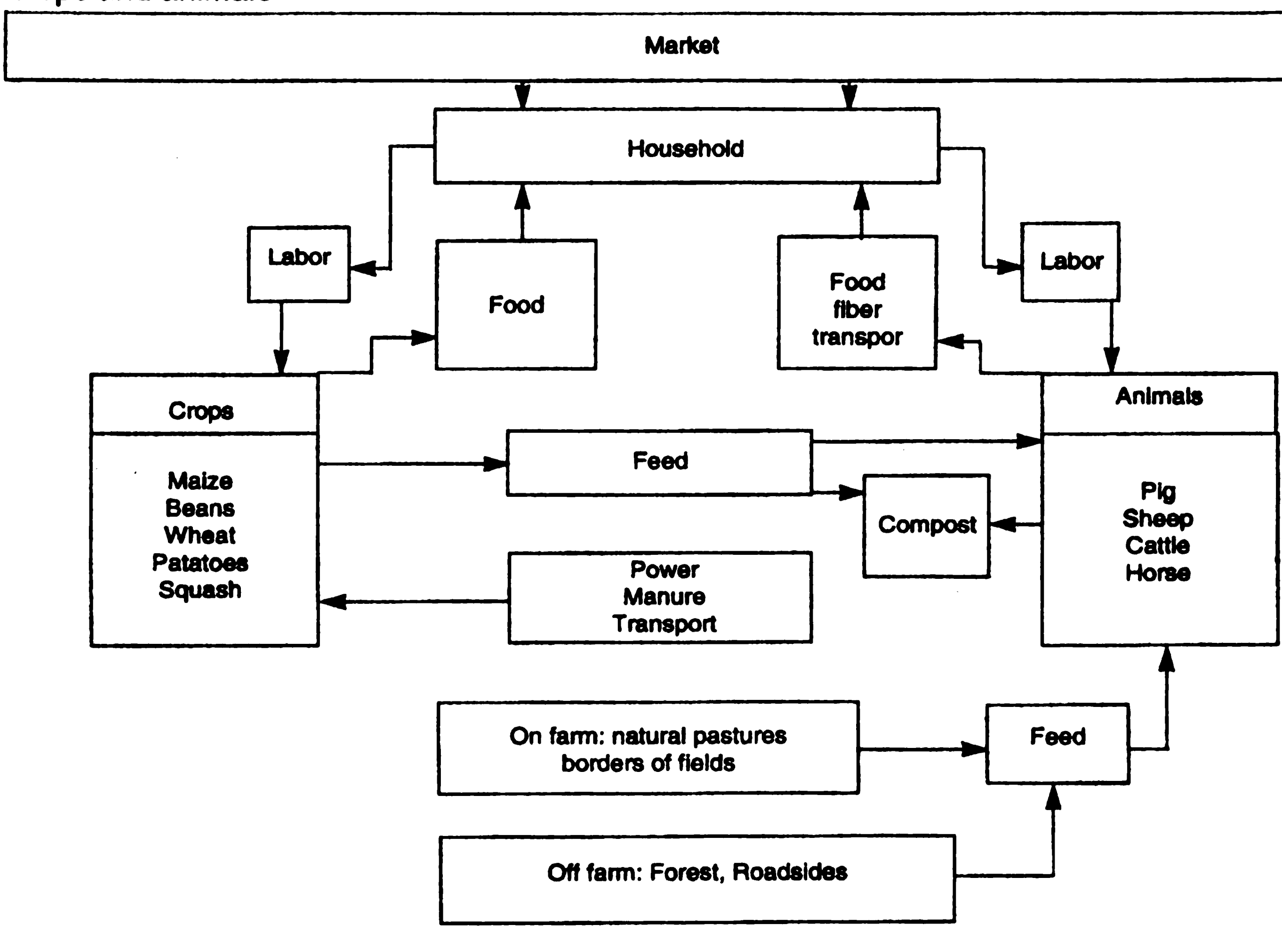
The discussion will focus on some projections for developing broader and stronger partnerships between humans and animals in the basin and elsewhere.

2. DEPENDENCY ON ANIMALS

People of the basin have about average dependence for developing countries on domestic livestock and fowl. We usually characterize the need for animals in supporting projected deficits in milk, eggs, and meat. This is a pragmatic approach, but overlooks the more important reason, that of the value in the contribution to total farm production and the economics to local communities. Small increases from sales of animals and their products increases income which becomes the capital to invest in fertilizer, improved seed and other enhancing factors, which is critical to elevating crop production on small farms.

Most farms of the world have varying degrees of integration for crops and animals with the strongest interdependence on small farms in developing countries. Mixed systems (crop-animal) in the highlands of Central America serve to illustrate this point (Figure 1). The HOUSEHOLD is the central unit. It relates to the community (MARKET) and provides labor to support the two sub-systems, CROPS and ANIMALS. Arrows show the flow system between the two sub-systems and indicate a high interdependence, crop residues serve as animal feed and animals provide power, manure

Fig. 1 Farms of Central American highlands, permanent cropping, high level integration of crops and animals



and transport support for the crop sub-system. Any new technology proposed for such farms to enhance output from either system will be closely scrutinized by the household for impact on the other sub-system (McDowell and Hildebrand, 1980). A specific example for a smallholder in Guatemala is included as Appendix 1, to demonstrate details of interdependence between cropping and animals and to show the complexity of decision making for a successful enterprise.

There are about 85% of the world's total farms that are dependent on animals as a means of bridging the gap between cropping, total food needs, and minimal income (McDowell, 1988).

3. FOOD FROM ANIMALS

There is a paucity of statistics on *per capita* consumption of animal products in the Caribbean basin. According to FAO, milk and milk products average 0.2 to 0.3 liters/day, with 50 to 66% coming from local sources and 40 to 50% from reconstituted using non-fat dry milk and vegetable oil. Eggs average 2.3 *per* cap *per* week and meat (pork, poultry and beef) 14-27 kg per annum. Pork and beef are the main meats with some from goats, sheep, marine life, and poultry. Poultry production is expanding rapidly in several countries, up to 10% per year. In 1990, six basin countries exported to the U.S. 52,000 tons of beef, but imports exceeded exports for meats and overall the basin is a high importer of milk products.

Globally, animal products from domesticated animals and fowl provide over 60 million metric tons (MT) of edible protein and more than 1 billion Mcal of energy yearly. The protein is equivalent to that from both corn and wheat, and about half that from all cereals. The energy is equivalent to wheat and greater than for rice. One kg of grain fed to a dairy cow, coupled with non-edible feeds, provides 6 kg of milk, which is a good investment.

4. NON-FOOD PRODUCTS

Non-food products from animals are quite significant (Table 1). Marketable goods from fibers, skins, and inedible products amounts to about $173 billion per annum globally. Wool and hairs are used in cottage industries in over 100 countries to produce clothing, carpets and handicraft.

Table 1. Products from domestic animals and fowl

Classification	Some products
Fiber	Wool, hair, feathers
Skins	Hides, pelts
Inedible products	Fats, horns, hooves, bones, blood, and endocrine extracts
Waste	Fertilizer, fuel, methane/gas, construction, feed
Income	Capital to support agriculture

Fats from animal slaughter are used widely for industrial products, and are equal in monetary value but not in volume to products used in medicine. The former include, from cattle, epinephrine, thrombin, insulin and liver extracts; and from pigs cortisone, norepinephrine, plasma, blood fibrin, heart valves, estrogen, relaxin, insulin, pepsin, oxytocin and burn dressings.

Approximately 40% of the farms of the world depend on animal waste to improve soil fertility. Returning animal wastes to crop agriculture lands is becoming more widely practiced, because it takes 18-20 Mcal of fossil fuel energy to produce 1 kg of nitrogen for fertilizer. On small farms, where crop cultivation is by hand, farmers prefer manure to chemical fertilizer because it improves soil structure. Crop farmers in much of Africa depend on pastoral herders to herd their cattle at night onto land they anticipate cropping. Unfortunately over 200 million MT of manure are used annually as fuel as a result of scarcity of trees and cost of fossil fuel.

Expansion of production from cropping following removal of ruminant animals because of their contribution of methane gas is possible, but elimination of foods and other goods from animals would require a rate of economic development to support cropping heretofore unachieved (Mellor, 1986).

5. SERVICE CONTRIBUTIONS

Services rendered by domestic animals are many and quite important throughout much of the world. Although the Caribbean Basin is not as dependent on services as elsewhere, they are important and should become even more so. The main services are grouped into classifications, along with the major animal species (Table 2).

Table 2. Some contributions of services

Classification	Contribution	Main sources
Traction	Agriculture	7 ruminant species, 5 non-ruminant species
	Cartage	Cattle, buffalo, yak, mule, camel, horse, donkey
	Packing	Camel yak, horse, mule, donkey, reindeer
	Herding	Horse, mule, camel
	Irrigation pumping	Buffalo, cattle, camel
	Threshing grains	Cattle, horse
	Passenger conveyance	Horse, donkey, mule, camel, buffalo
Storage in animals	Capital	All domestic species
	Grains	Buffalo, cattle, sheep, pigs
Pest control	Weeds between crops	Domestic ruminants, ducks, geese
	Insects between crops	Poultry, ducks, geese

	Irrigation canals	Buffalo
Cultural needs	Exhibitions, rodeos	Horse, cattle, sheep, pig, goat, buffalo, poultry
	Bride price	Cattle, goats, sheep
	Religious (Sacrificial Moslem & Jewish)	Sheep, goats, poultry
	Fighting	Cattle, poultry, buffalo
	Hunting	Most all species
	Pet	Numerous species
	Racing	Horse, cattle, dogs
	Status symbol	Horse, cattle, buffalo
Capital generation	Security	Cattle, buffalo, goat, sheep, pig
	Liquidity	Most all species
	Reduce risks of cropping	All domestic species
Labor	Output of cropping	Traction species
	Leisure time	Traction species
Nonarable lands	Income	Cattle, camels, goats, sheep
	Soil fertility in cropping	Cattle, goats, sheep
Research	Numerous	Domestic & laboratory
Conservation	Grazing	All domestic herbivore
	Seed distribution	All domestic herbivore
	Soil conservation	Most domestic animals
	Ecological maintenance	Most animals
	Restoration	Most animals

Source: McDowell, 1991

5.1 Traction

There are approximately 325 million oxen, buffaloes, camels, horses, mules, and donkeys utilized for power in agriculture. Globally there are 25 million animal drawn vehicles. These animals generate over 200 million horsepower. Replacement by mechanization would cost $300-400 billion of capital, $10-15 billion per year for fuel and over $20 billion for repairs. Draft animals feed principally on crop residues; hence, the on-farm cost is usually lower than tractor power. Use of animals for power will rise because prices of off-farm-energy sources and inflation will result in greater increases in prices of food grains than many economies can absorb.

5.2 Storage

Domesticated animals and fowl serve as a sink to store capital and grains. Many countries have stored in their animals sufficient Mcal of food energy and protein to provide up to one year needs of the people. To some, this is fool hearty but ignore the fact that our food grain crops today stem from narrow genetic bases. In case of a major disease or pest outbreak for which they have no resistance, the effects could, within a given year, be catastrophic.

5.3 Pest control

A major service paid by animals in pest control globally is reduction of weeds in croplands. When land is prepared by hand tools or animal drawn plows, it is desirable to have it nearly free of crop residues, and weeds or grasses. Many areas are heavily stocked with animals to "clear the land", which frequently occurs in the basin countries. In numerous countries the clearing of land is a major feed resource. It is common practice, in both upland and flooded rice areas, to move ducks into the fields after harvest to glean some residual grain but most important to harvest insects. Irrigation canals are often stocked with ducks to eat snails and leeches which transmit diseases to humans. In Africa, pastoralists know that close grazing of grasses and weeds adjacent to crops minimizes the presence of insects.

The projection is that as efforts rise to maintain or improve environmental quality, the use of animals to break cycles of insects and assist in weed control will enable marked reductions in the need for pesticides.

5.4 Cultural needs

Domestic, and some wild animals, provide cultural needs to almost all societies. Even though animals have vital roles in food supplies and for services, these can be secondary to the part several species play for cultural needs. Some of these are enumerated in table 2. Humans derive pleasure from the companionship of animals. Catering to recreational and educational needs gives rise to substantial industries, e.g. hunting, racing, natural history societies, anthropological societies, plus supporting services such as manufacturing of specialized clothing or equipment, feed firms, veterinarians, etc.

Exhibition of domestic animals and pets, sport fighting of bulls, rams, buffaloes, poultry cockerels, racing, hunting, fishing, and other events focused on animals, provides over 10 billion person days of recreation yearly. In developing countries, participation in animal recreational events is by far the largest outlet for human pleasure.

Animals that live closely with people become a thread in complex and highly involved social and cultural patterns. They become a source of identity and status or prestige for families, and a means of forming social relations through gifts or exchange.

Pilgrimage to Mecca in Saudi Arabia is made by more than 3 million people of the Islamic faith each year. Sheep, goats or poultry are purchased and sacrificed for a required "great feast". Failure to contribute an animal seriously downgrades the creditability of those making the pilgrimage. Many other ethnic groups require the sacrifice of animals at the time of birth or death of family members, and some require sacrifice of an animal before planting crops and after crop harvest, e.g. the Montagnard people of Vietnam and Cambodia. For societies throughout Central Africa, animals are a father's legacy to his sons. Animals are also used to formulate marriage or other contracts. We from Western societies view dogs, cats, and horses as having strong human ties, but we tend to overlook the delicate balance of economic productivity and cultural preferences associated with other animals in different societies. The value of animals for food, or even, traction may be secondary to their role in recreation, religion and social custom.

5.5 Capital generation

Another essential service from animals throughout almost all developing countries is generation and preservation of capital. Small farmers use otherwise unsalable labor to gather weeds from fields or along foot paths, and preserve crop residues for animal feed as a means of converting "unused products" into additional liquidity, to generate security against crop failure, and/or to produce capital to support cropping.

In developing countries it often becomes difficult to characterize the priorities for animal products and services *versus* storage of capital. Animal scientists frequently become dismayed over the performance of domestic animals, as all normal forces say it is time to sell an animal. But farmers are unresponsive because capital may not be required at the same time. Such actions lead to inefficient use of animals by Western standards.

5.6 Labor

Animals on farms serve to conserve, simulate and extend labor. The service of traction in land preparation and crop cultivation, cartage and packing represent means to conserve human labor. Without traction, the tillage of heavy soils of the mountain regions and very dense volcanic soil would be quite limited, as family labor could not meet the tillage tasks. The same holds for lifting water from irrigation canals to fields.

Often in rural areas there is little incentive for family activities. Social scientists have well documented that need for care of animals is a physical and social stimulus in reduction of drudgery. "Gives people a needed stimulus to maintain pride and serves to reduce daily frustrations". The same could be said for remote areas or small farms in the U.S.

The potential for cash earning from sales of animal products often will stimulate on-farm expenditures of labor. In both Africa and Asia, changes in livestock numbers and cereal crop output show a significant positive correlation. For Africa, an extra animal in the cattle population on mixed farms (crops and animals) is associated with an additional 0.25 ha of cropping and about 200 kg of incremental grain output per year, as well as increases of about 30 kg of meat and 39 kg of milk per year (Brumby, 1988). Although modest, these gains are crucial to family needs.

Numerous tests have shown that farmers with animals can much more readily be stimulated to hasten crop harvest and plant a second crop at the end of the wet season, which can serve as a soil conservation practice. Such activity requires more labor but potential return from the animals using more and better feed - a visible return - becomes a much better motivator for labor inputs than putting in a second crop merely for conservation of soils - low visibility return.

Village surveys have revealed a high value to leisure time. There is a positive correlation between the use of animal services and leisure time.

6. ENVIRONMENTAL CONSERVATION

Although conservation is classed as a service (Table 2), it is treated separately since an understanding of the vital roles domestic animals do and can play in soil and environmental conservation is important to this conference. Both directly and indirectly the potential for animal contribution to land conservation is tremendous (Table 2). With perhaps the exception of the rice paddy areas of southeast Asia and a few other areas of the world, tilled lands need periodic "resting" in order to maintain a suitable soil structure for cropping. The most practical inducement for farmers to "rest their soil" is to continue to generate some economic return during the rest or fallowing period. In slash and burn agriculture systems, traditionally practiced in much of the middle latitudes of the world (North-South 30^{O}), trees are cut and crops planted over 2 to 4 years without soil fertility enhancement. Afterwards, cropping is shifted to a newly cleared area and the cropped area rested for 10-20 years. Farmers are able to survive by cropping small areas coupled with food and income derived from animals grazing the fallow area among the regrowing trees and shrubs.

Started in Africa and now being tested in Asia and in parts of the Caribbean basin is a system termed "alley cropping". In this system, leguminous trees are planted closely in rows 3.6 meters (12 ft) apart and food crops like maize planted in the alleys. About twice, while the crop is growing, the trees are pruned. The prunings are laid between the rows to serve as mulch to reduce the rate of evaporation of soil moisture and the leaves add fertilizer (Kang *et al.*, 1986). The roots of the trees also recycle minor minerals that have been forced into the deep layers of the soil by the rains and are thereby unavailable to the crops. Where do animals come into this system? Part of the prunings (20%) are used as protein supplement to farm animals which enables them to consume greater amounts of coarse grasses and crop residues. Because the soil in the allies is bared between crops the hot sun burns the organic matter, so it is recommended that at four year intervals an alley is left to fallow while grasses and weeds, or a planted forage crop, are grazed by animals to give returns to farmers as an inducement to execute the recommended practices.

In a country like India there is a need for greater production. The recommendation for meeting the goal is to utilize new varieties selected for high grain yields which can be planted at greater density to further improve yields of grains. Such change can be good or poor as illustrated in table 3. When a native or local variety of rice is continuously planted, the yields of grain are inadequate to support the food needs of a family who has only small areas of land, but consistent because low plant density permits inter-mixing of weeds which helps in erosion control and preservation of soil organic matter. Using an improved variety, coupled with fertilizer, rice plant growth is rapid and shades out weeds. The first year yield is 72% greater with the new variety, but by year 4 the yield has declined 50% (Table 3). If on year 4, instead of rice, berseem clover (a leguminous forage crop) is planted, the yield level of rice is restored in year 5. The clover is cut and fed to animals adding to farm income to the extent that, over the 5 years, returns from rotation far exceed the other two systems.

Table 3. Yield of native and improved varieties of rice per hectare in India under continuous and rotation planting.

Years planted	Native	Improved varieties: Continuous	Improved varieties: Rotation
1	2,470	4,250	4,250
2	2,470	3,825	3,825
3	2,470	3,442	3,442
4	2,470	2,065	Berseem clover (animal feed)
5	2,470	1,010	4,800
Total	12,350	14,612	16,317
Gross returns, US$	1,435	1,695	2,528[1]

[1] Includes rice and milk value

Source: Hart and McDowell, 1985.

In India, Pakistan, Iran, Egypt and other countries bordering the Mediterranean Sea, it is now common practice to seed in early winter berseem clover (a forage legume) to build soil fertility for sustainable cropping, and the clover is fed to animals that provide power for agriculture plus milk and meat for food or sale. This system provides sustainable and environmentally sound means of food production in numerous countries. It should be noted that food crop legumes are not as efficient in soil building as forage legumes, and also food legumes have low tolerance to winter weather. The conclusion is that rotation of cropping to maintain or improve soil quality and reduce erosion could be useful on most all farms of the world.

In arid and semiarid areas, most of the now surviving plants usually produce hard coated seeds. Ordinarily, these will lie on the ground for several years before germination due to insufficient availability of moisture. During the interim, much of the seed may be lost from wind erosion or consumption by desert animals (rodents, lizards, etc., the "underground population") thus hastening the desertification process. Passage of these seeds, especially from woody dicots, through the animals' digestive tract scarifies the hard outer coat. After dropping in the feces, the seed germinates more readily in response to some moisture. Scarification of seeds by animals can be viewed as a plus in delaying desertification since this helps keep a greater plant ecosystem. Lack of constrain on animal numbers is the major problem.

Soil and labor conservation through animal use in tree cropping is becoming widely employed. Traditionally, establishment of a stand of rubber trees requires land clearing followed by weed control until the new trees have grown enough to form a full canopy, about 20 years. During the interim, soil erosion occurs and labor must be expended to control competition from weeds. Planting of a crop like the legume kudzu when the young trees are set controls weeds, supplies grazing for animals, and improves soil fertility. This markedly reduces labor costs and increases growth rate of the trees (World Bank, 1987).

Grazing of domestic animals in plantings of coconut and oil palm trees is now strongly recommended to reduce labor and use of pesticides for weed control. This practice raises yield of nuts per tree from added soil fertility with manure, hence animals become an integral part of these systems (Plucknett, 1979).

Traditionally the recommendation of foresters has been to plant trees. This practice is highly supportable for execution on public lands, but is much less attractive on farms. Few farmers are willing to give up land use and returns for 20 or more years before harvest can be made. Use of shrubs in place of trees with species selection so that the foliage is palatable to animals has the advantage of continuing returns from land while serving the goals of erosion control, water conservation, and provision of household fuel on a continuing basis, e.g. the sticks from pruning the trees in the alley cropping system cited above (McDowell, 1989). The opening of farm woodlots to browsing by cattle during the dry season has been found beneficial in Costa Rica (Conklin, 1987).

7. ENSURING FOOD SUPPLIES

FAO (1987) estimates that by 2025, the amount of potentially arable lands in developing countries will change from the present level of 0.85 ha to 0.60 ha per person; a decline associated with the rising human population. Human population is projected to increase from 5.2 billion globally in 1990 to 7.1 billion by 2000, an increase of nearly 40 per cent. The amount of land planted to a vital crop like rice has not risen since 1977. Yield per unit of land cropped with grains rose rapidly during the 1970's but has shown signs of leveling off since 1983 (Chandler, 1990).

World production of cereal grains was 1.83 billion MT in 1989. To meet the projected needs for 2000 and beyond will require a rate of expansion never achieved heretofore. Farmers will need high incentives to meet the challenge. The motivation to produce will be dependent on the ability of consumers to pay the costs for this production, one of the costs of failure to curb population growth.

The estimated 600 million MT or 33% of total grains currently fed to cattle, goats, sheep, pigs, poultry, ducks, and turkeys will be the prime target of many, even though the overall ratio in output of edible animal products to input of human usable grains is high (approximately 6 to 1). As in other aspects of the so-called human to animal competition for resources, the feeding of grains is a simple observation which bypasses the complexity of the grain to animal relation. Firstly, producers of grains must have an incentive to grow food to sell. The potential of the "second market", of grains as animal feed, has been for years a means of having "surplus grains" to ensure full human food needs in developed countries. Where the animal grain market has expanded in developing countries, total grain production has shown the greatest consistent rise during the last decade. In these countries dietary nutrient intake by humans has also risen.

An alternate "second market" for grains or even root crops like cassava could be the conversion of these crops to ethanol, to serve as fuel. Ethanol production can serve as a second buffer against climate and weather driven fluctuations which can greatly influence crop yields. However this has been slow to transpire due to government policy inconsistency on ethanol *vs.* oil. Production of crops like maize for ethanol leaves by-products useful for animal feed, hence ruminant animals help to modulate cost of ethanol. Essentially, grains are used for animal feeding only when there is no better market, e.g. human food, breweries, distillers, pet food, ethanol, etc.

Those advocating the production of grains in the U.S. or elsewhere and exporting these grains to feed the hungry, fail to recognize that providing free or cheap food retards or destroys incentive of local farmers to produce grains, since consumer demand at the market will be significantly reduced. Accelerated growth in the indigenous food and agriculture sector in marginally fed countries, is the crucial factor in reduction on hunger and meeting needs by the year 2000 and later.

The U.S. and countries of Western Europe use a high proportion of their grains for animal feeding. Even so, only 30-35% of the typical rations for feeding laying hens, broilers, pigs, beef cattle, and milk cows contain food that would be consumed by humans. Thus, even in intensive animal production systems, the major part of feed energy comes from grazing, forages and by-products. The recognition that even poultry and pigs fall into these groups is not widespread.

The facts are that if pressure groups in the developed countries become effective in removing domestic animals and poultry from the world food chain, it is unlikely that the loss of nutrients from animal products used by humans can be replaced through cropping, particularly by the year 2000 or later. The value of animals in providing farmer incentive to produce food grains, vegetables, fruits, etc. and in promoting environmental conservation through erosion control and water harvesting will be an added loss. The practical result will be a lowering of human nutrition and survival.

8. THE FUTURE FOR ANIMALS

Investments in animal agriculture will continue to rise since animals offer competitive returns on relatively small amounts of capital, and are easily marketed when cash is needed. Recognition will rise on the value of the integration of animals into cropping, via draft power and production of manure, valued in billions of dollars, to improve sustainability of crop production. Also closer integration, including the use of agroforestry, will become an appropriate incentive for environmental preservation.

Countries like Brazil, Belize and, Madagascar, which had problems of poverty in the past, viewed their rain forests as under-utilized resources potentially convertible to higher utility, hence began conversion of these forests to agriculture. These countries have already implemented, or have in progress, policies to reverse pulling down their rain forests for either animal or crop production. Soils from rain forests, which appeared highly fertile, have become recognized as poor soils; they would require far greater use of technology and chemical fertilizers to make them productive than can be realized from crops, and certainly are not profitable pastures for animals. This change is clearly supported by evidence that forest clearing costs are high in relation to cattle prices; the number of animals which can be supported on the cleared lands rapidly declines as the soil nutrient state declines to lower levels; and the encroachment of bush and weeds quickly increases operating expenses. For these reasons, cattle raising or rearing of other species in tropical rain forest lands generally follows land clearance for other purposes.

Alleviation of expansion of desert lands in the dry areas is now being attacked by the basic cause, human poverty and scarcity of renewable seed instead thinking of animals as being the sole cause. Unfortunately, because of slow economic growth and employment opportunities in most of the countries involved, decreases in desertification will come slowly as the cause-effect relationship requires fuller understanding. Among the causes of desertification needing closer examination is the destructive impact of "secondary animal populations", consisting of rodents, lizards and numerous other species which depend almost solely on the seeds of the grasses and shrubs. During dry years, the plants produce fewer seeds. The small species attempt to survive by scavenging more widely than usual. This essentially uses all the seeds, thus limiting severely new plants. Woody dicot plants, like the widely distributed species of *Acacia*, produce hard-coated seeds that are very slow to germinate unless the hard coat is scarified. This means *Acacia* depends largely on ruminants and some herbivores to improve seed germination and distribution of seeds. The consensus is that the contributing factors to desertification need further examination in order to prepare guidelines for policies to avoid further desertification.

The trade-offs between the production of methane and animal production require a more holistic examination than singling out cattle. For instance, is it more important to maintain wild ruminants for a small portion of the global population to view and photograph than cattle which provide food and many other services for nearly the whole world? In the U.S. and countries of Europe, cattle populations are declining. Growth in number for other areas is about one percent per annum. Expansion of methane from ruminants is largely coming from protection of wild species. Pursuit of methane from animals as a serious liability ignores the fact that they do not just emit methane; they utilize plant biomass and grains or by-products which remove the greenhouse gas, carbon dioxide, from the atmosphere through the photosynthesis process.

The Caribbean basin in an excellent location to strengthen the already existing partnership between humans and animals. The vast majority of the animals provide of means of deriving life-sustaining products from the lands. Animal life, plant life, and human life exist in a necessary partnership. This interdependence emerges more clearly when we more fully understand the complexities of sustainable relationships.

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APPENDIX

CROP-ANIMAL INTERDEPENDENCE. A SPECIFIC SMALL-FARM EXAMPLE[1]

The objective of this section is to further illustrate "linkages" or "events" at the farm level, in order to increase awareness of the complexity of a small-farm system. The farm under discussion is in an area near Quezaltenango, in the Western highlands of Guatemala, where the Instituto de Ciencia y Tecnolog°a Agr°cola (ICTA) is conducting extensive investigations on small farms.

The farm is larger than average in the Guatemalan highlands; it has 5.25 ha, of which 0.35 ha are in grass and forest. Although all types of livestock are not represented, the farm has been chosen as an example because the relationships among the market, household, crops, and livestock are a good demonstration of the complexities of life on a small farm. Dogs have not been included in previous models, but are included here because the family considers the dog as having a strong role in the culture, and in addition, dogs are used to derive income. Puppies are sold, and they do consume a significant part of the food produced on the farm. The bee is the other animal found on the farm that has not been mentioned before; although bees are not too common as a farm enterprise, some farms in all areas of Guatemala do have them.

The main crops are maize, a type of bean locally called "piloy" (*Phaseolus coccineus*), wheat, and potatoes. Produced in smaller amounts are fava or European broad beans, locally called haba (*Vicia faba*); fruits, vegetables and medicinal herbs for teas or medicines. The primary livestock enterprises are cattle for milk, swine, and chickens.

One-fourth of the farm surrounds the house (Fig. 1A), and the rest is scattered in various parcels. Two-thirds of the land is owned and one-third is rented from relatives. Land rent is half the value of the crop after deducting all costs. On the farmer's own land, he produces 75% of the maize, beans and fava, 80% of the wheat, and 63% of the potatoes. Only 30% of the forest and grasslands are owned by him. On the land surrounding the house, including some forest land, a portion of all the crops cultivated is represented.

The farmstead (Fig. 2A) contains several sheds for livestock and for forage and wood storage (both firewood and lumber). One bedroom of the house doubles as a weaving room for making sweaters, and another bedroom doubles as a carpentry shop.

The distribution of labor, sale of products, purchases, and sources of food for the Guatemalan highland farm are shown in Figure 3A. The farmer works 75% of the time on the farm and 25% off the farm. His wife works half time on the farm and half time off the farm. This latter situation is also not very typical of the region. Of the seven children, two work off the farm full time and are not counted in the farm picture, although they do consume eggs and send some money home. The other five, who are in school, work on weekends making sweaters and furniture.

About 80% of the labor for the crops comes from off the farm. Of the family labor, most of it (43%) is used in the various activities within the household, including gathering firewood; about 20% is expended on animals and 12% on the crops. Excluding the two children who work full time off the farm, about 25% of the family labor is used off the farm.

The family at present has three cows, of which one or two are in production at any one time. A small proportion of the milk is sold, but most of it comes into the household, where 10% is consumed fresh and the rest is used to make cheese and whey. Of the cheese, 20% is con-

[1]Source: McDOWELL, R.E; HILDEBRAND, P.E. 1980. Integrated crop and animal production: Making the most of resources available to small farms in developing countries. Working Papers, Rockefeller Foundation, New York, New York, USA.

sumed in the household and 80% is sold. Small amounts of whey are sold and consumed, but most is used to feed the pigs (60%) and the dogs (35%). All the cream removed from the milk is consumed in the household.

There is usually one sow that has a litter of six to eight pigs at approximately six-month intervals. Two of the pigs are kept on the farm for fattening, while the rest are sold in the market or to other farmers at weaning. The only meat produced for the household, from two pigs, is 2 to 3 kg every six months, when the fat pigs are sold and butchered. This amount represents 3% of the total pork produced on the farm, and about 10% of the pork meat consumed by the family.

The family maintains both laying hens and young chickens. All the old hens are sold for meat, and 58% of the young chickens are sold when they weigh 1 to 2 kg. The feathers from chickens killed on the farm are used to make artificial flowers as a household industry (20%), or composed to make fertilizer (80%).

Maize is the basic food staple of the family diet, and 20% of the wheat is consumed (most of the wheat grown in the highlands is marketed, but some is consumed in this particular area). Of the maize produced, 40% is fed to the pigs, 20% to the chickens, 10% to the dogs, 19% is consumed in the household, 10% is sold at the end of the year, when there is surplus, and 1% is used for seed. The maize stover is fed to the cattle. The parts rejected by the cattle (lower part of the stalks) is mixed with manure to produce compost. The same procedure is followed with the wheat straw. Potato vines are fed to livestock unless they were fumigated shortly before harvest, in which case they are left in the field for incorporating into the soil.

Of the vegetables, a wild turnip that grows as a weed in the maize (recently mixed with broccoli, which is allowed to reseed itself) is sold, consumed or fed to the animals. It is sold for human consumption and consumed in the house when the leaves are young, but fed to the livestock when the leaves are older. Recently, a small garden patch was established with cabbage, cauliflower, carrots and radishes, of which half is consumed and half is sold.

Besides providing fruit, the fruit orchard also provides herbs for medicines, which account for 25% of the medicine used by the family.

The forest (including the grasslands) provides leaf mulch, half of which is used for compost on the farm and the other half as payment for gathering the mulch. The forest also provides firewood and pinecones for fuel and raw materials for making implement handles and lumber. The lumber, which is sawed by off-farm labor, was used for building the house, and is used for constructing sheds, furniture and boxes for potato seed.

In addition to purchasing candles as a source of light, the family buys ocote, which is a special pitch-pine kindling used for starting fires. They buy cloth to make about 50% of their clothes and purchase the other half ready-made. Wool yarn is also bought for making sweaters, of which 7% is used for family needs and the rest sold. Food items which are purchased include tomatoes, garlic, onion, peppers, beans (*Phaseolus vulgaris*), coffee, sugar, chocolate, rice flour, oatmeal, cooking oil, lard, noodles, etc. Even though some "piloy" (beans) is produced on the farm, yield are presently insufficient for food needs. Bush beans (*Phaseolus vulgaris*) are being tested as a means of decreasing dependence on purchase.

The farm operation described is a very complex system. A wide variety of activities are carried on to maximize resource utilization and reduce risks. Due to the tenuous balance of the system, interventions intended to produce change must be carefully evaluated; otherwise serious imbalances will be created.

THE ROLES OF ANIMALS IN CULTURAL, SOCIAL, AND AGROECONOMIC SYSTEMS

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...livestock are not only the means of subsistence and the medium of transaction but also the measure of wealth. In addition to providing food and being the main cash resource, livestock transactions validate and legitimate meaningful and important social relationships. Such relationships are continuously affirmed and emotionally expressed by temporary transfers of livestock, as well as by cooperation in herding and communal sharing of...beasts. Livestock are the means of production, but they also fulfill the role of prestige goods and objects of mystification pertaining to social and ideological relations as well as to the relationship between man and the supernatural... The word for cattle...is often used as a metonym for people... ...[livestock] are representations of the good life (Talle, 1988).

Talle's sketch of the human-animal relationship in one stockraising society aptly enunciates many of the rich and varied meanings and roles of animals to be found among rural peoples throughout the world. Whether wild or domesticated, animals represent one of our most ancient, vital, and renewable natural resources. Indeed, since the dawn of humankind there has never been a society that did not rely upon animals for a host of cultural, social, economic, nutritional, technological, agricultural, or ecological needs. Strategies for environmentally sound and truly sustainable agriculture (animal or otherwise) cannot be devised and implemented in ignorance of the ways in which animals meet these human needs. This is the thesis of the present essay, which also seeks in part to highlight ill-informed, ethnocentric, or negative stereotypes of animal agriculture that have sometimes been evidenced among development professionals and/or environmentalists.

The perspective taken here is that of an agricultural anthropologist specializing in livestock development. Hence, the focus is on not what can be done to enhance stockraising or the environment *per se*, but rather on how a productive and environmentally attuned animal agriculture can enhance human well-being. All too often, determined to up livestock productivity or to preserve "Nature" at all costs, agricultural scientists and environmentalists alike lose sight of this fundamental rationale for the human-animal interface. Yet this is the ultimate goal of environmentally sound agricultural development -to make a better or at least a more secure living for people (hopefully, for generations to come) via the sustainable exploitation of the planet's natural resources, including animals.

From an anthropological perspective, animals' multitudinous roles fall into two broad categories: sacred and/or symbolic, i.e. what animals mean and how people relate to them in cognitive and ideological terms; and secular, i.e. the typically more tangible social, economic, technological, ecological, etc. goods and services that animals render to humans. The two categories are not clear-cut, however. In fact, this division is somewhat artificial and anti-emic, particularly for more traditional societies, where most aspects of life are imbued with sacred or symbolic significance. But partly for this very reason, the distinction is useful in pointing up for Western scientists, developers, and environmentalists correlations between the sacred/symbolic and agroeconomic/ecological roles of animals that may hold some clues to sustainability. This point is taken up again in later sections. Below, the two categories are first outlined in broad strokes cross-culturally. Then, drawing upon examples from specific cultural, social, and agroeonomic systems, the imperative of understanding animals' vital roles in all these realms in order to design sustainable approaches to animal agriculture is illustrated. Finally, from these discussions, some larger "lessons learned", recommendations for research and development (R&D), and key queries are offered to assist in the design of animal agriculture strategies that are sustainable **because** critical human values assigned to animals are taken into account.

1. THE ROLES OF ANIMALS IN HUMAN LIFE

1.1 Sacred/Symbolic Roles

The archaeological record suggests that animals may have been domesticated even before plants, some 15,000 years ago; and it shows that sacred and symbolic uses of animals antedate domestication and may even have been the original intent of domestication (Peel and Tribe, 1983). Certainly, "For as long as anything can be inferred about human cognition...humans have thought carefully about animals" (Shanklin, 1985), employing them as metaphors, mechanisms, and even gods to conceptualize, verbalize, model, and guide the human experience. This is hardly surprising or illogical in view of the fact that, like the human animal, many other animals live in social groups. Certainly, all societies in recorded history have found animals not only good to eat (among other secular ends) but also "good to think," by analogy, about interpersonal and societal interactions, the meaning of human existence, and such practical matters as human healthcare[1].

To take one example, most of us are familiar with the notion of a totemic animal. Such symbols have historically served to define clans and tribes, exemplifying characteristics or behaviors that the group so defined deems desirable, and enunciating what their relationship to other such groups should be -for example, whom they can and cannot marry, or which other groups are enemies or friends. This totemic function of animals persists in Western society. Sports teams, civic and youth groups (Elks clubs, scout troops), environmentalist organizations, political parties, or whole states and nations (the U.S.'s bald eagle, the Russian bear) are named after, organized around, and/or identified by the icons of animals admired for traits such as fierceness, strength, cunning, independence, or their general anthropomorphic or anthropopsychic appeal (the panda of the World Wildlife Fund).

Indeed, the use of animals as icons, idioms, and metaphors pervades every symbol system and language in the world. For instance, consider how we speak of human personalities, physical features, and so forth in our daily lives. In English, people can be sheepish, flighty, catty, foxy; they can be pigs, skunks, snakes-in-the-grass, stool pigeons, jackasses, and turkeys; or they can be wise as an owl, strong as an ox, gentle as a lamb, timid as a mouse, stubborn as a mule. They can also parrot or ape other people, horse around, and engage in monkey business[2]. In any language one would care to choose, the list of such animal metaphors is almost endless. Nor are such inter-species conceptualizations limited to popular parlance; they also enrich much of the world's finest literature.

Another familiar sacred/symbolic role is the importance of animals in feasting, sacrifice, and ceremony worldwide. Indeed, it is difficult to imagine a meatless "feast." Nor will just any meat do. For U.S. culture, the indigenous turkey is usually required. Elsewhere, the preferred

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[1]For much more complete discussions of the metaphorical, conceptual and other uses of animals, consult Shanklin (1985) and the references cited therein. For examples of symbolic analyses, see Willis (1974). On the relationship between human and animal healthcare, see various of the chapters in McCorkle et al. (in press) or the historiography of veterinary medicine generally.

[2]Interestingly, animal metaphors are universally applied to human sexuality; I leave the choice of examples to readers' discretion.

feast food may be chicken (as in much of Africa), pork (as among many Pacific peoples), or beef. Where a formal sacrifice is involved, the feast animal often must conform to additional stipulations. For many Moslem holidays, it must be an uncastrated ram. For certain ceremonies among the Quechua Indians of highland Peru, a pure-white, intact male llama is prescribed; for other occasions, guinea pig is required. The use of sacrificial animals is probably as old as humankind, and it continues to be important in many contemporary societies. Deprived of their sacrificial species, many peoples would be powerless to communicate with their gods. Nor can plant foods or other materials be readily substituted in this key role. As the Biblical story of Cain and Abel tells us, sacrificing, say, a carrot is simply not the same as offering up a lamb for slaughter.

In many cultures, rituals involving animal sacrifices or surrogates are also viewed as critical to ensuring humans' supernatural or psychological well-being. In highland Peru, for instance, sacrifice of a pure-black guinea pig is instrumental in treating the psycho-supernatural depressive condition known as "*susto* soul loss". In parts of Africa, from birth every individual is assigned an animal alternate to act as a sort of "lightening rod" for ills and misfortunes that would otherwise strike the person (Ibrahim, in press). Nowadays in the U.S., psychologists advise the lonely and the bereaved to keep a pet in order to improve their emotional state. And in both Western and non-Western societies, various species serve more generalized roles as companions and items of visual, tactile, or auditory pleasure (birds and tropical fish, cats, songbirds), good fortune, and still other psychological ends.

Around the world and down through history, animals have also provided entertainment in the form of recreational events. Fighting and racing come to mind first. Examples include bull, cock, dog, and (in Indonesia) ram fights; and horse, camel, dog, and even (in the U.S.) frog races. Other recreational uses include riding, fishing, hunting; stockshows, exhibitions, circuses, zoos, aquaria; butterfly collecting, birdwatching, and more recently, ecotourism (McDowell, 1991). This is a grey area in terms of the sacred/symbolic versus secular categorization. Depending upon the culture in question, such events may be imbued with sacred or symbolic significance (to reiterate and ratify cultural identities in the form of opposing tribes or teams, or as displays to please or appease the gods). Recreational events may also be perceived as innately aesthetic (bullfights), educational (trips to zoos, aquaria), or psychologically restorative (ecotourism's "getting in touch with Nature"). But they may simultaneously serve strategic or economic ends -e.g. to demonstrate the strength and skill of a group and its beasts to past or potential enemies, or to profit from bets, purses, or sales of animals, semen, shares in an animal enterprise, etc. (See ibid. for some impressive figures on the economic value of recreational uses of animals worldwide).

1.2 Secular Roles

Examples of the innumerable ways in which animals enliven, instruct, ease, enrich, and even poeticize humans' ideological and mental life could be multiplied literally thousands of times the world over. But as the preceding section has endeavored to suggest, absent the animal kingdom, human culture and cognition as we know them would be hard to imagine. So would human survival. Indeed, animal assistance has made it possible for humans to colonize even the most inhospitable parts of the planet — the frosty heights of the Himalayas and the Andes thanks to, respectively, the yak and the American camelids (llama, alpaca, vicu§a, guanaco); the life-giving oases of the Sahara thanks to the camel; and in past, the reindeer and the dog in the frigid European and North American Arctic. But nowhere has the genus *Homo* attempted to survive without at least some of the innumerable goods and services that animals render.

The list of goods is long. In addition to high-quality protein and other nutrients in the form of meat, milk and milk products, eggs, blood, fat, gelatin, oil, and honey, animals provide key soil nutrients in the form of manure and urine. They also furnish fiber, fur, silk, leather, hides, bristle, feathers, horn, bone, shell, teeth, claws, sinew, gut, tissue, hormones, etc. from which people manufacture almost anything conceivable: shoes, clothing, bedding, jewelry, furniture, containers, tools, building or tenting materials, cutlery, brushes, musical instruments, artwork of all sorts, weapons, suture, pharmaceuticals (cf. ibid.; Fitzhugh and Wilhelm, 1991). As Andean Indians observe about their sheep, "We use everything but the baa." Of course, in addition to meeting household needs, most of these items can be marketed, generating cash income and stimulating both rural and urban, household and national economies.

With respect to animal services, perhaps the most familiar are transport and traction. At one time or place in human history, almost every domesticated species of any significant size has been "drafted" to fill one or both of these roles. The roster ranges from elephants down to goats and dogs. Animals also assist in: fighting and hunting (sometimes serving as bait); herding (sheepdogs, Judas goats); and guarding against thieves and smugglers, pests, predators, and disease. Animals' role as guardians is particularly widespread. Throughout Latin America, guard-dogs are a common sight in fields, corrals, and yards or on rooftops. In Borneo, the Andes, and elsewhere, cats are enlisted to protect stored foodcrops from rodents and/or to destroy these and other disease-bearing pests (sometimes couched in terms of "evil spirits") from hearth and corral, barn, or fold (Mathias-Mundy and McCorkle, 1989). Both in the Andes and the U.S., llama are often placed with flocks of sheep to fend off hungry predators. In parts of Africa, urbanites keep guineafowl to warn of the approach of nighttime evil-doers; the roosting birds are easily disturbed and their loud, clacking calls can wake even the soundest sleeper (Ibrahim and Abdu, in press).

Other jobs performed by animals include assisting the disabled (seeing-eye dogs and, more recently, trained monkeys that aid paralytics). Of course, serving as medical models is one of animals' most ancient services to humankind. Much of early civilizations' knowledge of human anatomy and physiology appears to have derived from the sacrifice, necropsy, and butchering of animals (Schwabe, in press).

Both wild and domesticated animals have also long served many societies as early-warning and/or meteorological devices. Examples are miners' use of canaries to detect toxic gases, and the observation of unusual animal behaviors in advance of storms and earthquakes. Likewise for animals' function as agricultural or other calendars. Astute ethological observations (of nesting, mating, molting, hibernating, migrating) provide sensitive ecological intelligence, signalling people that it is time to plant, harvest, move seasonal camps, or as among the Tsembaga Maring of New Guinea, go to war to correct population and resource imbalances (Rappaport, 1968). Such calendrical functions have been little studied to date, however.

More familiar are animals' many financial and fiduciary roles around the world. In remote and/or rural areas and unstable or highly inflationary economies, livestock serve as one of the paramount (and often most lucrative) forms of capital storage. Via new births or gains in body weight, they accrue interest against critical future expenses such as funding children's education and marriage, providing for one's old age, or furnishing the cash with which to purchase emergency food supplies or to re-initiate cultivation after a cropping failure (McCorkle, 1992). Different species have different roles in this regard. However, throughout much of the developing world, poultry in effect constitute people's "pocket change," to be sold when minor household needs for cash arise. Larger needs are met through the sale of small ruminants (the family checking account, as it were). And large ruminants function as savings accounts, trust funds, and longterm "stock portfolios." Moreover, almost everywhere there is strong and growing market demand for animal products, such that usually stockowners can easily "cash in" their animals as needed.

Where livestock function as dowry or brideprice, human and animal procreation are intimately interlinked. In the classic "cattle cultures" of Africa, for example, a young man cannot hope to marry and have a family unless he acquires a share in a healthy and growing herd (Evans-Pritchard, 1951; Stenning, 1959; Talle, 1988)[3]. Similarly, rural Andean parents strive to endow each of their children (male and female alike) with a seed herd before and/or upon marriage, so as to secure young couples' economic future (McCorkle, 1983a; West, 1983). Indeed, for many rural peoples, manifold exchanges and transfers of livestock and their products in the form of inheritances, endowments, trusts, loans, etc. are necessary for the establishment and maintenance of kin ties, and thus for the very continuation of human society.

In much of the rural developing world, livestock are also key to initiating and cementing the long-term mutual-aid networks imperative for farm production and family survival. Animals and their services, products, and genetic material are constantly being shared, given as gifts, or contributed for charitable, religious, or civic purposes. In both Africa and Latin America, for example, two or more farm households often share in the purchase, care, and use of plow animals. In the Andes, households may also cooperate in the production and exchange of precious manure (McCorkle, 1983b). In Africa, herders constantly lend and borrow animals amongst themselves to seal ties of friend- or kinship, furnish the less fortunate with milk or calves, spread the risks of drought and epidemics, recruit extra herding help, and more (Scott and Gormley, 1980). All around the world, stud animals are often freely lent to kin, friends, and co-villagers who have no or poor breeding males. Without these kinds of cooperative networks, many families would be unable to pursue cultivation or to reap the many socioeconomic and other benefits that animals confer (McCorkle, 1992).

The line between these hard-nosed social and economic aims and animals' sacred/symbolic roles is sometimes blurry. The much-studied "cargo" systems of Latin America are illustrative. They encourage all families in a community to take turns across the years in sponsoring costly religious festivals. In the Andes, this includes donating animals and animal products for community-wide feasting. A family holding a major "cargo" may be forced to slaughter nearly all its herd to meet this and other "cargo" obligations (McCorkle, 1983a). But participation in this festival system earns more than just good standing with the gods. As with other exchanges and prestations of animals and their goods and services throughout the world, "cargo" families also build up social capital in a sort of social-security account, ratifying their right to call upon co-villagers' assistance in times of future need.

The vital roles of livestock in plant agriculture around the world are well known[4]. A number of these have already been mentioned: providing draft power, organic fertilizer, and cash and food to backstop cropping. Others include: transporting agricultural inputs and outputs to field and market; clearing land for planting; through grazing, making even fallow plots continuously productive; relatedly, via post-harvest grazing, gleaning the benefits of fertilizer residuals and thereby increasing returns to investments in cultivation; in case of crop failure, recovering at least some of the value of cropping inputs by grazing failed fields; and converting crop byproducts and wastes (straw, stover, chaff, bran, beer mash, spoiled grain and produce) into products humans can use.

Livestock also perform cropping-related environmental services. Properly managed herd animals systematically manure and re-seed fallowing fields (and rangelands), thereby promoting vegetative regrowth that helps forestall erosion[5]. Moreover, controlled herd movements and stock

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[3] *In fact, this is a wise policy; it helps ensure that new families are not started without theS economic wherewithal to support them.*

[4] *For overviews, consult Bayer and Waters-Bayer (1989); McCorkle (1992); McDowell (1980); Vincze (1980).*

[5] *In order to achieve significant germination rates, the seeds of some plant species must first pass through an animal; and the seeds of many plants rely on animals for their dispersion.*

mixes can be used to stimulate regrowth of particularly desirable plant communities. Of course, herbivores can exploit otherwise inedible or unusable plant and even insect biomass of non-arable biomes, turning it into fertilizer for crops, as well as high-value products for human consumption and animal muscle-power. Furthermore, power from animals that survive on otherwise nonproductive resources is not only very cheap compared to fossil fuels; in developing countries, where full productive use is typically made of livestock manure and urine, animal power is also virtually pollution-free. In fact, in the realm of environmental health, livestock and wildlife render a number of services. Along with other species, domesticated and wild birds hold down populations of arthropods that may attack crops or people. Herbivores help control brushy habitats that may harbor disease-bearing pests dangerous to humans. Where an animal species is the preferred host for vectors of zoonotic diseases, it can help deflect transmission to humans. As offal-eaters, dogs and especially swine provide sanitation services.

Perhaps animals' most unique role, however, is as "mobile production units." They can be deployed so as to exploit "patches" in the regional ecology that would otherwise be of little or uncertain productive value to humans (a striking example of such patch use is aquaculture). Unlike plants, livestock can be relatively rapidly re-positioned to take advantage of seasonal shifts or to exploit or escape unusually favorable or unfavorable localized climatic conditions, not to mention political-economic conditions, too. Their relative mobility is what makes livestock the "bottom line" in so many peoples' shrewd risk and resource strategizing — and in their very survival.

2. THE ROLES OF ANIMALS IN SYSTEMS CONTEXT

To this point, the roles of animals in human existence have been outlined in broad strokes. But before any steps toward environmentally sound and sustainable development action can be taken in animal agriculture, the precise functions each species plays in the cultural, social, and agroeconomic systems of the target human group must be teased out and assessed. In the process, nothing can be taken for granted. As the preceding section suggests, different species mean and do different things for different peoples. A simple cross-cultural comparison is instructive.

- Throughout much of the Western world, cattle are culturally deemed the ideal source of milk and meat. But elsewhere, other species or combinations of species are the preferred suppliers of these goods. For milk, for instance, Mongols turn to mares, Bedouin to camels, the Toda of India to water buffalo, and many peoples to goats. In contrast, traditional tribes of New Guinea do without milk and milk products entirely; and to them, meat means pork.

Such culturally assigned roles of animals may in fact have been experientially tested and refined (or rejected) down through centuries or even millennia, based on a given species' unique fit with the particular human and biophysical ecology. A familiar example is the Semitic taboo on pork, which also illustrates the fine line between sacred/symbolic and secular considerations.

- To survive in the hot desert climes that Semites traditionally inhabited, swine require good shade and constant wallows; to thrive and put on flesh efficiently, they also require grains, tubers, or other dietary supplements that people themselves can eat — foodstuffs that are already in short supply in arid lands. Unlike ruminants, the monogastric pig cannot survive on rough, fibrous forages alone. In return, pigs give only meat and leather — no wool, milk, traction or transport power. Under the ecological conditions

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[6]Worldwide, feast meats are by preference roasted. Unlike boiling, baking, or steaming, for example, roasting does not capture many of the juices and nutrients in the food; instead, they are allowed to fall into the fire or sublime in the smoke.

that Semitic groups historically faced, reliance on swine rather than, or even in addition to, ruminants to meet (rather than compete with) basic human needs for animal products would be foolhardy. Small wonder, then, that for such groups the pig is so powerfully tabooed (Harris, 1985).

The sacred or symbolic (and the often-closely-linked socioeconomic and agroeconomic) roles assigned to different species have immediate implications for the kinds of livestock development interventions a people will find acceptable or reasonable. In casting about for ways to "improve" animal agriculture, researchers and developers must beware of acting out of ignorance or ethnocentrism about a given species' meanings and roles in a given milieu. Sacred/symbolic considerations can be particularly powerful factors in a people's decisions about change and development. Just think: what if you were handed the job of introducing pig-raising among Moslem or Jewish farmers? Conversely, some species and/or their products may be so highly valued or so deeply embedded in a people's lifeways that they simply cannot be removed or substituted *in toto* by alternative animal or plant products without a sharp sense of loss of "the good life," severe cultural damage, or even virtual ethnocide — as in the demise of the American cultures dependent upon the bison. In addition to the earlier discussion of indispensable feast meats and sacrificial animals, consider the example of beefeating in the author's own subculture.

- In the Western U.S., beefeating is the norm and the quotidian consumption of beefsteak, in particular, is a recognized mark of social and economic well-being. People who cannot afford to have steak for dinner at least once in a while on no special occasion are considered distinctly culturally deprived. An especial luxury is sometimes eating steak for breakfast, too. The symbolic significance of beefsteak is often made manifest in a rite of reversal in which the meat is cooked outside by a male (even in the dead of winter!) rather than inside by a female. Another telltale is that roasting is involved. Roasting is the most nutritionally profligate form of cooking meat, and thus an act of extraordinary conspicuous consumption[6].

In the American West, attempting to eradicate the much-prized "steak dinner" — as some environmentalists would seemingly have us do (Durning, 1991; Durning and Brough, 1991; Rifkin, 1992) — would be difficult, to say the least. The "natives" would perceive such a move as a distinct attack on their cultural mores and quality of life. They would almost certainly resist efforts to definitively remove steak from their dinner (if not breakfast) tables. However, as recent surveys and statistics tell us, in the interest of environmental protection and other probably more compelling concerns such as personal health, U.S. consumers have in fact modified their patterns of beefeating somewhat. How is this possible? With regard to steak in the Western U.S., at least, this food is already "marked" as a semi-luxury, semi-ritual item. As a powerful psycho-social symbol of nutritional and economic security, the important thing is to have the choice of eating steak.

Foodways are one of the most elemental culture traits and thus sometimes extremely difficult to change (Messer, 1984). The foregoing case provides an example of a fundamental cultural norm that, with a full understanding of the meaning and roles of the animal or animal product in question, can be partly modified — just so long as members of the culture can continue to operationalize it on some level or in at least some contexts. Not all such norms may be so malleable, however. Along with the Semitic taboo on pork, the Tzotzil taboo on mutton is instructive.

- For nearly 500 years, Tzotzil Maya shepherdesses of Mexico's Chiapas State have bred and raised an exceptionally hardy race of sheep that provides the wool from which they garner up to 40% of their family income. Tzotzil consider that each sheep has a soul and that its health and productivity in large part depend upon the state of its soul *cum* emotional well-being. The whole goal of Tzotzil shepherdesses' very astute ovine management system is, in their words, to keep their sheep "happy" — their idiom for healthy, well-fed, and thus productive flocks. Among other things, however, this means never slaughtering and eating a sheep. For Tzotzil, such an act would be tantamount to cannibalism, and it is strictly prohibited in their religion. Expired sheep are left to the dogs and coyotes. For meat, Tzotzil instead turn to beef (Perezgrovas, in press).

Tzotzil would be horrified by any suggestion that — whether on behalf of environmental protection or other causes — sheep replace cattle for meat production. But they might applaud appropriate interventions to increase bovine productivity while better managing the natural resources on which both species depend. And they would probably welcome any environmentally friendly interventions embodying labor- and cost-saving ways to make their sheep "happier." The lesson here is that a solid understanding of a people's cultural (*cum* socioeconomic or agroecological) norms and beliefs can often be put to work in support of strategies for sustainable animal agriculture. Consider the following example from the author's field research in highland Peru.

- Quechua Indians hold very different attitudes toward their beloved llama and alpaca as versus swine or the non-indigenous herd animals (cattle, sheep, goats, equines). Quechua view camelids as semi-sacred beings and, in certain contexts, as another race of people. A Quechua stockowner interprets misfortunes in her/his camelid husbandry not just as economic setbacks due to anthropogenic or natural phenomena. They are also seen as signs of cosmological turmoil or the anger of powerful gods. These perceptions are grounded in the belief that camelids are only on loan to humankind from the gods; if the creatures are mismanaged or abused, the gods will reclaim them.

Many Andean husbandry strategies are dictated by these beliefs rather than by purely profit-oriented motives. Partly in fear of supernatural reprisals, Quechua take extra pains in caring for camelids. For instance, when a camelid is sick or injured, its owners will go to almost any trouble and expense to try to save it. But the same is not true for the far-more-costly bovine; and certainly not for sheep, which Quechua consider a dim-witted and, along with cattle, distinctly alien species. Also, Quechua breed their camelids very selectively, systematically castrating undesirable males; not so for sheep or cattle (Mathias-Mundy and McCorkle, 1989; McCorkle, 1982, 1983b).

In the Quechua case, stockraisers would likely be willing to invest in more costly or difficult interventions for camelids than they would for sheep — say, sustainable systems of range management that would simultaneously reduce overgrazing/erosion while ensuring a steady supply of forage. Whereas such an intervention might be of little interest to Quechua if offered solely in the name of improved ovine husbandry, it might garner their support if couched in terms of advantages for camelids. Given the frequent practice of mixed-species grazing, however, it would redound to the benefit of sustainable animal production generally.

In sum, astute insights into the sacred/symbolic meanings of animals within the target culture and society can forestall needless development missteps, guiding interventions in more fruitful and workable directions, extending useful local beliefs and husbandry practices or principles from one species to another, and enunciating them in terms that are more suasive and intelligible to stockraisers. The same is true for the secular roles of animals in agroeconomic systems. Yet in planning and designing for livestock interventions, scientists and developers all too often make *prima facie* or own-culture assumptions about the place and importance of animals in the local system (McCorkle, 1992).

One such mistaken assumption is that livestock are everywhere raised solely or even primarily with the aim of maximizing yields of the products that western or industrialized nations consider the most economically important (meat, milk, fiber) and for which highly specialized breeds and husbandry systems have been developed. But other peoples often have multiple production goals and raise a mix of more "generalized" breeds with the aim of optimizing yields of several products from even a single species. The experiences of the Small Ruminant Collaborative Research Support Program (SR-CRSP) in Peru and Kenya are illustrative.

- Animal scientists in Peru were puzzled to find Quechua farmer-stockraisers maintaining a large percentage of sick, aged, and otherwise unthrifty sheep that were long past their reproductive prime and their meat- or fiber-producing peak. A sheep might even be kept until it died of old age. However, further investigation into this seemingly irrational culling pattern revealed that a paramount goal of sheepraising among Quechua agropastoralists is not meat or fiber, although these are of course much valued. Instead, it is manure.

In retrospect, this makes sense. In the treeless heights of the Andes, dung is almost the sole source of fuel for cooking and heating. Manure is also the only accessible and cost-effective fertilizer; no one has yet found a way to economically move massive quantities of chemical fertilizers up into the roadless reaches of the high Andes. To meet basic subsistence needs, the typical highland family requires some 1.5 tons of manure annually (Jamtgaard, 1984). Without it, people of this ecozone would be unable to produce viable quantities of their staple foodcrops (McCorkle, 1983a; McCorkle *et al.*, 1989; and references cited therein). Indeed, this humble animal product is so valuable that, in certain situations, it can replace money as a medium of exchange. Fortunately, even ailing and aged animals continue to produce this desperately needed input.

- In western Kenya, SR-CRSP scientists' goal was to breed, test on-farm, and disseminate a dual-purpose meat+dairy goat, to address the growing demand for meat and especially milk in the face of burgeoning population on shrinking smallholds and commons no longer capable of supporting cattle. Farmer interest in the goats was therefore high. But the breeding/testing/extension process is a lengthy one, and for some years participating farmers realized few real gains in either meat or milk production from the experimental breed. As participant evaluations revealed, however, farmers greatly appreciated another product that scientists had overlooked — the precious manure that the new "triple-purpose" goats supplied. With the loss of their cattle, farmers had also lost access to adequate quantities of manure to fertilize their staple foodcrops or even to make spartan applications to their high-value cash crops (Conelly, 1992; Mbabu, 1992).

In the Quechua case, farmer-stockraisers predictably would reject "sustainable" development designs to, say, relieve stocking pressure on overgrazed and eroding lands via reduced herds of higher meat- or fiber-yielding animals. Without a complementary plan to replace the indispensable manure *cum* fuel and fertilizer provided by larger herds, such an intervention would directly prejudice Andean cooking and cropping[7]. Although Quechua agropastoralists are in fact interested in upping offtakes and/or placing their stockraising on a more ecologically secure and sustainable footing (Guillet, 1992), they would be unwilling to do so at the price of cold or raw meals and dangerously depressed crop yields. This case illustrates how — without an appreciation of animals' mix of roles in producers' overall agroeconomic system — developers could easily end up designing "sustainable" systems that are nothing of the sort. In the Kenyan case, farmers — acutely aware of the intimate links between their animal and plant agriculture — were quick to recognize an urgent, added benefit from the new goats, even if scientists didn't. As Conelly (1992) points out, an appreciation of to-Western-eyes "hidden" roles of animal can sometimes yield unanticipated development bonuses.

It is not enough just to understand animals' general functions vis-a-vis cultivation, however. Different species' roles relative to one another are also important, along with the interrelation of specific plant and animal crops in producers' overall plan of agro-economic and -ecological risk and resource management. In this regard, a common misconception among scientists and developers is that, merely because a people keep a certain species, they would therefore necessarily be interested in investing more time and money in it — for instance, by genetically improving the breed or by better managing the animals and the natural resources upon which they depend. But not necessarily — as the SR-CRSP's comparative findings on goat production in the Brazilian "serta~o" and the Peruvian "despoblados" demonstrated.

- Farmer-stockraisers in the semi-arid "serta~o" of northeast Brazil keep goats primarily as a low- or no-cost hedge against the severe, recurrent droughts of this ecozone. People devote little labor, capital, veterinary or other care to goats; such inputs are reserved to the household's more lucrative sheep, cattle, and cropping enterprises. The role of goats in "serta~o" agroeconomic systems is a straightforward one — to act as a last-ditch, emergency backstop to cover the family's basic needs for cash and food when their crops wither with drought and their sheep and cattle die of thirst and starvation. The goats themselves and cash earnings from them are not a production priority (Primov 1982, 1984, 1992). In contrast, in the agroeconomic system of the desert "despoblados" of northern coastal Peru — where there are few other productive options — goats are the mainstay of household consumption and also the primary source of cash income, from market sales of meat, cheese, hides, and kids (Perevolotsky, 1985, 1992).

In "serta~o" agroeconomic systems, the role of goats vis-a-vis other animal and plant crops is such that development strategies calling for increased capital investment in herd **quality** were soundly rejected by producers, since this vitiated the very reason for keeping goats in the first place. However, "serta~o" stockraisers might welcome such interventions for their sheep and cattle. And they showed some interest in modest extra inputs of labor or slight shifts in husbandry practices in order to maximize the **quantity** of goats and thus the number of animals surviving during droughts. In contrast, in the "despoblados" **both** such moves would likely be acceptable.

In designing truly sustainable strategies of animal agriculture, even the roles of different products from the same livestock species must be carefully examined for their relative payoffs and tradeoffs within the agroeconomic system as a whole and across both the short- and the long-term. A classic example is the delicate balance between production of young animals versus milk.

- For many Luhya farmers in Kenya, milk is the single most important source of high-quality protein in the diet. When on-farm dairy production is inadequate, households will divert a considerable portion of their scarce cash resources to commercial substitutes, to the detriment of other household needs (Conelly and Chaiken, 1987). In adopting the SR-CRSP dairy goat, people were therefore understandably eager to take off as much milk as soon as possible — with predictable implications for kid production, and ultimately for sustainable production of both milk and meat. Possibilities for addressing the problem of kid nutrition and survival were limited. Purchasing feed supplements for early weanlings did not make sense; the money could just as well be spent to buy milk in the first place. Cultivating special supplemental forages on croplands did not make good sense either; all available plots were already required for raising food for humans plus a few cash crops. With research and on-farm testing, however, an especially nutritious crop byproduct (sweet potato vines) traditionally used by Luhya as a feed supplement

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[7] *When this interaction was clearly understood, it was suggested (albeit somewhat tongue-in-cheek) that instead of or in addition to concentrating on bigger, meatier or woolier sheep, breeders should consider selecting for increased manure production — i.e. breeding for sh..tier sheep, so to speak. This suggestion did not meet with much enthusiasm, however.*

was identified and then reserved primarily for use as a milk replacer. This strategy yielded farmers an additional 87 kg of milk per doe with no loss in normal growth rate or weight among early weanlings (Semenye *et al.*, 1989).

This case illustrates the complexities that arise in understanding the roles of even a single livestock species within a specific agroeconomic system. In order to devise truly sustainable systems of animal agriculture, a context-sensitive balance must be struck among: production of the desired products (here, milk and kids, the latter both for replacement breeding does and for meat from young bucks) vis-a-vis considerations such as protection of future herd reproductivity; allocation of scarce capital to alternative ends (production versus purchase of the necessary livestock products and inputs); and appropriate land use patterns (for feed versus food).

Furthermore, development planners need to be aware that the roles of animals or their products can be "gendered" or otherwise linked to a given biosocial group. Ignorance of this fact can distort or derail even the best-intentioned development design.

- In central Bolivia, whether rightly or wrongly, developers associate livestock with environmental destruction. The normal pattern of animal ownership in the region is that large stock, particularly cattle, belong to men. Smallstock — the most important of which are goats — belong to women. Considerable environmental damage is attributed to goats' browsing and to erosion along the paths they wear into the steep hillsides. To date, efforts in sustainable animal agriculture in central Bolivia have focused on two strategies: increasing the quality and quantity of cattle maintained on shrinking rangelands, and decreasing the goat population. Along with other shortcomings, however, such an approach "represents a direct assault on one of the few areas of property...[and] the only form of savings available to most rural women" (Painter, 1992). Likewise for many rural African women and small ruminants (Talle, 1988).

- Among Fulani, Maasai, and other cattle-raisers of Africa, men derive their cash income from the sale of animals and women from milk and milk products remaining after the women have seen to their family's daily consumption needs. At times, this division leads to tensions between spouses over calves' versus women's rights to milk. Men, however, are the ones responsible for paying for and allocating any purchased herd inputs, such as supplemental feeds, minerals, or veterinary treatments. In consequence, dairy development schemes dependent upon purchased inputs would be unlikely to increase milk sales because men would direct the augmented milk production to calves, so as to justify their cash outlays through increased stock sales. In fact, this is what happened in the misnomered Smallholder Dairy Scheme — which its red-faced designers hastily re-christened the Dry-Season Cow Supplementation Scheme (Waters-Bayer, 1988; Talle, 1988).

3. LESSONS FOR SUSTAINABLE ANIMAL AGRICULTURE

Examples such as those presented above could be multiplied many times over. At the risk of repetition, the larger point should by now be amply evident. To wit, it is foolish — and also highly unscientific — to embark upon the design of strategies for "sustainable" animal agriculture without first investigating all the many and interlocking sacred/symbolic and secular meanings and roles that the target species hold for a given group of beneficiaries. Rather than belabor this point further, however, drawing upon anthropological and sociological research cross-culturally, this section extracts some lessons learned and some recommendations for R&D focused on constraints and opportunities in the design of truly sustainable systems of animal agriculture — systems that sustain not only the biophysical ecology but also the human ecology.

First, in investigating animal roles in a specific sociocultural or agroeconomic system, it is important to remember that the line between sacred/symbolic and secular is thin, and that each can impact the other. As anthropologists have repeatedly demonstrated, however, very often the former is grounded in the latter. Semitic taboos on swine raising and eating, the U.S. taboo on hippophagy (horse-eating), the Hindu worship of cattle, and the Tzotil proscription on slaughtering or consuming sheep — all are based, either historically or contemporaneously, on sound ecological and/or economic imperatives. To illustrate briefly from the Tzotzil example, for stockraisers to consume the species that provides them a sustained income from wool and weavings when alternative meats are available would be akin to killing the goose that lays the golden egg. Small wonder, then, that strong religious rules protect the life of Tzotzil sheep and urge their meticulous husbandry.

A second and larger lesson here is that, wherever powerful sacred or semi-sacred proscriptions or prescriptions pertaining to the use of an animal domesticate are encountered, developers can be sure that the species has some special implications (whether positive or negative) for the local agroeconomy and/or ecology[8]. Until such implications are fully understood in these contexts, as well as in sociocultural terms, interventions to increase, decrease, or substitute this species' production can be designed only at the peril of human health and well-being. Ecosystem "health" can suffer, too. Raising pigs in the desert, for instance, is dangerously resource-intensive. And in many researchers' view, the displacement of the native Andean camelids by sheep and goats — whose feeding habits, bite patterns, and hoof structures are more destructive — has directly contributed to range degradation and erosion in this fragile alpine biome (Flores, 1988; Painter 1992). Third, to fully appreciate and quantitatively assess the importance of a given animal domesticate or the mix of livestock species raised by the target group, developers and especially development economists must take into account all its contributions. This includes not only conventionally recognized goods and services such as meat, milk, fiber, eggs, and traction. Economic valuation must also incorporate all other tangible contributions from that species — whether major (transport, hides, hides) or minor (blood, crafting materials, winnings from competitive events, earnings from recreational uses or rentals, and still more), plus less tangible environmental (land clearing and brush control, restoration of soil fertility and vegetation, ecological mobility) and financial, fiduciary, and social-security services. Neither must difficult-to-calculate and -substitute cultural and social values be omitted (the extra cost of purchasing rather than producing special symbolic, sacrificial, medicinal, or magical animals and animal products).

For a specific suite of animal species in a given context, the list will of course be shorter than the foregoing. But it is useful to reiterate the possibilities, given Western-world myopia. Developers tend to view the flocks and herds of people in developing countries as so tiny or poorly maintained as to be almost negligible in economic terms. Holdings are often comprised of little more than a handful of nearly feral poultry, half a dozen sickly-looking sheep and goats, one or two scrubby head of cattle, a stringy sow or a scrawny donkey or horse, and perhaps a few "exotics" such as guinea pig or iguana. Yet the worth to both household and rural economies of such motley holdings cannot be captured in mere head counts. As smallholders well know, even a single animal can literally spell the difference between life and death — for example, by providing emergency cash with which to obtain vital medical care. When the total market and non-market value — cultural, social, financial/fiduciary, nutritional, technological, agricultural, and ecological — of the veritable galaxy of goods and services furnished by small but often diversified livestock portfolios is accurately tallied for non-Western production sys-

[8] *Or at the least, did have in past. Such historical information is almost always useful for achieving a more profound understanding of animal roles, and potential variations on them, in relation to human needs and natural resources in the milieu in question, however. For an in-depth discussion of this point, consult Harris (1985).*

tems, agricultural scientists and environmentalists alike may be in for quite a surprise.

Attention to the total value of livestock to producers is important, lest putatively sustainable schemes of animal agriculture inadvertently deprive the target group (or subgroups within it) of needed resources they cannot otherwise readily replace. De-contextualized interventions can leave people worse off than before their animal husbandry was "improved." For example, some livestock interventions that might indeed increase monetary incomes and benefit the environment could also decrease the varieties, numbers, yields, or local availability of key animals and their corresponding goods and services. What, then, will it cost the household (or the wife or husband) to acquire the equivalent constellation of goods and services in the formal or informal economy — if, indeed, they are available for purchase at all? (Recall the problem of chemical fertilizers in the high Andes, not to mention problems of runaway inflation and hoarding in some developing economies). In attending to such issues of relative payoffs and tradeoffs and in getting at the total value of animal agriculture in a given milieu, economists may find some useful theoretical and methodological pointers in the emerging field of ecological economics, which is currently wrestling with such multiple-use, long-term *versus* short-term, and marketed *versus* non-marketed social and environmental valuation challenges (Pearce, 1991)[9].

Fourth, for complete and accurate baseline data on animal roles and values as well as for follow-on investigations to determine what interventions will most likely be workable and sustainable, women as well as men must be included in survey samples, economic calculations, strategy design, and on-farm testing. While the reasons for this recommendation should be self-evident, perhaps they nevertheless bear repeating. Rural women worldwide typically participate directly or indirectly in some or all aspects of animal agriculture[10]. Beyond husbandry tasks that they may (or may not) share with men, women often have unique responsibilities and decisioning power over the use or disposal of animals and animal products — e.g. in dairying, food processing, weaving, marketing. These activities give them additional and sometimes exclusive insights into complex interrelationships and tradeoffs among livestock roles. Without this information, sound development planning cannot proceed. Moreover, virtually everywhere, women are the principal implementors of foodways and major consumer decision-makers with considerable aggregate purchasing power. Thus they stand at a crucial node in choices for change in the level and quality of consumption/demand (and thus also production/supply) of livestock goods. The larger point here is that design and implementation of proposed interventions must involve all the relevant actors in all four fields of agriculture (production, transformation, distribution, and consumption). Yet somehow, women are often overlooked...

In sum, the kind of broad-based, thorough-going analysis outlined in the preceding paragraphs is key to determining what sorts of interventions people would be willing or even able to accept in their production and utilization of animals and animal products. This entails answering questions like the following before embarking upon any strategy for environmentally sound and sustainable livestock development.

- What flexibility exists in sacred/symbolic meanings and roles of animals and their prod-

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[9] *Of this emerging literature, perhaps the most suggestive is recent micro-level work in ecological economics in biodiversity, forestry, and agroforestry, in the valuation of multiple non-traditional forest products.*

[10] *They may be stockowners; principal herders, herder supervisors, and range managers; home veterinarians; waterers, feed provisioners, and builders and maintainers of animal quarters; dairiers; culling decisioners, slaughterers, and butchers; certainly processors of both food and non-food livestock products; and buyers, sellers, and renters of animals and their products and services. The precise constellation and extent of such responsibilities among rural women vary by ethnic group and of course socioeconomic status, and therefore must be empirically determined. For discussions and examples of the importance of women's tasks, knowledge, and decisioning in livestock management and R&D, see Fernandez (1992); Ibrahim and Abdu (in press); Heffernan et al. (in press); McCorkle et al. (1989); Noble (1992); Stem (in press); Stephens (1990); Talle (1988); Waters-Bayer (1988).*

ucts, such that people may be able at least partially to accomodate more environmentally friendly interventions without insult to their relations with the gods, other cultural values, perceived quality of life, etc.? Recall the case of steak-eating in the Western U.S.

- Are there unexploited "niches" in the agroeconomic system that new (or old), more ecologically benign or efficient species could profitably and sustainably fill? Could they partly replace (and even increase) some of the goods, services, or earnings from current species, again with no loss in cultural or other values? For example, if cattle are inappropriate to Mayaland ecology, since this species has relatively little sacred significance for Tzotzil, might Tzotzil families be willing switch at least in part to another source of meat if it were made available — say, in the form of the indigenous turkey or possibly even guinea pig, like their South American cousins?

- A corollary question is: what role opportunities are there for indigenous and micro-livestock? In many scientists' opinion (Bostid/NRC, 1991; Fitzhugh and Wilhelm, 1991), these species offer considerable promise for addressing future food and income needs plus environmental concerns. *Ceteris paribus* indigenous species are better adapted to and "gentler" on their environment — like the American camelids. Whether for domesticated or wild animals, their husbandry or judicious management by local peoples is increasingly recognized as one of the surest ways of protecting them from extinction along with their threatened forest, alpine, etc. habitats. This is also a highly cost-effective way to maintain biodiversity and to conserve *in situ* invaluable rustic or exotic germplasm. Yet scant research has been devoted to such animals' potential.

- Are there any socioculturally acceptable overlaps, parallels, or precedents in the roles of different animal and plant species that, via their redirected use or the promotion of one species or product over another, would make for more environmentally sound and sustainable animal agriculture with no loss (and indeed, gains) in total value? Recall the SR-CRSP/Kenya substitution of dairy goats for milch cows and the targeting of a traditional crop byproduct to weanlings.

- Relatedly, could the special role(s) of a given animal species or product realistically be replaced by some semi- or non-livestock alternative of equivalent functional value? If large goat herds ensure the short-term viability of "serta~o" households at the expense of the longterm sustainability of the resource base on which the agroeconomic system as a whole depends, might something like a goat-banking system or a state drought-insurance fund substitute for the value of goats to "serta~o" households?

- At the same time, however, are animal roles and products gendered or otherwise "marked" in such a way that the success of proposed interventions may be prejudiced by the fact that benefits redound to one subgroup of beneficiaries and costs to another? The latter will likely resist the proposed changes, if they are able. And the overall impact upon human well-being could even be negative. For example, if control over a basic minima of animal food products is shifted from one subgroup to another — say, from women to men — who then divert the products or earnings from them to non-nutritional ends, family diet and health may suffer. Remember the role of milk in Kenyan farmers' diets, and the Boliva stockraising and Fulani dairying cases.

- In general, are there innovative mixes of animal and plant species plus other, non-agricultural activities that can supplement or replace some of the roles that animals currently play in a given milieu without longterm social, cultural, agroeconomic, or ecological damage?

The foregoing questions embody just a few of the kinds of constraints and, more importantly, opportunities that researchers, developers, and environmentalists need to jointly explore in designing livestock interventions that ensure sustainability in every sense of the word. Admittedly, this is a tall order. But such queries can be answered — or sometimes even posed — only after the many interlocking roles that animals presently play in the target systems are fully understood in terms of their implications for human well-being. Any efforts at truly sustainable agriculture must include the goal of ensuring (and hopefully enhancing) the livelihoods and vital lifeways of the rural populations who rely on animals as one of their key natural resources. Otherwise, human values, cultures, or even human survival itself may be needlessly sacrificed on the twin altars of well-intentioned but misguided agricultural "development" and environmentalism.

Acknowledgements

The author's participation in planning for the USAID/ROCAP/UGIAAG/CATIE conference and this essay was supported by the Title XII Small Ruminant Collaborative Research Support Program under Grant No. AID/DAN/1328-SS-4093-00 through the SR-CRSP Sociology Project housed at the University of Missouri-Columbia (UMC). Many of the case examples presented here are drawn from SR-CRSP work in Brazil, Indonesia, Kenya, and especially Peru — where the author carried out field research among Andean stockraisers in 1980-1981 under SR-CRSP Grant No. AID/DSAN/XII-G-0049. Return research was conducted in 1987-1988 under a CIES Fulbright Faculty Scholar Grant. Additional support for preparation of, respectively, the conference presentation and the present paper was provided by the Institute for International Research, Arlington, VA and by The Futures Group, Washington, DC. Special thanks are due to three colleagues in livestock development for their helpful comments on a draft of the manuscript: Dr. Evelyn Mathias-Mundy, a veterinarian with the Center for Indigenous Knowledge and Rural Development at Iowa State University; Dr. Patricia Vondal, ecological anthropologist; and as always, Dr. Jere Gilles of UMC Rural Sociology.

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TOO MUCH OF A GOOD THING: ALTERNATIVES FOR SUSTAINABLE ANIMAL AGRICULTURE

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1. OUR HERITAGE

Cicero recorded the following dialogue concerning the relative attractiveness to a country gentleman of cattle ranching pertinent to farming:

> *Cato, when asked what is the most profitable thing in the management of one's estate, answered: "Good pasturage". What is next best? "Fairly good pasturage". What is third best? "Bad pasturage". What is fourth best? "Tilling the soil".*
>
> Cato the Censor (234 - 149 BC)

All of us, Anglos and Latinos, share a common Roman heritage with our traditional veneration of the cattleman, the "hacendado". We attach prestige to raising, or in the case of the successful businessman-cum-rancher, having cattle. Our vocabulary reflects this heritage; goatherd or poultryman does not have the same panache as rancher or cowboy. The dominance of our "Cultura de Potrero", or pasture culture, has led us to focus on raising beef rather than producing animal protein, with profound negative dietary, social and ecological consequences. This indicates a failure in achieving one of the major goals of animal agriculture; to provide food and income for millions of people deficient in both. Failure to achieve this goal, coupled with the loss of forest resources and biodiversity occasioned by clearing for pasture beg consideration of major land use and economic policy changes.

The treatment of the socioeconomic and ecological issues raised in this discussion of the sustainability of livestock production in the American tropics is broad in scope. This paper focuses on cattle. The geographic scale is continental, from the Tropic of Capricorn to Cancer; the time scale covers half a millennium. After outlining the problem, we examine the consequences of Medieval Iberian people introducing an exotic ungulate in the American tropics. After an impact assessment, alternatives for sustained protein production are discussed. Finally, the need to recognize the economic value of the forest resource is posed as an effective means of providing a viable alternative to the deforestation blamed on livestock producers.

2. THE PROBLEM

Cattle were already present early in the Sixteenth Century and have become ubiquitous in the American landscape. Cattle are found from sea level to the lower Andean "Puna" and "Pŧramo" at about 3600 meters elevation. Above this elevation sheep become dominant. Cattle are found in virtually all humid life zones and in dry life zones where potential evapotranspiration is less than three times rainfall. Goats survive better in these drier areas. Cattle ranching under appropriate management and ecological conditions has a place in the tropics. However, given this broad distribution of cattle ranching as a land use, it is not surprising that it is often in conflict with optimum financial return, indicated land capability, social equity, and biodiversity concerns.

If the extensive raising of cattle on unsuitable sites causes degradation of the land and brings less than optimum return, why has this use of the land persisted despite known alternatives? The origins of the situation are complex. Among the reasons are the following:

- The cultural preference for cattle ranching over farming has persisted throughout the history of Iberian occupance of the Americas. Poorly adapted Medieval folk practice has been modernized, but not always improved.

- Given that the land holding elite are an integral part of the cattle culture, much of the hemisphere's best agricultural land has been traditionally used for pasture with resultant social and economic consequences.

- Policies governing credit and land titling have tended to encourage land clearing for crop and pasture regardless of the appropriate use, which is usually forest management or watershed protection.

- Land and tree values in the forested public domain are so low that extensive, wasteful use and conversion are encouraged. Similarly, neither tax policy nor land reform encourage the most intensive use of the best private land.

- The lack of services essential to a crop based economy, including applied research, extension, timely credit, transportation and functioning markets favor traditional extensive cattle production over more complex and intensive agricultural uses. - Natural forest management is not **perceived** as a viable, legitimate use of the land, either by law or custom. Forests may be cleared and timber sold, but only as a transitory activity to be followed by conversion to pasture or cropland.

- Advocates of ecotourism and "extractive reserves" for non-timber forest products in natural forest management offer only sustainable poverty to people living at the forest edge. Without the option of earning income from logging, they will as likely opt for poor pasture and crops on forested land.

- Conservation of biological diversity is a concept which has only recently begun to be recognized at the local level and gain powerful adherents.

What has been the U.S. role, or lack thereof, in recognizing the social, economic and ecological consequences of ill-adapted cattle raising? The U.S. economic, political and military influence over tropical Latin America has been powerful over the last century as this country has pursued its interests. Neither social equity, nor certainly conservation of biological diversity, have been areas of consistent concern. Lacking the tropical colonial experience of Britain or Holland, U.S. research, training and technical assistance in agriculture has been slow to adapt to the ecological reality of the tropics. Sons of Latino ranchers, not shifting cultivators, study at Florida and Texas A&M, perpetuating the North-South bond.

3. IMPACT ANALYSIS

3.1 Hemispheric

Cattle are exotic ungulates in the Western Hemisphere tropics where few native grazing or browsing mammals have existed since the Pleistocene, especially in the south. It is no accident that the pasture grasses used are predominantly of African origin, where the grasses coevolved in drier life zones with a wide variety of grazing animals. Even in Africa, cattle do relatively poorly when compared to the mix of wild animals in terms of effective forage utilization, a problem generally exacerbated by mismanagement, overstocking and diseases.

3.2 Life Zones

According to the life zone diagram (Holdridge, 1966), there is a basic division between the humid climates where precipitation (P) exceeds potential evapotranspiration (P>PET); and the drier life zones where evapotranspiration exceeds precipitation (P<PET). Most human population and the agriculture that supports it has been concentrated in the life zones bracketing the unity line: PET=P. All the capitals of Latin America, except Lima and Santiago, are located along the unity line. Both crops and pasture are favored by the osmotic movement of nutrients in the dry season that balances the leaching of the wet season. Under careful management cattle are able to utilize intermediate slopes along the unity line as well as the drier life zones where conditions for crops are marginal. In Africa the relatively less extensive humid life zones have few cattle, these areas are predominantly in agriculture or forest cover. In contrast, tropical America has relatively more extensive humid life zones with cattle everywhere, often in the wet tropical life zones where pasture is an ill-adapted, difficult to maintain cover.

3.3 Land Capability

There are various systems for classifying land capability. The system developed by the Tropical Science Center, in Costa Rica, combines factors related to the overall life zone framework mentioned above (Tosi, 1985). Within a given life zone slope and soil are taken into consideration. This system has been used widely in Latin America to define areas suitable for annual crops, pasture and other permanent crops, natural forest management and protection. This system has legal standing in Costa Rica, Colombia and Peru. Use of land for pasture rarely conforms to indicated capability. The most common deviations are pasture on land suitable for more intensive use. Such use is not directly damaging to the land, but is indirectly responsible for unsustainable pressures by displaced farmers on fragile slopes to produce food crops. The classification system also clearly indicates where cattle production on pasture is unsustainable due to combinations of slope, soil and climate.

3.4 Mismanagement

Exacerbating the social and biophysical damage created by the raising of cattle under inappropriate environmental conditions is mismanagement. This includes most commonly overstocking and failure to rotate animals; both resulting in overgrazing and soil disturbance resulting in erosion. Uncontrolled burning may affect forage species composition and damage adjacent forest areas. The most common means of increasing production or compensating for deterioration of existing pasture is to clear more land, a form of mismanagement encouraged by cheap land and lack of perceived alternative management strategies.

3.5 Focus on Cattle

The overwhelming emphasis on extensive cattle ranching in Latin America is reinforced by culture, and subsidized by preferential credit, scientific research and extension. This emphasis has had two major impacts:

- First, animal protein production in Latin America is far below that needed for an adequate diet for most of the population. Beef can only supply a part of the need, even under far higher levels of production. You can't kill a cow to feed the family. Neither an adequate distribution system or refrigeration is available to the poor, even if they could afford to compete with the national and international middle class consumer. In Mexico for example, some 25 million peasants cannot afford meat. Even the developing country "middle class" consumes less meat in a year than their counterparts in North America or Europe do in a month (NRC, 1991).

- Second, the extensive production of cattle without regard to land capability, available improvements in management or the consideration of alternative sources of protein - has resulted in the maximum loss of tropical forest cover with the minimum sustained economic benefit.

4. ALTERNATIVES FOR SUSTAINABLE PROTEIN PRODUCTION

Alternatives will be discussed from the perspectives of:

- Improvements in cattle production
- Other sources of animal protein
- Wildlife utilization/domestication

4.1 Improvements in Cattle Production

If a map of the land currently being used for pasture were to be superimposed on a Tropical Science Center land capability map, three areas of conflict would be evident.

- First would be those areas of high crop production potential currently in pasture. This social and economic problem should be the focus of careful policy assessment in the search for just and economically viable uses of the land.

- Second are the extensive areas in a wide range of life zones where pastures are found on slopes too steep and/or soils too fragile to sustain grazing. - Third are all the wet forest life zones of the tropics where PET/P = 0.5 or less. No justification exists for any further expansion of pasture on steep slopes or in the wet tropics. The areas actually suitable for pasture should accommodate the cattle industry with increased animal production applying technologies discussed in detail elsewhere in this volume. The challenge will be to find productive uses for already abandoned pasture land, land where pasture is unsustainable and remaining forest lands that continue to tempt the cattleman (US-AID, 1991).

Perhaps the drier and higher life zones offer some of the greatest opportunities for improved management of areas where grasses and browse are more a part of the natural landscape. Work with cattle and other animals in highlands above 3000 meters has been striking. In drier life zones some adaptation of the controversial approach to management advocated by Allan Savory is in order (Savory, 1988). Indications from one working farm in Namibia under lower than average rainfall were impressive (personal observation). Care must be taken not to push livestock out to the edges of Savory's "brittle" environments.

More than half of the Philippines' cattle production occurs in backyards, not on the range. The potential for cattle production under zero or limited grazing could be attractive as part of agroforestry systems. Significant advances have been made in the recognition of the feed value to livestock of "ciruelo" (*Spondias* sp.), "ram¢n" (*Brosimum* sp.) and leucaena (*Leucaena* sp.).

4.2 Diversification of Protein Sources

It would be ingenuous to harbor illusions about the appeal of beef to the majority of consumers...but after recently having rare tenderloin of springbok (*Antidorcas marsupialis*) topped with green pepper corns and mushrooms, it is obvious that there are competing options.

A recent book, Microlivestock, commissioned by the NRC of the United States, provides a text for the radically different approach to animal agriculture in the future. The opening is appealing:

> "Like computers, livestock for use in developing countries should be getting smaller and becoming more personal. Conventional mainframes, such as cattle, are too large for the world's poorest people; they require too much space and expense...tiny, user friendly species are the ones highlighted in this report.

Microlivestock are not a panacea. They have their own disease problems, demand in some cases for feed of relatively high quality, and often a dearth of scientific or folk management information. Nevertheless it is believed that diversification of animal production makes sense from both a socioeconomic and ecological perspective. These two perspectives are outlined below:

> **Socioeconomic.** For the large number of people living at the margins of the cash economy they cannot purchase meat on the open market. Animals must be capable of scavenging much of their food and/or to subsist on cheap feed readily accessible to the rural or urban fringe poor. A number of small animals meet these criteria. In addition small animals, better than large, offer more ready access by the poor into the economy because unit cost is lower, space requirements are lower, risk is spread over more individuals, growth to market or reproductive size is faster, greater flexibility is assured in responding to market or family needs, and animals can be used or sold one meal unit at a time. These benefits can be achieved with little competition with other resource use systems for space. To achieve these benefits will require major shifts in public and donor policies and investments in animal production. Investments to date in small animal genetic improvement, feeds and management have been limited. As a concrete example of cost/effectiveness, a successful nationwide rabbit production project in El Salvador cost the equivalent of one stud bull (NRC, 1991).

> **Ecological.** The wide variety of animals available can exploit an equally wide array of ecological niches. This applies both to those animals kept in confinement utilizing feeds from a variety of sources to animals feeding in different parts of the environment. This includes iguanas grazing in tree tops, pigs rooting for tubers, cows and sheep grazing on

grass, deer and goats browsing on shrubs, capybaras and ducks feeding on aquatic vegetation, poultry feeding on insects, seeds and shoots, even wider ranging pigeons and bees, and fish and crayfish feeding on plant detritus. Diversified animal production is highly compatible with agroforestry if animal production is considered an integral element in planning.

Investments in the genetic improvement of rustic, dooryard animals that are more noted for their survival ability rather than their weight gain can be justified. However, cost-effectiveness improvements in production can also be achieved through more selective interventions with wild or semi-wild populations. Examples include the management of the sustained yield harvesting of animals (deer) or eggs (marine turtles), habitat improvement (nest boxes for tree ducks in El Salvador), captive rearing and release of juveniles (iguanas), and supplementary feeding.

Pushing the concept of maintaining habitat for wild populations a bit further - we have the rapidly expanding hunting reserve industry. This is occurring not only in Zimbabwe and South Africa, but in South Texas as well, where income from hunters often exceeds that from cattle. Dove hunting is a poorly managed, but potentially viable example from Mexico to Argentina. In spite of the fact that the American tropics lack the highly visible charismatic megafauna found in Africa, such as lions, gorillas and elephants, ecotourism based on animal viewing...birds, butterflies and on the rarest of occasions, the jaguar... is gaining in popularity. Rural people must be convinced that a macaw or monkey is worth more in the binoculars of a tourist than in the pot. All that is required is the essential elements of development: **education, discipline** and **participation** in the benefits.

4.3. Examples of Wildlife Utilization/Domestication

The Green Iguana (*Iguana iguana*). The green iguana has been an important source of food from Mexico to Paraguay, so much so that populations have plummeted throughout their range (NRC, 1991). Iguana meat and eggs are popular in Central America where consumers willingly pay more for it than fish, pork, beef, or poultry. The rural poor hunt iguanas as a source of protein and for sale. In some areas iguanas are also considered to be an aphrodisiac. Iguanas make good pets and have a high demand in the pet market.

The green iguana can attain a length of more than 2 m long, but its tail is more than half of that length. Adult males reach 4-6 kg in weight and females 1.5-2.5 kg (Rand, 1984). Captive-bred animals can grow bigger than wild iguanas. After reaching sexual maturity, at 2-3 years of age, females lay one clutch of 10-85 eggs each year. The average clutch size is 41 eggs (Werner, 1991). Females lay eggs at the beginning of the dry season and hatchlings emerge at the beginning of the rainy season. The incubation period is about 90 days. Hatching success averages 30%-50% and mortality of young offspring is high in the wild. Life expectancy is estimated to be 7-10 years. Captive-raised animals can grow faster and reproduce sooner (Werner, 1991).

Captive rearing of iguanas from hatching through the first three months can greatly reduce mortality. Raising iguanas in captivity, however, has severe competitive constraints. Iguanas have a low metabolic rate and their growth is relatively slow compared to domestic animals (a wild iguana grows 9 times slower than a chicken). The greatest potential for iguana production appears to lie in the release of juveniles in appropriate habitats. Green iguanas are arboreal herbivores that occur in tropical and subtropical lowland forests (Fitch *et al.*, 1982). Iguanas are forest-edge species: they will grow well on farms and ranches as long as patches of trees are left standing. They live near water and feed on the leaves and fruits of trees. Iguanas are curious, social, and easily tamed at birth (NRC, 1991). These conditions make iguanas adaptable and manageable.

The Paca (*Agouti paca*). The paca is a spotted, tail-less rodent averaging 8 kg in weight, occurring in most of lowland Latin America from east-central Mexico to northern Paraguay. The appreciation of paca meat is legendary, resulting in unremitting hunting pressure throughout their range (Ojasti, 1991). In an effort to protect pacas, hunting has been prohibited in several countries (Fuller and Swift, 1985), but with little effect.

Given the appreciation of paca meat, they have the potential to become a source of protein for the American tropics (Freese and Saavedra, 1991). Many farmers in Central America already keep pacas in cages in their backyards and feed them kitchen scraps. Also, a few entrepreneurs are breeding and raising pacas for commercial purposes (NRC, 1991). Few animals present more challenges to domestication. Long gestation (146 days), low reproduction (2 offspring per year), monogamous pairing, intraspecifically aggressive territorial behavior (Smythe, 1991) and burrowing habit that makes containment expensive (Emmons, 1987). Without unprecedented success in genetic engineering, it appears that disciplined management of pacas in their natural habitat is the most promising means of maintaining viable populations.

The Capybara (*Hydrochoerus hydrochoeris*). The capybara is the largest living rodent with a weight of 60 kg. It occurs in eastern Panama and throughout lowland tropical and subtropical South America on the east side of the Andes (Nowak and Paradiso, 1983). Capybaras have been subjected to intensive hunting pressure throughout their range which has led to their being given (ineffective) protected status (Ojasti, 1991).

Using open habitats similar to those used by cattle, the capybara in the Venezuelan Llanos, where they are called "chigÁires", has been managed as an adjunct to cattle ranching for meat and hides (NRC, 1991; Ojasti, 1973; Jorgenson, 1986). In the lowlands, capybaras complement cattle because they usually feed on swamp grasses rather than dry-land grasses preferred by cattle.

The capybara is semi-aquatic and is rarely found more than 500 m away from water (Jorgenson, 1986; Ojasti 1991). They utilize vegetated areas around lakes, streams, marshes, and swamps for grazing, drinking water, and protection from predators. Low areas are used for wallows and dry ground to rest (Ojasti, 1991). Unlike most rodents, the capybara does not dig burrows or dens. Capybaras are gregarious and live in family groups of up to 30 (NRC, 1991).

Capybara meat is not considered to be in the same class as paca, due in part to intrinsic differences in the meat, but also perhaps to the manner and timing of its consumption. Because of its aquatic habits, the Catholic church in Venezuela have declared the capybara to be suitable to be consumed by the faithful during Easter Holy Week. The large annual consumption of poorly salted and inadequately dried capybara is more a measure of faith than market potential.

West African hair sheep. Though not an example of wild species utilization, the management of hair sheep in an agroforestry context warrants consideration in the context of alternative animal management systems (Bishop, 1983, 1980, 1978; Winrock, 1979). A system which includes sheep grazing and feeding together with trees for fruit, timber and fuel is relatively easy to manage and offers the opportunity to improve the level of living among the rural poor in the humid tropics. Recent studies have shown that fallow periods in less fertile lands in the tropics can be made more productive by integrating tropical forest hair sheep and forage/fuelwood legumes, (Bishop, 1983).

Hair sheep reach adult weight (35-45 kg) in approximately six months. They reach sexual maturity in about a year, have a gestation period of about five months, and they give birth to two or more young every year. Tropical hair sheep are perennial foragers. They are well-adapted to warm, humid conditions (Gonzalez-Reyna and Murphy, 1990; NRC, 1991; Bishop, 1983).

Tropical forest sheep are resistant to disease, being especially tolerant to trypanosomiasis, haemonchosis, and foot rot (NRC, 1991; Bishop 1983). Unlike cattle, tropical forest sheep cause little soil compaction and erosion on soils in the humid tropics (Sprague, 1976). Sheep are more able to exploit marginal areas more efficiently than cattle can because they are agile and climb steeper slopes (Bishop, 1983).

4.4 Valorization of the Forest

It is very easy to criticize the cattleman for deforestation because in most cases the criticism is valid. But, what have we done to valorize the precious tropical forest that conservationists want to save from the cattleman? Even if the 10% of total land area in each country of Latin America were set aside as protected parks, there would still exist huge areas marginal for pasture or agriculture, but suitable for forest production. Some of these areas are in mature forests, others have been drastically disturbed but still retain their productive potential as forests. What is the economic value of these forests? Forestry schools in the tropics produce foresters who only know how to plant pines and eucalyptus in a row; they don't know one tree from another in the tropical forest, much less how to manage them as a system. Despite worldwide concern for deforestation in the tropics, of the many tropical forests which are commercially used, few are managed (Ewel, 1981). Likewise, there are few models of tropical forest use and management that are both ecologically and socially sustainable (Murphy, 1990). State-supported forestry schools in the U.S. have little incentive to address problems outside their constituency. There has been no more tangible interest in natural forest management in Ministries of Agriculture or international development assistance agencies until recently.

Several management systems show promise as being both economically and ecologically sustainable. The experience of the Tropical Science Center (San Jose, Costa Rica) in the Palcazu of Peru should be replicated. The "Plan Forestal Estatal" (PFE) of the German Agency for International Aid (GTZ) in Quintana Roo, Mexico, the World Wildlife Fund BOSCOSA project and the CATIE San Isidro projects in Costa Rica show great potential. These last three are the subject of an AID-financed video prepared by a forest ecologist, industrial forester, forest economist and geographer (Dickinson *et al.*, 1991). The conclusion reached by this interdisciplinary team was that tropical forests can be managed profitably, probably yielding significantly more income than cattle.

The BOSCOSA project is new and shows promise in the wet Osa Peninsula where pastures for cattle have no place. Perhaps of even greater relevance to this meeting is the CATIE project near San Isidro in the El General valley of Costa Rica. This small but successful pilot forest management project is located on pasture abandoned 35 years ago. This CATIE experience has great economic relevance to the American tropics, as cattle production is intensified and focused on more appropriate sites, and hundreds of thousands of hectares of abandoned and marginal pastures revert to forest.

Because of its longer duration (since 1978), the PFE in Quintana Roo warrants more detailed discussion. In Mexico, land within communal holdings ("ejidos") has been set aside as permanent managed natural forest. With ten years of commercial experience, income is impressive in area previously logged and affected by hurricanes. When one sees a peasant community center with three satellite dishes and cable TV in every house, something interesting is going on. More than 25% of the income from the forest comes from plant and animal products (chicle latex and honey). In addition most of the ejido's meat comes from hunting in the forest. The PFE experience indicates that natural forests can be managed for profit while maintaining biological diversity. With proper silvicultural practices forests can provide a variety of valuable products such as resins, fruits, medicines, hard wood timber, and wildlife on a sustained basis.

The program is the result of a Mexican-German agreement to promote commercial forest exploitation on a sustainable basis as an economic activity for farmers in Quintana Roo. This program, initiated in the field in 1983, seeks to enhance the social and economic welfare of the local communities by requiring that the community organizes itself formally to make decisions about commercial forest exploitation, marketing forest products, and natural forest management.

There are 16 communities or "ejidos" participating in the PFE program; "ejido"s are lands in usufruct that were distributed to farm communities during the 1930s and 1940s as part of the agrarian reform program in Mexico. "Ejidos" range in size from 10,000 to 50,000 hectares and have about 50-200 families each. Most "ejido" members ("ejidatarios") work with subsistence agriculture and extraction of forest products.

While PFE 's approach to forest management is new, commercial forest exploitation in Quintana Roo is not. For about 150 years the forests of Quintana Roo have been exploited for timber chiefly mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrella odorata*). However, logging concessions were granted to large companies and "ejidatarios" did not participate in many phases of the forest exploitation. More recently, the forests have been exploited for chicle (*Manilkara zapota)* latex for the chewing gum industry.

Thanks to government agreements coordinated by PFE, "ejidos" now have forest exploitation rights and "ejidatarios" have an active role in the management of their forests. "Ejidatarios" now are participating in all phases of forest exploitation, such as marketing, administration, timber extraction, wood processing, and forest management. This allows "ejidatarios" to take control of the forest exploitation, increase their income, and attain labor and timber management skills.

The PFE promotes sustainable forest management practices, provides "ejidatarios" with technical assistance, and makes them more aware of the value of mature forest as an economic alternative to other types of development (ArgÅelles, 1991). The improved understanding of the economic and ecological values of standing forests that results from local PFE promotes forest conservation in Quintana Roo. Each "ejido" for example, has set aside areas of mature forest for long-range management and commercial exploitation. In this way, local "ejidatarios" are planning for a future based upon continued use of the forests.

The PFE has a number of advantages. Population density remains relatively low due in part to the unattractiveness of the rocky, excessively drained landscape to conventional agriculture and grazing and the large grants of land (400 ha per family) given to the "ejidos" originally. As chicle harvesters the people are preadapted to working in the forest. Constraining the overall success and replicability of the PFE is the lack of full appreciation of long-term forest management practices being demonstrated, lack of quality control in processing, and the internal conflicts which hamper community participation in sustainable forest management (Dickinson *et al.*, 1991).

Making natural forest management pay is an option which provides a viable alternative to simply decrying the destruction of the tropical forest by farmers and cattlemen. If forest management is shown to be an economically competitive use of the land and the other suggestions above on improvement and diversification of livestock production, new options will open for sustainable resources management.

4.5 Balance

The question is one of balance: a) balance in the use of the land - at the small farm ("finca") and regional levels guided by land capability - a balance among pasture, cropland, agroforestry, forestry and protection; b) balance between the production of meat for the middle class and export and the participation of the poor in supplying their own protein needs and participating in the economy.

Achieving this balance requires a concern for who benefits from development, implying a social as well as economic perspective in animal agriculture. Also required is removal of the Anglo-Iberian blinders that have prevented adequate attention being given to non-bovine protein sources. Finally, the animal scientist must learn that the forest has economic, aesthetic and ecological values for local people as well as internationally.

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LIVESTOCK PRODUCTION ON PASTURE: PARAMETERS OF SUSTAINABILITY

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1. INTRODUCTION

The difference between conventional and sustainable agriculture is more a question of philosophy than of practices or management methods. Based on this, some scientists conclude that the comparison falls outside the area of the exact sciences (Ikerd, 1991). Nevertheless, science must be used to analyze and study the processes in action and to determine what is the role of management of resources in achieving sustainable production systems.

Agroecology created a philosophical framework for the concept of sustainable agriculture. It seeks to synthesize agriculture and ecology (Altieri, 1983). While agriculture deals with increasing the productivity of nature for the benefit of man, agroecology views man as just another component in the interrelationships between biological and physical elements in an ecosystem. Agroecology implies the right of man to tilt the ecological balance for his benefit, and at the same time calls attention the care needed in achieving this balance, given the possibility of affecting the rights of future generations.

A brief definition of **sustainable agriculture** is the successful management of resources (labor, capital, soils, water, plants, animals, and technology) with the improvement in productive capacity over time, while considering the necessities of future generations in terms of economic growth and environmental health.

One of the most important participants in production systems in the American tropics are livestock. Table 1 shows the population of cattle and areas under pasture in the countries of Central America and the Caribbean. Like the rest of the American tropics (250 million head), in Central America cattle contribute in a significant way to the economic development and to the diet (milk and meat) of the populations. The ratio of cattle to people is 2 or more times greater in the American tropics than in Asia, Africa, or other tropical regions (Table 2). The consumption of meat and milk in our continent is high even amongst the populations of lower income (Table 3).

Table 1. **Cattle population and area in pasture in Central America and the Caribbean**

Country	Heads of cattle	Pastures, ha.
Costa Rica 2.50	2.17	
Cuba	5.10	3.04
Guatemala	2.00	—
Honduras	2.70	2.22
Tropical Mexico	16.20	19.57
Panama	1.40	1.30
Nicaragua	—	2.37
Dominican Rep.	1.01	1.19

Source: RIEPT (1987).

Table 2. **Relative availability of cattle in tropical regions**

Region	Cattle/humans
Tropical America	0.69
Tropical Africa	0.37
South East Asia	0.07
India	0.24

Source: FAO (1985).

Table 3. **Proportional expenditures on meat and milk by poor urban populations in tropical America**

Product	Range, %
Meat	12-26
Milk	7-13

Source: CIAT (1981).

Central America, just as Brazil, is a net exporter of meat and has a high degree of self-sufficiency in milk and dairy products. Being a region free of foot and mouth disease and having cattle herds of sufficient size, meat export from the region contributes in an important way to hard currency income for development of the countries. Nowadays that these countries confront the challenge of the competition in international markets, livestock production for export is of particular importance in the Central American region, being one of its clear comparative advantages.

Neverheless, livestock are accused by many environmentalists of being one of the greatest dangers to natural ecosystems (forests, savannas, and hillsides). In this presentation the validity of this accusation, the problems of degradation of pastures, and the technological alternatives for development of livestock as a component of sustainable production systems are analyzed. In addition, some indications on methods of evaluation and monitoring of the sustainable equilibrium in pasture systems are given.

2. PREDOMINANT PRODUCTION SYSTEMS

It is important to recognize and separate the two contrasting views of livestock development in our continent. On one hand we have semi-intensive livestock production on small and medium size farms and dual purpose (meat and milk) production. These tend to be independent of the ecosystems, and occur principally as a result of negative socio-economic pressures and migration of colonists from other economically deprived regions. On the other hand, the large scale livestock production (ranching) with extensive production of meat is the result of major investments by businessmen and other groups, in response to incentives and subsidies which are a product of policy programs for colonization and territorial occupation.

The origins of those two systems are different, but they present a similar series of problems of degradation and lack of sustainability. Nevertheless, they have different potentials and perspectives for conversion to sustainable systems through technology and management.

Extensive livestock production (ranching), particularly in areas originally under forest, is responsible for the bad image that livestock in general have acquired as an agroecological component. Economic calculations made by several authors demonstrate that the extensive livestock production without intensive technology, which has produced degradation in large areas of the Brazilian Amazon, is only economically viable due to governmental subsidies and incentives. In addition, modern pasture and livestock management technologies require highly intensive management in the use of resources such as labor, land, and cattle, and this is basically incompatible with the concept of extensive livestock systems.

Nevertheless, the systems of dual purpose production (meat and milk) on a medium and small scale (300-30 hectares) have a high potential for becoming systems which are not only sustainable, but also contribute to the improvement of the environment. This can be achieved with a greater level of intensification and the use of new technologies.

The profitability of this type of system of dual purpose management in six farms in Panama was studied by CIAT between 1981 and 1983. The return on capital varied between 15.6 and 2.5% annually with an average of 7.6% annually (CIAT, 1984), around double the return on capital obtained from typical extensive production systems in the tropics, which vary from 1.0 to 4.5% (Vera and Sere, 1985).

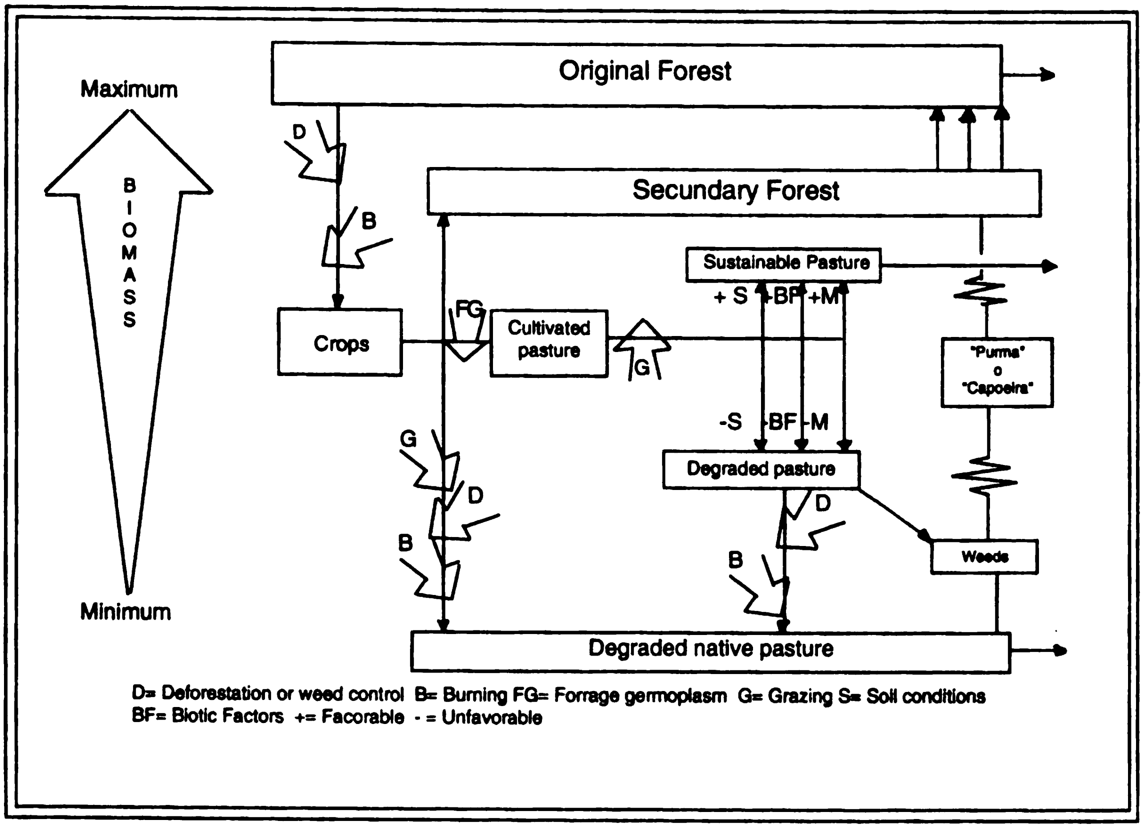
3. THE PROCESS OF DEGRADATION

Low productivity and environmental degradation are characteristics shared by all the traditional livestock systems in the tropics. Particularly in the humid tropics, Toledo (1977), Alvin (1978) and Serrao *et al.* (1979) recognized this phenomenon and described the typical process of degradation of pastures by species which are not adapted to poor acid soils, such as *Axonopus scoparious, Digitaria decumbens, Hyparrhenia rufa,* and *Panicum maximum*. For these species the acidity and low fertility of the soil, particularly the toxicity of aluminum and the deficiencies of nitrogen and phosphorus, are responsible for the lack of sustainability.

Nevertheless, solutions for the problems of adaptation to the soil, such as occur with the use of *Brachiaria decumbens*, and other factors such as "mion", "salibaso" or "mosca pinta" may be responsible for the death of plants and degradation of the pastures. Similarly, the disease Antracnosis (*Colectotrichum gleosporoides*) was the cause of disaster following the importation to the American tropics of Australian crops such as varieties Schofield, Cook, and Endeveour of *Stylosanthes guianensis* and the consequent degradation of areas sown with this legume.

Figure 1 shows a model (Toledo, 1986) which describes the sequence of changes in vegetation and the biomass which occur after the clearing of forest. Starting from virgin forest, followed by felling (T) and burning (Q) of the forest, the producer typically plants crops (one or two harvests) such as highland rice or maize. Invasion of weeds rapidly increases in the system of annual cropping. If no further actions are taken the area rapidly returns, increasing its biomass to a secondary forest which eventually regenerates the primary forest within at least 10-15 years, when it may be reopened for cultivation in a migratory agriculture system.

Fig. 1 Vegetation clynamics model after deforestation of the Wet Tropical Forest



When the forest is cleared for the establishment of pastures, whether this be with the initial harvest or later, the area is sown with forage species (G). Normally, the establishment is successful and grazing (P) is started and depending on the conditions of the fertility of the soil (S), the tolerance of the pasture to biotic factors (B), and the quality of the management (M), the pasture may effectively increase its productivity and establish itself at a level which is economically profitable and ecologically justifiable, that is to say sustainable.

On the contrary, it may rapidly enter a process of degradation in which the biological conditions of the soil and its management are in decline. This process of degradation includes the invasion of weeds and eventually the formation of areas of "Purma" or "Capoeira" which gradually return to the forest. If the grazing pressure continues and the producer takes effective measures to control the weeds (T) and burning (Q), the pasture may degrade further in terms of its biomass arriving at what, in this model, we refer to as degraded natural pasture or "torourco". This level of degradation may also occur directly without sowing of pastures. This occurs when, after cropping, the producer starts grazing simultaneously with an effective control of weeds and burning.

In Central America it is common to see pastures originally sown in improved grasses in a frank process of degradation, and invaded by local grasses (*Paspalum conjugatum, P. notatum, Axonopus compresus, Homolepis aturensis, Sporobulus* spp, *Pteridium* spp) or in "Ratana" (*Ischeamun ciliare*), especially in Costa Rica.

Degradation of the pastures is the basic problem in the lack of sustainability in tropical livestock systems. However, other factors also key in determining the level of sustainability of the system.

4. FACTORS AFFECTING SUSTAINABILITY

Sustainability of production systems is affected by both exogenous and endogenous factors. The important exogenous factors we must consider are:

Environmental Legislation. Frequently, our politicians seek to define the rules of the game through legislation with the intention of protecting the ecosystems from deforestation and degradation. Often however, these rules are respected or simply result in greater level of degradation.

In our developing countries where the law is an instrument of good intentions and an indicator of what should be done, but is not necessarily complied with nor is compliance forced, the concept of managing such a complex problem as the promotion of sustainable agriculture through legal measures is utopic. With or without environmental laws sustainability of production systems will depend principally on other factors.

Land Tenure. This may be a powerful instrument in promoting the sustainability of production systems and to decrease pressures for deforestation. Without a title to the land, the colonist does not have a basic conceptual incentive for sustainability. Without the possibility of property, the land does not have value and consequently, is poorly and extensively used. Those societies who wish to protect the natural ecosystems and promote sustainable agriculture for future generations must make every effort to consolidate property rights and to increase the value of the land as a sound basis for promoting sustainability based on intensification and use of technology.

Subsidies, Exemptions, Fines and Incentives. These are powerful instruments for promoting inefficiencies in production systems. On one hand they permit livestock and/or agricultural systems to subsist which are not well-managed from the point of view of either the ecosystem or society, and for the benefit of a small number of producers. In contrast, when such systems seek to benefit consumers or another sector (trade and industry) or where punitory fines are created, inefficiency of production systems of production tends to create further rural poverty and inability to adopt technology.

Markets. This, without doubt, is the principal force affecting rural development and sustainability of production systems. Without demand for the products of the system, there are no options for sustainable livestock or crop production. The systems which survive without a vigorous market will be those of subsistence which tend to make poverty a perennial problem. Conceptually, these systems by not satisfying the needs of economic and social development are not sustainable now and will not be in the future. On the other hand, vigorous markets and demand for the products of the system generate economic development which feeds capital back to the capable producer, who adapts technology and is concerned and invests in taking care of the natural resources under his control.

The sustainability of agricultural exploits (both crops and livestock) is not only going to depend on the implementation of key measures or laws nor on restrictive conditions for economic development. Sustainability will occur on a broad basis when best use is made of land and natural resources, within a dynamic economy, clearly dedicated to the generation of income, efficient production and economic competitively. To achieve this, the needs are: 1) access to the best lands; 2) lands titled according to their economic value; 3) access to and demand in a market for the products of the system.

The important endogenous factors affecting the sustainability of production are:

The Natural Quality of the Environment. Including the soil and its fertility (physical, chemical and biologic); water quantity and quality from rainfall and irrigation; climate, including the temperature, solar radiation and humidity. These will determine the natural and cultivated vegetation as well as the biotic pressure by pests and diseases.

Table 4 shows the relative importance of the poor and acid soils (oxisols and ultisols) of Central America. These are important in areas of Panama, Honduras and Nicaragua, but also of great ecologic importance for all of the countries of the region. These soils are most fragile in their fertility and occur principally in the areas of tropical forests. On the other hand, in areas with better soils (mollisols, alfisols, inseptisols) the problems of natural fertility of the soils are not a determinant factor in the failure of sustainability in the livestock systems

Table 4. Proportion of oxisols and ultisols in Central America

Country	Hectares (thousands)	% of contry
Mexico	4420	2
Panama	3590	63
Honduras	3130	29
Nicaragua	2920	20
Guatemala	960	9
Costa Rica 700	14	
Belize	400	18

Source: Cochrane (1979)

The relief of the soil may also be a key factor in determining the sustainability in areas with steep gradients (>25%), common in Central America. The simultaneous presence of steep slopes with heavy rainfall and a lack of vegetation coverage creates the potential for erosion and soil loss. At the other extreme, flat soils with the tendency for water saturation and seasonal poor drainage bring about the degradation of pastures by producing greater levels of compaction of the soils, and damage to plants on the pasture due to trampling. The aggressive root systems and the coverage capacity of pasture species can compensate this problem, maintaining the soil structure and decreasing the damage due to trampling. It is clear that the clay soils are most subject to damage by compaction and trampling (Pinzon, 1989).

In acid soils with high levels of aluminum, the root systems of grass and legume forages are not resistant of the toxicity of aluminum. They become deformed and superficial, preventing the expression of potential for absorption of nutrients in the plant. While the nutrients in the superficial layers of the soil may be sufficient for reasonable plant growth they are lost through leaching and the development of the plants is stunted, reducing their coverage potential and competitive value and increasing vulnerability to invasion by weeds.

The climate and the biotic factors in the pasture are very closely related. More humid environments (soil and air) promote greater and more varied biotic pressures from pests and diseases than do drier environments.

The germplasm. In livestock production systems on pasture in the tropics, the use of high-cost inputs is not feasible to bring about changes the environment (air conditioning, irrigation, pesticides, etc.). The germplasm of the plants and animals used in the system are thus a cornerstone of sustainability of the system.

The livestock must have the genetic potential for productivity, and hardiness to being able to tolerate and produce under conditions of environmental stress (heat, humidity, parasites, availability of nutrients in quantity and quality). The pastures (grasses and legumes) must have a high level of adaptation such as tolerance to aluminum and lesser requirement for nutrients. They must have deep and profuse root systems to maintain an effective utilization of the scarce nutrients in these poor soils, equivalent to nutrient recycling. At the same time as being environmentally well adapted the germplasm (animal and plant) must be capable of a good response to improvements in the environment.

Management. The combination of decisions and actions by the producer to optimize the use of resources is key in guaranteeing sustainability of production systems. For good productive management it is essential to understand appropriate technological packages. For sustainable management, however, an additional requirement is a deeper understanding of the cause and effect relationships in the dynamic processes of livestock grazing. To be able to apply techniques which favor sustainability, it is necessary at least to have a clear vision of the direction of effect which each management intervention may produce, as well as the economic possibility of implementation. Clearly, the best guarantee of sustainability would be a producer who is technically and economically solvent.

Without systems of production which are economically viable, we cannot think in terms of sustainability. The poor uneducated producer places his survival as a priority without concern for the environment, nor for future generations.

5. STABILITY AND REGENERATION POTENTIAL OF PASTURES, KEY TO SUSTAINABILITY

Primary production of the livestock system or pasture is the determinant for the stability of production, as well as for protection and fertility of the soils in the system. Achieving and maintaining high productivity, maximum vegetational coverage and an effective recycling of nutrients in pasture, would bring us closer to sustainable livestock production systems. As mentioned above, the cornerstone of sustainability is the utilization of adapted germplasm. In addition, and despite the bad reputation of pastures combining grass-legume in our continent, the nitrogen fixing capacity of the pastures is an essential component for sustainability.

Bad experiences with persistence of legumes in the past, were such that with the exclusive objective of animal production, many producers, extensionists and even researchers today not only have no interest in pastures combining grasses and legumes; but will do everything possible to discourage this option. Some, recognizing only the legume in animal feeding, accept the use of protein banks as a viable option but not in mixed pasture.

However, when we speak of sustainability, we must go beyond the short-term view and must recognize that a) there exists a new generation of adapted legumes suitable for poor and acid soils, with greater potential for persistence under grazing in association with grasses, b) the legumes makes an important contribution to stabilizing production and nutrient recycling.

The production of tropical pastures is limited by the availability of nitrogen, despite the fact organic material in the soil contains relativity high quantities of nitrogen. This is explained by the deficient rate of mineralization by means of which nitrogen is made available for plant nutrition. Only one percent or less of the nitrogen present in the root system is mineralized in forms which plants may absorb (Henzell, 1968). Thus it is necessary to improve the available nitrogen and/or increase the efficiency of utilization. The application of highly soluble nitrogenous fertilizers to grasses pastures may be a very effective means of improving the productivity of the pastures (Vicente-Chandler *et al.*, 1983). This model is used followed by the proposed dairy module at CATIE. For the majority of the producers of pastures and livestock in the tropics, however, the fertilizers are not available or are too costly. Thus, the only viable option is the nitrogen supplied through legumes.

5.1 Role of the Legume

The International Network for the Evaluation of Tropical Pastures (RIEPT) is developing a new generation of grasses and legumes for acid soils of low fertility of the already degraded savannas and forest areas already degraded in tropical America (Toledo and Nores, 1986). At present, producers have available grass, such as *Andropogon gayanus, Brachiaria decumbens, Brachiaria brizantha* and *Brachiaria dictyoneura*. Also available in the region are new legumes including *Arachis pintoi, Centrosema acutifolium, Centrosema brasilianum, Centrosema macrocarpum, Stylosanthes capitata, Stylosanthes guianensis* and *Stylosanthes macrocephala*. These plants are tolerant of the local pests and diseases and are adapted to the high levels of aluminum and the acidity of soils typically found with oxisols and ultisols.

5.2. Improvement of Livestock Production

New pastures combining grasses and legumes in the Colombian Llanos have more than doubled the weight gain per animal and have demonstrated an increase of more than ten times the productivity per hectare, when compared with well-managed native grasses (Figure 2). These grass-legume pastures also produce increases of 50% in weight gains per animal and increases in 20-30% in weight gain per hectare when combined with monocultures of grass.

The experimental results from different areas of degraded forests show that it is possible to obtain annual weight gains which are over to 600 kg/hectare when there are legumes included in the pasture (Table 5). This is an increase of 3 times the productivity of the degraded native grass ("torurco" or "grama") and a doubling relative to the improved pastures of grass alone.

In the Quilichao station (CIAT/FES), in the ultisols of the Cauca Valley, Colombia, the potential contributions of legumes have been studied as a way to increase milk production. Preliminary results show that productivity increases 20% when the grass *B. dictyoneura* is associated with legumes such as *C. macrocarpum* and *C. acutifolium* when compared with grass alone (Figure 3).

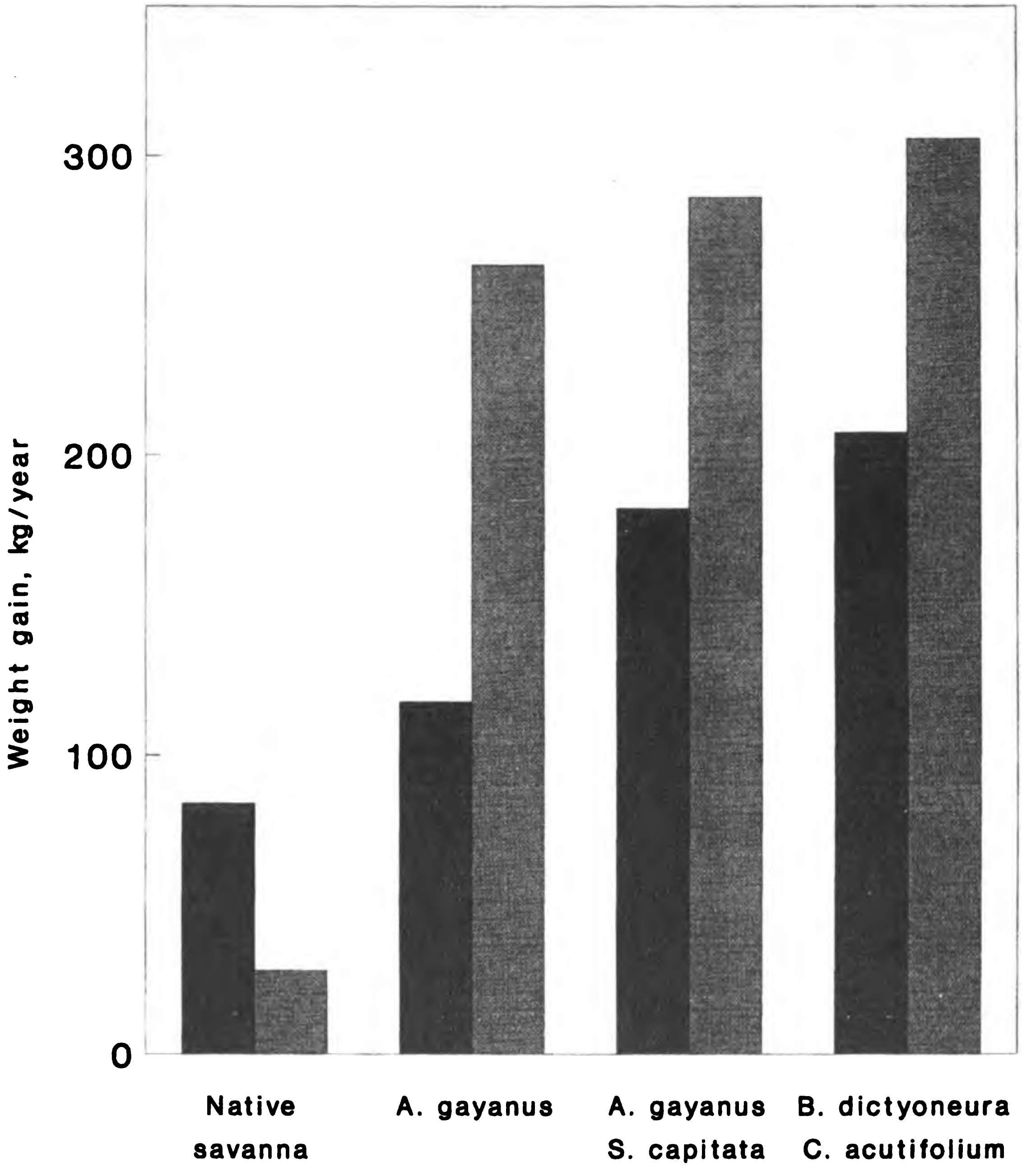


Fig. 2 Productivity of the native savanna with the best management and of new improved pastures at Los Llanos Colombianos (CIAT, 1988).

Cuadro 5. Weight gain in several pastures established in degraded sites resulting from forest cuttings

Pasture type Yeas[1]	animals/ha	Stocking rate kg/ha/year	Weight gain
Native pastures			
Homolepis aturensis (guadilla)[a]	1	1,5	110
Paspalum notatum (trenza)[b]	1	3,1	20
Improved grasses			
Brachiaria humidicola (CIAT 697)[c]	2	2,5	351
Andropogun gayanus (CIAT 621)[c]	2	2,1	340
Improved grasses-legumes			
A. gayanus + *C. macrocarpum* (CIAT 5452)[d]	5	4,4	660
A. gayanus + *S. guianensis* (CIAT 184)[e]	2	3,5	650
B. decumbens (CIAT 606) + *D. ovalifolium* (CIAT 350)[e]	5	5,5	897
B. dictyoneura (CIAT 6133) + *D. ovalifolium* (CIAT 350)[d]	4	5,0	803

[1] Years = Number of years under measurement

Sources: [a] Maldonado (1990); [b] Escobar *et al.* (1971); [c] EMBRAPA (1988); [d] CIAT (1988); [e] Dextre *et al.* (1987).

In Turrialba, they evaluated options for legume use in association with stargrass (*Cynodon nlemfuencis*). Higher levels of productivity were obtained when stargrass was combined with *Arachis pintoi*, than with pasture alone. On average, an increase in milk production of 15% was obtained with the inclusion of *A. pintoi* in the pasture (Figure 4). The association of *Desmodium ovalifolium*, a legume with low palatability and digestibility, regardless of the period of evaluation, did not show any advantages over the use of grass alone (Van Heurck, 1990).

Legumes associated with grass enhance the level of protein in forage in the dry season and also the level of protein in grass in the rainy season (Gardemer, 1980; Bohnert *et al.*, 1986; Lascano and Thomas, 1989). However, the legumes generally contain greater concentrations of calcium, sulfur and phosphorus than the grass (Whiteman, 1980). For this reason, it is expected that the consumption of legumes by the animals at pastures increases their weight gains (Lascano *et al.*, 1989) and the production of milk (Stobbs, 1976) on tropical pastures.

5.3 Recycling of Nitrogen and Stability of Production

When grazing pastures are compared to systems of cultivation, we find that the greater proportion of the nutrients return to the soil-plant system through the feces of the animal and the residues of the plant. The equilibrium between the recycling, decomposition and mineralization of the organic material in the soil determines the gain or net loss of nitrogen available to the plant in the pasture (Hoglund, 1985). As pasture utilization increases, more nitrogen passes through the digestive system and feces of the animal. The passage of nitrogen in the feces of the animal signifies considerable losses of this element (up to 80%) as a result of volatilization, denitrification and leaching of nitrogen from soil where the urine falls (Ball and Ryden, 1985). However, when the rate of volatilization is low, more nitrogen is remobilized and returned in residues of the plant. If the residues of the plant represent a high C:N ratio, the nitrogen remain unmobilized and unavailable to the plants (Robbins *et al.*, 1989). When there is no nitrogen fixing legume present, the nitrogen must come from the soil reserves or from fertilizer inputs.

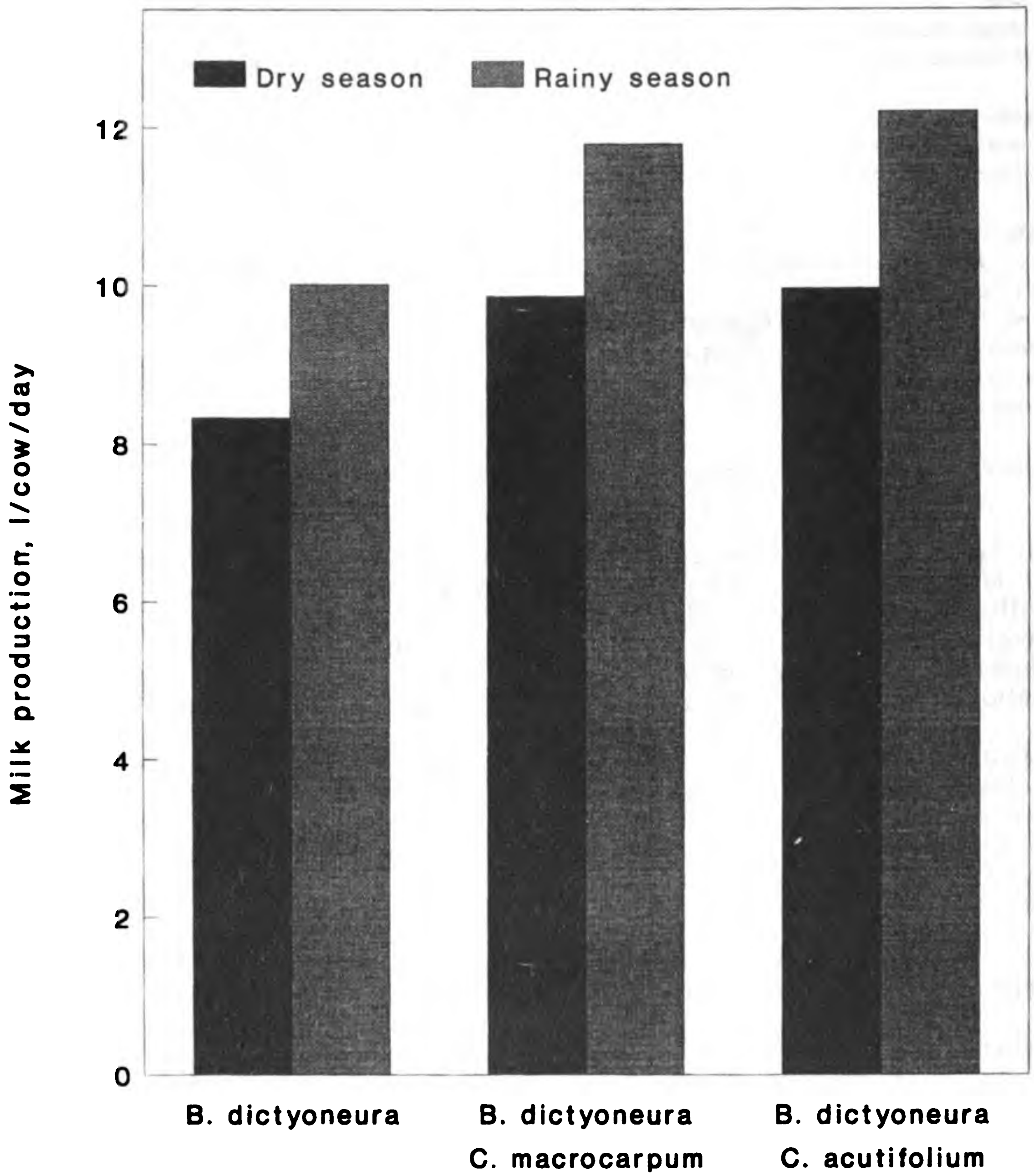


Fig. 3 Milk production from different pastures at Quilichao Experimental Station (CIAT, 1990).

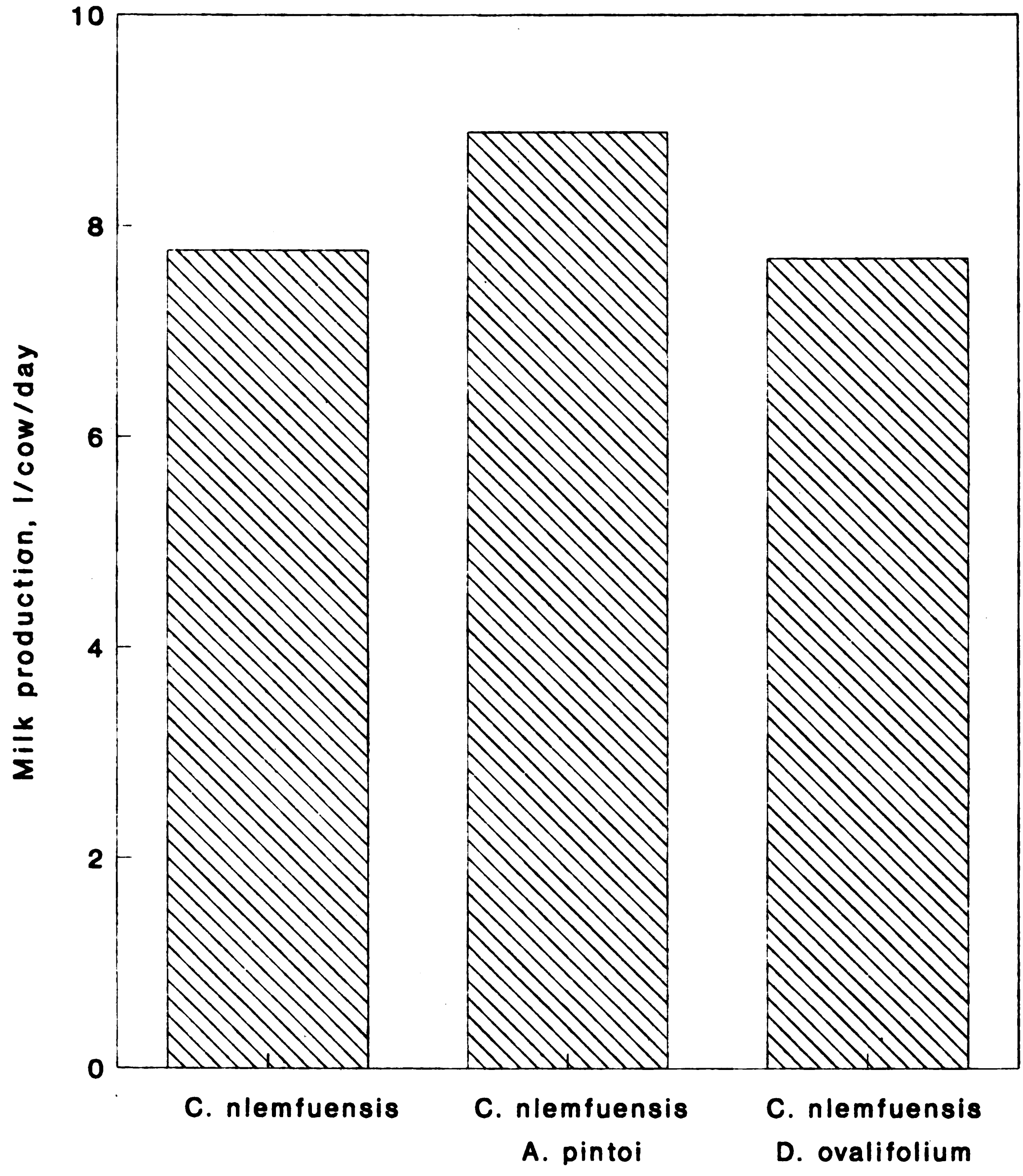


Fig. 4 Milk production from different pastures at Turrialba, Costa Rica (Van Heurck, 1990).

The contribution of the legume to the productivity and the long-term stability pastures has been documented in llanos of Colombia (Lascano *et al.*, 1989). The grass-legume pasture always produced greater weight gains than the grass monoculture in the dry seasons, depending on the severity of the dry season (Figure 5). Nevertheless, during the rainy season when water was not a limiting factor to growth of the plants, there was a tendency for high and stable production in the grass-legume pasture, contrasting with the tendency to decrease productivity at this time in a grass monoculture (Figure 5).

5.4 Improvement of Soil Fertility

The initial results of sowing a crop of dryland rice following different pastures or oxisol in Carimagua (Colombian llanos), demonstrated the potential of pastures to improve the fertility of soils for subsequent crops. More than 3 tons of rice per hectare were obtained from land after 10 years under legume-grass pasture, without there being significant responses in the nitrogen (Figure 6). Following a purely grass pasture, the yields of rice were more than 3 tons per hectare but only when 80 kg of nitrogen were applied per hectare. In contrast, the greatest yields of rice obtained following native grasses were only 2 tons/hectare.

There are other factors in addition to soil nitrogen which could explain the additional yield per hectare of rice when following the improved pastures. The deep and profuse root systems of well adapted plants (grass and legumes) have important effects in improving the structure of the soil, facilitating access by the roots of the rice to deeper sources of water and enhancing concentrations of nutrients in the upper layer of the soil as the result of more effective recycling. In addition, the effect of an inoculum of mycorrhiza at the start of the rainy season, is greater in the improved pastures than in the native grasses (Figure 7), and could have an important effect in the absorption of phosphorus for the rice plants. In a similar way, Pashanasi and Lavelle (1988) found that the biomass of microfauna (insects and earthworms) in the top 10 cm of ultisol under grass and legumes in Yurimaguas, Peru, was twice that found in primary forests, and almost 15 times the biomass of microfauna found under crops (Figure 8). It appears that nitrogen levels and biological activity of the soils under pastures of grass and N-fixing legumes are clearly higher than those found under pastures of grass alone on oxisols and ultisols of the tropics.

6. EVALUATION OF SUSTAINABILITY

Sustainability occurs at different levels from the national agroecosystem, watershed, down to the micro-level of the field or sub-component of the production system. Whatever measurement of sustainability is chosen, it will require measurements over time. These evaluations are going to be affected by changes in both the exogenous and endogenous factors and measurements at any one point may erroneously show sustainability or lack of it. The state of sustainable equilibrium (i.e. the system gaining or losing its productive potential), is very difficult to measure if insufficient efforts are made to eliminate background noise of the multiple confounding factors.

If we try to follow levels of sustainable equilibrium in a livestock system under pasture, the temptation is to evaluate everything at the level of the system (economy, labor....) and its components (animals, pastures, soils....) without knowing how to interpret the information. However, a realistic evaluation is going to depend on us measuring a few, efficient variables which determine the integral status of the environment soils/plant/animal.

Recognizing that we have to find a starting point, I will propose several variables which could be measured and which from my perspective would be good indicators of the state of sustainability of the environment at the level of soil/plant/animal as well as at the integrated level.

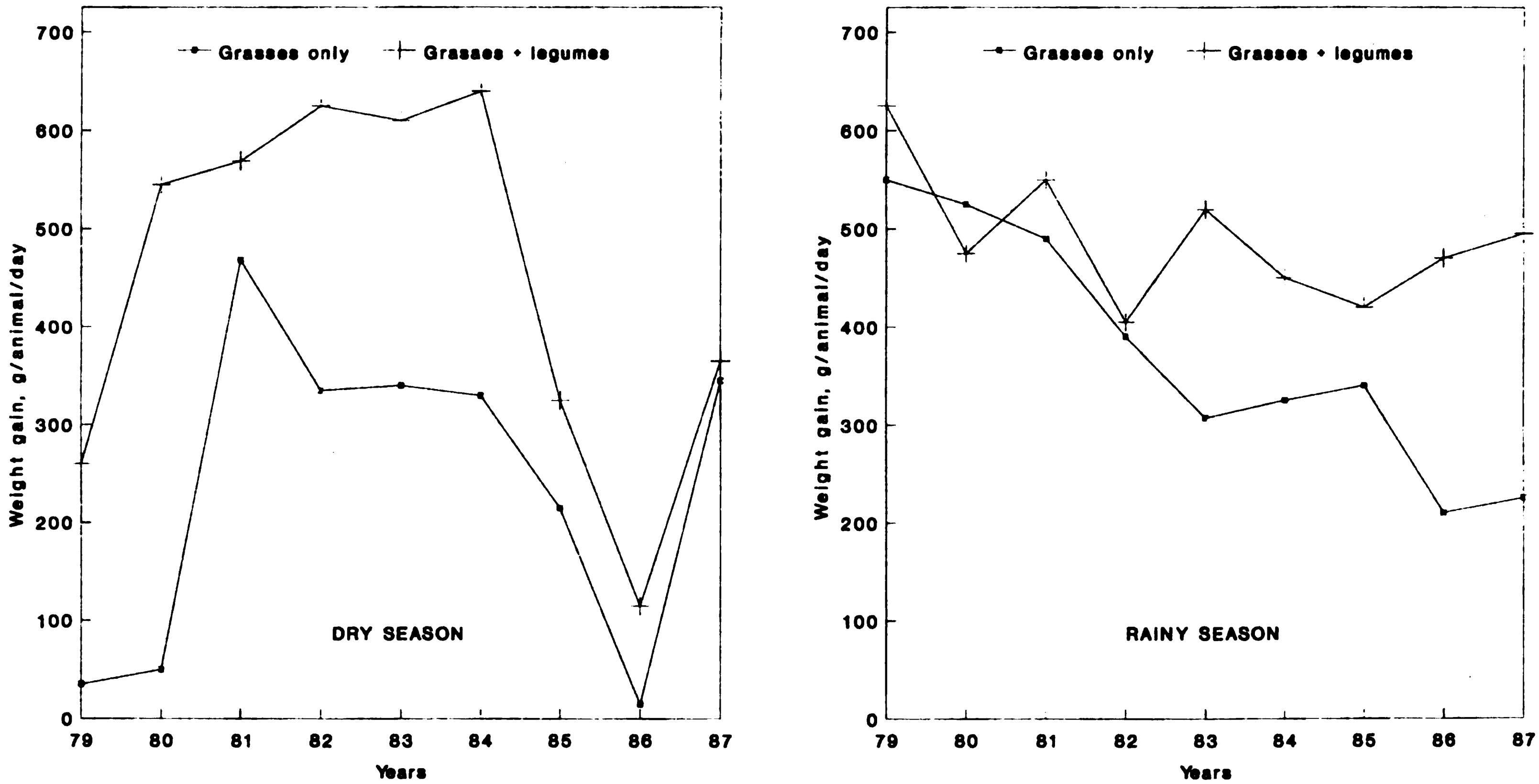


Fig. 5 Weight gain of steers on B. decumbens and B. decumbens + P. phaseoloides at Carimagua, Llanos de Colombia (Lascano and Estrada, 1989).

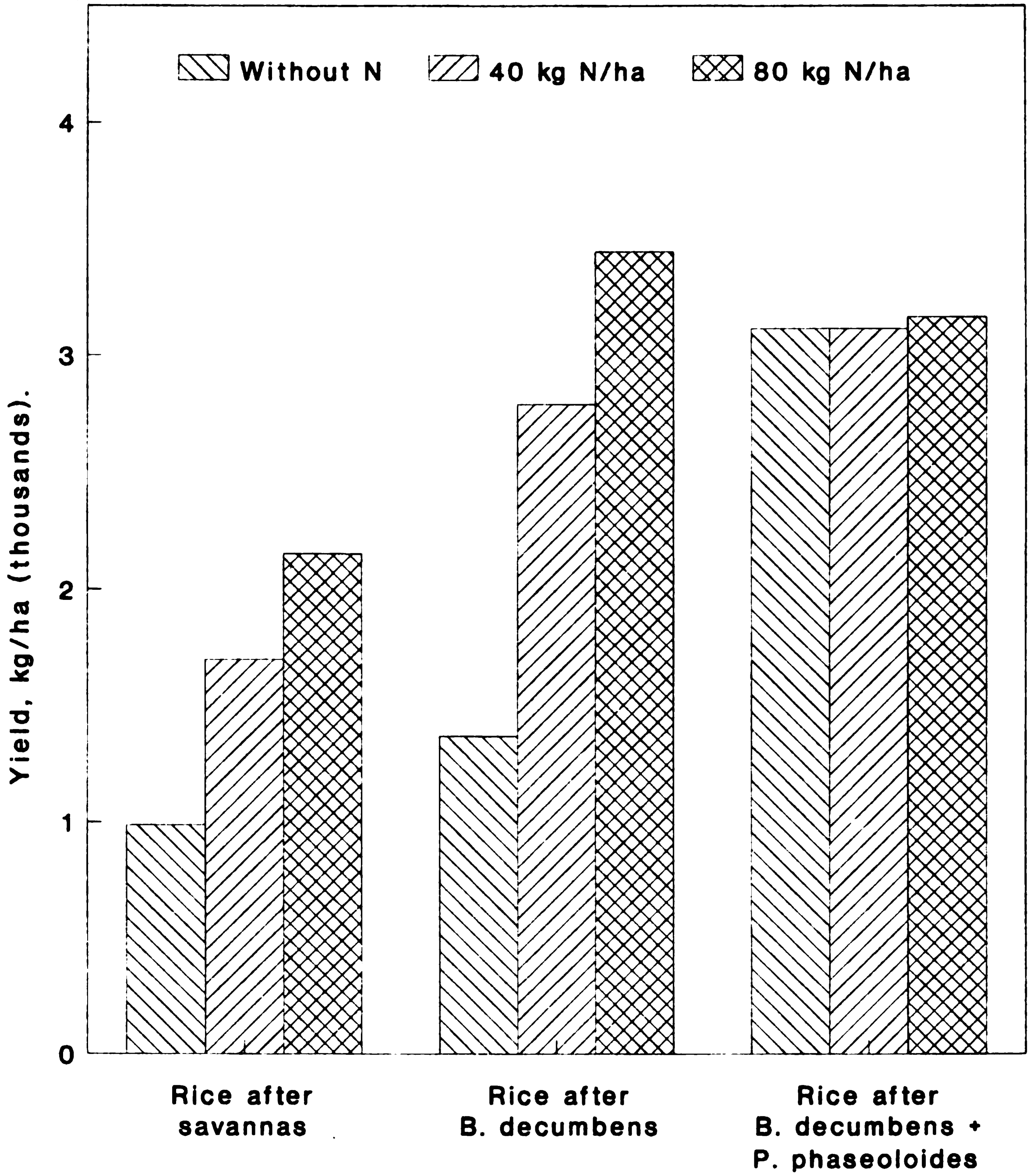


Fig. 6 Rice yield, after 10 years of improved pastures and savannas, in response to fertilization with 50 kg of P/ha and three levels of N (CIAT, 1990).

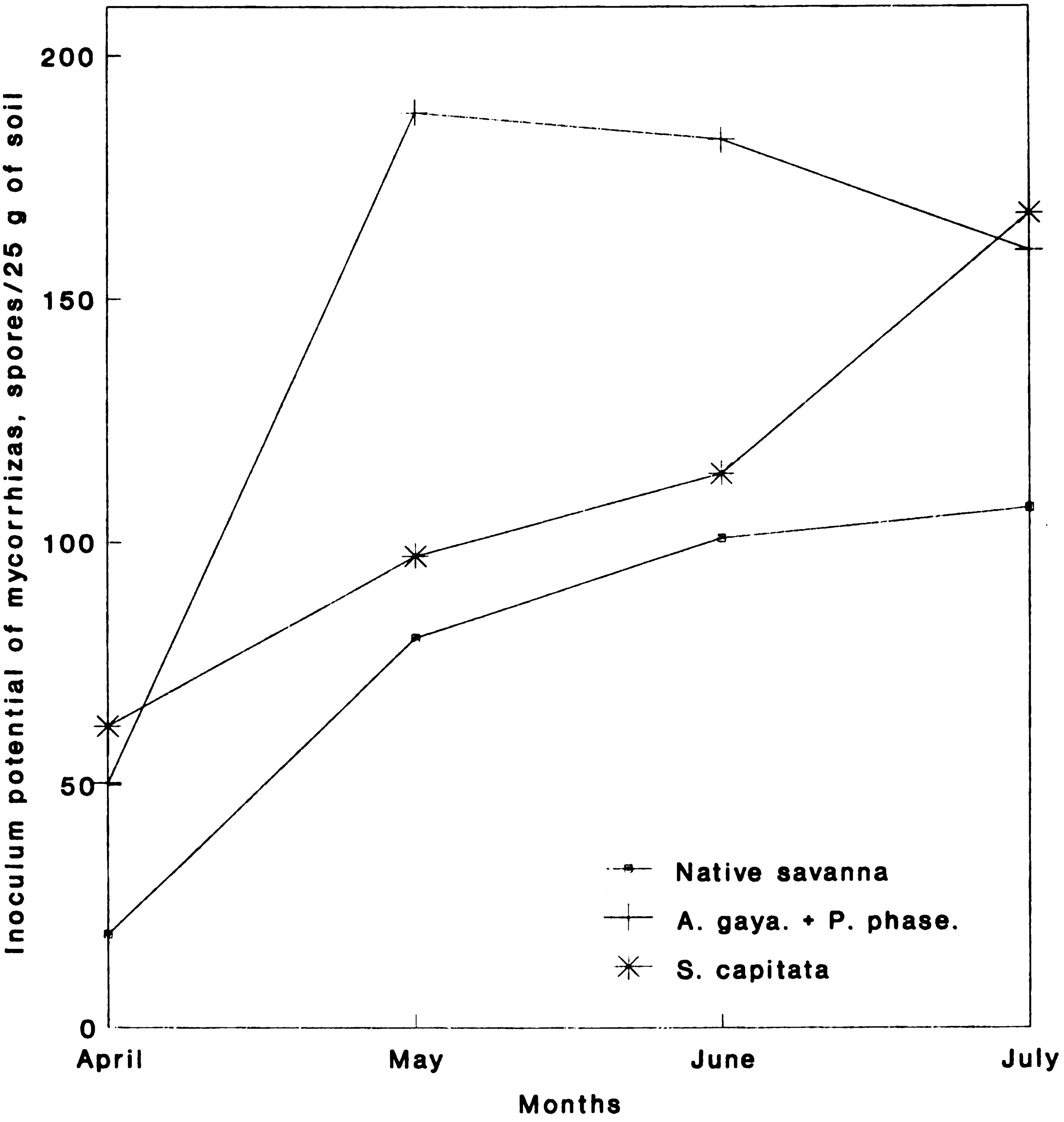


Fig. 7 Inoculum potential of mycorrhizas at the beginning of the rainy season in an oxisol at Carimaguas (CIAT, 1982).

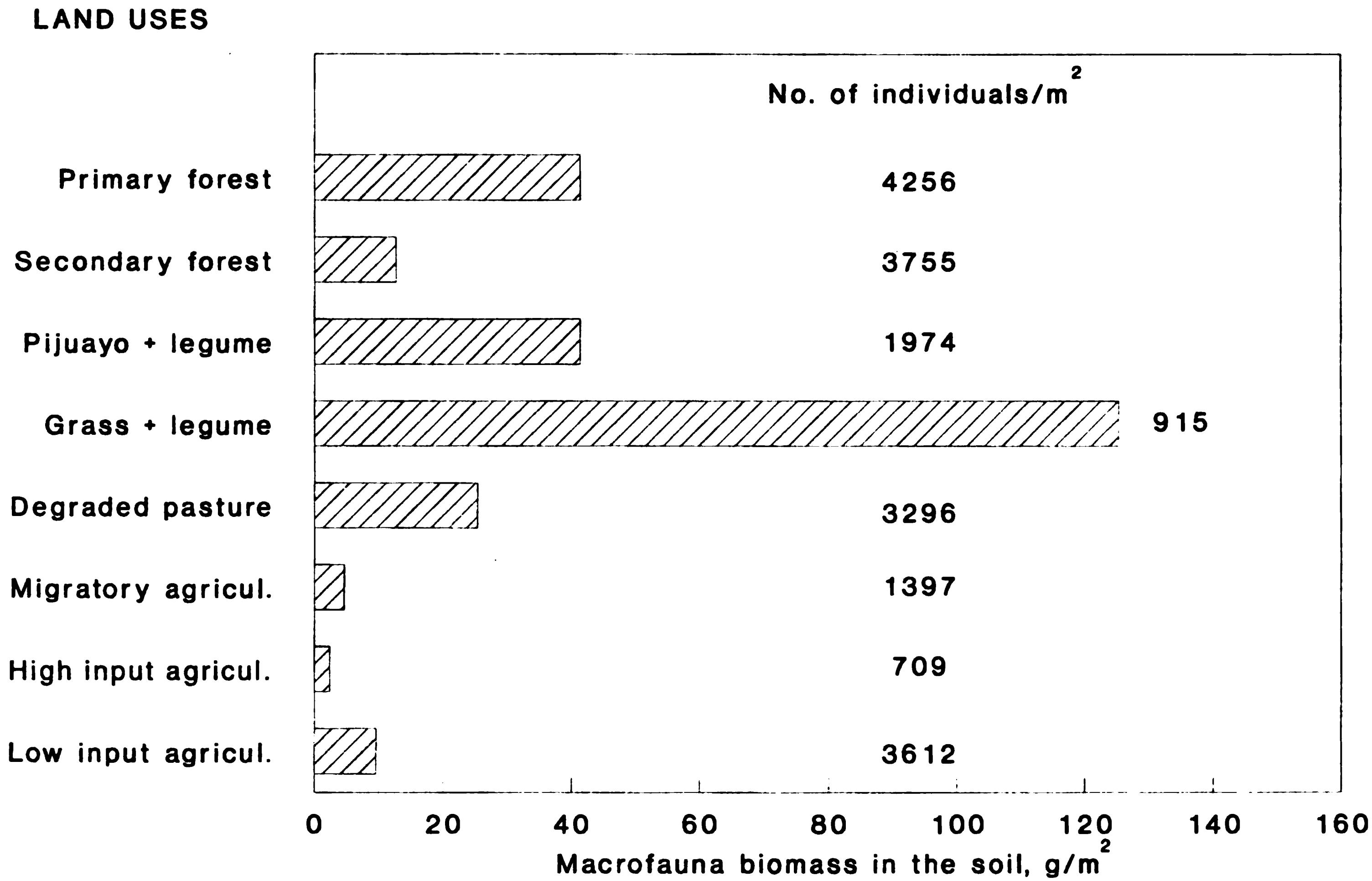


Fig. 8 Macrofauna biomass and number of individuals in the first 10 cm of soil under different land uses in Yarimaguas, Perú (Lavelle and Pashanasi, 1989).

6.1 Measurements at the Soil/Plant/Animal Level

Fluctuations in production throughout the year and between years are effected by complex climatic and environmental cycles which can easily mask whatever real differences in sustainable equilibrium exist between two points of measurement. The problem is, thus, to identify some measurements of animals and plants which synthesize the status of the environment, minimizing the noise of the seasonal and random climatic variation in order to express the status of the environment over the medium and long term.

6.1.1 Period of measurement.

It is necessary to find one or more periods of evaluation which will give greatest confidence and repetition (amount and frequency of precipitation in radiation) between measurements. These would be periods in which the productive potential of the system is expressed with no or minimum restrictions. The periods in the year when this occurs in the year are going to vary according to the climatic fluctuations in each site. What is sought is a short period of 20-40 days when measurements of the effect of the environment on plants and animals can be made without restrictions due to the availability of water solar radiation, nor biotic pressures by pests and diseases.

Defining these periods based on meteorological records of 10 or more years it is necessary to design a plan of measurement for the animal on the pasture and the soils. Measurement with animals in defining a period of one year of maximum uniformity between years we try to eliminate or decrease the variations due to climate. It's also necessary to eliminate the variability of the animals by including sufficient animals in the group. These in addition to being in good condition and having a uniform capability of responding to feeding. This can be achieved by using F1 cross animals from distant breeds (i.e. Zebu and European) in order to take advantage of the high-bred vigor and therefore minimize the differences in the response between animals of the same breed.

Selecting the period and the group of sentinel animals, we can annually make a measurement of the complex of soil, pasture and animal with minimal animal with minimal error although not entirely free of error.

Another important question is that of the sensitivity of the animals. Lactating cows are the most sensitive over short periods (20-40 days) of exposure of different pastures, the difference between the cows (genotype, physiologic status and number of lactation) is high and therefore demands that greater numbers of repetitions be included or the use of switch designs to eliminate the individual animal effect.

Growing steers between 12 and 24 months may provide good indicators of the state of productivity of the soil/pasture/animal complex when the period of exposure lasts more than 20 days.

6.1.3 Measurement with plants.

When selecting the period of maximum uniformity between years; for example during the start of the rainy season, once the initial 15 to 30 days of erratic rainfall have past and when there is still not an excess of rain. The level of cloud coverage permits a high radiation and the biotic pressure from pests and diseases is minimal. With plants, we are trying to detect the status of the soil fértility (physical, chemical and biologic) and its relationship with the plant. One possibility would be to complement the evaluation and the grazing excluding a number of plants of single condition cutting them at the soil level or at 5 cm and measuring the resprouting over 20-40 days during the selected time period. This measurement expresses principally ing over 20-40 days during the selected time period. This measurement expresses principally the state of reserves of the plant, the vigor and health of the root system in using the available soil nutrients and the conditions of the soil in terms of compaction and availability of nutrients as well as the microbial and microfauna activity.

Another indicator measurement of the contributions of the pasture components to its stability over time feed a number of live plants or the number of growth plants on species with indefinite growth. This is particularly important in mixed pastures.

6.1.4 Measurements of the soil. Just as with animals and plants, the physical and chemical condition of the soil is effected by the availability of water. Thus, in order to follow the balance of sustainability of the system it is only logic to complement the measurements of animals and plants with the measurements of the soil during the period of the year selected.

Recognizing the limitations in the methods of measurement for physical and chemical characteristics of the soil, it will be important to test:

- Compaction as the resistance to penetration, permeability, absorbativity or the description of the structure of the micro and macro conglomerates in the soil structure. The most simple and useful measurements could be the resistance to penetration (with the cone penetromator) and the absorbativity.

- The availability of nutrients through chemical analysis for levels of nitrogen, phosphorus, sodium, potassium, magnesium, aluminum, sulfur, micro elements and pH.

  It is important to use methods and extractants which best the indicate the absorbent capacity of plants adapting to the specific soil under study.

- The quantity of organic material and vegetation residues in the soil as well as its rate of decomposition and mineralization. This will give us information on the nutrient storage in the soil and the dynamics of recycling.

The traditional chemical analysis gives us a percentage of organic material which does not communicate anything. A new model of the dynamics of organic material in the soil is called the Century Model and has been developed by Parton, *et al.* (1987), for the soils of the American Midwest. This model is being adapted for the poor acid soils of the tropics and its use or in conjunction with other measurement techniques will be a key method for following the status of sustainability equilibrium of production systems.

6.2 At the Economic Level

Sustainability includes the satisfaction of the needs for economic growth in society. Thus, some economic measurement must be used as an indicator of sustainability.

The profitability of the production system over time could be a good variable for measuring integral sustainability. This includes in addition to the sustainability the soil/plant/animal level, within the framework the management of man of the political economy of the country.

A more complex option would be to measure and interpret in economic and physical terms (quantity) the inputs and products necessary to maintain the system in productive condition.

7. FINAL COMMENTS

Pastures and livestock in the tropics have been discredited by some environmentalists and some international bureaucrats, who reject the reality of their presence in the region. Instead of dividing opinions, efforts should be done to increase -with appropriate technologies and political frameworks- the advantages of livestock production to recycle nutrients, improve soil conditions, and generate income, contributing to the sustainability of agropastoral and agrosilvopastoral systems.

I wish to emphasize the fact that measurement of sustainability is not only complex but may be impossible in absolute terms. Nevertheless, I believe that with imagination and a little daring, we may reasonably monitor the state of sustainable equilibrium of the soil/plant/animal system which will eventually be inherited by future generations.

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RECYCLING OF NUTRIENTS IN TROPICAL PASTURES AND ACID SOILS

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1. INTRODUCTION

It is predicted that the population in tropical Americas will duplicate in the next twenty five years. This will result in a greater demand for basic products such as meat and milk, which can only be satisfied by increasing the production from the existing areas in use and from the addition of new areas. These factors augment the pressure on the natural resources, and accelerate the rate of degradation of areas with acid soils and low fertility which are common in the region.

An alternative for increasing the production without producing deterioration of the natural resources is the use of systems that minimize soil losses and make efficient use of the nutrients available. Such systems must be based on pastures which are efficient at recycling nutrients and at the same time conserve and /or improve soil fertility.

In this paper the components of recycling will be described, and the effect of some management factors on said components will be discussed. Emphasis will be placed on the cycling of nitrogen, phosphorous, and carbon. Finally, we will discuss the potential role of recycling on soil fertility and its effect on pasture rotations under annual crops.

2. COMPONENTS OF RECYCLING

Pastures are, in general, not particularly nutrient extractive systems compared with annual cropping systems. As shown by Spain and Salinas (1984), more than 85% of the nutrients consumed by the animal are returned to the pastures through the animal's excretion. On the other hand, a significant proportion of the nutrients adsorbed by the plants goes back into the soil through the decomposition of plant residues. These return mechanisms constitute the essential part of recycling of nutrients. Figure 1 shows the components of recycling and the processes that link them.

In the soil the nutrients are subject to changes in availability (immobilization and mineralization) or losses from the system (volatilization and leaching). In the plants the nutrients

4. NITROGEN RECYCLING

Nitrogen is an essential element to the productivity of the pastures. On pure gramineous pastures, nitrogen necessary for the growth of the plants comes from the soil, from fertilization, from nitrogen recycled via the plant and animal residues (principally urine) and from the mineralization of organic matter. Figure 2 shows an assimilation model of the recycling of nitrogen in a pasture of pure *B. decumbens*. The model indicates that in order to reach the utilization levels estimated, it would be necessary to mineralize the organic matter at a rate of 94.4 kg/N/ha annually. Over the long term the loss of organic matter from the pasture could be accelerated, or severely limit the productivity of the soils.

In mixed, pastures the nitrogen needs of the gramineae are in large part satisfied, given the ability of the legumes to fix atmospheric nitrogen. This nitrogen is recycled through the animals and the legume residues, and subsequently transferred to the gramineae. Figure 3 illustrates the effect of the inclusion of legumes in the previously shown model. The results indicate the cycle is balanced when legumes are introduced. The contribution of the legume to the system varies, of course, according to the species and the management of the animals. It is estimated that the proportion of legume needed to balance the cycle must be 15-30% of the total biomass (CIAT 1990).

According to the model mentioned above, the plant residues constitute the most important mechanism in recycling of nitrogen. The quantity of nitrogen that is recycled through plants depends on the quantity of residues produced in the pasture and its speed of decomposition (CIAT 1989). The quantity of residues, as mentioned previously is a function of animal management. In other words, the greater the levels of utilization by animals, the lesser the levels of nitrogen recycled through the residues. The liberation of nitrogen from the residues depends on their "quality". In general legume residues decompose more rapidly than those of gramineae. Nevertheless, there are species differences (CIAT 1991). The initial results of a recycling experiment in Carimagua show that there was a greater production of dry matter in mixed gramineae pastures than in pure gramineae. This coincides with a greater quantity and quality of residues found in mixed pastures (CIAT 1991). The efficiency of recycling of nitrogen through animal excretion is variable and, in general, the literature indicates that it is inefficient given its lack of uniform dispersion and susceptibility to leaching as previously mentioned.

5. RECYCLING OF PHOSPHOROUS

Although it has been shown that phosphorus is the most limiting element in establishing forage species in acid soils, very little is known about requirements for phosphorus during the productive phase of the pasture, and its efficiency of recycling. Figure 4 shows the principal components of the system in a simplified form.

Phosphorous, as opposed to nitrogen, is an element which is relatively immobile. This reduces the possibilities of leaching losses. Nevertheless, phosphorous is extremely dynamic in terms of its availability. The most available form, but the most scarce in acid soils, is inorganic phosphorous. This form is found in low amounts and generally in equilibrium with less available inorganic forms.

are adsorbed, translocated, and remobilized internally or returned to the soil as a function of the rate of decomposition of plant residues (leaves, stems, and roots). Through grazing, animals extract important quantities of nutrients, which are kept temporarily, but which are then returned to the soil through urine and faeces.

3. MANAGEMENT FACTORS AFFECTING NUTRIENT RECYCLING

Even though nutrient recycling occurs naturally in pasture systems, its efficiency depends to a large extent on various management factors: species selection, effect of the type of soil on the plants, and grazing and fertilization management.

For an efficient recycling of nutrients it is basic that plants are adapted to acid soils with low fertility levels. After several years of introduction and evaluation of forage species, CIAT has identified some gramineae and legumes tolerant to soil acidity, with a high potential for production of aerial biomass, and whose nutritional requirements are very low (CIAT, 1985). A significant part of the carbon fixed through photosynthesis is employed in root production by these species (CIAT, 1990). In a pasture of *B. decumbens* + *A. pintoi* under grazing, root biomass levels larger than aerial biomass levels were registered, under field conditions (CIAT, 1991). These characteristics give plants more capacity to adsorbe and store nutriments in the system.

However, the efficiency of recycling is determined, not only by the quantity of roots but by their distribution in the soil as well. Observations in a pasture of *Brachiaria decumbens* + *Arachis pintoi* planted in a loamy clayish Oxisol soil in Carimagua, indicated that most of the roots were concentrated in the first 20 cm of the soil, and a small proportion was found deeper than 1 m (CIAT, 1991). Possibly, this strategy permits the plant to absorb the nutrients from the decomposition of plant and animal residues, and also to utilize nutriments located at deeper levels.

The production of aerial and root biomass in gramineae and legume species is also affected by the type and fertility of the soil. In sandy soils, forage species (specially gramineae) produce more roots than in clayish soils (CIAT, 1090). This adaptation mechanism seems a response to the smaller availability of water and nutrients in sandy soils. The same behavior has been observed in the field (CIAT, 1991).

Grazing affects the aerial and root biomass in the pasture, as well as the velocity and efficiency of nutrient cycling in the system. Defoliation can stimulate, or affect negatively, plant growth and nutriment absorption, and can also modify the proportion of nutriments returned through plant or animal residues.

Nevertheless, the nutrients returned by the animals are concentrated in small areas and distributed irregularly on the pasture; these factors increase the risk of losses by volatilization and leaching, thus reducing the efficiency of recycling. Literature from temperate zones reports that more than 60% of the nitrogen returned to the soil through the excretion of animals is lost from the system (CIAT, 1990). Similar conclusions have been obtained in studies of recycling of potassium (Ayarza 1988).

The grazing system and the stocking rates can also influence the quantity and distribution of the nutrients returned. Rotational systems improve the distribution of the excretion (CIAT 1990). High stocking rates increase the proportion and availability of the nutrients recycled on the pasture.

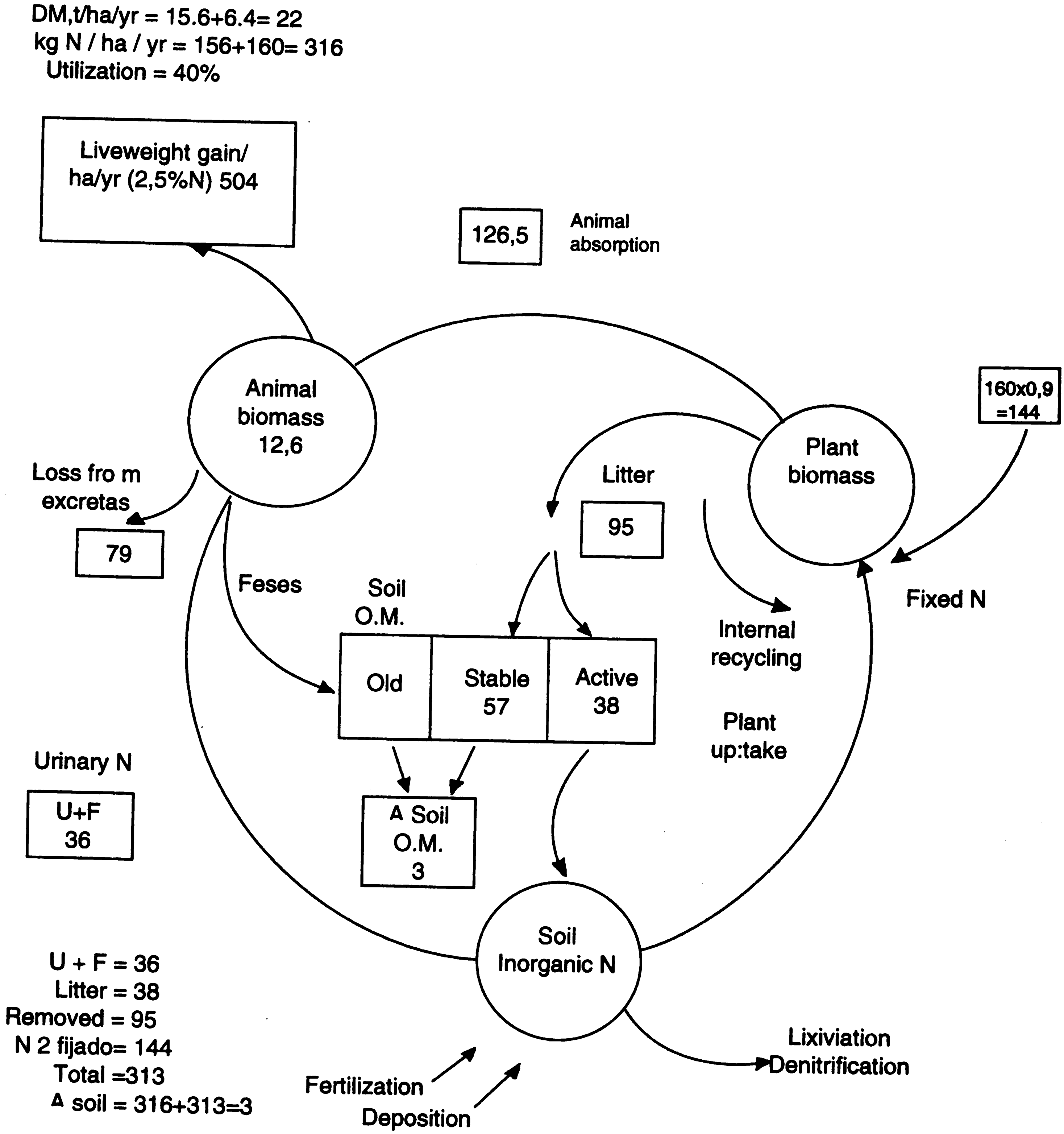

Fig. 3 Nitrogen cycle in a grass-legume association producing 22 t of dry matter/ ha / yr
Source: CIAT, 1989

The other form in which phosphorous is commonly found in the soil is as organic phosphorous. In many tropical soils, this fraction constitutes more than 40% of the total phosphorus (CIAT 1989). Nevertheless, little is known about the dynamics and the availability of this fraction. Newer chemical methods of fractionation suggest that there are different degrees of availability of organic phosphorus associated with its relationship with nitrogen and carbon (Parton, Personal Communication).

Plants accumulate relatively small amounts of phosphorus in comparison with the amounts present in the soil. However, they can modify the proportion of organic phosphorus in the soil. In accordance with analysis results for the first 10 cm of soil under a pasture of *A. gayanus* + *C. acutifolium*, the levels of organic phosphorus were twice those found under a native grass. Part of this could be the result of conversion of phosphorus absorbed by the plant in organic form, thus avoiding its fixation as colloids by the soil. On the other hand, other studies have shown that some legumes, such as *C. acutifolium*, produce larger quantities of phosphatases than gramineae (CIAT 1990). These are enzymes capable of solubilizing the organic phosphorus in the soil and the residues. Work is now in progress to determine the effectiveness of this mechanism in the utilization of these forms of phosphorus.

6. RECYCLING OF CARBON

Carbon is an essential element in the formation of the organic compounds in plants, and constitutes the source of energy for all the vital processes and the growth of the plant. The carbon adsorbed by the plant is recycled through decomposition of the air and soil residues, and by the excretion of exudates by rootlets. As a product of decomposition of residues, microbial activity is stimulated as is production of organic matter.

Until recently, we had a rather limited vision of the relationship between the residues present and the system, and the type of organic matter formed. The newer methods and the use of functional models have allowed us to determine that there are different fractions of carbon, whose release rate varies with the relationship of lignins and nitrogen in the residues (Figure 5). This has implications which are important in the manipulation of the type of organic matter as a function of the type of residues present.

In mixed pastures, legumes supply residues of better quality due to their higher content of nitrogen as compared with that of gramineae. This can influence the type of organic matter formed in their presence. Using techniques to discriminate between carbon isotopes, it has been found that more than 20% of the organic matter in the top two centimeters of soil comes from that supplied by the legume (CIAT, 1991). This type of organic matter may have different characteristics from that formed in pure pastures, which influences the rate of decomposition or the organic matter and release of the nutrients.

7. ROLE OF RECYCLING IN ROTATION OF PASTURES WITH CROPS

The positive aspects of nutrient recycling in pastures can also have benefits for the crops in rotational systems. The type of organic matter formed in pastures based on legumes, and the amounts of nitrogen liberated from the plant and animal residues, can increase the availability of nutrients from crops as observed in an experiment sowing dryland rice on a pasture of *B.*

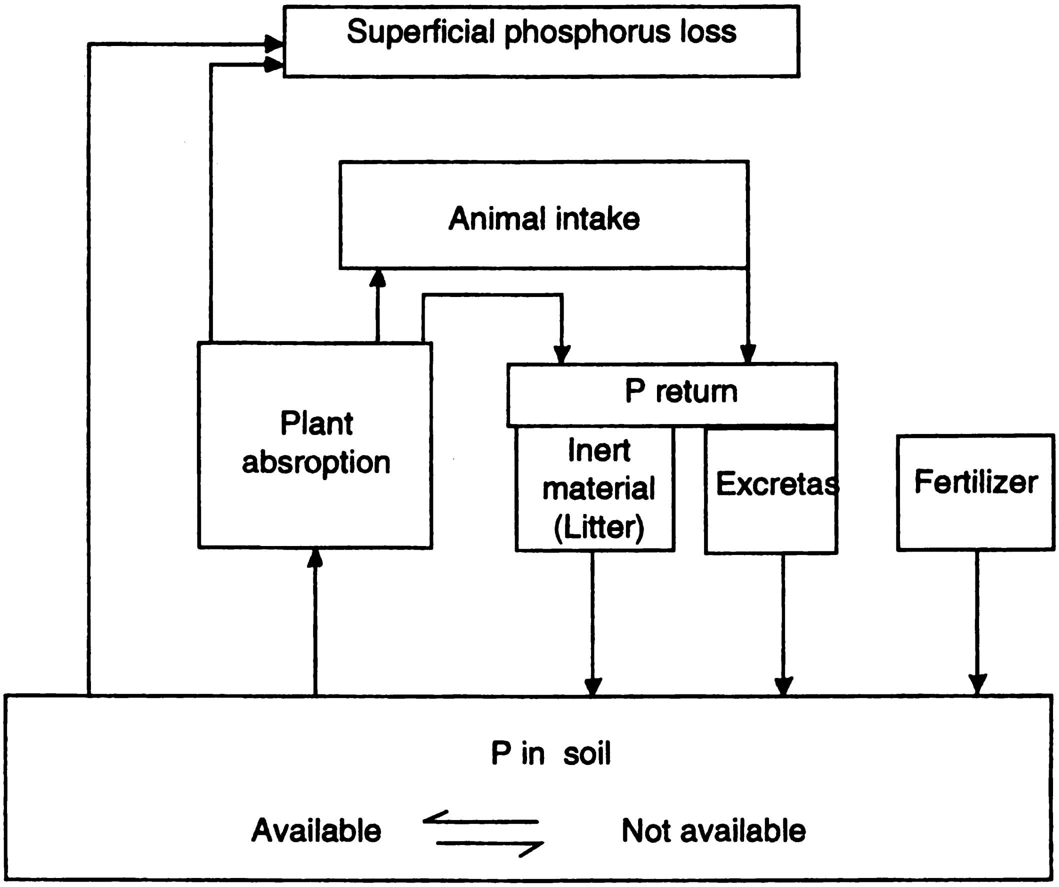

Fig. 4 Phosphokus cycle components in fertilized grass paddocks

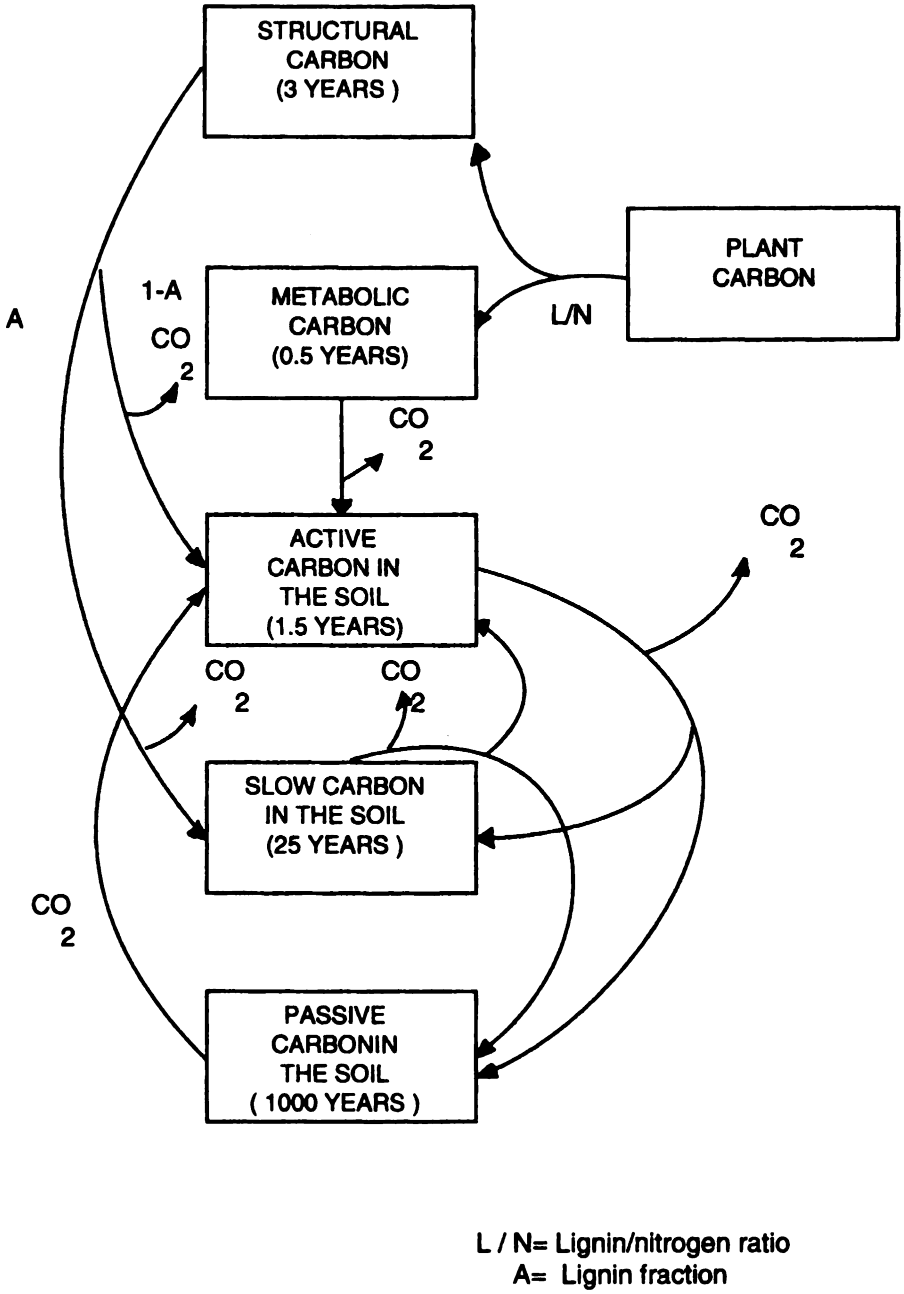

Fig. 5 Functional resivoirs of carbon in the CENTURY Model

Source: Porton et al, 1980

decumbens + *P. phaseoloides*. The yields of crops were double in comparison with those obtained in the use of a native pasture (CIAT, 1989). Also, it was observed that the physical properties of the soils improved with pastures systems (CIAT, 1991). This improves infiltration and reduces the susceptibility to compaction.

8. GENERAL CONCLUSIONS

Recycling of nutrients is a natural component in pasture systems. Nevertheless, the efficiency depends to a large degree on the management factors (species selection, fertilization, soil type, and animal management). An adequate management must permit efficient utilization of the available nutrients for the plants and favor recirculation in the soil-plant-animal system. However, it is necessary to understand with greater precision the interrelationships between the different components of recycling, and to define the most relevant parameters for the evaluation of the stage of recycling in the pasture. In addition, it is necessary to develop simple methodologies to measure the efficiency under the producers conditions.

The information presented here suggests the use of adapted species. It is possible to incorporate sufficient nitrogen and carbon to guarantee that the plant's requirements are met and to promote biological activity and the formation of organic matter.

The use of new methodologies is making it possible to determine with greater precision the contribution which legumes make to recycling of nitrogen and the quality of the organic matter. Advances are also being made in determination of the utilization of the different forms of organic phosphorus by plants.

The preliminary results of rotation of pastures and crops open a new frontier for research in integrated systems for sustainable production in conditions of low fertility soils. It is necessary to do more research to determine the management factors which optimize the synergistic effect between the pastures and crops and the possibilities for application under different conditions.

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CONSERVING BIODIVERSITY: INTERFACES WITH ANIMAL PRODUCTION

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"How the human species will treat life on earth, so as to shape this greatest of legacies, good or bad, for all time to come, will be settled during the next 10 years."

E.O. Wilson, 1988

1. INTRODUCTION

Central America, situated between Mexico and South America, comprises seven countries which cover 541,190 square kilometers. This region, which stretches 1440 km North to South and 480 km at its widest point, contains about 25 million people. The cultures of Central America are very diverse and of European, Indian, and African extraction, but culture and race mixtures vary from country to country. Although most countries are strongly influenced by Spanish culture and tradition, Guatemala and Panama have large indigenous populations; Belize has a strong English influence on a population predominantely of African descent. The majority of the human population lives in the temperate volcanic, mountainous areas although tropical lowlands make up most of the region.

The biota of the region is also extremely diverse because of its tropical setting, its land-bridge position uniting two continents, and great varieties of slopes, climates, soil formation, and altitudes. Despite their cultural, geographical, biological, and socioeconomical heterogeneity, Central American countries share a dynamic interrelationship between natural resources, population, and economic development. A heavy dependency on renewable natural resources utilization is found in all Central American countries. Unfortunately much of this natural resource base has deteriorated.

Less than 40% of Central America's original forest remains, and over two-thirds of the loss has occurred since 1950. In Central America, over 50% of the total surface area is devoted to cattle pasture (Vaughan, 1990). Unfortunately, the beef cattle industry in Central America uses land very inefficiently compared to other agricultural uses. In 1980, for example, cattle production contributed only about 13% of the export receipts for four countries compared to coffee production (US$ 134,600,000 *vs.* US$ 1,081,500,000), although it occupied 92,480 hectares compared to 5,450 hectares for coffee (between 17-18 times).

This paper will explore the biodiversity of Central America, the effect of cattle ranching on this biodiversity, and suggest ways to conserve biodiversity both in natural areas and cattle ranches.

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2. BIODIVERSITY

2.1 What is Biodiversity?

Biological diversity or biodiversity refers to the variability and variety of all plants, animals, microorganisms, and ecosystems on earth (McNeely *et al.*, 1990; Vaughan, 1989). It is the number and frequency of nature's variety at three levels: genetic diversity, species diversity, and ecosystem diversity. Genetic diversity is the total genetic information found in the genes of microorganisms, plants, and animals. Species diversity concerns the variety of the estimated 5 to 50 million living organisms on earth, recognizing that only 1.4 million have been classified (Wilson, 1988). Ecosystem diversity relates to those types of habitats, biotic communities, and ecological processes on this planet. It also refers to the tremendous ecosystem diversity in terms of habitat differences and variety of ecological processes. Ecological processes might include biogeochemical recycling, maintenance of soil fertility and water quality, and climatic regulation. Reducing biological diversity may or may not affect biological productivity, community stability or ecological processes. We suspect as much, but no present direct and obvious links exist between maintaining essential ecosystem processes and biodiversity (McNeely *et al.* 1990). Biodiversity is not evenly distributed in geographical space and some areas are much richer in diversity than others. Central America is considered a very rich biodiversity region.

2.2 Can we Classify Central American Biodiversity on a Macro Level?

Although hundreds of distinct vegetation types may exist in Central America, at least 20 distinct bioclimatic or life zones have been identified in the Region, with over 55 vegetation types for Costa Rica alone (Gomez, L.D., personal communication). For the sake of simplicity, these are summarized into five vegetation types (Vaughan, 1991).

The Pacific slope in Southern Costa Rica and Panama, and the Caribbean slope of Central America are considered lowland tropical rain forests (37% of total land surface) (Figure 1). Tropical dry forest is found on the Pacific slope North from Northwest Costa Rica (19% of total land surface). In central Nicaragua, Honduras, and parts of Guatemala, coniferous forests, dominated by Caribbean pine (*Pinus caribaea*) and Central American cedar *Cupressus lusitanica*) are present (20% of total land surface). Non-coniferous mountainous areas, which range from 500 to 4,000 m, have been classified as montane forest (19% of total) and have oak (*Quercus* spp.) and avocado (*Lauraceae*) species below 3,000 m. The highest mountaintops, above 3,000 m, contain subalpine paramo vegetation, but are classified as montane forest, Finally, mangrove swamps are found at sea level on both coasts (5% of total) and consist of very few, saline water tolerant species.

These vegetation types support an extremely high plant species diversity, with more than 8,000 vascular plant species and about 350 orchid species are endemic in Costa Rica alone (Vaughan and Solis, 1988). Central America's wildlife is equally diverse. Costa Rica, the only country adequately inventoried, has 1,565 vertebrate species (excluding fish), which include 376 species of reptiles and amphibians, 868 species of birds, and 216 species of mammals, including 103 bat species (Janzen, 1983). In addition, over 10,000 species of invertebrates have been described in Costa Rica. This compares to 1,443 species of vascular plants, 134 species of mammals, and 398 species of birds found in Europe.

If one compares the number of certain selected groups of organisms from megabiodiverse countries (Mittermeier, 1988), one can observe that Costa Rica is over 20 times more diverse per square kilometer than Mexico, one of the most megabiodiverse countries (Tables 1 and 2). Most Central American countries have a similar high biodiversity as Costa Rica.

Table 1. Absolute number of organisms known per country

Country	Birds	Mammals	Amphibians	Reptiles	Butterflies	Plant sp.
Mexico	961	439	284	717	52,000	25,000
Brazil	1,622	405	516	467	74,000	50,000
Australia	200	320	150	616		23,000
Costa Rica	848	205	162	216	10,000	12,000

Source: L.D. Gomez (Personal communication).

Table 2. Number of organisms per square kilometer per country

Country	Birds	Mammals	Amphibians	Reptiles	Butterflies	Plant sp.
Mexico	.49	.22	.14	.36	26.36	12.64
Brazil	.19	.05	.06	.05	8.70	5.88
Australia	.03	.04	.02	.05	2.99	
Costa Rica	16.56	4.02	3.18	4.23	195.70	234.83

Source: L.D. Gomez (Personal communication).

2.3 What is the Value of Biodiversity?

Among the values assigned to biodiversity are the economical, ethical, cultural, aesthetic, and social (McNeely *et al.*, 1990). Biodiversity conservation can be justified from many different points of view, such as: a) the recognition that man is part of nature; b) all species have an inherent right to exist; c) human culture must be based on a respect for nature; and d) all generations have a social responsibility to conserve nature for the welfare of future generations.

As examples of some of the values recognized in biological diversity, we can cite the 119 pure chemical substances extracted from higher plants and used in medicine throughout the world (Farnsworth *et al.*, 1985). These 119 substances are extracted from less than 90 plants, but there are an estimated 250,000 plants on earth. What is the potential for more medically important drugs derived from natural compounds in nature? Vincristine and vinblastine are alkaloids derived from a Madagascarian plant. They are used to treat childhood leukemia and Hodgkin's disease. In only one year of marketing these drugs, the Lilly Laboratories sold about US$ 100 million, of which 88% was profit for the company (Farnsworth, 1988). Another example of the economic value of a diverse gene pool, is the finding of *Zea diploperennis*, a primitive relative of the cultivated corn, in the Sierra de Manantlan, Mexico. This perennial species is resistant to 7 known viruses that attack the domesticated corn (*Zea mays*), and can be hybridized to its more susceptible relative (Iltis, 1983). The 1986 corn crop was evaluated at more than US$ 50 billion, worldwide.

Development projects which benefit local farmers and communities by conserving the biodiversity of a region might include: a) sustainable development of wild animal and plant products; b) marketing medicines, arts, crafts, food and other products from native wild plants or animals; c) strengthening or establishing management projects which ensure sustainable production and habitat maintenance; d) domesticating wild resource species to increase their sustainable yield; and e) utilizing nature tourism development where part of the revenue will go to the land owner or wildland neighbor in a manner compatible with long-term conservation.

However, choices and compromises have to be made when there are scarce resources. Unfortunately, until economic and social implications for biodiversity conservation are clear, human beings and governments will continue to degrade biodiversity. Local inhabitants of a region are aware of the species which surround them, and need to develop economically viable alternatives which enable them to preserve species that do not directly compete with them.

In general, approaches that combine economic development and biodiversity conservation have been neglected. Most projects pay little attention to their sustainability. For instance, few wildlife, silvicultural and aquacultural projects use native species, preferring instead exotic species whose ecology is understood and which are available in large numbers. Also, there is very little information on biodiversity in most countries. As stated earlier, only 1.4 million species have been described to date, and there may be up to 50 million (Wilson, 1988). Thus no information exists on the vast majority of species. However, there is no doubt that extinction is proceeding faster than 150 years ago, meaning that we will lose many species without even identifying them.

2.4 How do we Preserve Biodiversity?

Biodiversity reserves of varying sizes must be established and monitored. This requires motivating governmental officials so they declare conservation of large ecosystem reserves in the best interest. However various sized biodiverse areas exist in private hands and their owners must be convinced of their aesthetic and economic values.

3. CATTLE RAISING, PASTURE OPENING AND RESULTANT LAND UTILIZATION

In the next sections, we will discuss how cattle pasture can affect the biodiversity in a region and in the final section, alternatives and management practices for combining biodiversity and cattle pastures.

3.1 Inefficiency of Land Utilization for Cattle Raising in Central America

Is a discussion of cattle raising relevant in a paper on biological diversity? As we shall see, the declining cattle export market, combined with the low efficiency levels of cattle production per land unit have an important impact on economic tendencies and especially land use throughout Central America. In particular, presently there should be less deforestation due to a lowered demand for cattle (Lehmann, 1991) and a more efficient utilization of active cattle pastures, resulting in better opportunities for diversified approaches to farm management, including biodiversity conservation and restoration.

Beef cattle raising dominates the commercial livestock industry in Central America. Other ruminants, such as goats and sheep, are important only for local households. Therefore, we will focus primarily on the beef cattle industry and how it has become a major economical and land use force in Central America in the last 30 years.

During the 1960s and 1970s, beef production grew very rapidly in Central America, from an annual average production of 153,000 metric tons of beef, in the early 1960s, to 287,000 metric tons in the early 1970s. Percentage of total production exported increased from 22%, in the 1960s, to over 40% in the 1970s. Between 1960 and 1970, most of the increase in beef production was caused by the expanding United States meat market, because exports tripled while production doubled.

A greater proportion of total investment capital for the agricultural sector expansion in Central America has gone into the livestock industry since 1960 (Muller, 1991). Fifty percent of all agricultural credit given to Costa Rica in the early 1970s, as low interest loans from international development institutions (Agency for International Development and World Bank), and the national banking system was used to support the export livestock industry in medium and large cattle farms (Leonard, 1987). These farms are usually between 100 and several thousand hectares in size, with between 30 and 10,000 head of cattle. A second production system is found in small farms that raise livestock, including cattle, for subsistence as a sideline to crops. This system is the source of most of the beef consumed locally in Central America.

By 1980, the region was producing over 350,000 metric tons of beef yearly, but the relative percentage exported to the United States approached the 1960 levels. As the external market for beef cattle began to generate less income, and was replaced by local demand, a greater part of the economic rationale for cattle and pasture production was lost. Other agricultural uses would not only generate more employment, but had greater export value and/or produced greater quantities of food.

The rule in Central America is extensive utilization of pasture land with native species for cattle production, because cultivated grasses require more effort to plant and supplements (forage legumes, grains, and protein concentrates) are expensive and non traditional. The nutritive value of cultivated grasses (crude protein and digestibility) is much higher than that of native grasses. For these reasons, the carrying capacity of Central American pastures for livestock can vary greatly, but is quite low (Leonard, 1987). Several important economic, land utilization, and biodiversity related results are evident as a result of the inadequate protein supplement offered and the utilization of native grasses in Central America.

Stocking rates were very low in the 1980s, especially in newly created pastures from forested areas. But they were higher in pastures several decades old along the Pacific coast. Low stocking rates and poor nutrition result in an average 3.5 years necessary to bring cattle to slaughter, compared to 1.5-2.0 years in the United States. Despite rapid expansion and economic contributions made to national income in the region, the Central American cattle industry is very inefficient, producing a low return rate on investment. Belize had an annual yield on investments below the inflation level in the early 1980s.

By applying knowledge to existing pasture and animal resources, the production of beef cattle on Latin American tropical grasslands could be increased four or five times and the marketable meat increased tenfold (Leonard, 1987). Small scale Central American cattle producers are actually more efficient than the large cattle ranchers of the region. El Salvador has a significantly higher stocking rate per hectare than other countries of the region, because land and population pressures dictate that the cattle are more integrated as a complementary part of the rural subsistence sector.

How could one species come to dominate the landscape where before there were thousands? Of approximately 510,000 square kilometers of land in Central America, more than 200,000 square kilometers or about 40% were in forest or woodland (Muller, 1991). About 13 percent, or less than 7,000 square kilometers, were devoted to cultivation. But more than 110,000 square kilometers, or 22% of Central America's land was in permanent pasture. This has important economic, social, and ecological implications.

Costa Rica, Nicaragua, and Honduras have almost 30% of the land in permanent pasture, similar to forest and woodland which dominate the land use category. This is an underestimate because to qualify, land must have been in pasture use for a minimum five years, and much land is put into pasture immediately after clearing. For example, in 1973, the Costa Rican Agricultural Census found that 84% of the country's farmland was used for cattle pasture. The Census also showed that of the previously forested lands cleared for farming between 1950 and 1973, more than 70% had ended up as exclusively for pasture by 1973. Thus between 1960 and the early 1980s, land devoted to agriculture in Central America has expanded quickly, and forest cover has shrunk. The difference is that while the rest of Latin America is progressing towards intensive use of existing lands to achieve increased agricultural production, Central America's agricultural growth has been achieved mainly through exploiting land for pasture with limited cultivation.

In Central America, tremendous differences exist between agricultural uses in intensity of land use. The export receipts per square kilometer of land for major agricultural commodities in Guatemala, Honduras, Nicaragua, and Costa Rica show how little the beef cattle industry contributes to export receipts in relation to the huge amounts of land devoted to pasture in these countries (Table 3). For example, while coffee contributed between US$ 1,500-3,100 per square kilometer in Central America in 1980, the beef cattle industry contributed between about $18-47 per square kilometer of pasture.

Table 3. Export receipts per km^2 of land devoted to agricultural commodities

Country/ commodity	Export receipts, millions of US$	Area utilized, km^2	Export receipts, US$/km^2
Guatemala			
- Coffee	433.0	2,480	1,745.97
- Sugar	53.3	740	722.97
- Cotton	192.4	1,220	1,577.05
- Beef	41.1	8,700	47.24
- Bananas	48.0	NA	NA
Honduras			
- Coffee	196.9	1,300	1,514.62
- Sugar	NA	750	NA
- Cotton	NA	130	NA
- Beef	60.8	34,000	17.88
- Bananas	199.9	NA	NA
Nicaragua			
- Coffee	199.6	850	2,348.24
- Sugar	19.6	410	478.04
- Cotton	148.0	1,740	850.57
- Beef	67.7	34,200	19.80
Costa Rica			
- Coffee	252.0	810	3,111.11
- Bananas	169.0	280	6,035.71
- Beef	65.0	15,580	41.72
- Sugar	37.0	480	770.83

Source: Leonard (1987).

The comparison may not be totally valid as little of Central America's pastureland could be converted to coffee. Oftentimes poorer lands are turned into pasture worldwide. However, in Central America a high percentage of cattle pasture, especially in the Pacific slope, is potentially productive farmland. The Guanacaste Province of Costa Rica is a prime example. Called the breadbasket of Costa Rica, this area has 88% of the land dedicated to pasture. It is estimated that over 50% could be used for mechanized agriculture -corn, beans, sorghum, rice, soybeans, peanuts, and cotton.

4. WHY CREATING CATTLE PASTURES AFFECTS BIODIVERSITY

4.1 Habitat Fragmentation - Insular Ecology

The transformation of a large expanse of habitat into patches or "habitat islands", isolated from each other by cattle pastures or habitats different from the original, is called fragmentation (Preston, 1962; Wilcox, 1980). The original flora and fauna will be found in this landscape only if either the habitat islands can support species populations from the original habitat and/or high dispersal rates exist between patches (Preston, 1962).

Two major aspects of fragmentation have normally been discussed on the basis of island biogeography or insular ecology theory (Harris, 1984; MacArthur and Wilson, 1967; Soule and Wilcox, 1980). This theory states that biotic communities on oceanic islands represent an equilibrium between immigration and extinction rates. This equilibrium will depend on island size and diversity and distance from other potential sources. The formation of a habitat mosaic caused by habitat destruction challenges conservationists to preserve as much of a species pool as possible.

4.2 Deforestation for Pasture Affects Habitat Islands

Species extinction can be caused by the above mentioned insular ecology effects and because of increases in species populations harmful to the isles in the "ocean". A good example of this phenomenum is how nest predation and brood parasitism by brown-headed cowbirds impacts breeding forest songbird populations in forest fragments in the United States (Wilcove, 1985; Mayfield, 1977). The cowbird populations have greatly increased because of human-induced changes (increase in grasslands, increase in waste grain in southern rice fields, etc). A gene pool homogenization of a preserve's wild conspecifics because of genetic swamping by widespread agricultural populations could cause loss of local genetic adaptations to local biotic and physical conditions (Ledig, 1986).

4.3 Distance, Size and Edge Effects

An inverse relationship exists between distance and the rate of colonization. It can also indicate how isolation and fragmentation affects seasonal migrations, because with increased isolation, many seasonal migrants cannot travel between patches of suitable habitat. For example, Janzen (1986) refers to the inability of sphingid moths to migrate between increasingly isolated patches of tropical wet and dry forests, while Terborgh (1986) lists how fragmentation makes many tropical avian and mammalian frugivores with nomadic characteristics vulnerable to starvation.

With continuing fragmentation of habitats and ecosystems, knowledge of area and edge effects have increased to the point that it is difficult to separate their impacts. For example, fire encroachment in a protected area depends on relative humidity, its soils and its topographic relief, all related to reserve size. Livestock movements in a reserve and their effect on native vegetation and soils will depend on the carnivores found in the reserve, which is affected by reserve area. Lovejoy *et al.* (1986) mention several levels of effects, such as increases in populations of omnivores and small predators following local extirpation of large predators as inversely related to reserve size. A tertiary effect to this system would be the extinction of ground-nesting birds as a result of the secondary increase in small nest predators (Wilcove *et al.*, 1986).

The edge and size-edge effects might interact, resulting in a creeping edge moving towards the center of a reserve. Fire and the spread of seeds from secondary edge species are an example (Janzen, 1986). Other examples of edge creep related to human activities include cattle grazing or vegetation cutting by humans which facilitate access to deeper parts of a reserve and poaching which changes densities of hunted species, their prey and predators. Edge creep in small reserves might be exploited to establish habitats of exceptional quality for providing resources for secondary successional species. Management of these areas might take into consideration sacrificing the primary vegetation and deep forest animals of such reserves to benefit secondary species, especially because of the expense of combating them and because of the deep penetration of some edge effects (Janzen, 1986). This approach could be counterproductive if the reserve were established to protect plant species in high endemism areas (Gentry, 1986). Small reserves are unlikely to retain populations of many animal species that play critical roles in many ecological interactions, such as plant dispersal and reproduction (Culver, 1986). No habitat preserve is immune to the effects of human activity outside its borders, and one must understand the ecological effects of land development outside the boundaries of protected areas. Edges can benefit some plants and animals because of increased growth of secondary species. Many successional plants are insects hosts, and provide shelter and food for a wide diversity of vertebrates. For instance, white-tailed deer (*Odocoileus virginianus*) (Vaughan and Rodriguez, 1991), white-faced monkeys (*Cebus capucinus*) (Moscow and Vaughan, 1987) and tamarins and marmosets (*Saguinus midas*) (Lovejoy *et al.*, 1988) flourish in such habitats, especially in areas with few competitors or predators. However, forest edge has a strong negative impact on other members of the woodland fauna and flora (Hubbell and Foster, 1986). Ranney *et al.* (1981) have shown that seed fall in the cores of small woodlots is dominated by seeds of the edge species, which might change the woodlot species composition, as interior shade tolerant plants are replaced by shade intolerant edge plants. The author concludes by saying that very small or irregularly shaped forest reserves may be unable to sustain populations of forest interior plants.

4.4 Insular Ecology and the Reduction of Biodiversity

Extrapolation of studies of bird species in recently disturbed temperate and tropical forests between one and 25 square kilometers in size, have led to the prediction that extinction rates will be between 10% and 50% during the first 100 years. For example, in three patches of isolated Brazilian subtropical forest 0.2 to 14 square kilometers in size, the resident bird species suffered extinction rates between 14% and 62% (Lovejoy *et al.*, 1986). Unfortunately, it is difficult to measure the rate at which biodiversity is being reduced for three reasons:

1. As mentioned earlier, the number of species is unknown, even to the nearest order of magnitude.

2. Diversity reduction depends on the size of the island fragments and their distance from each other, which varies greatly between reserves and countries.

3. The home ranges and the ecology of most species have not been worked out, so it is not known which ones will be eliminated when tropical forests are cleared.

Using insular ecology area and size principles, Simberloff (1986) projected species losses due to rainforest destruction and resulting habitat fragmentation in the New World mainland. He found that within a century, 12% of the 704 bird species in the Amazon basin and 15% of the 92,000 plant species in South and Central America will be lost. In Central America, less than 15% of the total surface area is found in parks and reserves, and many of these are vulnerable to political and economic pressures. Thus, the region is already on a collision course toward an extreme reduction and fragmentation of tropical forests to be accompanied by a mass extinction of species, which could run as high as 50 percent.

The predicted extinction rate of hundreds of thousands or millions of species is probably conservative, because many tropical species are far more localized than those in temperate zones. As a result, if one reduces the forested areas by 90%, many species may go extinct. Secondly, even if a species survives, it may have suffered irreplaceable reduction in genetic variation (Franklin, 1980). These are the type of problems which organisms face in fragmenting habitats.

4.5 Loss of Keystone Species

The highly organized structure of neotropical forests is determined by plant/animal reactions. Coevolved food webs may be parallel and structurally similar, but taxonomically different and dependent on a particular plant species or keystone species. Keystone mutualists are plants supporting link organisms and indirectly supporting the food webs. Several authors (Gilbert, 1980; Terborgh, 1986; Leighton and Leighton, 1983) believe that keystone plant species probably play vital roles in sustaining animal communities of many and perhaps all tropical forests. This implies that these keystone plant resources establish the carrying capacity of most of the animal biomass, with important implications for management of the forest and its components (Terborgh, 1986). Some key organisms in the system are restricted to one microhabitat while others depend on the constant availability of several. Thus there is a need for management of disturbance rates in neotropical reserves, which increases towards areas of smaller size. Keystone mutualisms can be lost when reserves go below a certain size and with them, important links for the food web.

4.6 Fire in a Reserve

Pasture land is commonly burned during the dry season, both to release nutrients and control weeds. However, fire from areas adjoining a forested reserve is a severe threat and only occasionally beneficial to the reserve. A fire originating in a pasture will penetrate slightly and/or kill the borders of unburnable forest. However, in the following wet season this burned edge will produce a lot of herbaceous material which is highly combustible. In the Central American tropical dry forest, if the process continues, grasslands will gradually replace the forest. A forested reserve surrounded by pasture or secondary growth in a dry area is a great fire risk because of the large perimeter exposed to a large fire (Janzen, 1986). Embers carried by the wind from distant fires pose a threat to forest reserves, because they cause fires if they land on a dead log or tree. This fuel is common in seasonally dry forests and once ignited, can either produce ash or burn a small forest patch, with the resulting production of herbaceous, combustible material. A litter fire moving through the litter layer, might leave the larger trees unharmed, but kill part of the cambium near ground level. If another fire sweeps through the forest before the trees heal, fire can kill the internal dead wood of the trunk. Thus a litter fire can kill the trees in a forest and convert them into secondary successional vegetation which will burn year after year (Janzen, 1986).

4.7 Local Climatic Effects

Cattlemen should understand how deforestation affects the local climate (including rainfall and humidity) of an area. For instance, climatic changes in a reserve causing a 20% reduction in rainfall and shortening of the rainy season could drastically affect the habitat. Local extinctions, modifications of population densities, changes in microhabitat distribution and changes in species proportions could occur. Under normal circumstances, when a local population is extinguished, it can be reestablished by immigration or by traditional migration movements. Unfortunately, as reserves become more isolated and keystone species or important mobile links in food webs are lost, the opportunity for their reestablishment declines.

A large forested area found in a watershed may have higher rainfall than an adjacent watershed. This will provide ground water for extended time periods, especially during the dry season. Most reserves have very different vegetation from that of an adjacent pasture. The agricultural land may experience extremes in temperature, rainfall, and winds on a daily basis. Forest patches adjacent to pastures will have edge effects. This is why preserves of 10 ha each may be all edge, while a reserve of 100 ha may contain a small core area relatively free of physical edge effects; but this core area will probably not survive.

4.8 Threats from the Preserve

Animals in a preserve may be incompatible with contemporary livestock raising. For instance, in Central America examples of potential threats from reserve animals include: jaguar (*Panthera onca*), puma (*Felis concolor*), and ocelot (*Felis pardalis*) attacks on livestock (Schaller and Cradshaw, 1980: Rabinowitz, 1986); potential white-tailed deer competition with cattle for water and food sources (Vaughan and Rodriguez, 1991); duck (*Anatidae*), coatimundi (*Nasua narica*) and white-faced monkey feeding on animal feeds such as sorgum and corn (Hilje and Monge, 1988) and vampire bats (*Desmodus rotundus*) roosting in caves in forested areas and lapping blood from cattle in nearby farms (Hilje and Monge, 1988). Effects of these species on livestock should be evaluated and measures taken if necessary.

5. MANAGEMENT OF CATTLE FARMS FOR MAXIMUM PRODUCTION AND BIODIVERSITY

5.1 The Facts

The economic contribution from cattle operations in Central America is very inefficient, whether measured by cattle production per hectare of land or return on investment. The beef cattle production on tropical pastures of Central America could be increased four to five times, and the total marketable meat production increased tenfold with application of available knowledge to existing pasture and animal resources. Thus, by improving and intensifying Central American cattle production, especially on marginal lands, the pressure for deforesting new lands would decrease.

Another way to reduce pressure on cattle land is by diversifying production. An example of where cattle production has profitably been combined with agriculture and ecotourism is found at the 1,200 hectare Hacienda Curu on the Nicoyan Peninsula in Costa Rica. A herd of approximately 400 beef cattle is maintained, in addition to forestry, coconut, fruit, and annual crops. About 50% of the revenue in Curu is perceived by cattle sales, 35% from ecotourism and 15% from agriculture (Shutt, A., personal communication). Over 800 hectares of Curu are covered with natural forest, and cattle are concentrated on the flat lowlands.

An interesting situation has developed in Langtang National Park in Nepal, where large herds of chauri (a yak-cattle hybrid) are overgrazing the park, endangering the biota of the park, including the red panda (*Ailurus fulgens*). Because the chauri's milk is used to make cheese for Western tourists, it was recommended that the price of cheese be increased to augment the farmers' income and thus reduce milk production and chauri grazing pressure (Yonzon and Hunter, 1991). The overall objective in both Central American cattle and Nepal chauri is to decrease the pressure on the grazing land by finding economically viable alternatives which protect the biodiversity and avoid opening new areas.

The long-term security of natural areas in agricultural landscapes will strongly depend on the way that lands surrounding natural areas are used (Carroll, 1990). Much of the pasture land in Central America is heavily eroded, losing its topsoil, and in a degraded state. It cannot continue in pasture except at an extremely low stocking rate. The few remaining natural areas in tropical countries are increasingly located in areas which qualify as marginal lands (Carroll, 1990).

5.2 National Inventory of Biodiversity to Select Important Sites

Important biodiversity sites with high endemism or species numbers must be selected based on an inventory carried out at a local, regional, and national level. For instance, in Costa Rica, the Costa Rican National Biodiversity Institute (InBio) is focusing on collecting, cataloging, storing, organizing, and identifying the biota, and putting it to work for Costa Rica and the international community. This inventory will be the first for a tropical country (Lewin, 1988). With this information in hand, certain sites can be picked out. For instance, very small areas with high endemism can be very important (Gentry, 1986).

5.3 How Many, how Large and how Close?

Most of the remaining large forests in Central America should be protected if one wants to avoid the biotic collapse suggested by insular ecology theory. In this way, the maximum level of remaining biodiversity can be protected. One should protect the largest fragments for three major reasons. First, species have different area requirements, and the largest habitat islands will be the only refuge for species with low densities (Vaughan, 1983). This includes large carnivores or habitat specialists whose requirements are satisfied only in large, diverse areas. Second, large fragments may serve as sources of immigrants for marginal populations from adjoining small fragments. Third, large areas will always be eroded unless they are protected. Because of the costs and responsibility for acquiring and managing large reserves, national and international conservation organizations usually work with the local government in conserving these areas (Vaughan, 1990).

In Central America, approximately 15% of the land is protected in governmental reserves. Costa Rica is one of the best examples, with over 22% of its national territory in protected areas, in 1985 (national parks, biological reserves, wildlife refuges, national forests, indian reservations, etc.) (Boza, 1988). In 1986, the 60 odd wildland areas were combined into 8 regional conservation units, in most cases with one common boundary and an integrated administrative body per unit (MIRENEM, 1989). These units vary in size, but in general are the largest areas under conservation (up to 415,000 hectares) in a country.

Given the difficulty of having a national government manage all the habitat variation, ecosystems, and its biodiversity in a heterogeneous environment, it is necessary to work on the regional or local level. Thus, we propose biodiversity conservation in large and medium sized farms, especially where suitable habitat exists. A composite strategy with several large national reserves, a network of medium-sized reserves, and many small local reserves would provide for the maximum biodiversity conservation in a region (Wilcove *et al.*, 1986).

Clustering large national reserves would probably be very impractical because of their distant geographical location throughout Central America. However, these large reserves can provide isolates for smaller local reserves almost in a stepping stone manner. Those species would be able to pass through a variety of habitats in the neighboring "ocean". Flying organisms such as bats (Wilcox, 1980), and birds (Lynch and Whigham, 1984) will be most benefitted in such a reserve. It would be more beneficial for certain target species in an area if the land use surrounding a reserve would permit their populations to exist there.

5.4 Corridors

Habitat corridors between reserves of varying sizes have become increasingly popular in conservation strategies and landscapes. Because of the problem of habitat fragmentation, corridors might be considered useful for linking reserves (Noss, 1987). Corridors may have disadvantages which outweigh their positive aspects, such as transmitting contagious diseases, fires, and increased exposure of animals to predators, domestic animals, and poachers (Simberloff and Cox, 1987). However, there is no doubt that well-managed, a network of refuges connected by corridors may alleviate threats from inbreeding depression and allow population mobility and stability (Noss, 1987). In reserves found in cattle pastures, ribbons of forest corridors and even living fence rows and windbreaks could interconnect these.

5.5 Reserve Management

Over the long run, reserves will require active management to overcome the imbalance created by fragmentation or human activity. Management may include vegetation treatment to control fires and preserve successional stages; elimination of foreign species or populations of nuisance species. For management, it is important to understand how far into the forest the edge influence is felt. The major vegetation changes caused by edge can extend only 10-30 m inside the forest. Any edge-related increases in predation may extend 300-600 m inside the forest (Wilcove, 1985). For management purposes, if 600 m is taken as a liberal estimate of faunal edge effect, circular reserves smaller than 100 ha will contain no true forest interior. Besides, as indicated above, small reserves are unlikely to retain populations of many animal species that play critical roles in many ecological interactions, such as plant dispersal and reproduction (Culver, 1986). No habitat preserve is immune to the effects of human activity outside its borders, and one must understand the ecological effects of land development outside the boundaries of protected areas.

5.6 Restoration Ecology

Although preservation of existing natural areas plays an important role in biodiversity conservation, it may be necessary to put the pieces back together when something has been altered or destroyed. First, a body of biological knowledge is necessary to permit the managerial aspects to function. However, this is not always possible, and restoration must begin without adequate information. Within those areas designated to be restored, man-made fires, hunting, cattle grazing, and other perturbations should be stopped (Janzen, 1988). If the goal of restoration ecology is to conserve a maximum number of species, the management plan may be different than if the goal is to conserve habitats and "normal" interactions between species. Maximum species management leads us to fragment the remaining wildland into a mosaic of distinct successional types and stages, and introduce species from other areas. If one wants to conserve interactions and species, then the manager must predict rather than simply react. For instance, the Guanacaste National Park needs its large size for five reasons: maintain habitat diversity, maintain adequate species population sizes, provide dry season refugia and migration routes, minimize edge effects, and maintain replicated habitats for human park users (Janzen, 1988).

5.7 Management of Single Species

A number of neotropical animal species exist which provide primary or secondary products for mankind (Robinson and Redford, 1991). To survive, these animals need the habitat components of water, shelter, escape cover, and food (Dasmann, 1964). In Latin America, those important wildlife species which live in pasture-forest areas include: white-tailed deer (Vaughan and Rodriguez, 1991), capybara (*Hydrochoerus hydrochoeris*) Ojasti, 1991), and spectacled caiman (*Caiman crocodilus*) (Thorbjarnarson, 1991). The iguana (*Iguana iguana*) is another species whose management is compatible with biodiversity conservation and reforestation (Werner, 1991). Below we will summarize a management strategy for the white-tailed deer and the iguana, both found throughout Central America.

5.7.1 White-tailed deer coexists with cattle. The white-tailed deer has been the most important big game species in Mexico (Leopold, 1959), Central America (Mendez, 1984) and Venezuela, Peru, and Ecuador (Brokx, 1984). Also it is an important seed disperser and source of food for large predators. This is because of its large size and adaptability to altered environments and grasslands. In Central America, there is excellent habitat available for the species.

The deer herd in San Lucas Island (Costa Rica) lives in prime deer habitat. Seventeen percent of the 500 hectare island is covered with secondary forest, much of which is used for firewood (Vaughan and Rodriguez, 1991). This forest is found in mosaic form throughout the island, and offers cover and forage for the deer herd. More than 200 head of Cebu cattle graze the pastures, which cover over 70% of the island. The most important forage items in the white-tailed deer diet were browse in the dry season and forbs in the wet season (DiMare, 1986). Grasses represented a small proportion of the total diet. Ten watering tanks for cattle in the dry season also provided water for the white-tailed deer. Hunting is controlled and no major deer predators were on the island. Water, shelter, escape cover and food, the principal components of white-tailed deer habitat (Dasmann, 1964) are in abundant supply on the island. As a result, Rodriguez and Vaughan (1987) estimated a total population of 400 deer on the island at a density of 0.8 animals/hectare, higher than the highest deer densities in the United States (Teer, 1984). The tropical year-round growing season, the insular nature of the site, and the habitat conditions make San Lucas Island an excellent range for deer (Vaughan and Rodriguez, 1991). There are many cattle ranches on mainland Central America which could replicate San Lucas Islands excellent habitat.

5.7.2 Green iguana production in forested areas. The green iguana has been used as a source of protein by man for over 7,000 years (Cooke, 1981). The research on iguana management headed by Dagmar Werner of the Universidad Nacional (Costa Rica) aims at developing a technical and scientific basis for conserving and increasing iguana numbers to provide protein and income from iguana meat and eggs (Werner, 1991). Iguanas have several characteristics which make them a desirable forest species to manage. They are poikilothermic herbivores, and are very efficiently in converting plant materials to protein. They consume roughly 10 times less than an equivalent mammal or bird (Gradwohl and Greenberg, 1988). A female iguana lays an average of 35 eggs yearly or 300 eggs in her lifetime. Because in the wild only an estimated 2.5% of a clutch hatch survive to a year in age, this project raises young iguanas from eggs until they are a year old and then releases them into forests (Werner, 1991).

Up to the present, the Iguana Management Project has been successful at increasing the hatching success from 2.5% to 95 percent. Successful reintroduction of iguanas has been carried out in cooperation with local human communities. Werner (1991) estimated that iguanas produce meat at half the cost of the majority of domestic animals. After three years in a forested area, the iguana will produce the same amount of protein that cattle would in a deforested area without all the benefits of the forest products (Werner, 1989).

6. CONCLUSION

Originally one of the most biodiverse regions in the world, Central America has lost most of its natural forest vegetation to pasture land. In many cases, small patches of forest remain on farms, often on marginal soils. The decreasing size of many natural areas and the increasing distance between them contribute to the vulnerability of the biodiversity. Decreasing size of habitat islands results in such negative aspects as the edge effect from species, fire, and climate. It is proposed that biodiversity can be conserved and increased by incorporating insular ecology and restoration ecology principles in landuse.

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CHARACTERISTICS OF TROPICAL PLANTS THAT DETERMINE NUTRITIVE VALUE

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1. INTRODUCTION

Natural vegetation and crop residues are the most important feed resources for ruminant livestock in the tropical regions. The nutritive value of these feed resources is a major factor in the development of sustainable feeding systems for increasing ruminant production. This paper discusses the characteristics of tropical plants which determine nutritive value. Emphasis is given to natural vegetation, crop residues, and multipurpose trees.

2. FACTORS AFFECTING THE NUTRITIVE VALUE OF TROPICAL PLANTS

Most forages belong to the higher land plants (*Angiospermae*) which are divided into two groups (*Monocotyledoneae* and *Dicotyledoneae*) based on the number of embryo leaves (cotyledons) present in the seed. Monocotyledons forages have a single embryo leaf and are characterized by the grasses. Dicotyledons forages have two embryo leaves and are characterized by legumes and other broad leaf plants.

The leaf of a typical dicotyledons plant, such as a forage legume, has a low abundance of epidermal and vascular cells (xylem and phloem) and a high abundance of palisade cells in the mesophyll. These cells are very active in photosynthesis and contain many of the important nutrients. The palisade and mesophyll cells have thin cell walls that are readily digested by rumen microorganisms. The epidermal and vascular cells have thickened cell walls that resist digestion.

The leaves of a typical monocotyledonous plant (especially tropical grasses) have a higher abundance of epidermal and vascular cells, and a lower abundance of mesophyll cells than a dicotyledons leaf. Most tropical grasses have the C4 photosynthetic pathway which allows them to have very rapid rates of cell elongation and accumulation of cell wall. These species also have a higher proportion of vascular tissue in their leaves in comparison to grass species with the C3 photosynthetic pathway.

Immature plants contain a predominance of undifferentiated cell types and actively photosynthetic tissues with thin primary cell walls. As the plant matures, photosynthetic products are translocated to seeds, tubers, roots and other storage tissues, and the vegetative tissue becomes devoid of components within the cytoplasm. The cell wall becomes thickened into secondary cell walls.

The logic behind systems for estimating the nutritive value of plants is dependent on the separation of the cell contents (cytoplasm) from the cell wall.

Forage components can be classified by their bioavailability to enzymes of anaerobic microorganisms which inhabit the digestive tracts of mammals, or to mammalian digestive enzymes. There are three classes of bioavailability:

Class 1 are forage components which are completely available. These components are primarily present in cell contents. Sugars, storage carbohydrates, lipids, most proteins, and non protein nitrogenous compounds belong in this class. The digestion of these forage components is limited only by the rate of passage through the digestive tract. Most of these components are rapidly fermented so that digestion is usually complete.

Class 2 are forage components which are only partially available. These components are the cell wall carbohydrates and are only available for digestion by microbial enzymes. There are no mammalian enzymes capable of digesting these cell wall carbohydrates. The cell wall carbohydrates are only partially available because they are associated with components in Class 3, which limit digestibility.

Class 3 are forage components which are completely unavailable for digestion. Lignin, silica, and some types of tannins complex nutrients and make them unavailable for digestion by microbial and mammalian enzymes.

The classification of forage components by bioavailability is based on the separation of feeds into fractions with uniform or non-uniform nutritive availability as defined by the Lucas test (Lucas *et al.*, 1961; Van Soest, 1967). The test for uniform nutritive availability is based on analysis of digestible amount of feed fraction regressed on the percent of the fraction in the feed. For feed fractions that are represented in the faeces by indigestible feed, microbial debris and endogenous excretion, the slope represents true digestibility and the negative intercept estimates the metabolic amount as a percent of intake. A feed fraction with uniform nutritive availability has a regression equation with a low standard error and an intercept less than or equal to zero. A high correlation coefficient is not indicative of uniform nutritive availability. The concept of nutritional uniformity is useful in estimating the nutritive value of forages by laboratory and animal based techniques.

Cell contents (as estimated by the amount of dry matter soluble in neutral-detergent) is a feed fraction which has uniform nutritive availability. When the amount of digestible neutral-detergent solubles are regressed on the concentration of neutral-detergent solubles in the feed, the slope is close to 1 and the intercept in negative. The slope indicates that the true digestibility of neutral-detergent solubles is approximately 100 percent. The cell contents have a very high bioavailability. The negative intercept indicates that if there is no neutral-detergent solubles in the feed, then there is still excretion of neutral-detergent solubles in the faeces which originate in the digestive tract (the metabolic and endogenous amount in the faeces). The metabolic amount in the faeces is predominantly indigestible microbial debris (Mason, 1979).

Crude protein usually has a uniform nutritive availability. However, heat damage and tannins may cause the crude protein component of a forage to behave in a nutritionally non-uniform manner.

Lignin is a feed fraction with uniform nutritive availability, but has a true digestibility, intercept, and correlation coefficient not significantly different than zero. Lignin belongs to Class 3 of bioavailability and limits the digestion of cell carbohydrates. The Lucas test indicates that lignin is uniformly unavailable for digestion. However, as for crude protein, there are forages (especially browse) in which lignin can become nutritionally non-uniform because of the presence of tannins (Reed, 1986; Reed and Soller, 1987).

Cell wall carbohydrates are feed fractions with non-uniform nutritive availability. These forage components (Class 2 in bioavailability) are only partially available because of their association with lignin and other Class 3 components. The regression analysis for the Lucas test has high standard errors. Negative intercepts have no biological meaning because there can be no endogenous excretion of cell wall carbohydrates.

The cell wall is the most important forage component for determining digestibility, because the cell contents have a uniform nutritive availability and a true digestibility close to 100 percent. The non-uniform nutritive availability of the cell wall carbohydrates indicates that prediction of the digestible amount of cell wall cannot be predicted from the content in the diet. Cell wall digestibility can only be predicted by a separate analysis such as a chemical determination of lignin or a biological determination of digestion (*in vitro* or nylon bag).

Intake and digestibility of dry matter and forage components are the most important parameters in determining the nutritive value of a forage. The relationship between intake, digestibility and forage components is an important factor in the application of forage analytical systems. For instance, lignin has a highly significant negative correlation with digestibility but a very low non-significant correlation with intake. In contrast to lignin, the content of cell wall has a highly significant negative correlation with intake but a relatively low correlation with digestibility. The effect of lignin on digestibility is caused by its association with the cell wall carbohydrates which reduces their bioavailability. The negative effect of cell wall on intake is caused by the physical characteristics of the cell wall which limit intake by rumen fill (Van Soest, 1982) and pushing rumination time to its limit (Welch and Smith, 1969). The correlation between cell wall and intake can be improved by correcting for differences between animals in individual intake relative to a common forage (Osbourn *et al.*, 1974). Prediction of nutritive value of forages by laboratory analysis is therefore dependent on estimation of the total cell wall components in the forage and an estimate of cell wall digestibility, in addition to determination of nutrient content (especially nitrogen and minerals).

2.1 Secondary Plant Compounds

Plant compounds that lower nutritive value of forage are a heterogeneous group of biomolecules. They are termed secondary plant compounds because they do not have a direct role in primary metabolic processes (photosynthesis, respiration, anabolism, and catabolism). However, secondary plant compounds have important ecological roles in controlling animal predation (Swain, 1979; Whittaker and Feeny, 1971; Cates and Rhoades, 1977; Bryant, 1981). Also, many natural medicines, narcotics and poisons used by man are secondary plant compounds.

The anti-quality compounds in forages can be grouped by two different effects on animals.

1. Toxic compounds that are present in plants at less than 2% of the dry matter. These have negative physiological effects when absorbed, such as neurological problems, reproductive failure, goiter, gangrene and death. These secondary plant compounds include alkaloids, cyanogenic glycosides, toxic amino acids, saponins, isoflavonoids and many others.

2. Non-toxic compounds that lower the digestibility and palatability of forages when present at over 2% of the dry matter. Some of these compounds have a structural role, such as lignin, silica and cutin. The role of tannins and volatile-essential-oils (terpenoids) may be in plant defence against predation.

These distinctions are not absolute because some compounds may belong to both classes.

Routine methods for analysis of nutritive value do not include secondary plant compounds. However, many forages are low in palatability or limited in utilization by the presence of a secondary plant compound. Many tropical and sub-tropical legumes have this problem.

Natural vegetation utilized as forage presents more complex problems. Range plants may have high contents of secondary plant compounds. However, livestock poisoning is uncommon on range in good condition. Livestock have the ability to avoid toxic plants under free ranging management. There are also important differences in ability of livestock species to detoxify secondary plant compounds. However, it is impossible for livestock to avoid consuming compounds such as lignin, tannins, volatile oils, silica and cutin. Many forages that dominate vegetation contain high amounts of these compounds which lower their nutritive value. Understanding factors that control the dominance of these plants, and ways to manipulate vegetation so that dominant plants contain less inhibitory compounds, are important challenges in range management research.

2.2 Natural Vegetation

Grazing on non-arable land is seasonal and consists of unimproved species. Herbaceous legumes and other dicotyledons are important during the growing season but grasses are usually dominant. During the dry season, only senescent grasses remain in the herb layer and in many areas they are completely grazed before the beginning of the next growing season. Browse from woody legumes are important components of the vegetation which provide feed during the dry season. The leaves of shrubs are browsed and branches from trees are lopped to make leaves accessible.

The physical form of plant communities that recur in the landscape as a result of soil, topography and climate are termed physiognomic vegetation types (Whittaker, 1975). The physiognomic vegetation type is a convenient method for describing vegetation in terms of habitat for animals. However, plant communities are collections of species which grow in association. Species composition is important in evaluating potential of vegetation as food for livestock and wildlife. The diversity in the morphology of plant species, and the large differences in the nutritive value of plant parts, force ruminants to eat tropical vegetation in a selective manner. The prehensile ability of ruminant species is related to their choice of plant species and plant parts consumed (Mc Cammon-Feldman *et al.*, 1981). Plant morphology has a large influence on the intake of ruminants consuming natural vegetation.

The growth form (height, leaf to stem ratio, and crown structure) of tropical grasses affects eating time, bite size and intake (Stobbs, 1973; Chacon and Stobbs, 1976). Tall growth forms of tropical grasses have longer grazing times, smaller bite size and lower intake by cattle when compared to short growth forms. Herbage yield is also negatively related to bite size and intake. These relationships indicate that the presence of a large amount of grass biomass would be deleterious to ruminants. They also suggest that high stocking rates are necessary to maintain the nutritive value of tropical grass swards at a level to support maintenance and production of grazing ruminants.

The growth form of woody plants is also a factor in their nutritive value. Only the largest herbivores, such as elephants, can consume woody species without a high degree of selectivity. Ruminants select for leaves, apices and cambial tissues when consuming woody plants. Leaf size, thorns and leaf density affect the rate of intake of browsing ruminants. Bite size is positively correlated with leaf mass (Dunham, 1980). The rate of intake is low for woody plants with small leaves and thorns. Goats can select around thorns because they have a narrow muzzle and articulated lip structure.

2.3 Crop Residues

It is estimated that at least 50% of the annual metabolizable energy intake by domestic ruminants in tropical countries is derived from fibrous crop residues (McDowell, 1977). Low digestibility and limited voluntary intake are the major constraints to extensive utilization of crop residues. When the crop residues from maize, sorghum and millet are grazed in the field, there are large losses of up to 50% of the dry matter from trampling and spoilage (Chandler, 1983; Tessema, 1983). However, in many resource-poor farming systems these cereal crop residues are harvested, stored and traded for livestock feeding. More efficient use of cereal crop residues could increase livestock productivity.

Although much research has been devoted to upgrading straw through various chemical treatments (Jackson, 1978), little attention has been given to natural variation in the nutritive value of untreated crop residues as influenced by species, variety and environment. Research has shown that there is over a 20 unit range in digestibility of crop residues among different varieties of several food crops (Reed *et al.*, 1988). Quantity and quality of crop residue are important criteria in a farmer's decision to grow a particular variety. Small farmers have rejected new varieties that were proven to be agronomically successful at plant breeding centers, when they realized that yield and nutritive value of the crop residue was unacceptable.

Varietal and environmental effects on the nutritive value of cereal crop residues appear to be of considerable importance. Differences in growing conditions due to season, elevation or latitude cause crop residues from the same cereal to vary widely in nutritive value. High temperature during growth increases cell wall and crude lignin content, and decreases digestibility (Deinum, 1976). High humidity and rain during and after grain harvest cause deterioration of nutritive value. Loss of leaves through wind or trampling of cereal crop residues left in the field also causes deterioration. The losses can be eliminated by improved conservation practices.

It is well known that cereal crop residues are deficient in protein. However, supplementation with non-protein nitrogen and protein does not always lead to improved intake and digestibility because other factors limit nutritive value. These factors need to be determined because, within the range of energy intake of cereal crop residues, large increases in animal productivity can be achieved by relatively small increases in digestibility and intake.

Tropical cereals (maize, sorghum and millet), like other species of grasses with the C4 photosynthetic pathway, have rapid rates of cell elongation and accumulation of cell wall carbohydrates during vegetative growth (Volenec *et al.*, 1986). The digestibility of the cell wall carbohydrates as determined by their association with lignin and related phenolic compounds has a large influence on nutritive value. The cell wall accounts for 80 percent of the dry matter in cereal crop residues and represents a large source of energy for ruminant feeding. However, the ability of rumen microorganisms to digest these polysaccharides is limited by the presence of lignin and other phenolic compounds (Hartley, 1981 and 1985). The phenolic constituents of tropical cereal crop residues have received little investigation. The digestibility of cereal crop residues is correlated with the nature and amount of lignin associated with their cell walls. Environment also affects the nature and amount of lignin and related cell wall phenolics, leading to substantial variation in digestibility.

Low molecular weight phenolic acids are also important in limiting the digestibility of cell wall carbohydrates (Akin, 1982; Akin and Rigsby, 1985). The major phenolic acids associated with the cell walls of grasses are ferulic and p-coumaric (Hartley and Jones, 1977). These compounds are esterified to xylans (Muller-Harvey *et al.*, 1986). The brown midrib mutants of maize and sorghum have higher digestibility of cell wall carbohydrates as compared to their normal counterparts and commercial varieties and a lower concentration of lignin and p-coumaric acid in the cell wall (Porter *et al.*, 1978; Barnes *et al.*, 1971; Muller *et al.*, 1971; Akin *et al.*, 1986; Cherney *et al.*, 1986). There has been some interest in incorporating the brown midrib mutation into commercial varieties.

In sorghum, high levels of phenolic pigmentation are associated with higher levels of lignin and lower digestibility of cell wall carbohydrates (Reed *et al.*, 1987; Reed *et al.*, 1988). Both variety and site have significant effects on lignin, pigmentation and digestibility. The effects of variety and site on digestibility, lignin and pigmentation were greatest in the sheath fraction from highly pigmented bird-resistant varieties (Reed *et al.*, 1988). Pigmentation may also affect intake of sorghum crop residue (Reed *et al.*, 1988).

Level of feed offered also has a large influence on the intake and growth rate of ruminants fed cereal crop residues (Owen and About, 1988). Increasing the amount of sorghum stover offered to sheep from 25 to 50 g/kg of body weight increased average intake and growth rate by 26 and 72%, respectively (About *et al.*, 1990). However, feed refusals increased from 7 to 42% of the stover offered. Increasing the amount offered from 50 to 75 g/kg bodyweight gave little further improvement.

The crop residues from leguminous crops such as cowpea (*Vigna unguiculata*) and peanuts (*Arachis hypogaea*) are also important feed resources in tropical countries. Peanuts and cowpeas can be grown as a dual purpose crop for both grain and forage production. Both the leaf and stem fractions can contain sufficient amounts of crude protein and metabolizable energy to meet requirements for maintenance and production (Reed, 1987). However, some workers have reported low nutritive value of legume crop residues (Ayoade *et al.*, 1983; Mohan *et al.*, 1985). The variation in nutritive value is related to method of harvest, amount of leaf shatter and the vegetative characteristics of the variety grown.

Crop residues will continue to be important feed resources in developing countries. Better utilization of crop residues can increase productivity and increase income to both livestock producers and smallholder farmers. The crop residues of most food crops are essential in livestock production systems in tropical countries. There is increasing evidence that the variation in nutritive value among varieties of these food crops is large and selection for improved nutritive value should be possible (Reed *et al.*, 1988). The increases in digestibility that are possible through selection and crop breeding may be greater than chemical treatments. Plant breeding to improve nutritive value would be more appropriate than chemical treatments. Crop improvement programs could improve livestock production by developing crop varieties that are suitable for dual purpose production of both grain and fodder.

2.4 Multipurpose Trees

There is great potential for increasing soil fertility, subsequent crop yields and livestock productivity by introducing forage legumes into the cropping system (Haque and Jutzi, 1984; Tothill, 1986). The major constraints to the introduction of forage legumes into resource-poor farming systems are: scarcity of land and competition with food crops; labor shortages during peak periods of cultivation, planting, weeding and harvesting; inadequate supply and production of seeds; and, lack of adapted species.

Some of these constraints can be overcome by the introduction of multi-purpose fodder trees in alley cropping systems and for planting near households in "browse gardens" (Sumberg, 1984). *Leucaena leucocephala* and *Gliricidia sepium* are successful species in humid and sub-humid zones and in arid zones under irrigation. *Sesbania sesban* has been successfully used at higher elevations. Species for the more arid zones are lacking, but native and introduced *leguminosae*, such as African and Australian acacias, are promising (Le Houerou, 1980).

Improved animal agroforestry with multi-purpose trees could improve livestock production in tropical countries through increasing forage production (Torres, 1983). However, quantitative information on livestock performance on diets containing forage from trees is lacking. Cereal crop residues are deficient in protein and moderate to low in content of digestible energy. Forage from trees could improve livestock performance when fed in combination with cereal crop residues.

There are large differences in the nutritive value of fodder trees when fed in combination with cereal crop residues (Reed and Soller, 1987; Reed *et al.*, 1990; Ebong, 1989; Rittner and Reed, 1989). Much of the difference may be explained by the presence of high levels of polyphenolic compounds. Tannins and related phenolic compounds in fodder trees cause protein to behave as a nutritionally non-uniform feed fraction (Reed *et al.*, 1990). However, sheep can adapt to consuming leaves from some species and grow at expected rates although these leaves contain high levels of phenolics.

The selection of multi-purpose trees for use in forage production systems must consider that the large differences in nutritive value among fodder tree species are not easily predicted by content of nutrients (Wilson, 1977; Wilson and Harrington, 1980), or analysis of secondary plant compounds such as phenolics. Some species may be agronomically successful but unsuitable for feeding livestock.

Leguminous fodder trees have potential for use as high quality supplements. Simple feeding systems based on combination of fodder trees and cereal crop residues can provide productive rations for ruminants. The use of many fodder trees may be limited by anti-quality components. Some species of trees may be useless for developing feeding systems because they contain high levels of tannins and other anti-nutritional compounds. Other species may be useful because ruminants may be able to adapt to some secondary plant compounds.

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UTILIZATION OF TREES AND BUSHES IN RUMINANT PRODUCTION SYSTEMS

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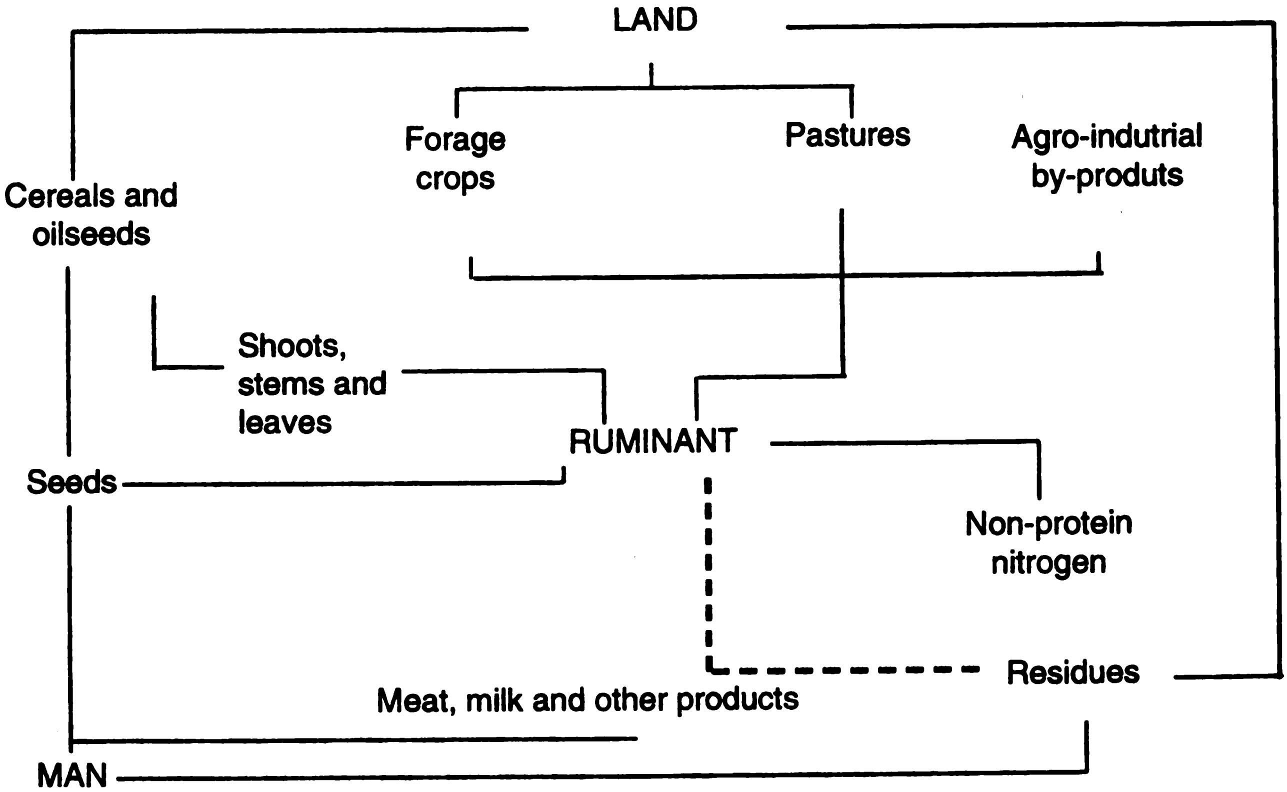
1. BACKGROUND

In tropical America, the causes of deforestation and deterioration of the natural resources cannot be separated from the socioeconomic reality of the region. In Central America, the human population is growing at a rate of 2.8% annually, and it is anticipated that by the year 2000 the region will have 39.7 million inhabitants. Nevertheless, the production of food has not matched this accelerated population growth; rather, during the last six years, the *per capita* consumption has decreased at a rate of 6.3% annually. This increase -in both the demands for food as well as income by a fast-growing population, and by the countries themselves for hard currency to confront a staggering external debt- is contributing to over-exploitation and degradation of natural resources.

In Central America it is calculated that each year 400,000 hectares of forest disappear. With them we are losing an important number of species of plants and animals whose attributes have not even been discovered, and whose future role could have been extremely important. The irrational exploitation of the forest is a product of the high demographic growth, but also of the marketing of wood of high commercial value, the establishment of agricultural products such as cotton, banana, rice, sugar cane, and pastures, and the necessity to collect firewood. Many traditional cultivation practices and the location of agricultural activities in inappropriate soils have also contributed to the serious deterioration of the ecological equilibrium and the productive capacity of the soils.

A few years after lands have become deforested and converted indirectly or directly to pastures, they become degraded. This is principally a result of the loss of soil fertility, as the natural recycling of nutrients is interrupted and inadequate practices of pasture management are applied.

This loss of soil fertility means that as there is no possibility of providing external inputs to the farm such as fertilizer, the quantity and quality of the pasture decreases significantly. Thus, in the majority of the livestock production systems of the region, decreased economic and biologic productivity results. Ruminants have the capacity to convert forage and agro-industrial by-products, high in cellulose and hemicellulose and unable to be used by humans, into foodstuffs of high nutrient value for the human population, such as meat and milk. In addition, the large amount of the nutrients consumed are recycled to the soil through feces and urine (Figure 1).



In Latin America, livestock play a very important role from the economic, social, and cultural viewpoints. From the economic viewpoint, livestock constitutes the principal income for many producers, and in many countries it is also an important source of hard currency. From a social perspective, livestock (cattle and goats) are found on a vast majority of medium and small farms, providing high-quality protein to the population. The animals are also a form of financial security and represent prestige for their owners. From the cultural viewpoint, it is important to mention the dietary habits of the population in the consumption of meat, milk and other animal products. It is important to emphasize that in Central America and the Caribbean the majority of those farms dedicated to livestock production are classified as small or medium (Leonard, 1987). In the case of goats, the majority of the animals are in the hands of producers of very low means, located in areas where possibilities for other types of livestock activities are limited and where the success of the activities depends in large part upon the use of low cost feeds, and the opportunity to use family labor (Table 1).

Table 1. Principal activity of goat owners in two regions of Guatemala and the Southern region of Honduras[1]

Activity	Guatemala — Highlands	Guatemala — Western	Honduras
	% of producers		
Small producer	76	41	31
Medium producer	5	2	7
Agricultural laborer	4	18	27
Urban laborer	12	36	3
Housewife	0	0	19
Others	3	3	13

[1] 74 producers in the Highlands, 87 in Western Guatemala and 137 in Honduras.

Source: Arias (1987); Amour y Benavides (1987).

2. LIVESTOCK ACTIVITIES IN AN AGROFORESTRY CONTEXT

The great challenge to modern tropical livestock production is to increase production of meat and milk in a way which is both rapid and sustainable to meet the demands of the rapidly growing population, and also to guarantee the conservation of natural resources and the environment.

There are two main strategies available to confront the problem of degradation of natural resources and deforestation:

a) To reverse the process through the restoration of those areas which are appropriate to forestry to their natural use, as well as the conservation and reforestation of lands which are appropriate for agriculture or cattle, but which must be reconverted to forest to assure the ecologic well-being of the planet. This position frequently overlooks the socio-ecologic components important to the population who live in these places, while favoring other more developed societies which now do not have forests left to conserve.

b) To direct this process, with the political and technical commitment needed to meet societal goals, to design systems of production which combine agricultural, ranching, and forestry activities and which may be productive and compatible to the rational use of natural resources.

It is clear that in some areas the first option would be the best; for example, those lands which have very pronounced slopes or for the protection of certain aquifers. Nevertheless, there are extensive areas of the region where it is necessary to direct the process through the introduction of sylvopastoral systems.

A sylvopastoral system is a situation where there is joint development of trees and/or bushes with pastures in an integrated management system whose principal objective is to increase the net benefit per hectare over the long term (Torres, 1983). Sylvopastoral systems must include the use of species of trees, plants, and animal germplasm adapted to the biotic and abiotic conditions of the region, in such a way as to increase in animal productivity in a rapid and sustainable manner.

The Tropical Livestock Program at CATIE has been a pioneer in the inclusion within its programs of work, of research on different forms of integrating trees and bushes in cattle and goat production systems. The starting point is that trees and bushes are resources that are potentially useful as living fences, for the recuperation of degraded pastures, and for ruminant feeding. Thus, during recent years research has increased on such topics as the identification, availability, nutrient value, and agronomic management of woody species with the potential for being used in ruminant production systems.

2.1 Spacial Arrangements

The species of trees and bushes may be localized in different arrangements at the farm level, among which may be included, living fences, protein banks, trees associated with pastures, and woodlots for the production of wood in problem areas on the farm (steep slopes) or in the middle of pastures where they also serve as shade for the animals.

2.1.1 Live fences. *Gliricida sepium* and *Erythrina berteroana* are two of the species frequently employed by farmers as live fences, which are pruned once per year to obtain live posts used in improving or building new fences. However, it was not known how to use these species as a grazing resource in order to obtain the greatest quantity of energy and protein, without compromising the survival of the trees. To determine the optimum frequency of pruning, an evaluation was made over four years on two locations in the humid tropics of Costa Rica, with a total of 240 trees of *G. sepium* and *E. berteroana*, which were submitted to three different frequencies of pruning (2, 6, and 4 months). Total and edible (leaves, stalks, and young shoots) biomass yield was determined as well as the nutritional quality. For both species, pruning every two months produced a high death rate of trees and therefore this treatment was discontinued after the first year of evaluation.

In the second year, the production at both sites was drastically reduced. However, after the second year with prunings every six months, production increased and tended to stabilize (Table 2). The total and edible production obtained at both sites shows that, over the long term, total pruning every 6 months was most favorable for both species.

Table 2. **Effect of pruning frequency on biomass production of *E. berteroana* and *G. sepium* in the humid tropics of Costa Rica**

Years	Frequency (months)	Cariari EB[2]	Cariari TB[2]	La Union EB	La Union TB
1	4	2577 (378)	5435 (800)	11755 (6664)	19103 (10872)
	6	3292 (1917)	9516 (3717)	7906 (2317)	22769 (7134)
2	4	1769 (393)	3132 (519)	5580 (501)	7771 (694)
	6	4218 (555)	8273 (734)	3546 (705)	7483 (982)
3	4	4093 (1271)	6978 (1928)	2661 (1047)	4082 (1918)
	6	9328 (1557)	18853 (2362)	6121 (1282)	11443 (2349)
4	4	4774 (1664)	8310 (2280)	3154 (619)	5646 (1546)
	6	9743 (1646)	18255 (3224)	6520 (875)	10479 (2168)

[1] Dry matter, metric tons/km of fence/year; in parenthesis the standar error.

[2] EB = edible biomass; TB = total biomass

Source: CATIE (1991).

The nutrient value of these species did not vary between farms, or over the years, but was affected by the frequency of pruning (Table 3). In *E. berteroana*, the crude protein content of the young shoots presented similar trends to those of the foliage, although at lower levels of protein (8.6, 8.1, 8.6% for 2, 4, and 6 months, respectively); in *G. sepium*, the protein contents of the young shoots were higher (14.6, 10.9 and 12.9% for pruning every 2, 4 and 6 months, respectively). The *in vitro* dry matter digestibility of the young shoots in *G. sepium* was 45.6, 44.1 and 51.2%; for *E. berteroana* 48.8, 37.9 and 45.8% for prunings at 2, 4 and 6 months, respectively. It will be noted that in both species the quality of the dry matter produced, in terms of crude protein content, is high. Despite the increase of age at pruning, there is not significant decrease in these values.

Table 3. **Effect of pruning frequency on the concentration of protein, and *in vitro* dry matter digestibility of foliage from *E. berteroana* and *G. sepium* in the humid tropics of Costa Rica**

Pruning, months	*E. berteroana* CP, %	*E. berteroana* IVDMD, %	*G. sepium* CP, %	*G. sepium* IVDMD, %
2	23.4	63.0	25.0	66.9
4	23.2	56.3	25.0	58.4
6	20.9	59.4	22.0	51.9

Source: CATIE, 1991

The *in vitro* dry matter digestibility is similar to that obtained with well-managed tropical pastures. Nevertheless, the decrease in quality with age is not so pronounced, giving important flexibility to the producer in the management of these forage trees.

These forage resources are sufficient for a producer, with a kilometer of live fence, to supplement one-third of the crude protein needs of 7.6 cows of 400 kilograms live weight, which are producing 8 liters of milk/day over a one year period of, regardless of which species (*E. berteroana* or *G. sepium*) is used.

2.1.2 Protein Banks. The planting of protein rich forage trees or bushes at high densities up to 20,000 per hectare has been called protein banks. These banks may be harvested by man and carried to the animals in a cut and carry system, or may be grazed directly.

Among the most frequently used tree species for protein banks is *Leucaena leucocephala* which is a good alternative. Nevertheless, it has the inconvenience of being difficult to establish and very dependent on soil conditions and precipitation. On the other hand, banks of *E. berteroana* harvested every 4 months have demonstrated their capacity to sustainably produce 30 tons of edible dry material (equivalent to 6 tons of edible protein) per hectare per year (Table 4). These levels of production per hectare during one year would allow the farmer to supplement a third of the required protein to a total of 49 cows at 400 kg live weight which are producing 8 liters of milk a day.

Similar to what was found with live fences, *E. berteroana* was superior to *G. sepium* in terms of biomass produced.

Table 4. Growth and biomass production (metric tons/hectare/year) of *E. berteroana* and *G. sepium* planted as protein banks

	E. berteroana	*G. sepium*
Number of regrowths	14.0	7.8
Heigth, m	2.6	2.7
Biomass production		
- Leaves	20.9	9.5
- Young stems	9.3	6.4
- Woody stems	23.8	12.1

[1] Average of the 3[er] and 4[th] years of prunning.

Source: CATIE (1991).

2.1.3 Legume trees in pastures. A high proportion of the pastures present in the region have some degree of degradation, reflected in lower soil fertility, as a result of inadequate pasture management. The inclusion of legume trees (in addition to the shade, foliage, and fruits which they provide to the animals) favors nutrient recycling, and improves structure and water balance of the soil. Depending upon species and soil conditions, trees are capable of reaching greater depths within the soil, absorbing nutrients and returning them to the superficial layers through the natural fall of foliage, branches and fruits (Budowski, 1981). This favors species which do not have deep roots by making nutrients form the deeper layers available in the superficial strata. The experimental results that have been obtained from the inclusion of leguminous trees in pastures tend to confirm this.

Table 5 indicates that the presence of leguminous trees in pastures increases the production of available dry matter when compared to pastures which do not have trees. This shows the advantage of the presence of trees in pastures, without this leading to a decrease in animal productivity.

Table 5. Effect of associating leguminous trees on dry matter production of pastures

Treatment	DM offered, kg/ha/year
Pasture only	4019[a]
Pasture and trees	4160[ab]
Pasture and livestock	4240[b]
Pasture and livestock and trees	4518[c]
Standard error	88

[a,b] Values with different suffix differ at $P<0.07$ level.

Source: CATIE (1991)

Another means of utilizing leguminous trees is to combine them with cut forages. When 100,667 poro trees (*E. poeppigiana*) per hectare were combined with "King-grass" (*Pennisetum purpureum x P. thyphoides*) pasture production increased from 13 to 20 tons of dry matter/ha, just because of the combination of trees and pasture species. Production increased up to 30 tons when the foliage fromf the trees wass cut every 4 months and 33, 66 or 100% of the cut foliage was used as a green mulch on the pasture (Libreros, 1990).

To establish combinations of trees and pastures, it is also necessary to select those gramineae which are most tolerant to shade (to date the selection of germplasm of gramineae has been based on growth under full sun). Bustamante (1991) tested eight different grasses with and without poro trees to determine the effect of shade on biomass production of the grasses (Table 6).

Table 6. Accumulative dry matter production of eight gramineae associated with poro trees and alone

Species	With trees	Without trees	Diff, %
Panicum maximum 16061	29804.0	20790.7	30.25
Panicum maximum 16051	27780.0	24986.6	10.00
Brachiaria brizantha 6780	14437.0	10470.8	27.48
Dwarf Elephant-grass	14343.0	16060.7	-10.70
Brachiaria humidicola 6369	9787.0	8161.5	16.61
Brachiaria brizantha 664	8885.0	6175.4	20.50
Brachiaria dictyoneura 6133	8393.4	9467.3	-11.35
Cynodon nlemfuensis	6818.0	4490.0	34.16

[1] Data from five cutting cycles.

Source: Bustamante (1991).

In the case of table 6, the trees were pruned twice a year and the material wwas deposited outside the plots, trying to isolate the effect of the shade.

3. NUTRITIVE VALUE

3.1 Identification of Promising Species

The identification of promising species has been made through various questionnaires and by direct testing in goat herds, to determine the possible differences in palatability between the different species of trees and bushes. For example, table 7 shows some of the species which were identified as having high nutritive value, especially energy, and thus have the potential to be most broadly utilized in goat feeding systems.

Table 7. Chemical composition of the foliage of trees and bushes utilized in feeding goats in Central America

Species	CP, %[1]	IVDMD, %[1]
Morus sp.	24.2	89.2
Cnidoscolus acotinifolium	41.7	84.4
Sambucus canadiensis	29.2	81.2
Sambucus mexicanus	24.3	75.8
Senecio salignus	22.7	73.8
Hibiscus rosa-sinensis	19.9	71.2
Verbesina turbacensis	20.3	69.8
Diphysa robinoides	26.9	69.8
Malvaviscus arborescens	21.0	68.3
Cestrum baenetzii	37.1	65.8
Libidibia coriaria	15.8	61.0
Mimosa platicata	16.4	59.1
King-grass (*P. purpureum x P. typhoides*)	8.0	49.0

[1] CP = crude protein; IVDMD = *in vitro* dry matter digestibility.

Source: Araya (1990).

This table shows that the nutrient content of many of these species exceeds that of tropical pastures such as King-grass. It must be indicated that the crude protein content and the *in vitro* dry matter digestibility of the foliage of tree species varies in accordance with the different components of the branches, the positions on the branch, and is also closely related with the age of the material (Table 8).

Table 8. Dry matter content (DM), crude protein (CP), and *in vitro* digestibility (IVDMD) of different fractions of poro (*E. poeppigiana*)

Fraction	DM, %	CP, %	IVDMD, %
Apical leaves	17.5	38.4	74.1
Intermediate leaves	25.5	30.5	33.5
Basal leaves	26.2	27.1	37.4
Apical stems	17.0	12.2	54.4
Intermediate stems	20.1	10.6	47.4
Basal stems	21.5	9.2	34.1
Bark	17.0	14.1	78.3

Source: Benavides (1986).

4. ANIMAL RESPONSE

CATIE has evaluated the benefits of supplying these foliages to goats and cattle from the economic viewpoint. Given that the nitrogen content of these materials is generally very high and very soluble in the rumen, it is appropriate to supplement with some source of energy which will promote greater nitrogen utilization. Nevertheless, it was not known what the consumption level of different forages was, or to what degree this differed between them, and, therefore, what would be an appropriate level of supplementation. We needed to know what energy source would be most appropriate, if this is to be given at the same time with the foliage or separately, and whether the foliage could be conserved for critical periods of the year. Above all, we needed information on whether this sylvopastoral approach would provide economic benefits to producers, especially under conditions of scarcity of capital and labor.

4.1 Goats

Research conducted at CATIE shows that goats can consume high levels of foliage over long periods of time, and no clinical effects, indicating the presence of toxic factors affecting the health of the goats, have been detected. Although there exist differences between the levels of consumption and efficiency of utilization (Table 9), when different foliages are offered, the results show that the weight gains in young goats is extremely satisfactory.

Table 9. Dry matter intake, and live weight gain of young goats consuming different forage trees

Response variable	*Erythrina poeppigiana*	*Erythrina berteroana*	*Gliricidia sepium*
Intake			
- Foliage, g/an/day	474	585	699
- Green bananas, g/an/day	179	200	222
- Total dry matter, g/kg $W^{0.75}$	67	79	88
Weight gain, g/an/day	35[b]	54[a]	60[a]

[a,b] Values with different letters are statistically different.

Source: ArgÜello *et al.* (1986).

Utilization of poro foliage supplemented with other resources present on small and medium farms has almost tripled daily milk production of goats, compared with those which do not receive the forages (Table 10).

Table 10. Effect of different levels of supplementation of *E. poeppigiana* on milk production of goats fed with green-chop and green banana

Response variable	*E. poeppigiana*, % BW 0	0.5	1.0	1.5	Signif.
Intake, kg/an/day					
- *E. poeppigiana*	0.00	0.20	0.40	0.55	
- Green bananas	0.47	0.47	0.47	0.47	
- Green-chop	0.69	0.67	0.65	0.60	**1
DM intake, g/kg $W^{0.75}$	95	113	126	139	**1
Milk, g/an/day	326	606	695	820	**1
Fat, %	4.4	3.6	3.8	3.6	N.S.

[1] The lineal effect of *E. poeppigiana* was significant ($p \leq 0.05$).

Source: Esnaola y Ríos (1986).

A global analysis of the research carried out with goats shows that production systems combining goats with forage trees provide a realistic and promising agroforestry alternative to promote better landuse, in conditions where there are already problems of soil erosion as well as in the agricultural frontier, where production systems which can stabilize migration of producers to avoid continued deforestation are required.

4.2 Cattle

Inclusion of forage trees in cattle production systems, in combination with other available resources (crop by-products, sugar cane, molasses, green banana, rice hulls, cottonseed, etc.) has become a topic of research at the Tropical Livestock Production Unit of CATIE. The challenge is to design sustainable meat and milk production systems which are compatible with conservation of natural resources. *Erythrina* has been the genus most utilized in the experiments on animal nutrition. Pineda (1986) demonstrated that it was economically feasible to substitute 67% of the protein in the rations of dairy calves with protein coming from poro even though the calves gained less weight than those supplemented with soybean meal. Vasquez (1991) fed dairy criollo cross calves with a sugar cane diet and compared different protein sources: urea, poro and fishmeal. Daily gains were higher in those fed fishmeal, when compared with the poro and urea fed animals (763, 647 and 592 g/day, respectively). Nevertheless, the economic analysis indicated that supplementation with poro gave net incomes 7.7 and 2.2 times greater than those obtained from fishmeal and urea.

Also, Vargas (1987) supplemented grazing Brangus steers with *E. cocleata*, and found an economic advantage when using the tree foliage in combination with green bananas, a source of starch that contributes to improve the utilization of the non-protein nitrogen typical, obtaining higher weight gains than to those obtained using only poro (Table 11).

In relation with milk production, when grazing Jersey-criollo cows were supplemented with poro, it was found that as the consumption of poro increased, milk production of increased in a linear relationship, as described by the following equation: $MP = 8.75 + 1.29X$; where MP is the daily milk production (kilos) and X is the intake of poro dry matter (% of live weight) (Tobon, 1987). These results, together with the research carried out by Abarca (1989), show that it is possible to use poro foliage to obtain milk production levels which are only 9% less than what could have been obtained with fishmeal (Table 12), a high-quality protein supplement very expensive for the producers.

Table 11. Weight gain of grazing[1] steers supplemented with *E. cocleata* as a protein supplement

Treatment	Wt. gain, g/an/d°a
Grazing only (T_1)	398
Grazing + 0.3% BW *E. cocleata*(T_2)	380
Grazing + 0.5% BW *E. cocleata*(T_3)	524
Grazing + 0.7% BW *E. cocleata*(T_4)	509
Grazing + 0.5% BW *E. cocleata* + green bananas[2] (T_5)	579
Comparisons	P ≥ F
E. cocleata, lineal effect	0.08
T_3 *vs.* T_5	0.06

[1] Pasture composition: 50.9% African Star-grass; 34.2% native grasses; 6.2% native legume and 8.9% weeds.

[2] Green bananas represented 20% of the total dry matter intake.

Source: Vargas (1987).

Table 12. Intake and milk production of cows grazing African Star-grass, supplemented with fishmeal or poro as protein sources[1]

	Fishmeal	*E. poeppigiana*
Dry matter intake, % BW		
- Star-grass	1.93a	1.24b
- Supplement	1.08b	1.55a
- Total	3.01a	2.79a
Milk, kg/an/day	9.0	8.2
Total solids, %	3.4b	12.7a
Protein, %	3.2a	3.3a
Fat, %	4.1a	4.3a

[1] Sugar cane molasses as energy supplement.

[ab] Values with different letters are statistically different.

Source: Abarca (1988).

Over the last two years, research has been directed towards evaluating energy sources (molasses, rice hulls, and whole sugar cane) and the levels at which they should be used to achieve maximum bioeconomic benefits from the utilization of forage trees for milk and meat production, either on pasture or when used as supplements to low-quality forages such as jaragua (*Hyparrhenia rufa*) in the dry season. Supplementation with poro to dairy cattle fed on sugar cane has been shown to be a bioeconomically viable alternative, obtaining productions of 9.6 liters per cow per day (Alagon, 1990). Similarly, Corado (1991) using Jersey-criollo cross cows on pasture, supplemented with poro (0.38 kg of dry matter/100 kg of live weight), reports a production of 8.8 liters of milk per day, that could be increased to 9.7 liters per day simply by supplementing the cows with a low level of rice polishings (0.2 kg dry matter per 100 kg live weight). This supplementation represented an increase of 12% in the net income.

Some of the results of these experiments are presented in the poster section where they are explained in more detail.

5. CONCLUSIONS

1) Preservation of the environment and the natural resource base can be combined with productive activities such as livestock production (cattle and goats) when this is done with an agroforestry approach.

2) Utilization of trees on livestock farms can increase the production of pasture, milk, and meat, simultaneously providing additional important benefits such as shade, fences, firewood and lumber. In addition, trees protect the soil from erosion and can increase the fertility of the soil under pastures through the recycling of excreta with a higher content of nutrients.

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THE EFFICIENCY OF INTERACTIONS BETWEEN ANIMALS AND NATURAL RESOURCES WITH PARTICULAR REFERENCE TO CENTRAL AMERICA

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1. INTRODUCTION

Traditionally, we consider that the efficiency of production of agricultural animals (animals of economic use) is supported by four pillars: a) the genetic base of the animal population; b) the nutritional inputs; c) health; and d) management. These four elements are closely linked among themselves along a vector of increasing complexity leading from the individual animal organism and its interactions with natural resources, to the interactions of the natural resources with society as a whole.

The analysis of these elements away from their integral context is frequently responsible for the failure of technological interventions in the Latin American context. For example, it is not uncommon to bring into a farm genetic material whose productive potential is not achieved because of insufficient feeding, or because of a high incidence of infectious diseases, inadequate management, or simply because there is no adequate market for this product. On the other hand, sometimes there is excessive investment in feeding, health control, and sophisticated installations for an animal population whose genetic base could never repay the investment.

The characterization of this vector, individual @—@> natural resources @—>society, through a systems approach focused on the four components of production, is also a partial or incomplete analysis. Insofar as the complexity grows along this vector, so do the impacts of external factors on the system and on the specific object of the analysis (the animal population).

Thus, the complex of natural resources, including the animal population, also contains the diversity of species which make up its biomass. The "natural" logic of ecologic productivity also implies preservation of biodiversity. Social intervention in the ecosystem in favor of any one species must take this fact into account as one of the fundamentals for a sustainable exploitation. On the other hand, society -the organized group of humans who exploit natural resources- command a very broad range of alternatives to make decisions according to its needs for survival, reproduction, and growth. Among those alternatives are animal agriculture, agricultural crops, trade, industrialization, food self-sufficiency, export, etc. (Figure 1). Thus, the efficiency of interaction of an animal population with natural resources can only be evaluated as a function of their economic, social, and cultural roles within a particular ecosystem. This is the reverse sense of the vector previously indicated: society-natural resources- animal organisms.

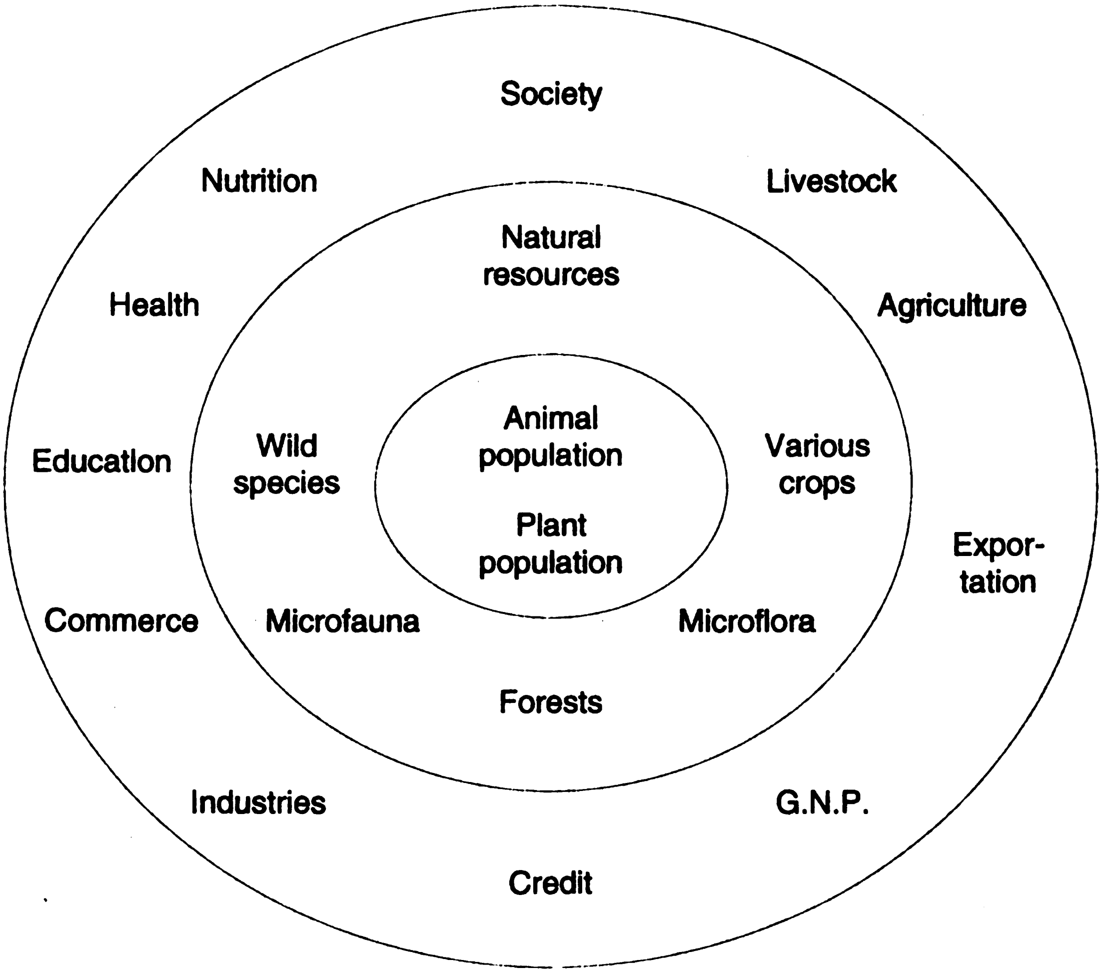

Fig. 1 Production alternatives of man in society

The scope, analytical categories, and the disciplines of study relative to animal production are unique at each one of the levels of complexity. Hence, it is necessary to consider: a) the "efficiency of the livestock block" within the national development, b) the social and economic efficiency of the different forms of livestock production in the context of development strategies, c) the ecologic efficiency of animal population in relation to its ecosystem, and d) the physiologic efficiency of an animal organism in converting vegetative nutrients to value-added products.

2. OBJECTIVES AND GOALS OF LIVESTOCK IN NATIONAL DEVELOPMENT

The determining frame of reference for the evaluation of the efficiency of interaction of livestock with natural resources, depends on the role played by the animal industry in the economic and social development of the region, and in each country in particular.

Livestock development fulfills, in varying proportions, three fundamental objectives: a) provision of food for urban populations, b) food self-sufficiency for rural populations, and c) export of animals and of their products or byproducts. In this paper we will not address the complexity of the livestock block which includes, in addition to the primary sector, a broad range of financial, commercial, and industrial interests[1].

In Central America, the first two objectives have as their goal food self-sufficiency (i.e. the reduction or elimination of food imports and a simultaneous increase in animal protein consumption). The third constitutes an important component of the trade balance.

2.1 Efficiency of Livestock in Feeding the Urban Population

The elevated malnutrition indexes of in most Central American countries are well known[2]. In addition to the problems of political, economic, and social nature, which impede access of an important group of the population to foodstuffs with an adequate content of calories and protein, food supply is not enough to guarantee that minimum nutritional requirements are met. This deficit is partly compensated by the importation of foods, especially milk. Thus, the efficiency of the interaction of livestock with the natural resources in the region must be evaluated, independently of indexes of production and current productivity, in relation to the generation of an adequate supply to satisfy the nutritional requirements in the region.

The goal must be established, therefore, in terms of the balance of supply and demand and the *per capita* consumption of total animal protein. The type of protein actually consumed is less important. Thus, the efficiency in production of foods of animal origin for local urban consumption will be related to the comparative advantages of the natural and social resources available, i.e. the relative costs and opportunity costs for the production of each one of the animal species and their products (cow milk, goat milk, eggs, poultry, pork, beef, etc.). To this end we must consider the cost-effectiveness ratio for social intervention to promote the production of various species, and for the correction of the most important constraints limiting their cycle of production. At the macrogeographic level, it is normally more efficient to consider a policy of modest increase in productive indexes in general, than a sophisticated technologic intervention directed at only one of them.

Let us consider the national production of milk. If at present we have production X, deficient for the nutritional needs of the population, a goal is proposed to increase production gradually to achieve X + Y in the time t1; X1 + Y1 in t2, etc. We assume the following actual average indexes:

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[1] *A methodological proposal and a detailed analysis of the livestock block can be found in Lifschitz and Zottele (1985).*

[2] *A detailed analysis of the situation can be found in: OPS/OMS (1987).*

- Age at first calving (precocity): 45 months
- % pregnancy (fertility): 60%
- % live births (- abortions and neonatal deaths): 75%
- Calf mortality: 10%
- Cow mortality: 5%
- Calving interval (for fertile cows): 15 months
- Average daily milk yield: 4 liters
- Lactation length: 240 days

With these indicators, the farm will produce about 20% female calves per year, which is scarcely enough for the replacement of cull cows. The size of the national dairy herd is therefore stagnant.

Decreasing age at first calving by 10% (40 months) and the calving interval to 13 months will produce at least one additional lactation during the useful life of a cow, which implies a potential increase in the herd of approximately 20%, reducing the percentage of cull cows from 20 to 16% percent. The intervention, aimed at improving 10% the percentage of pregnancies (66%), of live births (82%), and the survival of calves (91%) will yield an increase of 20% in the number of cows available for milking. A modest increase in average daily milk yield and lactation length, to 5 liters and 270 days respectively, will mean an increase of milk production of 60 to 70 percent. After 4 years of having achieved these new indexes, milk production will have been doubled.

To achieve this goal efficiently, it is necessary to take each one of the indicators mentioned and analyze the principal factors which affect them, and estimate the magnitude which each one contributes in the final result, and the technological, cultural, and economic feasibility of intervening to bring about changes in the indexes (Table 1).

Table 1. Factors limiting milk production

	Genetics	*Nutrition*	*Reprod. managmt*	*Herd managmt*	*Health management chronic*	*Health management acute*
Precocity	+++	+++	+++	-	++	+
% pregnancy	-	++	+++	-	++	+
% Calving	+	++	-	++	+++	+++
Calf mortality	-	+++	-	+++	+	+++
Adult mortality	-	+	-	+++	++	+++
Calving interval	-	+++	+++	-	+++	++
Milk/day	+++	+++	-	+++	+++	++
Lactation length	+++	+++	+++	+++	+	+

Let us examine the first one: average age at the first calving in the country stands now at 45 months, and the goal is reducing it to 40 months. In a particular area, the following causes may contribute to determine precocity; the relative influence is also given:

- genetic improvement: 40%
- nutritional improvement of calves: 30%
- elimination of some infectious diseases (brucellosis, vibriosis, trichomoniasis) and parasites: 20%
- reproduction management: 10%

This same process is carried out for each one of the productive indexes mentioned. Their relative weight varies with each ecosystem (livestock production system, geographic area) and intervention in some of them may impact simultaneously on one or several others[3].

2.2 Efficiency of Livestock Production for Food Self-sufficiency of the Rural Population

The goal of animal production in this case is the simple reproduction of "campesino" families and, optimally, the generation of excesses of product which can be sold. It does not matter here, from the point of view of the efficiency of animal production, what the animal species is, or the type of product obtained, as long as it is, directly or indirectly, used as food.

On the contrary, one of the factors which has contributed most to the decrease in the quality of "campesino" life has been the implementation of improved vertical technologies destined to increase the production and productivity, over a short term, of a single species or product (bovine milk, poultry, swine, rabbits, etc.) in detriment of biodiversity. The greater productivity of the economically active biomass per unit area, in this case, does not reflect a greater efficiency of sustained productivity. Also, some negative effects could appear over the long term: a) greater probability of exhausting or eroding the soils; b) less possibility of completing a trophic cycle which would benefit from eventual productive symbioses; and c) promotion of a greater degree of dependency on the market for inputs and products in a sector of the population that normally has a low probability for insertion in trading[4].

The efficiency of animal production must be evaluated based on the nutritional demand of the rural sector, and to the degree to which this demand is met by local production. The efficiency of animal production may be indirectly estimated based on the evolution of rural-urban migration. In addition, an objective should be to increase the production of excesses, which could be destined to urban consumption, but at the same time, should not endanger the overall scheme of diversified production.

Taking into account the characteristics of "campesino" animal production (see Section 3 below), genetic manipulation is not very feasible, mainly because of the nutritional care and management it requires. Rather, consolidation of the hardiness of local breeds should be sought. It is unlikely that facilities would be improved to significantly benefit management, or that nutritional practices using expensive external inputs would be adopted. The main impact of intervention in this production sector is, therefore, based on animal health practices destined to combat chronic diseases, particularly zoonosis due to close animal-human contact and the marginal conditions of hygiene.

The efficiency of production for local consumption can also be increased by the replacement or the addition of animal species more appropriate to local cultural practices and the available natural resources. For example, frequently a "campesino" with 2 or 3 cows will have one of these in milk. In some cases it is convenient to replace these cows by dairy goats.

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[2] *In relation to critical nodes methodology in strategic planning see Matus.*

[4] *A detailed analysis on the potential negative impacts of agricultural modernization can be found in Gligo (1981).*

Frequently, the "campesino" will retain the male calves after weaning as a financial security. The early elimination of the male calves and the raising of pigs as a financial fallback may be more efficient. The raising of alternative backyard species, such as rabbits and chickens, may also contribute to improve nutrition and family income in this sector.

2.3 Efficiency of Livestock Production for Exportation

Evaluation of the efficiency of animal production as an export activity is extremely complex because of the competitive role played by this activity with regard to food supply for urban and rural populations, discussed above.

At the macroeconomic level, in many cases the increase of production for exportation is achieved at the expense of production for local consumption, aggravating the deficit of available food. Frequently, the increased income in hard currency under the heading "livestock exportation" is accompanied by an even greater demand on hard currency to support importation of foods.

On the microeconomic level, production directed to exportation (for example, integration of poultry or swine), may place the "campesino" family in a position of yet greater dependency to meet their own nutritional needs. On some occasions, the generalization of production for export implies a general deterioration of soil resources. This is the case when cattle are raised extensively for beef at the expense of forest resources, but is even more frequent in crop plantations.

At present, the most obvious export activity is that of beef production, generally of lower quality, for the North American market. Assuming that livestock production for export does not compete with the production of food for local consumption, nor with the sustainability of natural resources, the increase in its efficiency could be facilitated by opening additional international markets and enhancing the quality of the products, more than by increasing the volume exported.

In this sense, the comparative non-tariff advantages for Central American countries exporting livestock products lies on the exclusion of risks of transmitting exotic diseases to the importing countries, on the supply of products of high "ecologic" value, and on the development of extraordinary genetic quality.

In the first case, a priority must be to continue preventing the introduction of foot-and-mouth disease and other exotic diseases, particularly some of the chronic diseases found in some of the traditional importing countries, such as spongiform bovine encephalitis, CAE, Scrapie, Maedi-Visna, mycoplasmosis, etc.

In the case of beef, it is important to promote production and industrialization within conditions ensuring excellent hygienic quality and the absence of undesirable contaminants (agro-toxics residues, antibiotics, hormones, etc.).

The development of better genetic quality, particularly that destined to the export of breeding stock, could take advantage, for example, of the possibility of creating a quarantine area for raising Zebu livestock of high quality. The current availability of embryo transplant techniques is, as yet, an underexploited resource in this respect.

3. OBJECTIVES AND CONSTRAINTS TO LIVESTOCK PRODUCTION IN VARIOUS PRODUCTION SYSTEMS

In accordance with the introduction of livestock production activities into the economic and politic system, it is possible to characterize the most important forms of production[5] in Central America in the following manner:

a. Pre-commercial systems
   - Pre-commercial extensive production of beef cattle

b. Commercial systems
   - Cow-calf operations
   - Growing and finishing cattle
   - Bovine milk production
   - Goat milk production
   - Raising and fattening swine
   - Poultry production for meat and eggs

c. Campesino production systems
   - Simple family marketing
   - Credit and supply cooperatives (multi-family)
   - Production cooperatives
   - Integration
   - Subfamily

The basis for this classification of production forms is not technologic and should not be confused with "livestock production systems". It responds, rather, to a structural system and its logic is basically economic and social (Table 2).

These forms of production are not randomly distributed; they normally predominate in certain geographic areas. Through the use of specific indicators, it is possible to characterize the predominance of each one of these forms of production according to political units or homogenous geographic quadrants.

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[5] *On characterization of livestock production forms in Latin America see Rosenberg (1986).*

Table 2. Relationship between forms of production and productivity of production factors

Forms of production	Productivity of Land	Productivity of Capital	Productivity of Labor
Precommercial	+	++++	++++
Commercial cow-calf operations	++	+++	+++
Growing and finishing cattle	++/++++	++++	++++
Commercial milk production	++++	++	++
Commercial swine production	++++	++	+++
Commercial poultry production	++++	+	+++
Simple family marketing	++	++	+
Credit and supply cooperatives	++	+++	+
Production cooperatives	+++	+++	+++
Integration	++++	++++	+
Subfamily	ò	ò	ò

Source: Adapted from Rosenberg (1986).

Let us consider an imaginary Central America country made up of the following areas (figure 2):

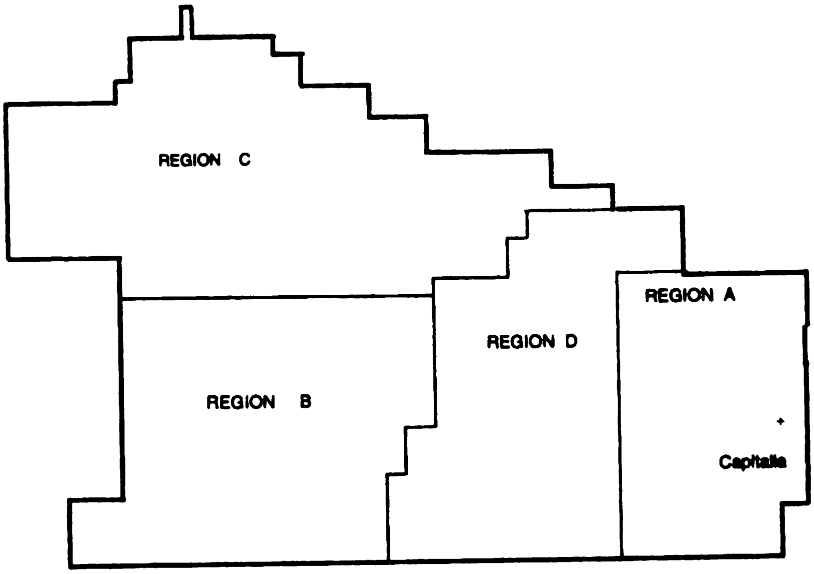

Fig. 2 CENTROLAND REPUBLIC : CATTLE REGIONS

3.1 Region A: Milk Basin

Here, there is a predominance of commercial dairy enterprises with processing plants; 30% of the product is exported and the rest is sent to the capital city. There are some family farms which produce milk, swine, and poultry for consumption in the capital city and the surrounding area. There are a few commercial swine fattening enterprises whose product goes to export packing houses, and meat processing factories.

This region represents one of the sectors of greatest potential development of livestock within the country. The reduced margin of profit of the commercial dairy activity, together with the dependency on a market for immediate consumption, given the perishable nature of the product, requires that each investment alternative be accompanied by an exhaustive economic-financial analysis. In the commercial systems the use of land is extremely intensive. On the other hand, it requires high investment in technology, facilities, and labor. The increase in production, therefore, must have the purposes of increasing the supply of milk products for national consumption and exportation, and of improving the profitability for the individual producer.

From the regional point of view, health programs with the dual objective of improving the productive indexes and guaranteeing the consumers' health are a must, along with programs of technical and financial assistance which will assure the producers' access to technological innovations in the area of computing, genetics, reproduction, milking, and processing. Characterization of the milk, based on sanitary and quality characteristics, constitutes an adequate stimulus for introduction of improvements in production.

Family farms take advantage of cull cows from the commercial farms to improve the genetic quality of their herds. Thus, it is common to bring congenital or infectious diseases into the herd, frequently contributing to further reduce their productivity, instead of increasing it. In these cases, as well as in case of the "campesino" swine fattening operation, the commercial sector should support the official activities designed to avoid the risks of transmission of endemic diseases. A good measure might be the detection and replacement of reactor animals through a commitment to improvement of hygienic conditions on the farms.

3.2 Region B: Pre-commercial Cow-calf Raising

Here the predominant farm is for extensive extractive raising of beef cattle. Steers at 18-40 months of age are destined to fattening, finishing and/or slaughter in region C, and cull cows go to the slaughterhouse in region D. Many subfamily production units are also present.

This region is ecologically characterized as having impoverished soils and scarce natural vegetation. There is underinvestment and the extensive exploitation requires very little labor. Thus, the productivities of capital and of labor are maximized while the production per unit area is minimum. The increase in the latter requires profound structural transformations at the regional level, possibly with the construction of dams, canals for irrigation, road improvement, and high investments at the farm levels, including the establishment of pastures and facilities. The profitability of these investments is doubtful and will depend on the potential for restoration of the soils.

On the other hand, in some cases animal health matters exceed in importance the logic of profitability of the operation. Because of the characteristics of the livestock production system, the herds typically become endemic ecosystems for a number of infections whose clinical impact on production is maybe less than their cost of elimination. Nevertheless, the maximum incidence of these diseases is manifested in region C, which receives cattle from region B; this makes necessary a greater investment in health control in region C, and the possibility of causing the imposition of restrictions on international commerce.

Normally the achievement of a sustained increase in the efficiency of animal production in this region will be made through decisive political intervention, and will require sound investment, rational division of the land, and the mechanisms of colonization or urban-rural migration to ensure a greater availability of labor. The mere incentive provided by the market (for example, a significant increase in the price of beef with the opening of external markets) may result in regional deterioration over the long term (increase in deforestation, exhaustion of the soils, badly planned dikes or dams, etc.) (Gligo, 1981).

3.3 Region C: Commercial Raising and Finishing Cattle

Here we find commercial breeders, growers, and fatteners of cattle for beef destined, in large part, to the slaughterhouses that exist within the region. Reception of young stock for fattening from region B. Sixty percent of the production is destined to the export market.

In this region we find the best pastures in the country. Various agricultural crops guarantee the seasonal existence of stubble and other feed supplements. Because of its position in the primary sector of the livestock block, it is here where prices are determined for the rest of the production systems but, at the same time, is dependent on the nutritional status, the genetic quality, and the health conditions of the breeding and growing farms (pre-commercial, commercial, and family). The economic logic, based to an important extent on cash flow (purchase of animals for fattening, possibility of establishing seasonal contracts for land use), gives it a great deal of flexibility in terms of the investment alternatives if the conditions in the beef market are not optimal (retention of cattle, replacement of livestock activities with seasonal cropping, investments outside the sector, etc.).

Therefore, the efficiency of this productive activity is closely and directly linked to the level of development of the livestock block as a whole (up towards the beef market, the packing houses, the supply industry; down towards the technological improvements in the steer production chain). The specific actions must give priority to: a) health programs in order to increase the rate of conversion (mainly through research and transference of technology on nutrients and parasite control) and b) prevention, control, and eradication of diseases which may lead to non-tariff trade barriers for exports.

3.4 Region D: Family Livestock Production Units

Here there is a predominance of family dairy farms, and some rustic production of swine. There is family poultry production, as well as some commercial poultry operations. Seventy percent of the producers are associated, formally or informally, to cooperatives or communities. The whole production is destined for consumption in the capital city of the country (Region A), and in the main urban center of the region.

This region has the highest relative rural population of the country. Animal production is subsidized by the abundant family labor available but, at the same time, the lack of efficient productivity may occasionally provoke waves of urban migration which further increases food deficiencies in the cities. Given the predominant family characteristic of production, and the scarcity of land for expansion, productivity increases can only be achieved through technological improvement including better animal health. Nevertheless, the simple social structure does not favor the accumulation of capital for this purpose. The most adequate solution, therefore, depends on cooperatives for production, credit, supplies, new technology and commercialization.

Because of their dealings with major commercial dairies and others, this region becomes an endemic ecosystem for certain chronic diseases which lead to culling in the commercial dairies (particularly diseases of reproduction including brucellosis, tuberculosis, mastitis, etc.). The availability of credit, therefore, must be accompanied by: a) a commitment of a hygienic/animal health nature on the part of the producer, and b) improvements in the industrialization and marketing channels as well as technical assistance on the part of official organizations and cooperatives. As mentioned before, the implementation of technologic innovations concentrated on a single type of production, may affect biodiversity as well as the economic, ecologic, and social strategies fundamental to this production system.

4. ECOLOGIC EFFICIENCY OF LIVESTOCK PRODUCTION

The intervention of man in the ecosystem of the Central American Isthmus was minimal before the conquest. Rather, as a natural component of the ecosystem, man extracted (through hunting and fishing) animal resources whose reproduction was assured.

The new animal species introduced with colonization were favored with privileged protection by man. In consequence, because of their reproduction and population growth they surpassed and replaced many of the native animal species.

The structuring of society into economically and socially defined production systems determined certain territorial occupations. The interactions of those occupations with natural resources became gradually differentiated, forming characteristic ecosystems according to their economic relationship with cattle.

The possible results of this process can be schematized as shown in table 3.

4.1 In Relation to Total Biomass

The objective of livestock colonization has been to replace socially unproductive biomass for renewable ecologic products whose exploitation will yield a direct benefit to society (food, clothing, byproducts of pharmaceutical and cosmetic use, etc.).

This replacement is accompanied by the following consequences on the total biomass of the ecosystem:

> **TYPE I:** The reduction in biodiversity may lead to a gradual and sustained deterioration of the capacity of the ecosystem to generate biomass. Eventually, the ecosystem will become totally unproductive.

This process is characteristic of the expansion of the livestock frontiers in amazonic and pre-amazonic areas, which had been previously subjected to a devastating exploitation of the forest. The destruction of the forest ecosystem drastically reduces the biomass at first. Subsequently, livestock occupation not only prevents its regeneration but usually unleashes a gradual process of soil erosion[6]. This is also observed when marginal lands are occupied by "campesino" families.

Table 3. **Determination of ecosystems according to the form of livestock production**

Form of productio	Ecosystem		
		Interspecific	
	Biomass production[1]	Acute infections	Chronic infections
Precommercial	TYPE I TYPE III	 Endemic	Endemic Indemnified
Commercial beef production	 TYPE II	Endemic[2] Paraendemic	Tendency to indemnified
Commercial milk production	TYPE IV TYPE V	 Paraendemic	 Paraendemic
Commercial swine (breeding) and poultry aves	TYPE V	Paraendemic	Indemnified
Commercial finishing (cattle and swine)	TYPE IV TYPE V (feedlot)	 Epiendemic	 Indemnified
Simple marketing	TYPE II	Paraendemic Epiendemic[3]	Endemic
Family association	TYPE II TYPE IV	 Paraendemic	 Paraendemic
Subfamily	TYPE I	Indemnified	Endemic

[1] See Section 4.1.

[2] Trasmitted byr vectors.

[3] In areas close to slaughterhouses, milk processing or biologic industries.

TYPE II: Biodiversity is affected and the total production of biomass is reduced but stabilized at a new level, which allows a greater sustained use of natural resources.

Commercial beef raising generally occupies medium to large extensions of land whose natural resources allow vegetative growth for the animal. However, the quality of the soils is not appropriate for intensive agriculture, or for the efficient conversion of pasture into animal protein. The development of pasture implies the reduction of biodiversity and biomass production, but the replacement of wild species for cattle generates a greater economic value. The preservation of the fixed investment, based on the animals as capital, requires the maintenance of the natural resources in order to sustain the commercial enterprise.

The simple forms of trading, either as single or multi-family, determine a similar process but, given the greater scarcity of land resources available, their strategy focuses more on the diversity of the species raised than on the technological investment. In this regard, this is the system which most closely mimics the natural logic in its ecologic maintenance.

[6] *The social, political, and ecological implications of this process are described by Revkin (1990).*

TYPE III: The replacement of wild animals by agricultural species is slow and of minimal significance. The total biomass produced is similar, but the proportion with social use is significantly greater.

This process occurs with the precommercial forms of raising cattle for beef. Here, the intervention of man is almost limited to the introduction of livestock capital to the ecosystem, to reproduce itself in open competition with the existing species.

TYPE IV: Biodiversity is critically affected but the technological investment is capable of making the ecosystems work "artificially", so that animal production may be sustainable as long as the investment is maintained.

This type corresponds to commercial milk production, commercial fattening of cattle and pigs; in some cases, vertically integrated cooperatives are included in this category. The intensive extraction of products relative to land is only sustainable through high investments, destined to complement external nutritional inputs and/or intensify the internal production of vegetation (artificial pastures, irrigation, fertilization, etc.). The commercial forms of fattening cattle, particularity those operating on rented land, are the ones with the greatest risk of exhausting the available natural resources, because of overgrazing, lack of soil rotation, etc. which, once they are exhausted, will be substituted by others. In this regard they have some similarity with the process in TYPE I.

TYPE V: Optimally, total production of absolute biomass will be increased, as well as the proportion of socially useful biomass, through the creation of a "quasi artificial" ecosystem.

This process is generated through livestock operations which depend on heavy investment, and produces an artificial microenvironment sustained through inputs of external origin. This is characteristic of intensive poultry and swine production, feedlots, and ultraintensive dairies.

4.2 In Relation to Interspecific Interactions

Of particular interest here are the interactions with parasitic microorganisms capable of limiting animal production and productivity[7].

4.2.1 Endemic ecosystems. The characteristics of the livestock production activity in the ecologic space determine a stable host-parasite relationship, whereby both species live without significant reproductive limitations.

The pre-commercial form of production based on intensive extraction provides ideal epidemiological conditions for the endemic reproduction of infectious agents (bacteria, viruses, endo and ectoparasites) of acute cycles, including those transmitted by arthropods and other vectors. Despite the investments destined to the prevention and control of these diseases, some areas where beef cattle production predominates might form endemic ecosystems for vector transmission.

Chronic infections are characteristically endemic in the family and subfamily production forms where, for the reasons already mentioned (some animals are carriers of chronic diseases eliminated from the commercial production herds). Some of the chronic infections, such as tuberculosis, may also be endemic in the precommercial production systems.

[7] *A schematized explanation of the ecosystems of infectious diseases is presented in Rosenberg (1976 and 1986).*

4.2.2 Epiendemic ecosystems. The infectious agents are endemic in the ecosystem because of their continued introduction from the outside. Occasionally, in a cyclic seasonal manner, there is a combination of an increase in the number of susceptible animals with the introduction of high doses of the infectious
agent, which results in epidemic outbreaks.

These ecosystems are characteristic of the systems of fattening cattle and swine, which are sometimes subjected to the introduction of animals from endemic areas. In addition, epiendemic ecosystems are found in areas of family-scale production, located near processing industries for animal products (slaughterhouses, or dairy processing plants), or laboratories for production of biologic products (production and/or control of vaccines, diagnosis, and research).

4.2.3 Paraendemic ecosystems. The infectious agents which limit animal production are naturally or artificially (due to prevention and control) excluded from the ecosystem. Nevertheless, occasionally they might be introduced, particularly if there are epidemics in other ecosystems.

In regard to the acutely transmitted infectious, these are paraendemic in regions where there is a predominance of beef and dairy industries, swine and poultry production, and frequently where there are cooperatives or associations of family units. Even though animal health interventions are scarce, the areas of simple marketing production are also considered paraendemic. This is due to their natural isolation and the characteristic epidemiological conditions (low or very high regional density, small herds).

Chronic infections are occasionally found in milk basins and in the family production groupings.

4.2.4 Indemnified Ecosystems. Indemnified ecosystems are those where, due to natural barriers or to the preventive actions of man, infectious agents are totally excluded. In Central America, only marginal areas with subfamiliar production systems are protected from the majority of acute infections (we refer here to those infections which are already endemic in the region).

On the other hand, those areas which are predominantly commercial are, or tend to be, protected from chronic infections.

5. PRODUCTIVE EFFICIENCY OF ANIMALS OF ECONOMIC INTEREST

From the individual point of view, the efficiency of an agricultural animal is evaluated as a function of the economic potential it is capable of generating. This level of analysis is based on the physiologic capacity of the animal; therefore, it disregards the concrete considerations of its exploitation which were previously analyzed.

The following indicators of efficiency must be taken into consideration, according to their order of priority:

5.1 Reproductive Capacity

- **Ecological value:** Every healthy, well-nourished, and adequately managed female in reproductive age should achieve parturition at each estrous cycle. Any result less than this must be considered as inefficient, independent of any consideration of cost/benefit.
- **Genetic value:** Depending on the genetic background, the number of young produced per parturition constitutes a second level of evaluation for their reproductive efficiency. This consideration is particularity important in small ruminants and swine.

- **Technologic value:** The availability of embryo-transplant technology nowadays allows the evaluation, based on economic considerations, of the potential for increasing the number of offsprings per parturition, particularity in the case of bovines.

5.2 Milk Production

- **Ecological value:** Any female, independent of its economic utilization, should be capable of adequately nursing its offspring.

- **Genetic value:** In general, the genetic value of milk production (in any species) is measured through the total volume produced per lactation, and through the content of fat and total solids in the milk. The availability of artificial insemination and embryo transplant techniques allows considering the possibilities for replacing the genetic potential in a herd over short periods of time.

- **Technological value:** In the first place, we must consider the effects on ration formulation. In addition, the milk production capacity has been increased tremendously through the use of anabolic hormones, particularity hormone precursors of the somatotropin.

5.3 Production of Meat

- **Ecological value:** The offspring should have a minimum weight to guarantee their growth potential.

- **Genetic value:** Some genetic characteristics are weight at birth, precocity, and feed conversion curves. Depending on the demand, the quality of the product may be selected genetically.

- **Technological value:** The dietary composition, and the utilization of growth promoters (hormonal and non-hormonal).

5.4 Resistance to Disease

- **Ecological value:** In order of priority: the individual must not die from the disease, it must not be affect in its reproductive cycle, nor its production be decreased.
- **Genetic value:** There are breeds and crosses (generally with indigenous cattle) with greater resistance to the impact of certain diseases. Generally, this genetic effect is opposed to selection for production.

- **Technological value:** From the point of view of scientific and technologic understanding, it is possible to recognize that nowadays, most diseases can be diagnosed, prevented, controlled, or eradicated.

6. PERSPECTIVES FOR A SUSTAINABLE INCREASE IN LIVESTOCK EFFICIENCY: CONCLUSIONS

Despite the critical economical and financial situation which limits substantially the ability to invest, both in the public and in the private sectors, there are important steps that can be taken to increase the efficiency of livestock production in the region. Moreover, the very possibility of social development and economic growth is based, to a great extent, on the rationalization of the use of the existing natural resources.

At each of the four levels of intervention identified (policy, production system, ecosystem, and individual) there is technical knowledge available, to adapt the best possible solutions to the different existing realities (national, regional, and local).

Nevertheless, in our opinion, two strategic considerations transcend political will: economic capacity and availability of technology to intervene correctly in the sector. On one hand, it takes wholehearted belief, commitment, and participation of the community in the planning and execution of the relative actions. On the other hand, this participation is only possible when there exists a system of information that permits the recognition of the principal constraints of production, their origins and possible solutions[8].

As in any productive activity, the efficiency of livestock production depends in large part on individual initiative, in response to market conditions. Nevertheless, competition for the use of limited natural resources, as well as the eminently social character of animals as a source of food, demand active communal participation in sectorial decisions.

One of the most important constraints on livestock production and productivity are infectious diseases. Because of their transmittable nature infectious diseases require community action for their control.

While community participation should occur at all levels of development of livestock policy, it is at the local level (town, county, locations) where it should be most marked and active. To this end, some mechanisms should be found (preferably formal mechanisms) to bring together, under the responsibility and coordination of the state, representatives of the different forms of primary production: producers of inputs; representatives from processing industries; agents of financial and technologic services (both official and private); and representatives of consumers. The objective of their work would be to evaluate the alternatives (individual and joint) for achieving a sustainable increment in livestock efficiency.

The fundamental input for the work of these "Local Livestock Development Commissions" shall be given by the organization of an information system, based locally, which would allow for the monitoring of the evolution of some critical demographic and bioproductive indicators, including birth rates, death rates (of calves and adults), and production. These indicators would be complemented by epidemiological vigilance, which would generate lists of outbreaks of important infectious diseases, livestock flows, populational diagnosis, etc.[9]

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[8] *In relation to the role of community participation at the local level of veterinary services, and development of bioindicators vigilance systems see: Astudillo, Serrao and Dora (1991) and Cotrina and Astudillo (1991).*

[9] *A similar system has been implemented by the Veterinary Medicine Institute in Cuba, in cooperation with the CPFA/HPV/OPS.*

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EFFICIENCY OF PROCESSING ANIMAL PRODUCTS

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1. INTRODUCTION

Data from the World Health Organization indicate that with current technology we could provide the food necessary to feed the world population. Nevertheless, the problems of feeding the population of the planet and the elimination of hunger in the world cannot be resolved solely through an increase in agriculture production.

While many countries in the developing world have not achieved even the minimum requirements of nutrition, other countries continue to have an excess of food. Regrettably, often within developing countries there exist regions with an oversupply and other zones which cannot cover their basic necessities. One of the features which should concern us most is that in tropical and subtropical areas of the third world, it is not really the deficiency of meat or cereals which is responsible for the undersupply to the population, but rather that 20-60% of all of the food produced each year deteriorates before it reaches the consumer.

According to FAO researchers, at least 800 million people in the world suffer from hunger or show clinical symptoms of malnutrition. The solution has generally been to send basic foodstuffs from the industrialized countries to the developing countries, but this is anti-economic. It is anti-economic because the developing countries generally lack the necessary logistical infrastructure (storage facilities, transport, financing, etc.). In addition, these type of measures tend to retard the potential development of the country itself, which could endanger the local food security.

Thus, countries of the third world need industrial technology and equipment to increase the production of foods. Improvement in post-harvest handling of agricultural products could not only increase food security for the population but also improve the situation of the producers. Due to the inefficiencies in the system their returns sometimes do not even cover the cost of production. Greater post-harvest efficiency could lead to better sale prices, better investments to make livestock production more intensive, sustainable, and able to meet the changes needed at present. To make the best use of our natural resources it is necessary that the whole production system and the mentality of those participating in the process share this goal and that production be as efficient as possible.

This paper is based specifically on the analysis of the post-harvest process, if I may call it way, of beef and pork.

2. LOSS OF WEIGHT AND QUALITY

First of all, a table is included which summarizes the loss of weight and quality occurring at each different stage in the transformation of the live animal to fresh meat and processed meat products. In this way we will have an idea of the critical points which need to be controlled, and where we need to dedicate the most attention (Table 1).

Table 1. Losses in the different stages of processing live animals to meat ready for consumption

Stage	Weight, kg	Loss, %
Live weight at farm	380	
Live weight at slaughterhouse)	349	8
Hot carcass weight	202	42 (by-productos and wastes)
Cold carcass weight	198	2 (refrigeration)
Transport to plants	196	1 (transport)
Deboning	147 145	25 (bones) 1 (wastes)
Industrial meat - fresh meat	142	2 (refrigeration)
Point of sale processing	139	2 (transport and refrigeration)

We start with the live animal which is transported from the farm to the slaughter site. The losses of weight begin at this point, depending on factors such as inadequate management, including bad conditions in the trucks (when trucks are available). The time of day when the transport of animals occurs is another stress-determining factor. In a study carried out in Guatemala, it was shown that the distance of transport was not as critical as the state of the road. In some cases, the animals are walked for very long distances and this results in a large weight loss.

On arrival at the slaughterhouse, the animal should have a rest and fast period sufficient to favor the quality characteristics of meat. For example, when animals are submitted to a great deal of stress prior to sacrifice, there will be biochemical changes in the muscle which provoke detrimental effects in the quality of the meat and in its characteristics for processing and storage. In the case of swine, the effect may be so severe that animals which are very tense prior to slaughter may die even before stunning. We will see the effect of this in greater detail later on. During slaughtering, the stunning and bleeding processes must be carried out with great care in order not to further increase yield losses.

From live weight to carcass weight we have a loss of 42 per cent. There could be a better utilization of by-products, such as blood, which represents 7.7% of total body weight. It has been calculated that in modern slaughterhouses it could be possible to obtain approximately 4% of the total weight of the animals as blood during the first 60 seconds of bleeding.

Products which can be obtained from the blood include blood meal, used as a protein ingredient in the preparation of animal feed, (for pigs, calves, and poultry). This is only one example; after special treatment blood can also be used as a foaming agent to fight fires caused by hydrocarbons. It can also be used to make blood charcoal.

The great number of pregnant cows which are slaughtered not only affects yields in general but affects the livestock herd of the country. Also, a large number of animals are slaughtered in clandestine slaughterhouses on the farm itself, in totally unhygienic conditions. This not only results in great losses because of the deterioration of the product, but also represents a significant risk to human health.

We can reduce the losses by providing adequate cleansing of the carcasses. Depending on the operator and the system, washing may produce more or less shrinkage.

In some Central American countries there is a distinction between meat for local consumption and that produced for export. The export meat produced in Costa Rica, for example, constitutes 38% of the total, whereas that for local use is 62 per cent. Export meat is deboned 20-48 hours after slaughter. The finer cuts (loin and others) are generally vacuum packed, and other cuts, which are referred to as industrial cuts, are shipped frozen to the overseas markets. Depending on the systems of refrigeration and the technology used, the losses may be increased up to 3% or reduced significantly.

In the case of meat for domestic consumption, the carcasses may be chilled for 24 hours before shipping to the butchers. Many times, however, the carcass goes from the slaughterhouse directly to the consumer in trucks without refrigeration. This results in considerable losses in weight and, of course, the risk of contamination of the meat when there is no temperature control and the hygienic conditions are inadequate. The losses here can be considerable (up to 3%) and in some cases total.

The ideal situation is to have a cold room in which to maintain the carcasses in adequate temperature and humidity conditions. Systems of aspersion have been introduced in cold rooms. By spraying with chlorinated water at low temperature, it has been possible to reduce the loss of weight and also to achieve the optimum temperature in less time, thus improving the microbiological quality of the carcasses. Also, there are simple practices which may be used to reduce the losses in transport. For example, even if refrigerated trucks are not available, at least it is possible to insulate the trucks to reduce the temperature in transit. Although this may not completely resolve the problem, it is a practice which can reduce the losses and the microbial contamination, at least over short distances.

Another technique which may be used is electrical stimulation. This can be used effectively to improve the quality of the meat and the yield, and to reduce the cost of production. Electrical stimulation consists in applying to the animal an electrical shock of sufficient voltage and duration to provoke an acceleration in the process known as *rigor mortis*. By producing this condition, the carcass can be deboned a few hours after slaughter, thus reducing the possibility of cold-shortening and improving the tenderness of the meat. If this were done at the export plants it would be possible to debone 3-5 hours after slaughter, vacuum pack the fine cuts, and freeze the industrial cuts, which would reduce the process cost. Some of the possible benefits are: reduction in energy usage by not having to chill bones and scraps; a reduction of shrinkage in the chilling chambers; a reduction in the storage area; and greater yield per boning.

Something similar could be done with the meat for local consumption, deboning in the slaughterhouse, packing, and shipping deboned meat. In this way the bones and the waste material are not chilled nor shipped to the butchers, thus reducing transport costs and energy usage, as well as contamination. Only those cuts which are going to be consumed would be refrigerated. This would eliminate an additional 3 to 5% shrinkage, and at the same time allows the comercialization of graded meat cuts. Sale premises would require less space and less specialized personnel and, above all, a high degree of hygiene is maintained during transport.

Now to deboning. This is where the "art" enters, as it depends on knowledge and experience to achieve greater yields. At this point, approximately 20% of the carcass is bone, which ends up as a by-product. In addition, 2 to 4% is fat, tendon, and other by-products. Depending on the quality of beef and the type of deboning used, according to the preferences of different consumer groups, the yield obtained is around 75 per cent. The value of yield can be measured by the quantity and quality obtained; if a cut is altered it will result in reduced commercial value. During the deboning process it is estimated that an additional 1% loss occurs. A deboning room with adequate temperature (maximum 10 ^{o}C) will not only benefit the characteristics and conservation of meat, but also will reduce the shrinkage caused by high temperatures.

From deboning, we move on to consider the meat shipped for sale as fresh meat, and also the meat which is channeled into industrial use. Meats stored under refrigeration suffer further losses which may be 1-2%, depending on the conditions of storage. Because of the degree of subdivision which has already occurred, there will be a larger surface exposed, making the meat more susceptible, not only to weight loss but also to deterioration by manipulation.

Shrinkage may also occur at the point of sale during refrigeration, for improper handling and inadequate storage. A factor which helps to avoid these alterations is the use of adequate packing such as vacuum packing.

If the sale or processing of the different cuts is not achieved simultaneously, either at the packing plants or at the point of sale, steps must be taken to avoid deterioration, such as freezing. This results in loss of the fresh value, and also represents a stuck inventory. The nutritional value is also at risk, especially when there is inadequate understanding of the freezing and thawing process. Also, this stuck inventory induces sale promotions which affect the rentability of business.

3. SWINE STRESS

The majority of the steps that we have mentioned, in one way or another can be applied to all the different species of meat animals. However, I wish to refer to a phenomenon which severely impacts the post-harvest process in swine. This is the Porcine Stress Syndrome and it occurs very frequently. A few decades ago the fatty tissue was still considered to be desirable, while nowadays the consumer seeks meat which is as lean as possible. This change in the consumer preferences means that the swine producers have had to bring about a radical modification in their selection of animals, resulting in animals with great muscular mass. The proportion of meat in the carcass has increased enormously; so much so that the relationship of meat to fat has changed from 1:1 to almost 2:1. This successful effort to obtain an increase in the meat yield has been realized in many production lines at the cost of quality. A negative phenomenon which accompanies these changes is frequently an extreme sensitivity to stress in these animals. Stress is common during transport, holding in pens, movement to the slaughter plant, etc., and brings about metabolic changes which produce negative changes in the meat quality. The most important deficiencies are Pale, Soft, Exudative meat (PSE) and Dark, Firm, Dry meat (DFD). During the processing of meat products, PSE and DFD meat can change the absorption of water, the curing quality, and the conservation properties of the meat.

Meat with an abnormal quality may cause considerable difficulties in industrialization. The failures in the production line due to alteration in the primary product may vary from significant levels of losses of weight during heating, failures in the curing process, and very rapid deterioration.

In the industrial processes there may be losses resulting from lack of standardization of the types of industrial meat. This affects the market since users can detect the variations in the products, in the variations of grease content, for instance. Adopting the system of deboning warm carcasses, could help to take advantage, for example, of the natural phosphate in muscles, and thus favor the fixing of water, and the uniformity in quality of the products.

Often, processors are not aware of techniques such as extracting protein from lean meat and then incorporating fats to obtain more stable emulsions and greater yield in processing. When utilizing frozen meat in processing, there is loss of color and texture and there may be decreased capability in the meat to retain water. During the following stages of processing there is wastage and weight loss during drying, smoking, cooking and cooling, depending on the type of packing or wrapping used. Nowadays, greater advances have been made in packing materials. There are water-tight packing materials available now which have reduced losses. An example is the production of bologna which formerly was prepared in a porous coating containing 12% cellulose, but now uses coatings which have 0% cellulose. Products which are in permeable packings continue to shrink during storage, transport, and at the points of sale.

4. AN EXAMPLE

Finally, I wish mention the following example from Costa Rica. Within the country there are four packing plants for export of meat, which are active only during 106 days per year. This is a tremendous level of sub-utilization of facilities. A single plant could satisfy the needs of the country and if it was operating efficiently could save from 3,000 to 4,000 colones per animal processed. It would seem a logical practice to have only the essential facilities operating at full capacity and increased efficiency at far less cost. But something so simple in theory does not occur in practice.

THE RELATION BETWEEN LAND TENURE AND DEFORESTATION IN LATIN AMERICA

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While most forest damage has occurred in temperate regions since agriculture began some 8,000 years ago, the balance recently has begun to change.

Over the past three decades, deforestation rates in tropical areas have been faster than in temperate zones. Furthermore, while there is net reforestation in temperate areas, deforestation in the tropics is ten to twenty times greater than reforestation (WRI-IIED, 1987). Some 7.5 million hectares of closed forest are now cleared annually, mostly in tropical areas, half in Latin America.

1. DOES LAND TENURE MATTER?

Deforestation occurs for a number of obvious reasons: burgeoning populations need more farmland and other infrastructure (roads, dams, etc.), commercial logging or mining in forest areas is profitable and countries need foreign exchange. Also local communities may need wood for fire.

Sometimes land is used for speculation and/or protection from inflation or for livestock; to fool the government into thinking land is being utilized, individual or corporate claimants destroy trees.

Deforestation, it is hypothesized here, may be hindered or facilitated by prevailing land tenure systems[1]. In some instances tree destruction occurs as a direct result of particular patterns of land tenure; in others land tenure may play a mediating function. Some tenure systems appear to favor conservation or even replanting of trees. I propose to trace some linkages between land tenure and deforestation in Latin America, site of 24% of the world's forests (Postel and Heise, 1988).

Deforestation may occur when: a) government policies neglect agriculture *in situ*, actually providing incentives for forested-frontier settlement or failing to enforce access prohibitions to wilderness areas; b) capital, technology, and knowledge are unavailable to intensify existing agricultural areas so new forested areas are cleared; c) jobs outside of agriculture are insufficient due to slow industrial development, cyclic depression, or economic growth in which costs do not reflect true labor abundance; and d) harvesting and selling products from frontier regions offer possibilities of economic gain. Of course, if population grows unchecked for long periods, it cannot be prevented from swamping any deterrents, and the result is forest destruction at a faster rate than society deems desirable.

These may impact upon the populace through an important intermediary factor, land distribution which is inequitable and tenure regimes which are so insecure and/or so inflexible that forests destruction is facilitated. Their opposites may help maintain forests. As examples, land tenure frequently plays a role in accommodating the surplus population, sometimes in so

[1] *"Land tenure" or "land tenure system" means control over and access to land that may be of a legal or customary nature; it includes the interrelationships between landownership and social structure, land distribution, and farm-size composition. Subsumed under the term are labor and management patterns and the roles (often of a hierarchical nature) of those who farm: landlords, administrators and managers of various types, resident farm laborers, sharecroppers, nearly landless workers and/or proletarians.*

exaggerated a fashion that labor productivity falls nearly to zero (as in the case involution described by Geertz (1983)[2] or exaggerated accommodation in Sri Lanka (Thiesenhusen, 1991); or it may act to evict people too rapidly in the course of economic and structural change, causing labor productivity within agriculture to rise but at an enormous cost of greater underemployment and unemployment in society at large (the "latifundio-minifundio" structure is prone to this characteristic) (Thiesenhusen, 1991). This latter speeds forest destruction while the former slows it.

There are two situations in which land tenure problems may play an auxiliary role in deforestation: a) that in which farm families remain to farm *in situ* but in conditions in which a faulty land tenure system impels them to cut on-farm trees or encroach upon forested surroundings, and b) that in which farm families migrate to areas where they cause forest damage. In the latter case conditions in the sending and the receiving communities which may instigate deforestation will be briefly examined.

2. DEFORESTATION BY FARMERS IN PLACE

The link between rural poverty and environment was clearly articulated by the World (Brundtland) Commission on Environment and Development (1987), which notes, "Those who are poor and hungry will often destroy their immediate environment in order to survive: they will cut down forests; their livestock will overgraze grasslands; they will overuse marginal lands; and in growing numbers they will crowd into cities". If people are poor, they tend not to plant trees and to give little attention to the maintenance of proximate forestland. Instead, these small plot farmers may exploit forests by pruning, often indiscriminately, for firewood. They frequently destroy trees to establish another patch of cropland. Or they may allow animals to graze low branches, weakening the trees. Short-term income —how to feed the family today— is a major goal for these peasants and little heed is given even to the medium term.

If these farmers would have a slightly larger farm, they might be encouraged to remain on it year-round; as it is, it is common for small farmers or their family members to seek wage work elsewhere during, say, harvest and planting seasons. A full-time "on-farm" labor force, one which also has security of tenure, often busies itself with long-term projects, some of which might be important to conserve forests.

At some threshold size, family members remain year-round on the farm, available to engage in activities appropriate to environmental conservation. Collins argues that being semi-proletarian leaves little time, energy and means to practice conservation, using Bolivia and the Tambopata Valley of Peru as examples. She shows that smallest farms require most off-farm labor in order to earn the families' subsistence. Only if families can garner sufficient income from property they own to support themselves can they husband their land year-round; then, when harvest ceases, they have slack time to engage in activities that conserve natural resources, like planting trees (Collins, 1984; 1987).

At the size and degree of security at which plots become "family farms" and are no longer microplots or "minifundios", their owners may be encouraged to plant trees (or bushes) for conservation purposes with the same motivation they run livestock: tree plantations might

[2] Geertz (1983) details how rice culture becomes particularly labor-absorptive, using Java as his primary example. He compares swidden agriculture to rice culture and refers to involution in wet-rice culture as its unusual ability to "maintain levels of marginal labor productivity by always managing to work one more man in without a serious fall in per capita income". This was accomplished through labor-intensive practices and technology such as double cropping, special techniques of weeding, and so on. But Collier (1981) shows that some simple but capital-intensive and labor-extensive technology is adapted even as population rises in rural Java. Since this capacity to support dense populations holds, there remains something to the involution concept (Brush and Turner, 1987).

be convenient protection from inflation or even "savings accounts", a bond of sorts maturing over the long run; the bond is divisible to the extent that the tree provides a crop: coffee may be picked in three years, nuts may be harvested, resin tapped, etc. Of course, tree crops also hinder erosion. And forests often have the advantage of involving minimal labor at peak labor periods for annual crops, and trees can be tended during slack times of the agricultural year. Short of adding land to "minifundios", polices such as subsidies for tree planting might be appropriate if they are located in especially fragile areas, among other measures.

Unaided small acreage farmers, of course, tend not to plant trees; their time preference is for crops that mature in a much shorter run. Even tea, cacao, and coffee (in favorable ecological zones), which begin to yield after several years, may demand too long a time span for them to consider.

A usual situation for small tropical farmers is outlined by Jones (1988) in his work on Honduras: "Since farms are generally temporary due to the migratory farming pattern and lack of land titles, the plantation of slowly maturing crops is less likely... In the case of Honduras, patterns of land ownership and current forestry laws combine unintentionally to discourage an optimal forest use by peasants. The lack of security of land tenure also discourages improvements such as fruit trees or plantations".

Security and customary practices influence whether deforestation occurs in other ways also. Celis (1991) notes that in Jutiapa (Guatemala), neither landless tenants nor landlords have incentives to reforest. Landlords traditionally feed their livestock on crop residues produced by renters, while in exchange their tenants took firewood gratis from the estates. The result was "severe and indiscriminate" deforestation. Under this system the tenants had no incentive to conserve, and since benefits would accrue to the renters, landlords had no incentives to plant trees either.

In sum, while planting trees and maintaining the forest make economic sense to family farmers who are available for year-round labor on the farm, smaller peasant plots in Latin America and Asia tend to be row cropped or dedicated to swidden agriculture. Both of these land uses highly compromise forest resources. If their poverty is alleviated, farmers will be more likely to conserve trees. Smaller farmers understandably have a time preference for crops which yield at least a yearly subsistence for the family. Also there are often customary and legal barriers which figure into deforestation. The policy conundrum is how to prevent forest destruction amidst an agriculture made up of growing numbers of landless and rural semi-proletarians.

3. MIGRATION AND ITS RELATION TO LAND TENURE AND DEFORESTATION

In some instances peasants are so disillusioned with farming in one location that they seek employment elsewhere, perhaps, in cities or towns, perhaps on the frontier. It is the latter that concerns us here, for it probably involves deforestation. Conditions in the sending and the receiving areas which are related to land tenure matters necessitate analysis.

3.1 Land Tenure Characteristics of Sending Areas

There are at least three characteristics of a sending community which have to do with land tenure and they are often found in combination: a) best land may be in the hands of the rich who farm it in an extensive fashion while b) marginal land is in microplot agriculture; it becomes less fertile and eroded as families put more demands on the soil (these small farms produce more per hectare than large farms, usually because they possess a smaller percentage of unused land), yet do not have the capital to fertilize it properly or use required conservation measures; c) small farmers may have tenure which is more insecure than large farms. All three conditions have an ultimate impact on deforestation because they determine who must migrate. Also, whether a country utilizes its already existing cleared agricultural land to feed its people decides whether new land must be cleared. If those who have the best land do not husband it properly, deforestation will occur, especially in countries with a frontier.

The first two of these three characteristics can be treated together. The "latifundio-minifundio" land tenure system provides inadequate niches for the rapidly growing residual labor force to earn a living until the industrial and service sectors are able to absorb it, and small amounts of city-based economic growth cause large spurts of internal migration (Thiesenhusen, 1969; 1971). Small farms almost always are more labor intensive than large ones, but the difference between them in labor intensity is particularly marked in Latin America: the farm-size spectrum is long there and while small farms use their "homegrown" labor force, large farms hire theirs (economizing on manpower when they can because their labor bill is a significant operating cost). Chayanov (1966) believes that small-farmer families "exploit" this labor force, but the alternative, if that means being an unemployed worker, is worse. On small farms, therefore, a choice must be made by owner-managers: Should some family members remain on the farm even though they are not producing or earning much, or go to the cities or the frontier where they might contribute remittances? Should the entire family or only a part of it move? From society's point of view, an affirmative answer may result in either unemployment in the cities or deforestation on the frontier.

Meanwhile, the evidence is that the best land in the region is occupied by the large farms while small farms have, on average, poorer quality land. In the Dominican Republic, 9% of large landlords control 64% of the irrigated land, while the remainder of the farmers, smallholders, have only 36% (de Ceara, 1987). In southern Honduras, Stonich (1989) shows the initial endowment of small farmers to be poor, documenting that "in general, the smallest landholdings and the highest population densities were located in the highlands, the area with least agricultural potential. Nevertheless, farmers strove to enlarge production in these marginal areas by more intensively farming land already in cultivation and by farming previously uncultivated, steeper areas". The 1970s and the 1980s saw the best land in the southern highlands taken up by export "latifundios", Stonich argues.

Leonard (1987) argues the prevalence of this land tenure "syndrome" in Central America: "Even though large farms occupy the flattest and most fertile lands in the region, they generally do not use these lands nearly as intensively as possible. In El Salvador, for example, one-third of the land on large farms was actually fallow. The paradox, of course, is that the vast majority of smallholders ... must use (their) land as intensively as possible. Thus... better lands are used less intensively while the poorer lands are used more intensively".

Schweigert (1980) corroborates Leonard's conclusions with respect to Guatemala by analyzing the three decades, from 1950 to 1979, in which there was an enormous transformation of the forests of the South Coast, which covered 39% of land in farms in 1950 yet occupied only 6% by 1979. Now, the major use of this land is for extensive grazing, on "latifundios", on what Schweigert shows to be some of the best land in Central America, land where the highest corn yields in the country are obtained and a second crop is possible (rice, sorghum, soy, cotton, and a variety of permanent crops could be grown economically).

As Leonard (1987) points out for Central America, land is also used suboptimally in Brazil. "Fazendeiros" use proportionally less of their available farmland and leave more land idle than do smaller owners. This contributes to a system that lacks labor retention and promotes its migration. Large farms also have a less labor-intensive cropping pattern; they more often devote larger areas to livestock while smaller farms (those under 50 hectares) have more crops, vegetables, and fruit trees per unit of land area. In Brazil, in 1980, only 5% of the land on farms from 2,000 to 10,000 hectares in size was cropped; the lion's share of the remainder was in pasture or fallow. Sixty-four per cent on farms from 1 to 10 hectares was cropped. Meanwhile, yields of some crops, predominately those for export, were higher on large farms than on small ones (Cardoso and Helwege, 1989; Thiesenhusen and Melmed-Sanjak, 1990). Intensity of cropping overwhelms the yield result (Thiesenhusen and Melmed-Sanjak, 1990), however, the net effect turns out to be the inverse relationship between farm size and production per hectare in Brazil, which is the rule for most countries (Dorner, 1971; Berry and Cline, 1979; Cornia, 1985).

Roughly 35 million hectares of farmland lay idle in Brazil at the time of the last available agricultural census in 1985, up from 33 million in 1980, and most of this was on middle-sized and large farms[3]. Yet, there are about 9 million landless in the country's agricultural sector. This raises serious questions about a land tenure system that rigidly permits such wastefulness of agricultural production and engenders forest damage as landless peasants move to the Amazon frontier.

Another way in which the Latin American tenure systems effect deforestation is through tenure insecurity brought about by short leases, seasonal rental, squatting on public or private unused lands, and land conflicts. Insecurity tends to lead to migration and deforestation if there is reestablishment of the prevailing settled-agriculture land tenure pattern at the frontier. Hecht (1985) notes that "cultivators are often harassed by landowners or land speculators and are unable or unwilling to cultivate carefully because they have no title and even their short term squatter rights may be violently curtailed". Montgomery (1989) concludes, "The psychology of ownership provides an incentive to protect and develop land for a long-term future, thus reducing the temptation toward over-exploitation. The prospect of inheritance also encourages continuity in farming investments..."

In Stonich's (1989) farm sample, short-term contract renters in the southern Honduras highlands had insecure tenure on very small plots. They exhibited the poorest conservation practices, tending to grow mostly annual crops, to farm the worst and steepest property, to burn crop residues, and to clear the land of all trees. In contrast, smallholders who owned their properties farmed intensively but preserved trees... and followed other soil conservation measures.

Evidence suggests that, to the extent that titles are insecure or rentals are indefinite, "campesinos" may well believe that they will not receive the benefits of their long-term investments so they will refrain from making them.

Hall (1989) adds land conflict to a list of factors contributing to peasant insecurity: "In areas marked by intensive land conflict the pace of peasant farmer expulsion had quickened unmistakably. In the municipality of Santa Luzia, Brazil, which has a long and violent history of land-grabbing, the number of peasant squatter farmers or "ocupantes" fell by 20% from 1875-80 but the total area occupied by these farms fell by 74%, indicating a strong polarization of landownership. The 1985 census shows that this trend continued unabated between 1980-85; the number of smallholdings under ten hectares, as well as the area occupied, fell during this period, while the proportion of farmland covered by units of 100-1,000 hectares increased from 36% to 49%, quite a substantial change in the relatively short time-span of five years".

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[3]*Calculated for 1980 from Censo Agropecuario IX and X (Brazil, 1983-84). For 1985 from the preliminary tabulation from SEPLAN-IBGE.*

3.2 Land Tenure Issues at the Receiving End

There are six characteristics of receiving communities related to land tenure which have a direct impact on deforestation:

1. Non-tribal immigrants may encroach upon land which belongs to tribal people without recognizing the latter's legitimate rights often because of a clash between customary tenure systems and more formally legalists notions of landholding.

The importance of land tenure issues in development projects is analyzed by Mitchell *et al.* (1990): "However, local land-tenure issues are often overlooked in forest management planning, as most unsuccessful development activities reflect. Respect for traditional land tenure and the rights of indigenous communities, together with community participation in management, is essential if forest management is to benefit, rather than displace, forest communities".

Why this occurs is remarked upon by Dubois (1990): "Among various tribes, trees planted in regenerating forest fallow are interpreted by indigenous peoples to give usufruct rights, which by outsiders these lands are often considered to be abandoned".

2. Migrants or concessionaires may bring another tenure system and style of farming with them, which will be wasteful when it is compared to that of native forest dwellers: a style in which fewer forest products are used, there is more agriculture, and perhaps larger families. Row crop or annual crop agriculture is probably more destructive than most types of livestock farming (the two most obvious alternatives to maintenance of forested land which recent in-migrants are likely to follow) and recent migrants are more likely to engage in row-crop farming, a practice more erosion-prone than swidden systems.

Hall (1989) expresses this particularly well for Brazil, where indigenous peoples have an "in-common" restricted-access notion of land tenure while migrants view land as state-owned prospective private property: "Incoming colonists often do not have the skills of indigenous farmers and find it extremely difficult to adapt to the harsh environment. Colonists bring with them farming systems which are usually inappropriate to Amazonian conditions; they do not cultivate the wide variety of crops planted by indigenous shifting cultivators, and their short-cycle subsistence crops rapidly exhaust the already poor Amazonian soil. Their larger and more homogenous fields are thus more vulnerable to pest and disease problems... Decreased yield, leaching, laterisation, weed invasion, soil erosion and permanent nutrient loss are the unavoidable results...

On environmental grounds, the chief objection to occupation of the rainforest by migrant peasant farmers lies in the fact that, given the generally poor quality of soil in such areas, traditional forms of slash-and-burn agriculture are not sustainable beyond a certain population density. Such techniques are successful on a small-scale, but this demands that the same plots can be recultivated only after many years, a fallow period long enough for the soil to recoup its fertility..."

In some parts of Latin America, indigenous systems which conserve resources have been almost completely destroyed by the expanding frontier. Peck (1990), for example, commenting on the rarity of indigenous agroforestry systems in the Ecuadorean Amazon, notes: "This rarity is in large part due to the nature of frontier expansion in the American tropics, where large-scale land uses such as cattle pastures predominate and frequently encroach on small-scale production systems. Practitioners of the latter often originate from other regions and have little prior knowledge of local resources and technologies. Faced with uncertain land tenure, distant markets and lack of technical support, the indigenous small holder is frequently compelled to practice degenerate forms of shifting cultivation for subsistence".

Southgate and Runge (1990) reinforce Peck's point: "The periodic fallowing scheme long practiced by the Amerindian community of Pasu Urcu, in eastern Ecuador, was abandoned during the 1970s after IERAC (Instituto Ecuatoriano de la Reforma Agraria y Colonizacićn) agents informed the community that fallow lands could be claimed by agricultural colonists, who were 50 kilometers away at the time. This and other case studies indicate that Amerindians respond to tenurial incentives much as do the agricultural colonists. As a result, indigenous resource management regimes are discarded".

3. Clashes in the forest itself between those who would use the forest products and leave the trees undisturbed and those who want to cut the trees and run livestock are caused by lack of a clear system of land tenure in the forest and the desire of the outsiders with resources to disturb the *status quo.*

Most believe that the best examples of this lie in the Amazon: There are perhaps 500,000 people in the Amazon today whose principal source of income is the extraction and sale of native rubber latex. There may be as many more who make a living collecting and processing other products such as Brazil nuts, and various oils, resins, fibers, medicinals, and nuts, as well as firewood and charcoal. No reliable data exist to suggest what the economic contribution of products extracted from the forest might be for the agricultural population of the Amazon, but isolated studies suggest that it is significant... "Extractive producers" historically have had a number of subsistence and income generating strategies available to them, aside from rubber and Brazil nut or other extractive production for sale, including small scale subsistence agriculture, manioc flour production for sale, hunting, fishing, raising domestic animals including chickens, pigs, and occasionally cattle. Of people who call themselves "seringueiros" for census purposes, some 165,000 live in the westernmost part of the state of Amazonas, the state of Acre and the northern end of the state of Rondonia (Schwartzman and Allegretti, 1987).

This point is elaborated by Hecht and Cockburn (1989): "The predominant tendency has always been the clearance of forest to claim land. However, several committed agronomists and researchers are working with peasant groups to incorporate extractivism with agriculture, allowing the areas such as the valuable Brazil-nut forests to exist along with securing the livelihoods of peasants. In Rondìnia, the precarious economic conditions of the rural poor have resulted in many of them being involved in rubber tapping to augment their incomes. An emerging concern with the importance of extractive resources coupled with agroforestry has resulted in several small projects which involve local organizations and base communities working together to establish a system of production that would sustain the settlers".

4. Colonization, which usually involves the transformation of state into private property, is established to reduce pressure on the settled agricultural parts of the country, thus to pre-empt calls for land reform.

Sawyer (1990) notes, "Frontier migration served as an escape valve, at least symbolically, relieving pressures for land reform and other profound changes in the Northeast, Southeast and South of Brazil.... Pressure on the Amazon environment would be less intense if there were better living conditions in the Northeast, Southeast and South of Brazil. If there were agrarian reform, urban reform, health and welfare reform and other changes..., small farmers would be more secure and would not have to seek sustenance in the rain forest".

5. Recent migrants are more likely to fail and sell out to larger speculators, thus reproducing the land distribution inequalities and pushing the line of forest destruction further.

Government programs, for example, which were established to qualify Nicaragua as performing a land reform so that it would qualify for Alliance for Progress funding, set up displaced "campesinos" on the agrarian frontier. These spontaneous settlers took over virgin forests and became basic grain farmers. "After a while, were again forced deep into the forests by large land-holders expanding their land for cattle breeding". Between the beginning of the 1960s and the Sandinista revolution, the amount of land used for agriculture and livestock production doubled, at the expense of forests. Also to be noted is the fact that spontaneous settlement grew during the Sandinista agrarian reforms because expectations for rapid change exceeded the speed of the reforms (Ram°rez, 1986).

Jones (1988) notes, "As pawns in the development process, peasants find themselves irresistibly pushed toward programs of colonization and deforestation". In Honduras, the poor clear the forested areas but find that these lands cannot sustain agriculture. They sell out to cattle ranchers and move on to new areas of the forest. "Since peasant use rights are based on clearing the forest, reforestation diminished the value of the improvement they might otherwise sell..." (Jones, 1988).

In Brazil, the means through which property for cattle ranching is obtained are various. The normal pattern is for cattle-breeders to follow in the wake of small pioneer farmer settlers, taking over land either through agreed purchase or, as is commonly the case, through violence and coercion in situations where genuine land-titles are the exception rather than the rule and a whole corrupt industry exists to fabricate such documents. Often small farmers trade a year's use of the land for pasture formation and exit from the area... Frequently also, logging companies will in the first instance open up crude trails through the forest, or official highway construction will be commenced, facilitating subsequent penetration. The original vegetation will be removed usually by the small settlers so that they may practice slash-and-burn agriculture for a few years until moving on (Hall, 1989).

Furthermore, land tenure patterns of the more agricultural parts of the country enjoy a reprise in the forest, as explained by Collins (1986), who notes that differentiation was imported to the Amazon with the migrants. "Brokers" frequently possess managerial experience and small savings upon their arrival while "clients" had neither. Brokers became market intermediaries and transporters and a system of patronage emerged. Clients became increasingly dependent on brokers and often sold their land in recompense if they were unable to pay loans extended by the intermediaries. All those who "succeed" at the frontier are from the broker class (Collins, 1986). When the Brazilian government began to emphasize larger land units on the Amazon after 1974, inequalities increased, extending a social process that was already under way (Branford and Glock, 1985). Hecht and Cockburn (1989) show that settlers to the Amazon arrive with varying amounts of capital and credit: "the better-endowed were able to capture more of the state resources and also snap up the lots of faltering neighbors, thus repeating the familiar rhythm of the Brazilian countryside: consolidation of large holdings and fragmentation of small ones".

What is more, according to Fearnside (1985), "Pasture has pernicious effects on Amazonian society. Ranching drives small farmers off the land, either by violence... or by tempting smallholders to sell their plots to more wealthy newcomers. Land tenure distribution becomes highly skewed towards large with absentee owners. Only a minimal amount of employment is generated after the initial clearing phase is over".

As in more settled regions, the frontier's cycle of poverty may be connected to the inability of small-scale settlers to obtain ample credit. Collin's (1984) study of peasants in the upper Ecuadorean Amazon concludes that clearing costs are high and title cannot be obtained until the land-debt obligation are fully met. In an effort to repay debts, small cultivators frequently intensify their operations beyond sustainable limits. In the process, production drops and settlers become even less able to repay, finally selling their property in discouragement. Hay (1988) summarizes the settlement process on the Brazilian frontier as a progression through stages, which are marked by an increasing level of needed capital —and, therefore, a growing proletarianization of the poorest and least prepared for frontier life— and a market concentration of land in fewer hands. "Finally... the high value and productivity of land demand larger capital investments to maintain and expand production... At this point, capital begins to replace labor as machinery and chemicals perform the work of men and women. Unemployed labor and failing smallholders have no alternative except migration to cities..." The problem is deeper than lack of credit, however. Redclift (1989) concludes that only 20 percent of the land in the Amazon is sustainable for agriculture. Pereira (1989) claims that 80% of frontier settlers in Brazil fail.

And patterns vary; sometimes large holders are on the forefront doing the forest damage directly. Rodr°guez and Vargas (1988) outline the provisions under which private owners can obtain permission to cut trees in Costa Rica, concluding that the total land area supporting a stand of trees shrunk considerably between 1961 and 1983. Over half of this deforestation was illegal, and large landholders accounted for more direct deforestation than did small owners.

6. The legal or administrative system may work in such a way that the tenure system is rigged against presentation of forests in some way.

The Dominican Republic, for example, in 1966 passed a law that no trees should be cut in the entire country. So farmers came to resist planting trees because they were not be able to realize a profit on their investment. As a result, peasants came to regard the forest as a direct competitor for their subsistence; they began to kill seedlings before they could be classified as trees. "Contrabandistas" moved in to exploit the forests, selling lumber illegally at night. The law has become quite successful in protecting mature stands in some parts of the country, however. In Brazil and other countries, deforestation may secure land claims; it may be "needed", in a legal sense, to show "use" required for preemption by large and small holders.

The incentives for livestock ranching in Amazonia included, for a time, investment tax credits against federal income liabilities elsewhere in the country. Cattle ranching produces little actual beef, and hardly any local employment, but is a certain way to gain land title; the land appreciates in value and can be used to secure credit for other business ventures (Mahar, 1989).

Binswanger (1987) argues that Brazil's policies were instrumental in assuring that land at the frontier is used wastefully. Brazilian income-tax laws, for example, virtually exempt agriculture, thus converting idle land into tax shelters for large-scale farmers and speculators; thus the mere purchase of land (or clearing land as a way of claiming it) becomes profitable. Denevan (1982; 1988) argues, "There is a tradition in Amazonia... that it is the act of deforestation, or other "improvement" which gives one the right of possession of land. ...As a result, there is great incentive to clear as much land as possible as quickly as possible" and simply wait for it to appreciate in value. Speculators may either claim large virgin tracts directly or buy out unsuccessful peasant settlers.

4. CONCLUSIONS

The premise of this paper is that land tenure problems are often root causes —or play an important mediating role— in deforestation, whether peasants are *in situ*, in sending or in receiving communities. Currently in Latin America some large farmers, who hold the best land, practice extensive farming, though the situation differs from country to country and cases must become specific before corrective policies can be formulated. Consequently, policy should be made based on in-the-field research (Rodr°guez *et al.* 1991).

A search for polices to rectify a situation in which trees are destroyed in such a wanton fashion is a priority in Latin America. Poverty and deforestation are inextricably linked; those in most poverty are direct actors in deforestation, but are usually only agents for the elite who hold the prime agricultural land. What form of subsidy-tax system is in order to force more intensive use of the land? How can the flow of these resources only to rich farmers be prevented? If large farmers do not intensify their operations can they be deprived of their land? Is agrarian reform appropriate? How should extant colonization programs be modified? How can the rural poor become genuine participants in development? What kind of organization is needed for them to be genuinely empowered? How can most fragile parts of each country be identified so that conservation can begin there? These questions can only be answered based on country-specific research. Slogans such as "Privatization", "Integrated Rural Development", "Agrarian Reform" are insufficient policy goals.

In order for progress to be made on the environmental front a broad group of the rural poor who live in settled agricultural parts of the country must have their situations rectified. Until they do, they will continue to be at the forefront of forest destruction. But "campesinos" are only the victims. The real beneficiaries of deforestation are small groups of speculators, traditional landlords, those who have credit. Government policies, sometimes unwittingly, sometimes not, often make them beneficiaries of deforestation.

A search for policies which make possible more intensive farming in settled parts of Latin America while bettering "campesino" incomes must continue.

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THE MACROECONOMIC ENVIRONMENT AND THE SUSTAINABILITY OF LIVESTOCK PRODUCTION

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1. INTRODUCTION

For livestock production to be sustainable it must be practiced in such a way that it will be profitable in the short-term (in each agricultural year) and viable over the long term, without needing increasing levels of protection. This long term viability is provided in large part by the consolidation and improvement of the capital basis, constituted by the animals and the natural resources. Genetic improvement, health, and the implementation of good reproductive and herd management practices[1] are the basic means for improving the quality of the livestock. Adequate management of soils, water and the vegetation cover are also key to the continued improvement of the state of the resources. They are also the basis for an adequate food provision to the different animals and so are determinants of short-term profitability. The feasibility of improving the quality and quantity of the base stock is not only determined by human capabilities, but also by the social and economic environment within which people make decisions. In this document we will be dealing with the sustainability of livestock production within a scenario of climatic instability and a complex social and economic environment in which the "livestock enterprise" has to be carried out.

Regardless of the herd size and the educational level of the farmer, in the current environment it is not possible to accept the concept of dedication to livestock production exclusively for the purpose of accumulation of capital reserves. Our modern context demands an economic-financial rationality congruent with the function of the markets, goods and capital. Within this environment, this paper has as its objective the illustration of sustainability of the livestock enterprise as something very much influenced by the social and economic environment. In particular, it is influenced by the market characteristics, relative prices of products and inputs, interest rates, financial mechanisms, and public policy incentives. The discussion will focus on these aspects in the context of the on-going process of structural adjustment and the rapid evolution to liberalization of markets. An on-going consideration for this discussion is the time factor, given that this is a necessary component of sustainability. Sustainability will be viable to the degree that we learn to value the future and make decisions congruent with our future needs. Such decisions may imply sacrifices of income in the short-term with the expectation of achieving well-being in the medium or long term.

In Section 2 we refer to the prospects for the beef market and its close substitutes. In Section 3 we discuss the interactions between endogenous and exogenous factors, in the search for sustainability in the livestock enterprise and refer, in particular, to the options for production systems and the way in which selection of one of them will be influenced by the macroeconomic environment. In Section 4 we analyze some aspects of public policy, mainly in the economic and financial context, to establish adequate conditions for those undertaking livestock production to be successful. By successful in this case we mean to have adequate profit margins in the

[1] In this discussion we will focus on beef production and in general terms to the herd; it is understood that depending on the specific interests and purposes of the producer (breeding, growing or fattening), the herd will have a different composition.

short- and medium-term and at the same time not penalize the well-being of future generations.

2. PRODUCTION FOR THE MARKET

The prospects for sustained development of livestock are determined by profit capability in the short- and long-term. Before discussing the components of production affecting profitability, this section will mention some characteristics of the meat market.

In general, domestic and international prices for beef have been stable, with a general downward trend in real terms (prices adjusted for inflation), revealing a stagnant demand. The factors which have most influenced this trend include technologic advance and aggressive penetration of the market by the poultry industry (Table 1).

Table 1. Indicators of productivity in the poultry industry

Indicators	1960	1987
Kg of feed/kg liveweight of poultry	3.5	2.0
Mortality per 1000	15.0	4.0
Growth period, weeks	12.0	7.0
Final weight, kg	1.0	2.2

These technologic advances, added to the downward trend of grain prices and the economies of scale in the poultry industry, as well as their aggressiveness in the market, have led to a smaller increase in the price of poultry meat relative to beef (Table 2) and a significant increase in the *per capita* consumption of poultry. In industrialized countries this increase is also reflecting health concerns. The situation in the United States is clearly indicated in table 3.

Table 2. Average prices and average annual rate of growth for livestock products in Costa Rica

	Prices, current colones							
	1985	1986	1987	1988	1989	1990	1991	Growth
Beef	33,2	36,6	51,6	63,1	74,4	81,6	117,0	0,22
Pork	61,3	82,2	85,1	79,3	106,4	128,6	160,0	0,15
Poultry	55,5	59,6	60,3	71,6	111,3	120,0	105,0	0,15
Milk	12,6	13,3	15,4	18,2	23,1	26,8	32,5	0,18
Eggs	59,2	73,0	67,3	82,5	83,5	93,7	120,7	0,10

Source: SEPSA, based on information supplied by institutions in the sector and CORECA.

Cuadro 3. *Per capita* consumption of the principal meats in the U.S.A.

	1968	1978	1987
Chicken	25,2	32,0	43,4
Turkey	6,4	7,2	12,1
Total Poultry	31,6	39,2	55,5
Beef	77,3	82,3	69,5
Veal	2,6	2,0	1,3
Pork	48,3	42,4	45,6
Lamb	2,4	1,0	1,0
Total red meats	130,6	127,6	117,4
Fish and shell fish	11,0	13,4	15,3
Total for all meats	173,2	180,2	188,2

Source: Jones Putman and Allshouse (1991).

Nevertheless, it is appropriate to point out that behind the aggregate indicators of consumption are some situations of particular interest, when one considers segmentation of the markets. A short time ago the Washington Post (July 10, 1991) pointed out how consumer preferences have been changing from the big juicy steak with abundant marbling to the recently launched sophisticated Mac Lean de Luxe. The former continues to be preferred for special occasions but not as an everyday meal. In 1989, 7 million pounds of ground beef were consumed in the United States, which represents 44% of the fresh beef consumed. The average fat content of this meat is 22.5 per cent. The trend is towards the production of ground beef with a lower fat content. This also brings changes in the process of cattle fattening, with the inclusion of more forage and less grain in the diets. These preferences pose important challenges for livestock producers in Central America. There could be an increase in the markets for the region, due to the breeds and feeding systems used, which produce leaner beef than that produced from the English breeds and grain based diets.

With these prospects, it is also evident that beef, and especially carcass beef, tends to be differentiated and have a "brand" identification. Young grass-fed Zebu beef is "different" and could have a special niche in the market. Without trying to build up hopes, it is important to remember the Japanese Wagyu (kobe beef)[2] with a very high degree of marbling (more than double that of Hereford grain fed beef in the United States) is sold at prices which are four times that of the best beef produced in the United States. Thus, in a Manhattan restaurant a 14 oz kobe beef steak now sells for US$ 109 (Washington Post July 10, 1991).

3. THE ENDOGENOUS AND EXOGENOUS FACTORS AFFECTING A LIVESTOCK ENTERPRISE.

Management decisions at the livestock enterprise level tend to rotate around the assignation of resources among the alternative uses over time. When the producer has made the basic decision to orient his activities to a specific production system, many other decisions must be made to assure the best use of the available resources. This process always has two interacting elements: the animals and the physical resources. Eventually it is difficult to isolate the interactions. There should always be a balance to allow for the best conservation of resources attending to the maintenance of the animals, and of an adequate vegetation coverage.

Over and above whether the system is one of beef, milk production or both, or if the stage of the production cycle is breeding, growth, or fattening, it is important to emphasize two criteria about the production system: the intensity of use of natural resources, and the intentions regarding their conservation and quality enhancement. The intensity of use of the natural resources will be influenced primarily by the relative prices of land and the other production inputs, and the availability of water. The intentions towards conservation are more difficult to quantify, however, it can be linked more to future values and thus to interest rates and capital discount values. As shown in figure 1, with these two parameters it is possible to define the curves for possible sustainable production and, through the capital discount rates, also define the curves of preference for sustainability. In this analysis, for the time being, we will maintain the price of meat and other products constant.

When pasture lands do not have an alternative use, their price is determined basically by their stocking capacity. In semiarid zones with seasonal rainfall and no irrigation, livestock production is primarily extensive, with a low stocking rate, showing a progressively diminishing capacity. This decreasing capacity is exacerbated when there is no adequate management of the pastures, either for lack of technological understanding, or for economic limitations in the use of the correct practices. In areas with excessive rainfall or fragile systems, the problems are equally severe and alternative uses of the land are more limited. In both cases they are exposed to climatic instability which implies risks in feed security.

The relative prices of production inputs, in relation to land use and the quality of human resources, are the basic aspects that influence the pressure on resources. Regrettably, the insufficient supply of inputs and technology has kept their price high and will determine that, over time, it will increase more rapidly than the price of land and of livestock products. This process, together with the limited capacity and technological understanding, are in part responsible for the slow progress towards more profitable and efficient livestock production.

It is difficult to anticipate better margins of profit for livestock production unless the structural conditions change. It is necessary to recognize and understand the prevailing structural conditions, and to overcome them rather than to adopt simplistic solutions based on the argument that there are no comparative advantages. The comparative advantages can be constructed if there is an explicit effort by the State in this regard. The proof is evident in the countries of the European Economic Community (EEC), where livestock production receives a significant percentage of community subsidies. Although subsidies permit "inefficiencies", they have been the basis for developing livestock production and natural resources of high value in the EEC. Figura 1

[2] *Kobe beef has this characteristic for genetic reasons and because the fattening period extends to 16 months as compared to the typical 3-4 months in a feedlot.*

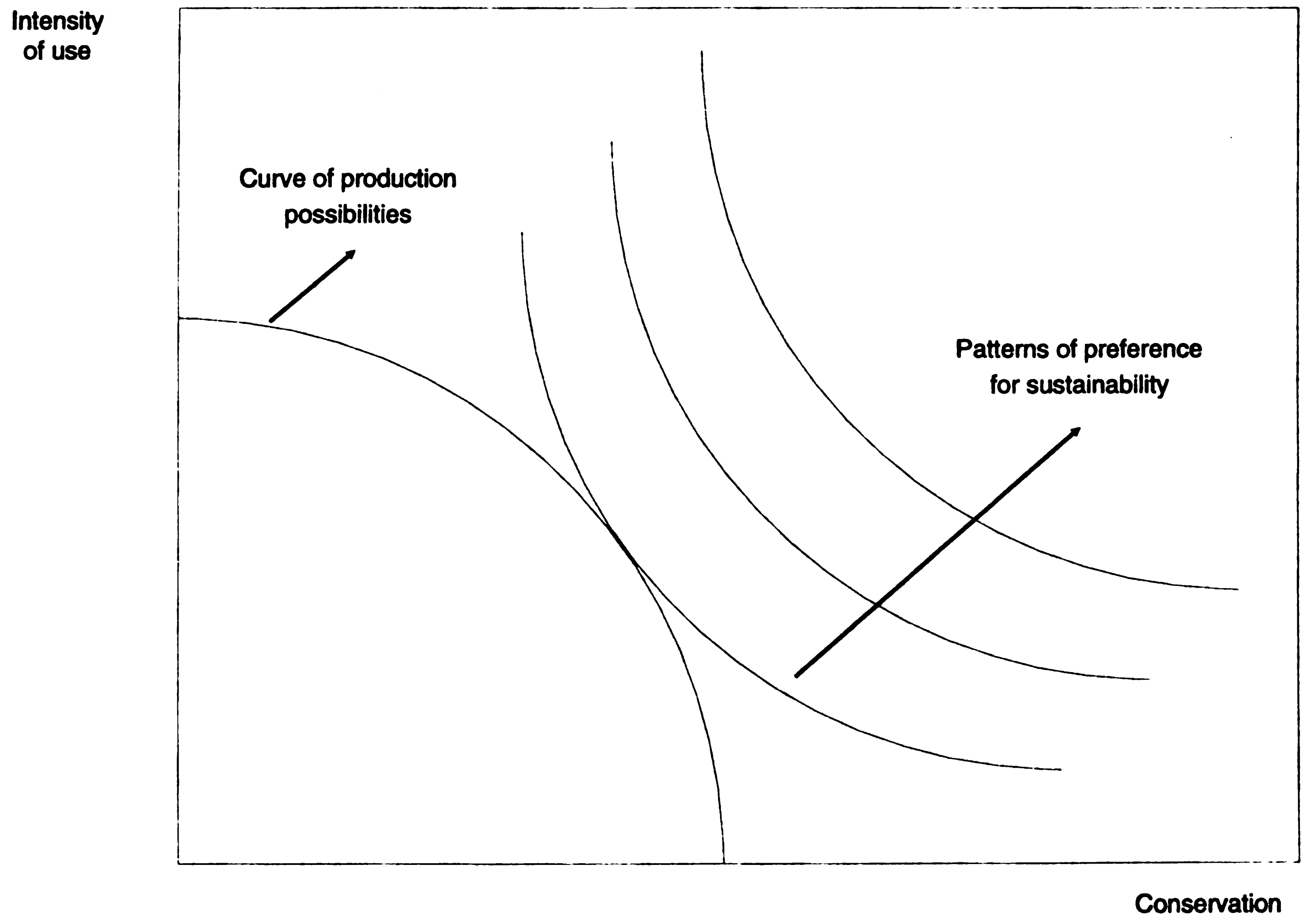

Fig. 1 Patterns of sustainability.

The prevailing relative prices can be corrected if there is an effort to stimulate private investments and healthy competition, if the dissemination of knowledge is encouraged, and if conditions are offered for preferential financing for investment in production leading to increased efficiency. The imperfections are too great to pretend that the markets will function without some governmental guidance to maximize the social benefits.

Beyond the productive efficiency, it is necessary to consider the requirements for sustained development from the economic point of view. In a social economic context where aggressive competition and the struggle for survival are foremost, it is not easy to construct the basis for the future and, therefore, for sustainable development. The situation becomes yet more difficult for those whose poverty conditions demand their total effort just to survive. In this effort the resources within reach are exhausted, even when in many cases this is done with complete awareness that the resources for the future are being consumed today.

There is severe pressure to compete effectively in markets and hence to reduce the costs of production. Reduction of average costs of production is being sought under a short-term vision,based on the expected increases in productivity and efficiency. But, by adopting a short-term approach, the achievements are not sufficiently permanent. This has led to technological practices dependent on an excessive use of chemicals, which focus on the product and have left aside any consideration for the quality and durability of the resources.

In the specific case of livestock production, conservation practices may be adopted and made to fit with the profitable productive activity in the short-term, resulting in improvement in the natural resources. Nevertheless, a fundamental issue is that conservation practices must be seen to have benefits in the not too distant medium-term. This need is met by the agroforestry and agrosilvopastoral systems which permit complementarity between agricultural, livestock, and forestry activities in the field. In the next section we will make a tentative analysis of the profitability of some of these alternatives.

The management of pastures and forages is fundamental for any livestock enterprise. Nevertheless, agroforestry offers important advantages; it uses perennial wood species on the same land devoted to agriculture, and to the grazing and raising of animals. Various combinations of these activities in the same physical space and time, and also in consecutive periods can be used. The benefits are unquestionable and well recognized. These practices require investments whose benefits are felt in the medium-term, and thus their viability is geared to the availability of financial resources under adequate conditions.

4. SENSITIVITY OF THE ENTERPRISE TO THE ECONOMIC ENVIRONMENT

Tables 4a and 4b present the results of a simulation model for a comparative analysis of the prospects for achieving sustainable development in livestock production by means of increasing productive efficiency, and the conservation and adequate management of natural resources. The model (Piskulich and Pomareda, 1985) has been developed for a ten year horizon and a herd of 100 breeding cows. Four alternative scenarios have been simulated for the conditions present in Costa Rica in 1991.

As can be seen in the original situation, the basic assumption is the absence of investment in development, and only basic maintenance costs. In this case there is an increase in stocking rate from 0.66 to 1.01 animal units per hectare in ten years, and a Benefit/cost ratio of 1.29. In this situation the profitability would slightly exceed passive interest rates obtained for the money.

The achievement of technological change and better management can be seen in the second column, where an initial investment of 120 000 Costarrican colones (CRC/) is made and the annual costs of inputs are doubled. This allows for significant achievements in the birth rate (from 60 to 80%), mortality of animals under one year of age (5 to 4%) and over one year (2 to 1%), and rates of extraction of females 3 to 4 years old (10 to 5%) and of more than 4 years (15 to 20%). There is a considerable increase in the stocking rate (from 0.66 animal units per hectare to 1.9 units); there is an improvement in the benefit-cost ratio (of 1.29 to 1.44), and a doubling in the net current capital value. Thus, it is evident that technological change and management do have decisive impacts on the progressive increase in profitability of the enterprise.

The viability of the investments are nevertheless limited by the cost of capital. Under the same technical conditions mentioned, various simulation models were done under different interest rates up to the current value of 37% applied now to livestock loans. It is evident that at this interest rate it is not possible to attain sustained development of livestock production.

Table 4a. Simulation of an extensive beef production unit: Initial values of variables and simulation changes[1]

ENDOGENOUS AND
EXOGENOUS
FACTORS INITIAL
SITUATION MODIFICATION
OF ENDOGENOUS
VARIABLES IN
MODE1 MODIFICATION
OF EXOGENOUS
VARIABLES IN
MODE2 ADDING THE
FORESTRY
COMPONENT
IN MODE2
File name MODE1 MODE2 MODE3 MODE4
Birth rate 60% constant in 10 years From 70% to 80% in 10 years Idem to MODE2 Idem to MODE2
Mortality of animals less than 1 year old 5% constant in 10 years 4% constant in 10 years Idem to MODE2 Idem to MODE2
Mortality of animals older than 1 year 2% constant in 10 years 1% constant in 10 years Idem to MODE2 Idem to MODE2
Extraction rate of females 3 to 4 years old 10% annual 5% annual Idem to MODE2 Idem to MODE2
Extraction rate of females older than 4 years 20% annual 15% annual Idem to MODE2 Idem to MODE2
Feed costs/A.U. CRC/ 2,000 CRC/ 3,000 Idem to MODE2 Idem to MODE2
Stocking rate Initial 0.66 heads/ha;
final 1.01 heads/ha Initial 0,66 heads/ha;
final 1,90 cabezas/ha Idem to MODE2 Idem to MODE2
Interest rate 0% (works with own money) Idem to MODE1 37% (works with loaned money) Idem to MODE2
Income from byproducts 0% (exclusively a cattle unit) Idem to MODE1
Value of investment in pastures and fences (CRC/) (only considers investments in cattle activities) 0.00 during the initial year;
30,000 during each year of operation 120,000 during the initial year; 60,000 during each year of operationIdem to MODE2 Idem to MODE2
Value of melina planting investments (CRC/), 2,800 individuals 68,258 during the initial year; 7,272 during the second year;
3,493 during the third year

[1] Only those values changing during the simulation process are mentioned.

Table 4b. Simulation of an extensive beef production unit: Value of economic indicators resulting from changes in value of factors

10 YEARS OF	EVALUATION	MODE1	MODE2	MODE3	MODE4
Benefit/cost ratio	1.29	1.44	0.49	1.55	
Net actual value (CRC/)	4,923,960	8,354,676	(27,903,810)	10,344,540	

Figure 2 shows the benefit/cost ratio for different interest rates. It can be seen that the B/C ratio of 1.29 achieved in the original base situation, without technological or management changes, is also achieved with technological change and with an interest rate of 9 per cent. This shows that investment in livestock production with current market prices could not be without preferential conditions of financing. Regrettably, this reality originated a series of programs of subsidized credit for livestock which has been seriously questioned. Its efficacy, nevertheless, would not be questioned if the money had been used for the purposes for which it was released.

It has been suggested that extensive livestock is one of the principal factors of deforestation in Central America (ROCAP/AID 1990). However, deforestation in Central America has occurred as a result of the profit incentives for those engaged in the lumber industry and, above all, because an indiscriminate cutting process has been tolerated. Extensive livestock production came later, as a logical use of the cleared areas. From that point on the management practices of extensive livestock have contributed to ecologic deterioration. Cattle production has gone on as an extensive operation, due in part to the inefficiency of the programs to stimulate changes but also, to a larger extent, because of meat prices. Average international meat and lumber prices are shown in figure 3, illustrating these arguments. In some measure, the increasing concern about environmental deterioration, started towards the end of the 1970's, contributed somewhat to decreasing the exportation of cut timber. In Honduras, for example, in 1989 these exports were only 30% of what they had been in 1977 (Table 5).

Increasing lumber prices constitute an important motivating force for the development of silvopastoral systems. Using the model mentioned at the beginning of this section, simulations were made to evaluate changes in profitability of the livestock enterprise under consideration. The investment and the operational

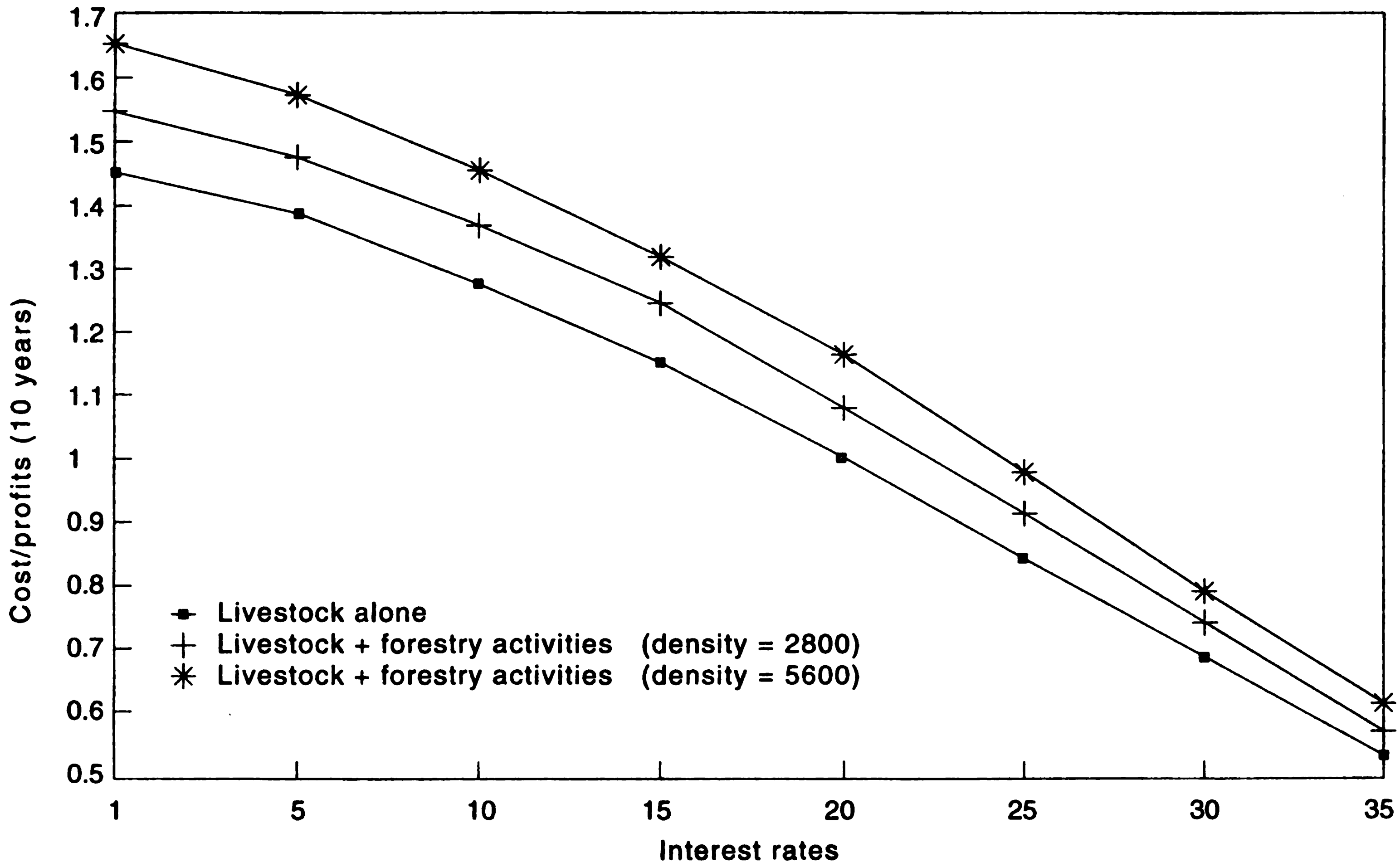

Fig. 2. Cost/profit relationship at different interest rates for livestock alone or in association with forestry activities.

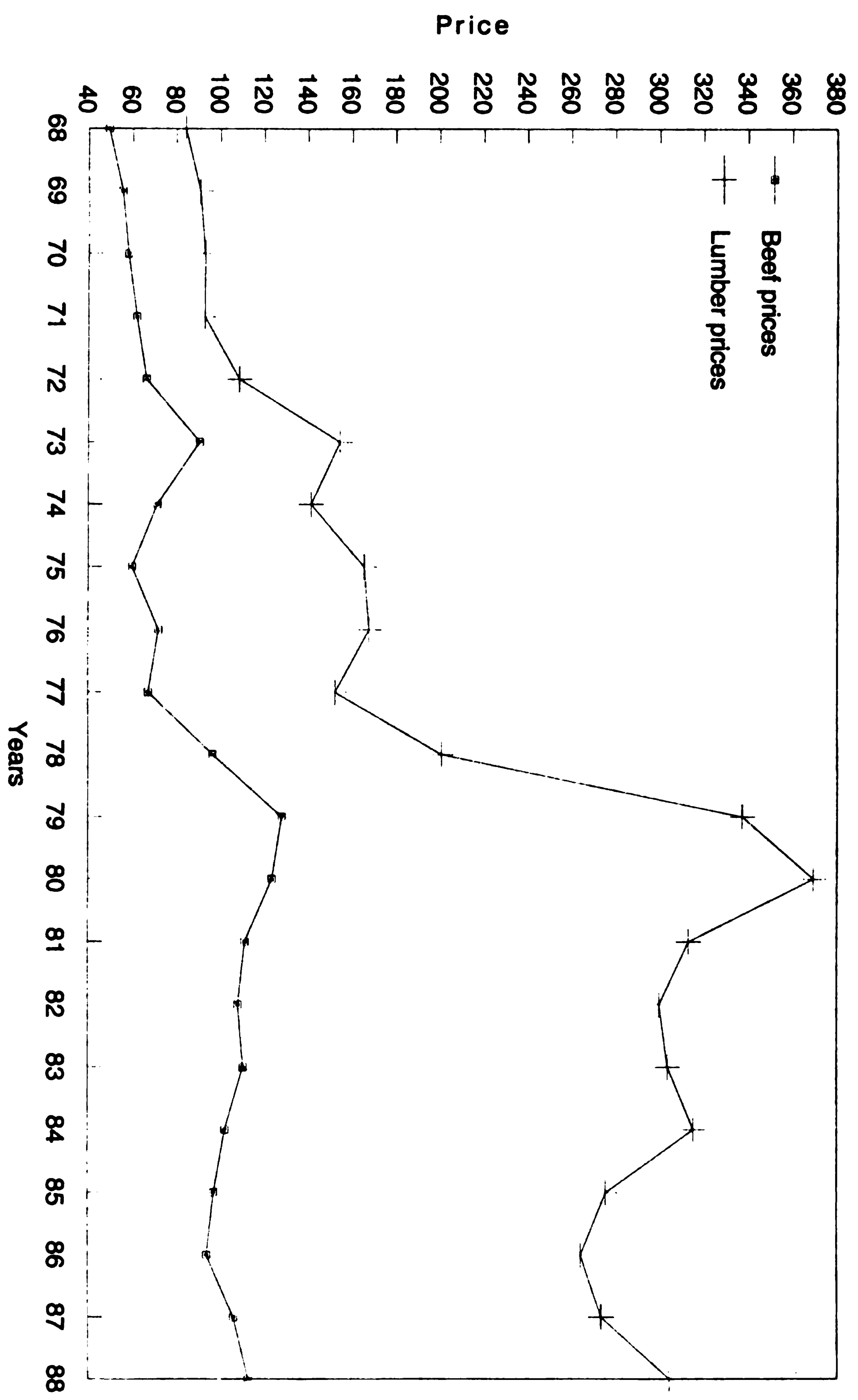

Fig. 3 International beef and sawn lumber prices: 1968-1988.

costs needed to plant 2800 young melina trees[3] were considered (Alfaro, 1991). Sensitivity analyses at different interest rates were conducted on the investment. As seen in figure 2, this activity makes the enterprise more profitable than when it is only dedicated to livestock. It must be emphasized, nevertheless, that we are dealing here with an investment whose maturation rate and relative benefits are greater when the interest rate is lower. This situation provides arguments for innovative financial mechanisms to make livestock production possible using silvopastoral systems.

Table 5. Honduras: Volume of sawn lumber (m^3) exported to different markets in various years

		Markets				
Years	Total	Caribbean	Europe	Latin A.	U.S.A.	Japan
1977	443,519	290,353	79,729	67,522	349	5,567
1982	309,129	208,358	38,631	49,273	6,422	6,445
1989	141,000	83,322	42,022	9,178	1,017	5,461

Source: Corporacien Hondure§a de Desarrollo Forestal (COHDEFOR).

5. STRATEGIC ACTIONS

The economic context of the 1990's, in which livestock activities in Central America must be carried out, can be described as both complex and unpredictable. Some important characteristics include the increasing internationalization of economies, the greater interaction of the capital and merchandise markets, and the trend to more selective intervention by the State into the markets.

This process in related to political and social aspects, among which we can stress the efforts to maintain democratic regimes, and the political will to solve the overwhelming problems of poverty and environmental decay. The latter two constitute a huge challenge especially when, at the same time as promoting a liberalization of the economy, there is an effort to diminish public deficit. There is a high risk that in this effort the perspective will be lost; the State might not receive the necessary resources for a process in which the social economy of the market and the welfare of the future generations must be balanced. Achieving sustainable livestock development requires, in first instance, technical planning of the orientation of the sector in the context of the development model. In second instance, it calls for political will and thus legislation, selective incentives and institutional capacity to support private initiatives in the proposed direction, and fully congruent with the market directions. In third instance, a commitment of the organized private sector to acquire collective responsibilities complementary to those of public institutions with a view to making private enterprise viable.

Insofar as the technical changes needed, there is sufficient support for the hypothesis that in the economic environment of the next few years, livestock enterprises can be viable and achieve characteristics permitting sustainable development. There exists technical knowledge on how to make livestock production sustainable and there are on-going programs to expand this knowledge. What is lacking, however, is a significant effort to transfer the technology. The

[3]*Gmelina arborea is a woody species that reaches maturity in 10-12 years. It grows in areas with average temperatures between 21 and 26 °C, whith a well defined dry season, and rainfall averages between 1,780 and 2,300 mm per year.*

human resources must be trained; the human capital must be developed to give support to sustainable development (Longworth, 1991)

In relation to the livestock industry as a productive activity, within the model for sustainable development, it is necessary to change the philosophy and negative image of this activity as unsustainable, environmentally degrading, and in need of substitution by more profitable and efficient activities. In reality, livestock production is compatible with improvement of the quality of the natural resources. This philosophy should prevail and technical knowledge should be used as the building blocks in the development model (Pomareda, 1989). The arguments must be solid to be convincing and to merit political support.

In relation to the second consideration, that of legislation of selective incentives and institutional capacity, there is wide scope for action by the State. In the current context and based on experience, it would not be prudent to invoke price controls nor to introduce generalized subsidies for interest rates. What is needed is a body of law and a system capable of assuring compliance by penalizing deliberate destructive actions, such as clandestine cutting of forests, pasture burning, and actions leading to forest fires and contamination of waterways. On the other hand, incentives are indispensable, through fiscal means, to promote the construction of infrastructure for protection, reforestation, productive management of soils, and maintenance of vegetation cover.

Construction of a basis for sustainable development requires investment; it is important to make an effort to provide the financial resources for this purpose. Debt for nature conversion has emerged as an interesting alternative; nevertheless, this must be structured in such a way as to avoid proliferation of opportunism not conducive to development. Sometimes the esthetic, cultural, and even spiritual benefits are exaggerated to attract projects of debt conversion which contribute little to sustainable development. The financing of silvopastoral systems and development of livestock production itself are justifiable alternatives of debt conversion resources use, particularly when oriented to poor communities and fragile areas in a serious state of deterioration and risk (US-OCDC, 1990).

Finally, the third consideration, that of collective action by the organized private sector, is of fundamental importance, particularly if it evolves towards a redefinition of the role of the State, and if it leads to consolidating the role of the small and medium enterprise as the basis for a productive social structure. If a collective organization of the private sector in the livestock sector does not appear, the options are limited. The few surviving enterprises will necessarily be those controlling great extensions of land, even if it is inefficiently used and irresponsibly managed. Their viability would be greatly facilitated by increasing degrees of vertical integration and by access to benefits with questionable social impact.

Proposals of joint State and private responsibility for sustainable development must rest on three points. The first is what livestock production offers as a means for generating economic activity in the rural areas and in related sectors. This must be within the framework of a market economy. Secondly, the need must be explicit that short- term objectives must be reached within the longer term strategy for sustainable development and commitment to future generations. Thirdly, the management of the economy as a whole, and assumption of the social responsibility for future generations must be considered as a framework for the development of livestock policies.

It is very important to state that livestock development must be presented, not just as a unique problem or a need for policies for livestock *per se*, but as a component of an integrated strategy for regional development. The livestock issues must be inserted in policies concerning irrigation, agroindustry, mechanization, rural education, and regional development. In any case, the strategies and policies which achieve the sustained development of livestock must be focused on the modernization of this sector. We understand modernization as the capacity to conduct successful enterprises in times characterized by high degrees of competitiveness, abundance of information, economic turbulence, and other related factors.

Acknowledgements

The author wishes to express his gratitude to Rolando Piskulich and Ana Jiménez for their participation in the preparation of the present document.

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THE NATIONAL AND INTERNATIONAL LEGAL FRAMEWORK FOR THE CONSERVATION OF NATURAL RESOURCES

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This is an ideal moment to be reflecting on the legal framework that we have in the Central American region for environmental matters.

1. RELATIONSHIP BETWEEN THE DEVELOPMENT MODEL, THE ADMINISTRATIVE ORGANIZATION AND THE LEGAL FRAMEWORK

One of the methods for classifying development models in the Central America region has been according to the level of support received by different productive activities. Thus, the first phase has been called the agro-export economy. The second, the substitution of imports; and the third, the exportation of non traditional exports. These economic schemes have determined our administrative organization and the legislative production.

Initially, the attention of the state was directed first to agricultural production, stimulating the production of coffee, bananas, cotton, and sugar cane. Simultaneously, the related institutions centered around such production, and the legislative process was directed to regulating the incentives and benefits to encourage these products.

Subsequently, great support was given to livestock production. This led to the transformation of administrative institutions, such as in the case of Costa Rica, where the Ministry of Agriculture, became the Ministry of Agriculture and Livestock.

Later on, in the seventies, the scientific community began to sound the alert on the effects of these models of utilization of our natural resources, warning us of the negative consequences to health, due to the use of pesticides, and the impact of the elimination of the forest cover, with the consequences of erosion of the soils, and sedimentation in our rivers.

The decade of the eighties marked a definitive change towards concern for the effects of productive activities on the environment, turning it into a subject of political importance and general discussion. This fact also caused changes in the administrative organization and the legislative production. The Ministries of Natural Resources, or the Secretariats for the Environment, or some such names, began to appoint institutions for the administration of protected areas, and for the protection of forest areas and of wildlife.

Studies conducted in Central America have identified the following as the principal characteristics of the administrative organization and environmental law:

1. The environmental laws exist dispersed through the judicial organization, which produces confusion in their application and uncertainty as to their effectiveness.

2. There exists duplication of responsibility for any one resource within the same institution and among different institutions. In consequences there exist: a) lack of coordination among related institutions; b) wasted resources, duplication of efforts and limited results; c) sectorial treatment of each resource, with no overall perspective of the environment.

3. The civil servants lack training, which results in: a) ignorance of their responsibilities, rights and duties; b) preparations for legal processes are not carried out correctly, which results in negative effects on judicial decisions; c) their vision is at the institutional level and do not have a broad vision of the mission of the state as a whole; d) it is not easy for them to work in coordination with other institutions; e) they will not go beyond what they consider their specific duties.

4. There is a lack of human resources with adequate professional training and economic resources to carry out their functions.

5. A lack of political will to go beyond declaration of principles.

Up to this point we have not asked what is the cause for this situation. We must discover the cause of these problems if we are to seek their solution. In my opinion, the administrative and legal situation of the environment reveal a peculiar perspective. This is not simply a case of disorganized proliferation of regulations, it did not just happen. I believe that what has given rise to this situation is that there exist two state administrations: one for productive activities, whether this be agriculture, livestock, or industry, and a different administrative unit for the environment, which deals with it as something which should be preserved and protected, but not conserved. Thus, although the slogan "development with conservation" has been widely discussed, it has not resulted in the adoption of this concept at the state level, but rather they continue to be seen as two separate activities.

2. SUSTAINABLE DEVELOPMENT AND ITS ADMINISTRATIVE IMPLICATIONS

Let me underline the difference again. Preservation tends to maintain things as they are found. Protection protects resources from outside threats. Conservation tends to utilize resources in a manner which could be continued without exhausting them. From this last concept has arisen that of "sustainable development".

The challenge of the 90s is therefore to achieve an administrative organization which understands that development of productive activities requires parallel environmental conservation measures to assure its sustainability.

This supposes with the need for a reorganization where the utilization of the resource also includes programs for its conservation.

In the "Strategy for Conservation and Sustainable Development of Costa Rica" (ECODES) there exists a proposal for an interesting administrative reorganization. As a response to the institutional challenges created by the environmental problems, I believe it is worth our reviewing this proposal, as it is an initiative which has considerable advantages.

In first place, it tries to resolve the problem of management of natural resources in an integral way. For this it groups together institutions that have to do with final uses, and brings them into the process of global planning for the resource. In second place, it establishes important mechanisms of support for making and following-up of decisions, their application, and control. Third, it proposes a systematic coordination process between the Ministry in charge of planning (MIDEPLAN) and the Ministry in charge of natural resources (MIRENEM), trying to take advantage of the existing experience and resources.

The proposal does not promote the creation of new institutions, but rather an administrative reorganization which proposes to take advantage of an integration of the existing institutional efforts for conservation of resources. Two interdependent councils would be established:

1. The Council for Territorial Organization that would deal directly with land use; the regulation of spatial location of human activities. It would be made up of the following sectors, and the leading institution would be MIDEPLAN:
   - Human settlement
   - Agriculture and livestock
   - Forestry, protected areas, and wildlife
   - Fisheries and coastal areas
   - Mining
   - Transport

2. The Council for Environmental Quality that would see to the mitigation and control of environmental degradation. This would be made up of the following organization, with the leadership responsibility being assigned to MIRENEM:

   - Water resources
   - Energy
   - Tourism
   - Industry and trade
   - Science and technology
   - Health and environmental contamination

The members of these two councils would be two officials from each sector, preferably one at a high political level, and the other with technical understanding of the resource and of the institution. This is to guarantee the political decision on one hand, but also the permanency and appropriateness of the decisions.
Each one of the sectors would in turn relate to the institutions responsible for the delivery of services, the final uses, or the definitions of policies associated with the resource.

The interesting part of the proposal is that it integrates the two Ministries most closely related, providing at the same time technical support and orientation through three units:

1. **Legislation and Administration.** This unit would have the responsibility of avoiding legal and administrative conflicts arising from recent judicial initiatives, and of promoting new initiatives. It would continue to evaluate the impact of new legislation on the existing legal framework, an activity which until this moment has regrettably not been carried out.

2. **Implementation and Technology.** This unit would have the responsibility of maintaining the appropriate banks of specialized data, in close coordination with the academic and research centers at the national and international level.

3. **Communication, Education and Culture.** The objective of this unit would be to promote a change attitudes concerning natural resources, to permit the establishment of a more harmonious relationship to guarantee that activities would be sustainable over the long-

term for future generations. This aspect has not usually been sufficiently taken into account and is seen as one of the most important ones to correct problems over the long-term.

This initiative is worth reconsidering, discussing, and analyzing because it seems to be a very reasonable proposal to allow us to move from the sphere of diagnosis into the area of action.

3. SUSTAINABLE DEVELOPMENT AND ITS LEGAL IMPLICATIONS

In the area of legislation, we find the same phenomenon. The laws protect productive development or seek preservation or protection of resources, as though these were two separate goals. For example, what is the field of application of forestry legislation? Some lands may be appropriate for forestry, but they might be actually dedicated to agriculture or ranching. Are they submitted to forestry legislation?

Legislation, in order to be an instrument for sustainable development, must be the product of alternatives, viable from the administrative and economic viewpoints. Otherwise laws become simply written words which are not applied in reality.

They must take in account, not only the administrative and economic consequences, but also take a very close account of the technical basis. Law is a simple instrument of regulation. The content must come from other sources: scientific knowledge translated into political will, and the acceptance of the same.

We have far to go in Central America to be able to utilize legislation as a judicial instrument for sustainable development, which will commit us to rationally use our natural resources while not compromising the future of our children.

4. ECOLOGIC CONCERTATION AS A PATHWAY TO ARRIVE AT SUSTAINABLE DEVELOPMENT

The challenge of the 90s is how are we going to give real significance to the concept of sustainable development. I believe that the only way for a democratic society to arrive at this result is through concertation. Concertation is a judicial institution within labor law, which has proved efficient in the resolution of problems that arise between sectors opposed in their interests. This is the case when the employer and the worker sit down to negotiate together as equal participants convened by the state as arbitrator of the negotiations. To achieve sustainable development a similar process is needed, if we are to arrive at really viable policies which will be accepted by consensus. Consensus is difficult to achieve because all of society and all of the sectors are directly or indirectly involved:

- The private sector as user of the natural resource base and actor in the process of transformation.
- The community at large as participant, and as the party affected by the policies established.

- The institutional sector, which is in charge of applying the legislation on current policies.

In this process the role of the state is that of the facilitator of negotiations which must define, through consensus, profound issues of relevance to the future of the country. For example: What should be the organization of land use? Based on available technical criteria, and in accordance with the land use capacity and its current use, what will be the future use of the soils? Where are productive activities to be carried out? Which activities will be promoted? To what degree will urban expansion be permitted?

This is definitely not an easy process, but it can ensure that those policies achieved through consensus will be better applied. In this process, all of the sectors must give a little and perhaps some ideal positions will not prosper. Subsequently, the role of the state moves from being a simple facilitator to being a rigorous watchdog for the agreements achieved.

Much has been discussed, at the ideological level, concerning the appropriate functions of the state. There is generalized consensus that national security is a responsibility of the state, no matter if it is liberal or socialist. Furthermore, the concept of security has gone from one of merely military significance, of external protection, to guaranteeing a healthy environment for all of the citizens who share a common human right.

5. CONCLUSION

I cannot find a stronger argument for bringing about this transformation, which necessarily will involve changes in attitude, than that of our own survival. Our culture is based, to some degree, on faith in science and technology. We have been made to believe that although technology can sometimes bring about problems, it can also resolve them. I hope that this may be so, and also that we will not have to adapt to live in a very different world. I enjoy the green fields, the pure water and the clean air.

The most profound philosophic reason I have found to support conservation, was that expressed by Lord Baden Powell, founder of the Scout Movement at the beginning of the century, when he said: "the scout loves Nature because in it he discovers the presence of a Supreme Being".

PLENARY SESSION

On October 10, following the presentations of the different discussion groups, participants gathered for a panel discussion. A transcription of the comments made by the panelists is presented in the following paragraphs:

JAN A. J. KARREMANS (CATIE)

I believe that all of us recognize that, in the last few days, the topic of social research in relation to the appropriate management of natural resources has been touched only tangentially, with the obvious exception of the very interesting anthropological information presented by Dr. Constance McCorkle. When we seriously review the observations made by the other speakers, concerning the fact that livestock production is not the starting point of degradation of natural resources, but rather this results from bad management of resources by human beings, through decisions that they take as producers, large and small, we have to accept the implication of this observation and investigate the social aspects of production systems.

Joshua Dickenson mentioned the cultural aspects when he reminded us of our Iberian heritage -the culture of fenced fields, for example, a factor which explains certain customs of the "campesino" livestock producer. Christopher Vaughan mentioned ethical, esthetic and cultural values in biodiversity. James Simpson spoke of the "demand as the driving force in animal production." I believe, although true for those who produce primarily for the market, it does not provide us with an adequate explanation for the behavior of the small producer, especially in this region, where production is primarily for subsistence of the producer and his family. In the case of risk avoidance, the distribution of risks among multiple production activities could be considered a driving force in decision making. Of course, the emphasis which this same speaker placed on urban growth and related consumption, by the urban population, of products of the rural areas does seem to be well focused. Similarly, the comments that Francisco Leon made about population growth in recent decades and the ups and downs in mortality and fertility are important points.

Robert McDowell's presentation left, more than those previously mentioned, the greatest opportunity for evaluation of the role of social factors in the production systems under discussion, because he presented a holistic model emphasizing also the great utility of livestock beyond the simple production of meat and milk, to which we have limited most of the research on profitability and viability of cattle production.

Be this as it may, as we consider the social aspects, the presentations this week have not visualized the objective of this meeting: a strategy for sustainability. Nevertheless, I believe that the working group on education and training, which made its presentation a few minutes ago, provides a solid base to begin to "seed sustainability". I would like to add to the observations of this group, without pretending to present a unique or final solution, some comments on the integration of education with extension, placing the "campesino" family in the center of attention.

Let us consider the model for sustainability. There are two elements which enter into all of the many definitions: production and conservation. Conservation of natural resources (where necessary restoration) and -as a sociologist- I would also say conservation (or restoration) of society and culture, without which there cannot be sustained production.

Who should be conserving and producing? Agriculturists, men and women. Here I wish to limit myself to the "campesino" family, not producing primarily for the market, but mostly for their own subsistence. For improved production there is the requirement for some kind of extension. At the same time, in order for this "campesino" family to consider important the inclusion, in their production system, of the conservation of natural resources, there has to be certain degree of sensitization. How can we do both things, at the same time, in an efficient and lasting manner? For this is what we mean when we speak of sustainability.

An inexpensive way, with wide dissemination, is popular education. Not only to children but also, and perhaps more important, to adults. This strategy has various advantages. The most important is the ease of using the same message used for extension, on repeated occasions, as a theme in the educational effort. Working with groups also implies a greater degree of discussion between participants, on subjects which facilitate sensitization. At the same time, we know that without a sufficient level of education in the population, many development projects cannot achieve the projected application of their recommendations among the producers. Also, group education generally implies a greater degree of participation of populations in society, and access to authorities, credit agencies, etc. Concerning demographic expansion, which has been mentioned in this symposium as an element which eventually leads to destruction of natural resources, we can affirm that sexual education must be included in the school curriculum for youth and adults, emphasizing family planning. When directed, not only to present heads of families, but also to children, education on natural resource conservation will have a lasting and multiplied effect. Finally, and perhaps a very important aspect in view of the scarcity of financial resources, popular education is an inexpensive form of outreach.

In summary, popular education can be a part of a strategy for sustainability. With this conclusion, we locate the "campesino" family in the center of attention, emphasizing that sustainable agriculture means the effort of the "campesino" family to produce and conserve.

I would like to present two examples of a social focus in pursuing the sought-after sustainability. In the first case we shall deal with the design of community action in relation to forest management. The second case refers to the level of measurement of indices of sustainability, particularly in livestock production.

Often we make reference to social and cultural factors which impinge on the development efforts of projects. We must not forget however, that the structure of society offers elements which, when appropriately used, can resolve various field problems. I refer to the problem which Christopher Vaughan examined, concerning the biogeography areas, limited areas such as patches of forest among pasture fields. In our research on the Colombian Amazon, in Guaviare, we found a solid social base among the colonists to set up a forest under community management, where by uniting the areas covered by forest in many farms, a single area can be created which allows for a far greater biodiversity and hence, a greater possibility of survival of many different species. At the same time, and this is to the interest of the colonists, this strategy caters some of their needs, as it allows hunting, fishing (by protecting water sources), provides firewood, wood for fence posts and construction, fruit collection, protects the beds of rivers and streams and functions as a fire break. The basis for social action are the Community Action Committees, which the colonists have formed for each rural hamlet, as their own internal authority and as a legal entity to respond to the municipal and regional authorities.

The second example concerns the systemic, holistic approach, typical in anthropology, and to some degree in rural sociology. Various presentations at this symposium have mentioned the very low net return (of 1 to 4%) on livestock investments, using this argument mostly against livestock and therefore in favor of the forest. It is interesting that in Guaviare we arrived at similar figures using the traditional means of calculation. Nevertheless, when we analyzed livestock as an element within the total farm system, we found that only farms with livestock were enterprises with a high level of gain. When diverse variables were controlled in the analysis, we always found livestock as the factor which explained the level of gain in various production systems.

How can we explain the apparent incompatibility of these data? Livestock is intimately associated with other activities on the farm. A farm without livestock or with a reduced herd size does not have the same capability for economic growth because it does not have a place, within the farm, to invest when there is income from harvests, an investment which can form a buffer for future unfavorable economic conditions, which eventually will arrive - when crops do not result in a net gain because of a drop in prices, a bad harvest, etc. In the Amazon, the low fertility of the soils means that the colonist has few options for land use after one or two harvests. He can sow pasture and put in cattle -this is a rational decision from the point of view of the "campesino" investor. When analyzing cattle production alone, it may not seem profitable but, at least in the case of the Guaviare, we found cattle to be an integral element and a *sine qua non* for the farm to be economically viable as a whole. We must therefore not calculate the value of cattle on the basis of their net return alone but also, and perhaps preferentially when we think of sustainability, as an element within the whole production system. This way, we will understand better the role of livestock in decisions taken by producers. If we try to measure sustainability, I would suggest that we must seek, apart from indicators at the subsystem level, indicators for the entire production system, especially social and economic indicators.

Summarizing, I recommend the following strategies for sustainability:

1. Combine extension of improved technologies with sensitization to conservation of natural resources as a single effort through popular education. Of course, this should not preclude the development of other means of extension.

2. Seek socioeconomic parameters for measuring the sustainability of new technologies at the farm level, not just at the level of each production activity.

3. Seek community level solutions.

In this way, the support that the social scientist can and must offer in seeking solutions to the deterioration of natural resources will be greater.

CARLOS CHAVES (EARTH)

On Monday, when we had the first few presentations, I felt pessimistic, especially when we were shown production data from livestock production systems of the region and deforestation maps. I would like to make myself clear in this respect; every time I see those maps I react adversely; it seems that foresters want to make cattlemen feel guilty; nevertheless, those maps should be looked at very carefully.

When one sees a map of Costa Rica (these comments I make as a Costarrican) and is told that in 1940, 80% of the territory was covered by forests, and then is shown a 1980 or 1990 map, and is told that we have no forests left, and cattlemen are looked as if they were responsible for it, logically, one must react. It must be clear that it is the population growth what exerts pressure on natural resources.

I ask those who show such maps, what would had happen to Costa Rica if the cattle industry had not developed in the San Carlos area, which produces over 50% of the milk consumed in this country? Many times Costa Rica has been mention as the only country in the region which is self sufficient in milk. It is very romantic to think that we should had maintained the forest, but is more realistic to understand that, given its population growth, the country had to use those lands in efficient production systems, such as milk production in that area.

With the subsequent presentations we were shown a more realistic panorama, concerning population growth over the last 30 years and what is expected for the next 30 years. It was said, and I agree with it, that beef production will tend to disappear toward the year 2020, because of pressure from other more profitable livestock production activities, which eventually will take its place.

I was very pleased with Dr. McDowell's presentation; I anticipated a presentation of that sort because I know his work. I was also very pleased with Dr. Constance McCorckle's presentation. Both of them showed, very clearly, that animals are essential for man's life.

The meeting has maintained a very positive attitude, and I must congratulate Dr. Toledo's presentation. I must indicate to him that in Costa Rica we have several examples of farmers who are using *Brachiarias* with excellent results, replacing species such as Jaragua (*Hyparrhenia rufa)*, which has been with us for the last 40 or 50 years. I must also say that in relation to herbaceous legumes I still have my doubts; I have heard about them since I was a student. Excellent results have been obtained at the experimental level, but we cannot say the same thing at the producer's level.

I enjoyed Dr. Romero's presentation very much. He discussed the possibilities of integrating trees into livestock production systems. I will not make further comments on this because someone else will refer to this theme later on.

Dr. Zaglul discussed how we can improve the efficiency of beef production through better meat processing methods. He even mentioned a case for Costa Rica, a bit questionable depending on which sector is analyzing it, where the slaughtering capacity of the processing plants is well above the actual number of animals killed, something that both consumers and producers have to pay for.

I believe, probably not in the short term, but in 20 or 30 years, that cattle production will focus on milk production systems, where meat will be a logical byproduct. I also see cattle in very intensive production systems. I believe it is towards this end that policies should be focussed: intensification of the production systems. One possibility is the association of livestock with crops: livestock making use of residues from cropping activities.

Finally, I consider essential that the results from this meeting be taken to a forum where there is more participation of the producers. Although we have had some producers present at this meeting, they had little chance to express their feelings, and it would had been very interesting to hear the comments they have about sustainability.

Sustainability is a term that I have heard defined on several occasions; incidentally, I did not quite understood what economist mean when they refer to "internalize the externalities". However, Alberto Amador gave us a definition which I think we could carry in our proposals to the producers. He said that sustainability is having systems that will let us eat properly today, while also allowing our future generations to eat as properly as we have.

RODUEL RODRIGUEZ (Hondure§a de GenÇtica y Tecnolog°a)

I would like to thank the organizing committee for having invited me to this event. I consider that the expected success has been achieved, not only becuase of the conclusions and recommendations presented by the five or six discussion groups, but also in the strategic planning and development of this activity. I would also like to thank the committee for giving the opportunity to an agricultural engineer to express an opinion —that of those who are cropping experts— on this very important theme of sustainability.

I would like to take up again one of the concepts which was expressed by the group on Policies. We should not be talking about livestock production, but about agricultural production (including livestock). The truth is that if we analyze the information to which we have been exposed in the last three days, we realize that there is a very great diversity of farms, a great diversity of productive units with mixed systems, where both the cropping component and the animal component are important, as well as other farms in which there may be an additional forestry component. Thus, it is necessary that all of us, involved with agricultural development, realize that we are involved with **integrated development**, and therefore we must keep in mind the three components just mentioned, as well as their interactions.

As an agronomist, I would like to indicate that all the situations mentioned in this event, which are affecting livestock production, are also seriously affecting the production of crops. Let me underline once again some very important data, in order to orient our function as cropping specialists within the development of a sustainable agricultural system. In the first place, we have spoken of the accelerated populational growth in the Central American region. Of course, there are variations from one country to another but, in general, this population growth exceeds the rate of growth of production. Therefore, our countries are actually suffering problems of supply of food and other products derived from the agricultural/livestock sector.

This deficient food supply and lack of other products is affected by many factors, which have been discussed during this meeting. Let me re-emphasize some of them. Deforestation is not only affecting livestock production, but also affects the production of crops, since due to deforestation, we have serious problems with the region's rainfall. If we do not have a good supply of water, it is very difficult to achieve good yields. Also, there are soil fertility problems throughout the region, with variations between countries. About 66% of the soils on which cropping or livestock production is practiced are poor or superficial, and have conditions in which it is very difficult to sustain sufficient production to meet the demands of the population in Central America. Erosion also presents serious problems. For a long time we have been practicing cropping systems which have made only a very limited contribution towards the reduction of erosion. One of the very serious problems, related to exports, is the intensive use of agrochemicals. We all know that this is causing serious problems to the natural resource base, especially the soil, the water, and the environment. For example, some research has been carried out in Honduras to determine the level of toxic products; very high levels have been found in maternal milk. There have also been high levels found in wells which the "campesino" population uses to extract the water needed for its daily activities. So we are facing problems of degradation of the soils and degradation of the water and, consequently, there are impacts on production per unit area and on the environment.

At this meeting we have also discussed the problems of rural poverty. Rural poverty continues to increase in our countries, and this has been clearly established in this meeting. Rural poverty is clearly related to the degradation of natural resources. This tragic situation presents a great challenge to all of us, professionals working in the area of agricultural development. The challenge is to contribute rapidly and effectively, to reach sustainable agricultural development in our countries. As we can see, our agricultural production is at the moment, has been in the recent past, and probably will be in the years to come, in a state of permanent stress and under permanent pressure from the factors that we have mentioned. There are biotic and abiotic stresses as well as economic stresses. As long as our agricultural sector is submitted to these stresses, it will be difficult for us to achieve sustainability. Therefore, meetings such as this one are important to seek alternatives and programs that can offer the best chance of achieving sustainability.

There are three interesting data which will allow me to define the importance of the cropping specialist in agricultural production. In first place, it has been indicated that 60-80% of the farms have mixed systems (systems where crops are as important as livestock production). We have also been told that 30% of the crop production is used to feed animals, and, finally, that the dynamic of land use follows three phases. First deforestation, with subsequent extraction of wood; then planting, usually basic grains; and finally, the establishment of pastures. Considering these figures, we can see that the production of crops clearly plays a very important role. Therefore, it is important that the actions we take be from an interdisciplinary and interinstitutional perspective. In other words, the response to the challenge that we face must be **integrated**, in order to really contribute to sustainable agricultural development in our countries.

Finally, I would like to mention areas in which we, as agronomists and specialists in crop production, may be able to contribute to sustained agricultural development. I hope my observations will serve to enrich the recommendations which have already been made by the discussion groups. In the first place, it is important for us as agronomists to have the capacity to identify systems. I will mention a few examples, which can provide us with clear lessons and information in relation to sustainable technology. In first place, we should consider coffee. Coffee is one of the production systems which is really sustainable on our hillsides. In this case I am referring to coffee under shade, where a legume tree is used for shade, and is very important in the conservation of the soils in the coffee producing areas. Another similar example is cacao. These are two examples where production is not only for national consumption, but is also for export. With them I want to indicate that we already have very important sustainable production systems from which we can be learn.

There is another example which is well known to the colleagues from El Salvador. In El Salvador, there is an area where producers use conservation practices; for fifteen years the producers have not burned crop residues, they are using a system which allows them to accumulate the residues and, at certain times of the year, the producers allow the livestock to go into the fields to graze. This system is contributing significantly to reduce erosion and to improve the physical and chemical characteristics of the soil. There is also the case of beans used as mulching in one region of Honduras. Producers do not burn either, and sow maize and beans together, using the beans as mulch at certain periods of the cropping cycle. This permits them to really improve the soil and avoid erosion, and at the same time to control weeds. In conclusion, we have several sustainable systems in use that can serve as guidelines to identify and improve other systems, and propose new alternatives to the producers.

There are other areas in which agronomists can participate in the development of crop/livestock sustainable systems. One is the development of integrated pest management, and the development of varieties tolerant or resistant to biotic or abiotic stress. Another area is development of cover crops and intercropping using legumes. I have noticed in this meeting that colleagues who are working on livestock research have advanced a long way in this regard. We, as agronomists, have also been working on the insertion of legumes into the crop production cycles, in order to improve the soil and obtain some nitrogen for the subsequent harvest.

In the area of conservation tillage, a very important field is that of plant genetic resources, and this has to do with biodiversity. The fact is that through deforestation we are losing many valuable species: forage species, food species, medicinal species, forest species, etc. The agronomists can contribute in the identification and characterization of those species that may be included in improved management systems. One of the important issues is to promote alternative sources of energy. We have heard a lot about firewood, but the truth is that there are other sources of energy which agronomists can promote.

We should utilize the information that already exists in our countries. Right now, within Central America and the Caribbean, there are thirteen research networks —each network doing its own work, and the information generated by one network is generally not known by another. For example, each network is currently trying to establish its own data banks. We need to seek a mechanism that will allow us, through these networks, to take advantage of all the information for the benefit of crop production, forest production, and livestock production.

Agronomists must also participate, very actively, in training activities. There is a great need for intensive efforts in training and education at several levels, from the primary school to technicians. If we do not train our technicians, it will be difficult to promote sustainable agricultural systems. We have to train our producers, and finally we have to train our general population. Both the urban and the rural population are not aware of the benefits that they are receiving from the forest. They are also unaware of the role they are playing in the process of degradation of natural resources. We, as specialists in crop production, must also play an important role in training, and I think we can do so through our professional organizations. I believe that the moment is appropriate for these professional colleagues to be used as a means for the implementation of training activities. Through these same organizations, we may be able to find a way to create an awareness in the different countries, not only within the general population, but also at the legislative level, to create incentives and laws that will favor the conservation of natural resources.

TOMAS SCHLICHTER (CATIE)

I am not going to address the topic of small livestock production, intensive livestock production, nor mixed systems, in which I believe there is no major conflict between production and conservation of natural resources. Indeed, in these cases, the appropriate management of the system may optimize the energy flow and the circulation of nutrients. I am going to address the conflicts that exist with extensive beef cattle production. This has been an activity developed under various different modalities in different parts of the planet. No doubt, it is one of the main sources of animal protein in the world. Other agricultural practices, such as basic grain production, fiber production, etc. are carried out in extensive areas of the world, and have also been developed over the centuries. There are very few activities which maintain a continuing contradiction with humanity. We might say that humanity at large produces relatively few commodities to feed itself, at most 10 or 12 commodities feed 90% of mankind.

Recently livestock production has been strongly questioned by some sectors of society, especially those interested in the conservation of the environment. Why do they question this activity? Basically because the vegetation system which is in equilibrium with tropical ecosystems is the forest. As cows do not eat forest vegetation, it has been necessary to replace forests with pastures. At this point, it does not matter whether deforestation is brought about by timber extractors, or by slash and burn agriculture, or by livestock producers. The issue is that, to produce cows on an extensive basis, the forest must be replaced by pastures, at least with the current technologies available.

Timber producers also cut the forest and open the way for colonization and for livestock producers, who finish the process of deforestation. It so happens that slash and burn agriculture is done to provide food for rural families. There is little excess to be sold from the production of these colonists. Extensive livestock has profit as a fundamental purpose, so that —without questioning profit seeking as a human activity— the social acceptance of slash and burn agriculture is greater, therefore is less criticized. Nevertheless, alternatives are being sought. On the other hand, extensive livestock production brings the best returns to labor. Extensive livestock employs little labor, and in many cases, it causes expulsion of the population. The third group, the timber producers, are as questioned as the livestock producers, so I will not refer to them.

What is the common pattern of livestock producers, agriculturists, decision makers and technicians? The pattern is: we have knowledge and technologies to produce nine, ten, or a dozen commodities. We know how to do this and can adapt it to any latitude so we have good crops yields. Well, let's do it then. On hillsides, we make terraces; if the soil is too wet, we drain it, we dry it, and we produce cereals or meat.

On the other hand, from presidents to peasants, we have all acclaimed the tremendous diversity of the tropics, the marvelous diversity of habitats, of species, of functions and so on. Far fewer people have mentioned the diversity of the human cultures, different from those in the West and who know much more about biological diversity, who know how to feed themselves, cure themselves, construct houses, and various utensils —that is, to make use of diversity. They do not know everything; nor do we. We replace thousands of productive options for just one, two, three, or even ten production options. The reason is found in what I said before, because we know these options very well. The livestock producer offers proteins, but there is good animal protein in wildlife — wild turkeys, the tepezcuintles, deer, and these are consumed not only by native populations, but also by contingents of tourists. Tourists from the same countries from which we are sometimes importing the technology to produce cattle under extensive conditions. Why then are we not researching other kinds of livestock production? Why are we not investigating what is already present here? Not because we are nationalistic, but rather because this fauna is well adapted to our ecosystems. We don't have to drain anything, we don't have to replace the vegetation, we don't have to terrace the land.

Biodiversity is not the only loss by the imposition of 10 or 12 commodities for all humanity; cultures are also lost. Biodiversity and cultural diversity are the victims of this homogenization. When people loose their surroundings they also loose their way of life, their rites and their gods. In other words, we are not going to sacrifice cultures if we investigate how to feed ourselves from the diversity of local fauna. It seems we are more interested in deepening our knowledge on a particular discipline, trying to improve the way the animal looks, its level of production and the efficiency of conversion (that will never be higher than 10-15%) at a very high cost, with no real significance or impact on preservation.

I am not questioning what is being done; I question what is not being done, what is not being investigated and what is not being promoted. I question the lack of innovation, there is ample capacity to deepen on what is known, but not to innovate. To innovate means to search for new alternatives, in this case new cattle production systems. The same thing coud be said about cropping and smaller animals, but as I said before, these are used in the tropics in order to satisfy basic needs so they are not seriously questioned. Management in the this latter activities should also be adjusted, but socially they are more acceptable.

I am not saying that we have to cease producing cattle; what is not valid is to produce cattle everywhere. It is illogical to have no respect for the many things that exist and that we know very little of, by replacing them with very few things taht we know a lot of.

In some deforested areas with low fertility soils that are not very prone to compaction, extensive cattle production can contribute to increase the fertility of the soil. Even if does extensive cattle production does not optimize the flow of nutrients and energy, it optimizes the circulation of nutrients. On the other hand, it is also possible to think of livestock production with large animals in farms where there is coexistence with reasonable amounts of forest, with forest corridors between farms: a mosaic of cattle pastures and forest. Similarly, silvopastoral system with fodder tree species coming from the same forest, in order to take advantage of the genetic richness and avoid invasions by exotic species. This would be a start on diversification, while respecting and constructing diversity of habitats and maintaining options open. In addition it would be possible to do research on livestock production with animals that we currently consider wild, and to arrive at some kind of combination between the two levels of livestock production.

For this, the technical assistance has to change. Technical assistance and the land use must be planned at the landscape or watershed level, depending on the area. The word planning seems to be almost undesirable, but there is no other alternative. Land use planning would be an important and necessary technological change. Forest corridors must be managed not just to preserve but to produce fauna, timber, and other products. Clearly, a farm with cattle, wildlife, timber, and other products is complicated due to its diversity; but we have to learn how to manage diversity.

Sitting down at the city, looking at how cows get fat on the countryside is not sustainable; monoculture or monoproduction is intrinsically non sustainable. Sustainability is complicated and requires more mental and physical work; however, if a future is to exist we must forget about simplicity and homogeneity, be it productive or mental. The resilience of humanity in the face of the coming climatological changes, or any other important change, lies on cultural diversity and biodiversity. If extensive beef production respects these diversities, it will have a future.

DOMINGO MARTINEZ (University of Missouri)

As an economist, I find myself without many externalities left to internalize. But I believe that Dr. Schlichter has posed a large number of challenges which we must study and confront. Economy relates to all of this, so I will try to reorganize my ideas and mention some of the things which have impressed me most in this meeting, things which are innovative.

First, the demographic issue. This is a variable that we must take into account in order to establish any kind of viable alternative for the near future. The population is applying pressure, it is invading the forest, and we have to do something in order to give this population an alternative now. Using our jargon, we have to internalize an externality, which is the value of the forest. We must do this with concrete actions not wishful thinking.

A second aspect, which is important and has been emphasized here in this meeting, is what I would call the historical geography of the territorial occupation in Central America. This has been mentioned, but we still lack precise information. I am not sure whose task it is to review the ecological history, or the geographic history as I am calling it, but we do need to understand how and why we arrived at this situation, and to know if this is really a consequence of external forces, or a consequence of the biological processes of this animal species which we call *Homo sapiens*. The history of *Homo sapiens* is the history of the transformation of the landscape. Sometimes of course, *Homo sapiens* has made many mistakes, above all, when the demographic pressures are very strong. This we must not forget.

Now, about the internalization of the externalities, I like this term. I'm going to try to translate it; it simply means to pay the costs which we did not have to pay before. For example, if we have a car which contaminates and the government decides to measure the contamination and tells us, Okay, for every cubic centimeter or cubic meter of contamination emitted by your car, you will have to pay a certain amount of money. This is internalization of an externality. In the same form, if we want a producer interested in protecting the forest, we must, in one way or another, make sure that this has a value to the producer. If we are talking in terms of the market economy, we have to give a value to this resource. This brings up a questio: how do we place a value on natural resources?

The market problem is not frequently addressed at animal science meetings, and when presented, it is done in a very academic manner, with a description of some form of market, and generally, the presentation concentrates on the most visible and easily measurable aspects of the process of marketing. We generally do not have many elements by which to judge how prices are defined at the farm level, and this is very important, especially when we are accustomed to live in directed economies. The campesino producer sometimes does not understand why he is paid 100 when the neighbor producer is paid 150; of course, the neighbor is much closer to the highway. This market behavior not totally comprehensible to the campesino. I do not know if this is good or bad, I'm not going to make a judgment as to whether the market system is good or bad. What is indisputable is that the market forces are winning the battle now, and we must therefore prepare ourselves. Its nice to think of a barter economy. I have taken many pictures of people exchanging meat for potatoes, but regrettably the market is the force which obliges us to formulate our policies.

This takes us to another problem. It is the development of markets, which was emphasized in the presentation here, and I believe must be continued to be taken into account, especially at the farm level. The information that reaches the producers is only partial, and in many cases distorted. Distorted by those who are interested in making more money in the process of transactions. That terrible individual is the middle-man. But then, the intermediary or middleman plays a role which nobody else can play. If we improve the flow of information to the producer, the intermediary will not be able to benefit as much from his additional knowledge.

Finally I would like to make some comments about the problems at the macroeconomic level. The framework exists, it is there and we cannot avoid it. Whether we like or not, there are international policies; whether we like it or not, sometimes New Zealand will have an excess production of beef, that will always be turned onto the market and bringing the prices to the ground, and Costa Rica will have to accept these prices. These are the external realities that we have to accept, and it is important for researchers on the biological side to be thinking of how we can develop technologies to make our production resistant to the challenges of these uncertain external factors. This was mentioned three weeks ago at an IDRC sponsored meeting, celebrated here in San JosÇ. The issue was that we have to add flexibility to our production systems.

There is another aspect which I think we have not visualized very clearly. This is the need to utilize the crystal balls that the macroeconomists have, to be able to understand the future trends of the meat market in Latin America for the next 3 or 4 years. Based on this, we can adjust our technology, but of course we cannot get a definite response to these questions, and therefore our technology cannot be definitive. I believe that the key word for all of us is flexibility.

FRANCISCO ROMERO (CATIE)

I am going to refer to agroforestry at the level of farm production systems, without implying that we should forget other levels of organization, as the systems theory indicates. We must never forget the macroeconomy levels, which are very important for they are the forces behind so many of the phenomena that we have discussed in these days. I feel much has been said about destruction and conservation, but we haven't really put words into action.

I believe that in agroforestry we have an alternative for harmonizing production with conservation. This is one of several possible alternatives, but one that will enrich soil resources, and at the same time may contribute to the protection of aquifers. We know that the presence of trees will facilitate the infiltration of water into the soil instead of run-off. This is an alternative which will permit enhancement and sustainability of the production of crops for a growing population. One can sustain crop production using chemical fertilizers. Environmental contamination has already been discussed here, as has the lack of availability of chemical fertilizers, and the inability of many of our smaller medium sized producers in Central America to purchase them.

From the point of view of animal production, the use of fodder trees allows to increase the production of milk and meat, not only from bovines, but also from small ruminants such as sheep and goats. We must not forget livestock of smaller sizes, such as iguanas and rabbits, which can be produced and fed on browse, and represent important potencial sources of protein for human consumption.

Obviously, much information is lacking about how to measure sustainability, but I also feel we have to start walking to make progress. We have to be innovative, we have to apply those technologies which, based on our current knowledge, will allow us to implement sustainable activities.

There are areas of land whose vocation is indeed the production of cattle or mixed production. We know that the forestry component, although sometimes restricted to fence lines and stream lines, is present in many of the farms. Many of these farms are small and the use of available resources in combination with some tree species would permit the intensification. There are some excellent ideas such as forest corridors along hedge lines, but our small producers do not have enough land available to make large scale buffer zones in the middle of their fields or corridors between small farms. As somebody explained very well, the only corridor some of them have are the live fences.

On the other hand, the market forces which drive them, call for reduced production costs. Producers must not only increase the milk production, but also this milk must be accessible to the consuming public. This producer is not in the position of being able to use expensive inputs such as soybean meal or fish meal, he will use inexpensive inputs which permit the cost of milk production to be reduced. In addition, it must allow for competitivity in the international markets.

At no time can we afford to forget that there are areas where the only alternative is to leave the natural vegetation as it is, or to try to restore natural vegetation. This is not a simple process of reforestation, because many of the exotic species which are planted, do not fulfill their role within the ecological chain. Instead, the forest must be allowed to grow to its native state once again. We must also not forget that in other regions, and in very rational ways, we must increase the production of food for people who need to eat now and not in 30 years. In a recent meeting atn CATIE, Dr. TartÇ explained how the gap between the hunger of the population and the production of food is increasing in Central American, instead of being reduced, and so, we cannot afford much time to see if the alternatives are indeed sustainable or not, and if the market affects them or not. We must begin now, be innovative, and consider all of these aspects to increase the production of food for a population who is demanding it at this moment.

POSITION PAPER

STRATEGIES FOR SUSTAINABILITY: NATURAL RESOURCES AND ANIMAL AGRICULTURE IN CENTRAL AMERICA

I. INTRODUCTION

Donor agencies, government ministries and non-governmental organizations are concerned about the need to increase agricultural productivity without jeopardizing the natural resource base. The Regional Office for Central America and Panama of the United States Agency for International Development sponsored analysis of the interactions between sustainable animal agriculture and preservation and management of natural resources in Central America in a symposium/workshop entitled, "Animal Agriculture and Natural Resources in Central America: Strategies for Sustainability", held in San José, Costa Rica 7-12 October, 1991. The symposium/workshop drew on the experiences and expertise of many individuals from within and outside the Region, as well as several previous analyses, including the USAID strategic report "Environmental and Natural Resources Management in Central America" undated but issued in 1989, and the USAID sponsored symposium "Animal Agriculture: Development Priorities Towards the Year 2000" held in Washington, D.C. in 1988. The symposium provided an analysis of trends in livestock production and the status of the natural resource base. The workshop drew on this analysis to formulate a series of recommendations in this position paper.

II. OBJECTIVES

The objectives of this position paper are to:

Summarize the current status of livestock production systems and their importance to people of the Region.

Identify trends in the status of the natural resource base, and the relationship of these trends to animal agriculture.

Recommend approaches and practices for improving animal production that will also preserve the natural resource base.

III. BACKGROUND

The wellbeing of the peoples of Central America will ultimately depend on the reconciliation of past, present and future budgeting of the use of natural resources. Burgeoning populations demand food and income; international debt places increasing demands for greater economic growth. These demands are placing great pressure on the resource base of both altered and undisturbed ecosystems of the region. Ecological disturbance is causing significant loss of biodiversity. Yet the integrity of the natural resource base and its biodiversity are the insurance and the patrimony of future generations. Formulation of strategies that will allow sustainable use of resources, and permit both economic growth conservation of environmental quality, necessitate unprecedented multidisciplinary communication and action.

Throughout Central America, demand for increased agricultural production for food security, greater income for a growing population and for expanding exports of agricultural and forest products to pay external debt, are contributing to natural resource degradation. Domestic animals form a vital part of nearly all agricultural systems in Central America, but animals have rarely been managed to gain the greatest productivity per unit area. Animal production systems, especially extensive cattle ranching, are often blamed for destruction or degradation of forest or natural grasslands. Two issues require further analysis: (1) are animal production systems the main causal factor for resource degradation and ecological change? (2) what is the full potential of animals for positive contribution to sustainable agriculture? The challenge for all countries in the region is to recognize the basic causes of environmental degradation and then design and implement alternatives that will enhance sustainable agricultural productivity. Agricultural development requires a trade off with preservation of undisturbed ecosystems, improved management of agriculturally productive areas and rehabilitation of degraded lands. Because of the importance of animals to agriculture in Central America, this position paper focuses on the development of sustainable agricultural systems involving livestock.

Few farms in Central America have no animals at all. Several domesticated animal species play a variety of extremely important roles in rural life in the Region (McDowell, 1991). They often provide traction and transportation for many small producers that are crucial to the operation of their agricultural production systems. Animals also play other roles for the peasant. Domestic animals constitute a store of value for individuals without access to banks or insurance. Animals convert crop residues into food or income. They generate manure for fertilizer or fuel. They guard property and herd other animals. They also may play a role in religious practices (McCorkle, 1991).

IV. REGIONAL TRENDS: ANIMAL PRODUCTION, PROCESSING AND CONSUMPTION

A. Livestock populations and systems. Animal agricultural systems generally can be classified into three groups: pre-commercial, commercial, or campesino (minifundio), and involve a variety of species (Rosenberg, 1991). The interaction of each of these systems with the natural resource base differs. Cattle raising in Central America is not homogeneous. Large, extensive commercial beef cattle ranches are located mainly in lowland areas. Dual purpose (meat and milk) production systems usually are a part of diversified medium-size to small farming systems which provide milk and meat for local markets. These systems may be more profitable than specialized beef or dairy production systems which also produce for local consumption. These dualpurpose systems are currently extending into new areas. Although milk production per cow in Central America increased only 5% from 1974 to 1989 (Simpson. 1991), income from the beef that these animals produce must be included in the total economic return to the owner. Although increases in the regional beef herd have contributed economically to the area, extensive beef ranching is generally inefficient in terms of rates of reproduction and time to achieve market weight compared to North American production of similar breeds. Importantly, small and medium scale producers, often utilizing dual purpose animals, are more efficient and profitable (as a percentage return on investment) than large ones, and their animals tend to be an integral part of more complex subsistence or partially market-oriented agricultural production systems (Leonard, 1987; CIAT, 1984).

The expansion of national cattle herds in Central America between 1960 and 1980 was dramatic (Leon, 1991). A large part of the investment in the agricultural sector went into expansion of the beef cattle industry. Regional production of beef animals increased 2.4 times from 1960-1980 (Leonard, 1987). During the past decade, there has been a modest (3.2%) increase in cattle kept mainly for beef production, but a 14.7% decline in the number of dairy cows (FAO, 1990). There are differences in trends among the Central American countries during this period, however. For example, total cattle populations increased in Honduras, Panamt and Belize, but only Panamt and Costa Rica increased their numbers of dairy cows. The future of beef production in the Region is difficult to predict, and will be affected by a variety of market factors (Amador, 1991).

Except for El Salvador and Panama, beef exports were an important source of hard currency for countries of the Region during the 1961-1980 period, but have declined since. Compared to other agricultural activities, beef production is an inefficient land use for hard currency generation (French, 1991). Future demand by large markets and potential competition between Central American and other international producers is uncertain. At the national level, there have been dramatic changes in per capita human consumption of animal products in Central America during the decade of the 1980s. The average annual rates in the decline in the consumption of beef, milk, eggs and pork were 2.3%, 2.3%, 1.7% and 1.8%, respectively (FAO, 1989).

B. Range and pasture lands. Pasture is the main feed resource for almost all ruminant production systems in Central America. Very little supplementation is provided. Pasture and rangelands represent an important land use system in the region. Pastures covered 23.8% of the territory in 1980 and increased to 26.4% by the end of 1990 (FAO, 1990). Newly established pastures may rapidly degrade (Toledo, 1986). Much of the region's grazing areas have been left in native grasses, especially the relatively recently cleared pastures in the
humid Caribbean lowlands. However, most of the areas cultivated with socalled improved grasses are now considered degraded. Overgrazing has led to invasion and dominance by less palatable native grass species of lower nutritional value. The carrying capacity of the pastures of the region is very limited, and the stocking rate further declined in the last decade from 0.89 to 0.83 animals per ha (FAO, 1990). From these data, it is clear that the slight increase in the

region's cattle population is due to increase in pasture land rather than to improvements in the productivity of existing pastures. This trend could be reversible, offering hope that livestock production can be increased and intensified without additional conversion of forest to pastures. Both research results and some farm-level experiences in the Region indicate that the potential for increasing productivity in a economically justifiable and sustainable manner is possible through the use of adapted grasses, legumes, and fertilizers (Ayarza, 1991; Toledo, 1991). These measures would permit increased milk and meat production through more efficient use of areas already cleared (Romero et al., 1991).

C. **Agroforestry practices.** Most farming systems in Central America include some agroforestry practices that contribute partially to sustainability. Live tree fences and agrosylvopastoral systems provide forage, shade for animals and other benefits. Trees also may contribute fuel wood, timber or fruit to the farm. Nitrogen-fixing trees improve soil fertility and more effectively recycle nutrients (Romero et al., 1991). Use of forage species in cropping systems can provide additional sources of nutrition for the animals in those systems. A variety of tree and shrub species hold considerable promise as sources of high quality forage for ruminant animals in the tropics. The palatability, nutritive value and digestibility of many of these species is excellent (Reed, 1991). Current research trends in CATIE and the national agricultural research institutions are providing a better understanding of more traditional agroforestry practices, and are leading to the development of new alternatives involving woody perennials for more productive and sustainable animal agricultural systems. Moreover, increasing timber prices provide important economic incentives to adopt sylvopastoral systems (Pomareda, 1991). In addition to the forage, fuel wood or timber qualities, other characteristics of the tree and shrub species have to be considered in developing sylvopastoral systems. There may be biological constraints to tree planting and establishment, such as the ability to compete with existing vegetation and to resist insect pests and diseases (Neptstad et al., 1991).

D. **Animal Product Processing.** Meeting public demand for a variety of safe and wholesome products and subproducts of animal origin at reasonable cost requires more than efficient on-farm production. Improvement of post harvest food handling and processing is needed to reduce losses and provide added value accruing both to processors and producers (Zaglul, 1991). In Central America, there are considerable losses from farm to consumer. For example, in beef animals there are significant losses in quantity (approximately 8% in Costa Rica) in shipment from farm to slaughterhouse. Inadequate and unstandardized processing practices results in variable quality and quantity (shrinkage) of products. A 42% loss of potential subproducts occurs. Slaughterhouse under-utilization drives up processing costs. Further losses occur between slaughterhouse and retail outlets. The variety of meat and dairy products produced is limited (Zaglul, 1991).

V. TRENDS: NATURAL RESOURCES

In Central America, the rapid disappearance of tropical forests has not been offset by an increase in agricultural productivity. Projection of current deforestation trends casts serious doubt about maintenance of an adequate resource base that will provide forest products, maintain biodiversity, and protect soil and water.

A. Forests and Their Products. World-wide, some 7.5 million hectares of primary forest are being cleared annually. Most of the clearing is in the tropics, and about half of that is in Latin America. In Central America, less than 40% of the land area remains forested. but the rate of deforestation is
high in comparison to other tropical regions of the world. Over the past decade, the average deforestation rate for the region has been 2.9% per year (Leonard, 1987).

Forest clearing in Central America is economically wasteful, since many of the trees cut have been burned in situ or left to decompose in the fields. Except for Honduras, forest products have not generated a significant amount of employment or national income, despite extensive forest clearing in recent years. In Central America most trees (58% in 1980) are cut not for commercial purposes, but rather for firewood or to make agricultural clearings (Leonard, 1987). Moreover, since 1983 there has been a net depreciation of forest resources in the Region of approximately US $50-150 million (1984) per year (Flores, 1991).

B. Biodiversity. The actual number of living species in Central America, and the effects of deforestation on their extinction, is open to debate. It is clear that habitat loss due to human activity is occurring at a rapid rate. Central America is an ecologically rich area. There are at least 20 different life zones in the region (Holdridge et al., 1971). The transition of ecologically complex tropical forests to simpler agroecosystems, including cattle pastures, results in a decrease in the number of species found in that area (Vaughan and Mo, 1991). The extent of the decrease in species richness is affected by the size, shape and physical juxtaposition of remaining forest patches (Moermond, 1991). Given the geographic extent of human-caused ecological change, species with highly localized distributions are at significant risk of extinction (Diamond, 1990). Some 45% of the world's tropical rain forests have been cut, and the remainder is disappearing at the rate of approximately 1.8% per year (2.9% in Central America), with simultaneous extinction of 0.2% to 0.3% of the species that occur there (Elrich and Wilson, 1991). Most of these species will disappear before their role in the ecosystem is determined or their possible benefits to humankind are defined.

The genetic storehouse that biodiversity represents, has provided people with food, medicine, shelter and a variety of products for everyday use. Loss of biodiversity has adverse consequences for the production of food and fiber (National Science Board, 1990). Effects include loss of plant and animal species suitable for domestication, genes for resistance to diseases and drought, species useful for biological control of pests and parasites, and pollinators.

C. Soil. Most soils in Central America are of low fertility, and many are highly acidic. Only 34% are classified as both good and deep; about 400,000 sq. km. (77% of the total area) are located on steep slopes. Most of the land on the west side of the continental divide has been intensively exploited for crops and pasture for many years. These Pacific watersheds have serious erosion problems due to the presence of highly erodible soils, more concentrated and intensive rainfall patterns during a marked wet season, the absence of natural vegetative cover, repeated seasonal burning (mainly pasture areas), steeper slopes, lack of soil conservation measures, and higher concentrations of people (Flores, 1991).

Estimates of soil loss or degradation made in 1972-1981 indicated a land area of between 1% (Belize) and 45% (El Salvador), with a regional average of approximately 17%, is seriously eroded or degraded. Some estimates of economic impact have been made. For example, in Costa Rica the value of soil loss (depreciated) in 1984-1989 was estimated at 13.3 billion colones (approximately 1984 US$295 million), or a calculated 7.7% loss per year of gross agricultural product (Flores, 1991).

It is clear that the mechanized, high input approach used to maintain soil fertility in the industrialized countries is not feasible in most of Central America because of the topographic and economic conditions (Ayarza, 1991). Nutrient recycling through organic matter is a more rational approach to maintenance of soil fertility, in a soil-plant-animal association.

D. Water. Land degradation and soil erosion in higher elevations of most Central American watersheds has led to large amounts of sediment flowing into fresh water sources and coastal bays. Sediment adversely affects agricultural development, hydroelectric power generation, urban water sources, shrimp fisheries and marine life that depends on estuaries. In Guatemala, for example, the annual soil runoff in areas still covered by vegetation is estimated to vary between 20 an 30 MT per sq km, whereas in unforested areas corresponding values vary from 700 to 1100 MT per sq km. In addition to adverse effects on hydroelectric generation, these high sediment rates are rapidly reducing the storage capacity of the reservoirs that supply water to the cities. Sedimentation also threatens irrigation programs and is responsible for flooding problems down stream in the watersheds, causing millions of dollars of damage (Leonard, 1987). Lack of water retention capacity in the upper reaches of watersheds reduces stream flow during the dry season, when water is most critically needed.

E. Climatic change. It is difficult to predict the nature and extent of climatic change from global warming that Central America may experience over the next century. It does seem probable that changes in temperature and rainfall will occur, and at unprecedented speed. Decreases in rainfall due to shifts in hydrogeologic cycles as forests are converted to grasslands have been of concern in the Amazon basin (Salati and Vose, 1984). However, regional changes in rainfall due to deforestation in Central America have not been assessed. Rain forest destruction contributes to the buildup of atmospheric carbon dioxide and other greenhouse gases (Crutzen and Andrade, 1990). The extent to which agricultural systems of the Region can adapt to these changes is uncertain.

VI. FORCES AFFECTING SUSTAINABILITY

It is easy, but overly simplistic, to blame the agricultural system, and the animals in it, for the observed ecological degradation. In fact, unsustainable agroecological systems develop as the result of a complex factors and a chain of events that must be recognized and dealt with if destructive land use practices are to be reversed or prevented.

A. Animal production systems. By most normal parameters such as yield of products per animal or per unit area per year, animal production in Central America is inefficient. The efficiency of agricultural animals depends on selection of animals genetically suited to local conditions, and optimizing their performance through nutritional inputs, health measures, and management practices (Rosenberg, 1991). Many attempts to improve animal production have failed because they have not provided the appropriate genetic base with all the supporting factors. Human factors can not be overlooked either. If changes to achieve sustainable systems are to be adopted by producers, new approaches must be socially acceptable, ecologically sound and economically viable.

B. Human Populations. Human population pressure in Central America is acute, with a growth rate of 235% in the last 30 years, greater than in any previous period (Leon, 1991). Those countries with the greatest population densities have the highest rates of increase, with corresponding pressure on the natural resource base (Flores, 1991). Despite the current trend for lower rates of population increase in the Region, pressures remain severe. The number of inhabitants per hectare is expected to almost double before stabilizing. The population in the Region has become predominantly urban, with increasing demands for animal products (Leon, 1991). The growth of the urban populations, particularly in one or two principal cities of each country, have led to spatial concentrations of markets for livestock and other agricultural products, particularly in the case of meat and milk production. This has led to competition by animal production systems for croplands near those urban markets, in some cases driving crop production to areas away from urban centers, and explains some current land use patterns involving cattle production on soils that would otherwise be apt for cultivation. Demands by the increasing urban population for services, infrastructure and employment (an estimated 600,000 new jobs annually in the region within 30 years), generate the risk that national governments will exploit part of their natural
resource capital to meet social needs while attempting to remain economically solvent. Government and general public support for extensive animal production systems will likely decrease in the future because of the low capacity these systems have to create employment per investment unit, leading to a corresponding reduction in meat production and loss of meat exports (Leon, 1991).

C. Infrastructure. In the 1960s, both the Alliance for Progress and national governments of the region emphasized development of road infrastructure (Leon, 1991). These initiatives opened up large areas for crops, livestock, and for forest utilization. Road accessibility, availability of international credit and favorable meat prices between 1960 and 1980 resulted in expansion of extensive beef cattle production. Roads opened the way for forestry concessions, and facilitated the entry of itinerant agriculturalists, with the eventual conversion to other, more irreversible, ecologically unsustainable agroecosystems. The cost of road development and related loss of potential productivity from natural resource degradation are not included as costs of production, nor reflected in the prices of goods that come from the land. These costs should be included if an accurate assessment of costs versus benefits is to be made.

D. Land tenure. Pressure for agrarian reform in the 1960s and 1970s led to liberalization of land concessions and permissive legal occupation, resulting in wide-scale privatization of national lands. Much of this privatization resulted in degradation of natural resources because (1) destruction of resources (forests) was requisite to develop a "productive" property that could be titled and (2) the sustainable use of natural resources was poorly understood by users and public policy makers alike. The more secure landholding ("latifundios") were often not intensively used, nor do they generate substantial employment. Excess labor migrated to the cities, or moved to unutilized hillsides or to the agriculture frontier, where land title is much less certain. Poverty and uncertain land tenure have led to shortterm exploitation of natural resources for immediate survival of the minifundistas and their families, and an unwillingness to make labor or capital investments necessary to achieve sustainability (Thiesenhusen, 1991).

E. Land Speculation. Land speculation and the distribution of natural resources at the agricultural frontier has led to inequitable distribution of land and natural resources (Leon, 1991). Migrants to the agricultural frontier have often failed after a short period of time. They then sell out to large land speculators, and move on to clear new areas. Thus, inequitable land distribution has been perpetuated and the forest destruction process has continued (Thiesenhusen, 1991). The quest for short-term profits has not provided incentives for sustainability. Curbing speculative processes and related practices that degrade natural resources are usually left to environmental or natural resource organizations and agencies that are marginal to national economic planning. Although "debt for nature" swaps have been used as vehicles for promoting sustainability of natural resources, they are not a substitute for sound governmental tax, land use and tenure policies.

F. Markets. Without vigorous demand for agricultural products and systems for their sale, only subsistance agriculture persists, with resulting chronic poverty (Toledo, 1991). One reason why intensive animal production in the Region has not increased rapidly is that product prices are relatively low, especially at the farm gate, and input prices are relatively high. Thus, extensive systems tend to predominate. Product prices are low because many governments have controlled them as part of a cheap food policy, aimed mainly at urban populations. Goverments may interfere with markets and restrain beef prices during cattle cycle-induced beef shortages, for example (Jarvis, 1984). Low product prices nationally may also be the result of protectionist policies and non-tariff trade barriers that limit or prevent importation of animals and their products by the industrialized countries.

G. Import/Export Policy. Import restrictions have generated scarcity of some commodities, and thus provided incentives for the production of certain crops
and other products in ecologically fragile zones. Export restrictions have produced surpluses,

driving the prices of agricultural products to low levels, favoring urban consumers to the disadvantage of producers (FAO, 1990). In order to gain short-term comparative advantage, stimulation of agricultural or natural product exports in the Region has been without regard to the ecological cost over the long-term (Pomareda, 1991b). Animal product exports from Central America have a comparative advantage because of the absence of foot-and-mouth disease and other pathogens. The presence of these diseses in exporting countries excludes their animal products from entering many world markets (Rosenberg, 1991; Toledo, 1991). Currently, the strategy of most of the countries in the Region is to develop strong export markets generated by the use of renewable natural resources in intensified agriculture and agroindustries to achieve both added value and to generate employment (Madrigal, 1991; CEPAL, 1991). Under this policy, unless extensive livestock systems become more labor intensive and more responsive to developing internal markets, these systems are likely to become increasingly marginalized and less competitive with crop agriculture or with specialty and non-traditional exports French, 1991).

H. Credit. Conversion of forest to extensive cattle ranches has been promoted by credit policy (Foy and Daily, 1989; Toledo, 1991). Unavailability of credit has been a major impediment in making capital-demanding improvements necessary for the development of sustainable production systems. This is particularly true in agroforestry, where returns on investment are likely to come at a much later time. Where credit is available, rates of interest have a significant effect on the ultimate cost:benefit ratios that accrue to the producer who implements the technology (Pomareda, 1991). There is a tendency to provide credit at rates of interest well above current inflation, and for short periods of time, which tend to foster short-term, highly profitable extractive activities, rather than long-term, sustainable ventures (Pomareda, 1991b).

I. Labor Availability. Initiation of new practices, such as intensive, confined livestock production systems or terracing, are labor demanding. When small producers may have to work off of the farm to generate additional income, there simply may not be enough available time to embark on new activities (Castillo, 1991), such a agroforestry. Tasks for care and management of different animal species are gender-related in many cultures, so labor availability must be assessed in term of who has responsibility for what types of work (McCorkle, 1992). Intensification of large cattle production systems would substantially increase the costs of production.

J. Tax Policy. Land tax policy has helped to provide incentives for the use of the most fertile areas for extensive livestock production, driving small producers into more fragile, marginal areas, especially hillsides, with adverse ecological consequences (FAO, 1990). Taxation of forested lands, while exempting agricultural lands has provided economic incentives for deforestation or for agricultural systems aimed more at tax avoidance than production (Binswanger, 1987). Tax policy can be a powerful tool for providing incentives for sustainable land use (Pomereda, 1992).

K. Energy Policy. None of the Central America countries is self-sufficient in petroleum-based energy. The profitability of large-scale commercial agriculture, to the extent that it is based on cheap energy, is at risk. Energy availability affects rural families in a different way. As deforestation continues, the availability of free or inexpensive fuel wood and charcoal for cooking will become more limited.

L. Subsidies. Subsidies have often favored urban consumers, or encouraged land occupation and use, especially for development of extensive livestock production, even though they were aimed at relieving rural poverty (FAO, 1990). Extensive livestock production systems in some areas, such as the Brazilian Amazon, have been shown to be economically viable only if government subsidies and incentives are provided (Hecht et al., 1988). Such policy consideration should be evaluated in Central America as well. Subsidies can also affect decisions by producers in other ways. The substantial subsidy
that some Central American governments have provided have resulted in the use of agricultural chemicals at higher than recommended rates, because of their low cost to the producer (Repetto, 1985). Suspension of fertilizer subsidies have resulted in reduced soil fertility with subsequent declines in production, resulting in clearing of nearby virgin forests to compensate for the loss (Flores, 1991).

M. Cultural Practices and Beliefs. The cattle culture and high social status of large ranchers dates back to the time of Spanish colonization (Dickenson, 1991). Thus, present extensive livestock production systems have deep historical roots (Leon, 1991).
Similarly, the tradition of exploitation of natural resources for the development of agricultural systems has its origins dating at least from the time of European settlement. However, agricultural development in the Region has varied from country to country, reflecting differences in ethnic and social composition as well as political and economic history.

N. Government Agencies and Policy. The sustainability of animal agriculture and the natural resource base is often not effectively supported by public agencies and their policies (Toledo, 1991; Madrigal, 1991). Ministries of agriculture and livestock are well established, and are concerned about shortterm increases in production for national urban markets or export. Ministries of natural resources and forestry are relatively new, and of limited power and influence. Four year terms of political office make long-term project or policy planning and execution difficult. The legal structure supporting natural resources is often weak or unenforced. There tends to be a duplication of responsibility and lack of coordination between the agricultural and natural resources sectors. Civil servants in these agencies often lack adequate training. A variety of international institutions and agencies are active in the Region, and their objectives and priorities may not be optimally coordinated to achieve the best combination of agricultural development and natural resource management and conservation (Amador, 1991).

O. Debt. Arrangements to cope with international debt have led to short term stabilization policies that may not consider, or may even be adverse to, natural resource management and conservation (CEPAL, 1991). On the other hand, debt for nature exchanges have been used to preserve natural areas and reserves in some countries of the Region. Much of the pressure and financial support for these nature swaps has come from the industrialized countries, and has been aimed at creating parks and preserves rather than for development of sustainable agricultural production systems.

VI. NEW STRATEGIES

A. Management and Development Goals. The challenge to harmonize animal agricultural production with natural resource conservation and management has never been more urgent or daunting. The estimation and reduction of resulting environmental impact should underlie the development and implementation of any new technologies and land use practices. Realistic environmental impact assessment requires that objective standards for sustainability of animal agricultural production, biodiversity, as well as soil and water conservation.

Besides contributing to total output of food and fiber, animal agricultural production and processing practices should meet six criteria:

(1) Preserve soil, water and biodiversity;
(2) Use scarce land resources efficiently;
(3) Be profitable (for market oriented systems);
(4) Be technologically feasible and socially acceptable;
(5) Minimize product postharvest waste; and
(6) Respond to population needs.

Natural resource and management and conservation should meet five criteria:

(1) Conserve species diversity;
(2) Conserve habitat diversity, interactions and functional ecosystems;
(3) Provide sustained production of forest products for those areas not under strict protection;
(4) Provide economic and social incentives for sustainability (or disincentives for misuse) at local and national levels; and
(5) Maintain the functional integrity of watersheds.

Despite the wish by some from outside the region, all the remaining ecologically undisturbed areas in Central America can not be, and will not be, turned into untouchable preserves. A variety of approaches to natural resource conservation and management have a greater likelihood of being socially, politically and economically accepted by people of the region. Soule (1991) has proposed the establishment of eight different conservation systems to preserve entire ecosystems, biogeographic assemblages, indigenous and endemic species, and variation within species. These systems include: wild protected areas; non-arable controlled use areas; extractive reserves; restored degraded habitats; zooparks for targeted species; agroecosystems; living collections of plants and animals; and stored collections of living materials (seed banks, embryo and semen banks). In the Region, agroecosystems, utilizing agroforestry approaches and habitat or ecosystem restoration offer the best opportunity to combine more efficient animal production with maintenance of biological diversity in those areas already converted to pasture (Vaughan and Mo, 1991).

B. Scope. Decisions and strategies that affect agricultural production or the natural resource base can be site-specific (micro level), or involve larger geographic areas (macro level). The practices and policies at micro and micro levels need to be coordinated, but the approaches will be different because the decision makers are different. The micro levels consists of units such as the individual farm, park or preserve, where decisions are made by individual owners or operators on a day-to-day basis. The ultimate fate of these units is influenced by the accumulation of these daily decisions.

The macro level is landscape-based, and includes larger geographic areas such as watersheds, ecozones or ecosystems, and may be national or international in scope. Macro level systems may also be economic, commodity, or trade pattern based. These systems are usually complex and must be viewed holistically. Because decisions are made by a variety of individuals and institutions, coordination is essential. Attempts to intervene in one part of the system may have unanticipated results in another.

VII. ACHIEVING CHANGE

A. General Approaches

1. Establishing Priority Areas. Ideally, sustaining optimal agricultural production while preserving the natural resource base would require a detailed land use plan for all of Central America. Such a plan would have to be technically, economically and socially sound, as well as political acceptable. Development and implementation of a detailed, comprehensive plan for the entire Region would require many years. The Region cannot wait. Needs must be identified and priorities established now. An agricultural and ecological rapid assessment system must be put into place, and operated within the scope of well defined national policies on animal agriculture production and on natural resource conservation and management. High priority areas suitable for sustainable development or requiring protection must be identified so they can be dealt with first. These areas should include:

- The best locations for long-term agricultural or forest production
- Fragile lands that are deteriorating rapidly or with high potential for degradation
- Key areas for preservation of biodiversity or water resources

RECOMMENDATION: Each Central American country should establish a national land use diagnostic and cadastral system, based on current information, to identify geographic areas where attention is most urgently needed. Land and geographic information systems, supported by on-site groundtruthing efforts, are powerful tools to accomplish the diagnostic effort rapidly.

2. Human Population Pressure. The increasing demand for food, fiber and energy is not being met. Increasing populations, especially of the rural poor, is one of the major driving forces in unsustainable utilization and degradation of the natural resource base.

RECOMMENDATION: Efforts must be intensified to slow the human population growth at local, national and international levels. Industrialized donor countries and agencies must assign the slowing of population growth their highest priority, and support that effort with incentives such as aid programs that provide choices for women.

3. Policy for Sustainability. Efforts to improve agricultural productivity and to manage and conserve natural resources tend to be fragmented, with the uncoordinated involvement of many individuals and organizations. National policies, developed in conjunction with donor agencies, must guide initiatives to increase productivity. Because natural resource protection and management transcends national boundaries, regional policies are required. These policies must be incorporated into long-term international treaties, and thus go well beyond the duration of incumbent national political administrations.

RECOMMENDATION: Each country should develop a national policy on sustainable agriculture and natural resources that identifies long-term (10 years or more) objectives, sets goals and creates strategies to obtain them. Regional policy on natural resource management or preservation must be incorporated into international treaties. Individuals and organizations involved in agricultural development and in natural resource management or conservation, be they public, private, NGO, operating at the local, national and international levels, must be made aware of national and regional policy and plans and incentives provided to follow them.

4. Resource Valuation. Unutilized natural resources tend to be unvalued or undervalued compared to productive agricultural systems or forest utilization, to which economic worth can be more readily assigned. In some situations, natural ecosystems are considered valueless, and must be destroyed (property "improved") in order to title land. Esthetic worth alone is not a sufficient basis for assigning value to unused or underused natural resources. Although esthetic values are important in prosperous societies, economic value is more compelling to individuals and societies trying to improve their lot.

RECOMMENDATION: Methods to assign value to biodiversity, soil and water are urgently needed for comparative economic analysis and for planning purposes. Land titling should be restricted to areas ecologically suitable for agricultural or forestry practices, and deforestation should no longer be a condition for land titling (Goodland, 1991).

B. Micro-Level Approaches

1.Sustainable Animal Production. Sustainable animal production on small or large farms requires the provision of scientifically sound appropriate technical practices and social and economic incentives for their adoption. Producers themselves must be involved in developing economically and socially attractive alternatives to short-term exploitation. These technical practices must include an on-going evaluation element so that strengths and constraints can be measured and modifications made.

RECOMMENDATIONS: Emphasis should be placed on development and field validation of practical agricultural production modules, including their animal components, in high priority areas. These micro-level modules must involve multidisciplinary input, and treat the animal component of the production unit (farm) as an integrated part of the whole. These modules should provide increased production and/or income while conserving or improving the natural resource base at the site of application. The modules should include:

- *Highly site-specific sustainable or restorative technical approaches developed jointly by scientists, extensionists and producers and applied on the farm. The animal-plant-soil relationship requires special attention. These approaches, probably including agroforestry, should (1) increase profitability of production, without loss in quantity and quality of soil and water, and (2) generate economic benefit derived from preservation of on-farm biodiversity. Since animals are a vital part of most agricultural systems, their efficiency must be improved by optimizing their genetic base, supported by good nutrition, management and health measures. The development of sustainable animal production systems will require research to provide information that is needed on the components of the production units, and how they function as a whole (Edwards et al., 1990). To the extent possible, research goals should be formulated with and supported by producer associations. The research effort should be supported by national research organizations, supplemented by information and assistance from international centers and donors. Successes or problems resulting from the adoption of new technical approaches must be assessed as they are implemented, and the system modified accordingly.*

- *Economic incentives must be provided for implementation of these sustainable or restorative approaches, including availability of credit at reasonable rates of interest, favorable tax treatment, and availability of, and access to, free markets. Provision of these incentives must be based on objective measures of the beneficiary's preservation of the natural resource base.*

- *Social incentives and constraints must be taken into account for successful adoption of new technical approazches. Long-term commitment to sustainable production systems requires secure land tenure and operational practices that the producer is willing and able to carry out. Labor must be available as needed. A long-term perspective requires a change in both individual as well as societal operational philosophy; the development of a land use ethic should be achieved through a strong public education program.*

Parks and Reserves. Specific parks or nature reserves are required to protect critical small (micro) terrain features (such as limited watersheds, steep hillsides, unique habitats, and buffer zones around parks).

RECOMMENDATION: The national land use diagnostic systems must include teams of biologists and ecologists to make rapid general inventories of flora and fauna. Because of the highly specialized nature of these inventories, critical expertise and information should be shared between countries. Because biodiversity in many of these limited and larger areas are part of a world patrimony, it is reasonable that international sources of support contribute to their operation.

Macro-level approaches

To accomplish change or protection over a broad (macro) geographic area such as an extensive watershed or ecozone, national and international policy becomes more important. It is imperative that policy be based on sound biological, physical, social and economic information.

Increase Animal Agricultural Production Sustainably. Food and fiber production, including that of animal origin, is not adequate to meet national demands and provide exports . Production must be increased, but not at the expense of the natural resource base. Animal agriculture in Central America is generally inefficient, and should be made more productive and sustainable.

RECOMMENDATION: Appropriate technical approaches applicable over broad geographic areas should be developed to increase sustainable production of affordable products of animal origin. These package must improve the genetic base, management, nutrition and health of the animals involved.

o Profitable approaches to permit intensification andincreased efficiency of extensive animal productionsystems should be developed. Elements of these systems include selection and management techniques for appropriate breed and species of animals, forage production, nutritional support and disease prevention and control. These production systems must be developed to avoid adverse effects on soil nutrients, water quality and forage ecology. Development of these systems will require an investment in basic and interdisciplinary applied research best undertaken by international groups and centers of excellence.

o Profitable production of non-traditional animal species should be developed within existing agricultural systems.

o Greater attention should be given to basic and applied research for development of ecozone-level agroforestry systems, with emphasis on forage species.

o The scarcity of people qualified in the area of development of sustainable animal agricultural systems, combined with natural resource management and conservation requires a concerted effort to provide appropriate short- and long-term training programs for agricultural and natural resource professionals. Centers of excellence for practical training in applied agricultural research and extension should be developed. Since resources for these centers will be limited, they should be regional.

Policies for Sustainability. Successful adoption of production programs at the large watershed or ecozone level will require incentives to the producer that can only come through national and international policy decisions. Many of these policies will be codified as environmental law, an area new to the Central American legal and legislative systems. Most political leaders do not have a background in ecology or in sustainable agriculture, and require access to that expertise to make sound public policy. Political leadership does not act independently of public opinion and will. Implementation of new policies will require support from an enlightened public.

RECOMMENDATIONS: In order to achieve sustainable systems at the macro level, governments of the region must provide: o Incentives to make agriculture generally, and especially animal agriculture, sustainable ecologically and economically. These incentives include secure land tenure (titling and registration), fair tax rates, available credit at reasonable interest rates, technical assistance, adequate rural infrastructure (communications, roads, education, health care), commodity processing facilities, free national and international markets, and favorable import/export policy. Some of these incentives can only be provided at great expense, so priority must be again to those that will provide the greatest benefit per unit of cost. International donor agencies and organizations must encourage establishment of these priorities and promote their implementation. Debt for conservation exchanges should contemplate development of sustainable agricultural and forest production systems, utilizing sylvopastoral strategies where appropriate, to relieve pressure on forested areas, and contribute to maintenance of the overall natural resource base (Pomareda, 1991).

o A body of sound, functional and enforceable environmental law must be developed on a national and regional basis and should be facilitated by:

- Formation of a Central American network (perhaps through the Cental American Commission for Environment and Development [Comision Centroamericana de Ambiente y Desarrollo]) to share experiences and measure impacts, with additional opportunities to communicate with experts outside the Region.

- Orientation and education programs in natural resource management and conservation, and in sustainable agricultural development for political decision-makers at all levels.

- Public education at all levels to achieve understanding that everyone has a vital stake in wise land stewardship. Mechanisms are already in place (government ministries, formal and informal educational systems, international and regional centers, networks and communication media) but require development of educational materials, coordination, and an opportunity to share experiences. Leadership and coordination should be provided by a regional center of excellence. Because the need is urgent and the task vast, a multiplier effect should be achieved through teacher training (kindergarten through university levels).

Functional Ecosystem Management. The global importance of natural resources requires that they be protected, managed or utilized at the macro level on a sustainable, scientifically sound basis. The structure, composition and function of many natural and disturbed ecosystems are poorly understood. This lack of information and understanding impedes rational decisions on approaches to protection, management and utilization. Unfortunately, regional human and financial resources are not adequate to develop the comprehensive ecological and agricultural knowledge base and apply that knowledge on the ground. A variety of funding mechanisms must be found. Some examples include debt for nature swaps, conservation easements and public-private partnerships employing market incentives, such as those used to restore dry tropical forest in Guanacaste, Province, Costa Rica (Allen, 1988; Katzman and Cale, 1990).

RECOMMENDATION: Teams to analyze large ecosystems, or more restricted ecozones and watersheds should be part of the national diagnostic and priority setting effort, to maximize maintenance of functional ecosystems and of biodiversity and to effectively protect fragile lands and critical watersheds. These analyses must be translated immediately into action on the ground, through establishment of functional parks, preserves and protected areas. Incentives must be provided to keep human disturbance to a minimum. Given the global importance of the natural resource base and limitations within the Region, substantial financial and technical support must come from the industrialized countries.

Involve the Community. Since the local communities will ultimately determine the fate of the high priority areas, they must have an economic stake in, and philosophical commitment to, sustaining the natural resource base over the long-term (Karremans, 1991).

RECOMMENDATION: Community involvement must become a keystone in land use in high priority areas:

o Since many areas are too large to initiate activities throughout them, projects will have to be done on pilot or demonstration sites.

o The communities must participate in planning, execution, evaluation and modification of regional and area development initiatives.

o Economically and ecologically compatible businesses that add value to agricultural or forest products should be stimulated within high priority areas, to provide employment and increase the income of those most likely to protect or degrade fragile areas.

o Ecotourism should be promoted in appropriate areas, and managed to avoid ecological and environmental degradation.

o Well focused public education and information efforts should be implemented.

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SYMPOSIUM/WORKSHOP AGENDA

Monday, October 7

07:30 - 09:00 Registration.

09:00 - 10:00 Inauguration.

10:00 - 10:30 Coffee.

10:30 - 10:45 Objectives and results expected of the Symposium/Workshop.

10:45 - 12:15 **Session I** Moderator: Thomas M Yuill

Current Status and Trends in Animal Agriculture in Central America. *James B. French* (EARTH, Costa Rica).

Current Status and Trends in the Utilization of Natural Resources in Central America. *José Flores* (CATIE, Costa Rica).

12:15 - 13:30 Lunch.

13:30 - 15:30 **Session II** Moderator: Oscar Fonseca

People, Cattle and Natural Resources in the Landscape of the Central American Isthmus. *Francisco León* (CEPAL, Chile).

Driving Forces: Economics of Animal Agriculture in Relation to Natural Resources. *James R. Simpson* (Univ. of Florida, U.S.A.).

Policies relating to Livestock and Natural Resources: Institutional Factors. *Alberto Amador* (CORFOGA, Costa Rica).

Aspects of Meat Marketing. *Alberto Amador* (CORFOGA, Costa Rica).

15:30 - 16:00 Coffee.

16:00 - 17:30 **Session III** Moderator: Miguel Vélez

Role of Animals in Resource Conversion and Conservation. *Robert E. McDowell* (North Carolina State Univ., U.S.A.).
The Roles of Animals in Cultural, Social and Agroeconomic Systems. *Constance M. McCorckle* (Institute for International Research, U.S.A.).

17:30 - 18:00 Moderators and Rapporteurs meet with Organizing Committee y Relatores con el Comité Organizador.

Tuesday, October 8

08:00 - 09:30 **Session IV** Moderator: Hugh Poponoe

Too Much of a Good Thing: Alternatives for Sustainable Animal Agriculture. *Joshua Dickinson* (Tropical Resources and Development, Inc., U.S.A.).

Livestock Production on Pasture: Parameters for Sustainability. *José M. Toledo* (FUNDAGRO, Perú).

09:30 - 10:00 Coffee.

10:00 - 12:00 Discussion groups.

12:00 - 13:30 Lunch.

13:30 - 15:30 **Session V** Moderator: Joyce Turk

Recycling of Nutrients in Tropical Pastures and Acid Soils. *Miguel Ayarza* (CIAT, Colombia).

Conserving Biodiversity: Interfaces with Animal Production. *Christopher Vaughan* (School of Filed Studies y Universidad Nacional, Costa Rica).

Characteristics of Tropical Plants that Determine Nutritive Value. *Jess D. Reed* (Univ. of Wisconsin, U.S.A.).

15:30 - 16:00 Coffee.

16:00 - 18:00 **Session VI** Moderator: Carlos Chtves

Utilization of Trees and Bushes in Ruminant Production Systems. *Francisco Romero* (CATIE, Costa Rica).

The Efficiency of Interactions Between Animals and Natural Resources with Particular Reference to Central America. *FÇlix J. Rosenberg* (PANAFTOSA, Brazil).
Efficiency of Processing Animal Products. *José A. Zaglul* (EARTH, Costa Rica).

Wednesday, October 9

08:00 - 08:45 **Session VII** Moderator: David Stanfield

The Relation Between Land Tenure and Deforestation in Latin America. *William C. Thiesenhusen* (Univ. of Wisconsin, U.S.A.).

08:45 - 12:30 Coffee. Poster presentations.

12:30 - 14:00 Lunch.

14:00 - 15:30 **Session VIII** Moderator: David Stanfield

The Macroeconomic Environment and the Sustainability of Livestock Production. *Carlos Pomareda Benel* (IICA, Costa Rica).

The National and International Legal Framework for the Conservation of Natural Resources. *Patricia Madrigal Cordero* (CODECE, Costa Rica).

15:30 - 16:00 Coffee.

16:00 - 18:00 Discussion groups.

Thursday, October 10

08:00 - 10:00 **Session IX.** Moderator: Federico Holmann

Presentation of reports by discussion groups.

10:00 - 10:30 Coffee.

10:30 - 12:00 **Plenary session** Moderator: Thomas Yuill

Discussion Panel. *Jan A. J. Karremans, Carlos Cháves, Roduel Rodríguez, Tomás Schlichter, Domingo Martínez* y *Francisco Romero.*

12:00 - 12:30 Closing ceremony.

Friday and Saturday, October 11 and 12

Workshop at CATIE's Headquarters in Turrialba.