# "Sustainability" & Pastures Research in the Humid Tropics: a case study of the impact of public policy debates on international agricultural research

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September 1988

Paper presented at the "Farming and Food Systems" Symposium organized by the Rockefeller Foundation and CIP September 1988 Lima, Peru.

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## Introduction

Technological innovation has for many years been seen as the principal means of raising agricultural productivity in the developing countries. The dramatic increases in food grain production achieved in the post-World War Two period are largely attributable to increases in yield per hectare rather than bringing new areas into production (Brown 1982). These yield increases have been made possible by the application of scientific principles to farming, first in the developed countries and later in the developing countries. The application of science to agriculture in the developing countries -- through plant breeding and the use of chemical inputs (fertilizers and pesticides) -- represents the main thrust of what became known as the Green Revolution of the 1960s. Technological innovation continues to be the focus of research in the centers for international agricultural research and in many national agricultural research institutions.

Despite the success of modern farming practices to raise yields and maintain per capita food production in the face of exponential population growth, these agricultural techniques have not been immune to criticism. For many years questions have been raised regarding the effect of agrochemicals on the environment and the capacity of hydrocarbon-based technologies to support high levels of agricultural production without serious environmental costs. For example, the US Department of Agriculture studies indicate that groundwater pollution from agricultural chemicals affects the drinking water of 50 million Americans (O'Brien 1989).

With the sharp rise in oil prices in the 1970s this criticism acquired an economic aspect as well when concern was raised that high input, energy intensive agriculture was consuming excessive amounts of energy to maintain and extend yield increases (see Pimentel et al. 1973, 1980). When high input agricultural practices were transferred to the Third World as part of the Green

Revolution, many of the same concerns and criticisms were extended to agricultural development efforts. The high yielding varieties developed as part of the Green Revolution require significant amounts of fertilizer and pesticides to realize their genetic potential. If the energy requirements of this type of farming were excessive in the developed countries, critics asked, what was the logic in introducing them in Third World countries many of which were hit hard by increases in energy costs, and where many farmers lacked the capital, credit and management skills to use agrochemicals correctly.

It is now widely recognized that Green Revolution technologies were not appropriate for massive numbers of developing country farmers. Efforts to reach the small, resource-poor farmers largely bypassed by the Green Revolution have brought researchers into increased contact with people farming "fragile lands:" hillslopes and lowland humid tropics. These marginal lands are even more subject to environmental degradation than high potential areas under intensive production (Novoa and Posner 1981, Brown 1982). On marginal lands the central problem is to raise yields and intensify production without provoking unacceptably high levels of soil erosion and fertility loss. Agricultural expansion must be directed to areas which are relatively more apt for agricultural production while avoiding cultivation of fragile range and forest lands.

The question of agriculture's impact on the environment is the central problem in what has come to be known as the "sustainability" issue. While concern over sustainability is not new (see Barbier 1987) the concept has gained increasing prominence in the development community in this decade. This reflects a number of interrelated factors including rapid rates of population growth and pressure to feed the approximately 82 million people currently added to the world's population every year (World Resources Institute 1988). Population pressure demands yield increases through intensification of agriculture (which often means increased use of agrochemicals), while simultaneously driving the opening of new lands for agriculture by land-hungry rural populations. (The latter often exacerbated by skewed land distribution in more favored areas.) The increased interest in sustainability is also linked to the rise of environmental movement in the developed countries, the transfer of that movement to the developing countries and a widely recognized deterioration in environmental quality that has made environmental questions difficult to ignore.

One of the principal intellectual products of this process has been the forging of an explicit conceptual link between environmental quality and development in its broadest sense. This phenomenon is forcing a rethinking of the nature of the development process, the relationship between natural resources and economic growth and a more explicit recognition of the trade-offs and impacts of various development strategies (Norgaard 1988).

The term "sustainability" can be stretched to cover virtually any and all aspects of development. This paper examines sustainability as it applies to agriculture and attempts to assess the impact of the sustainability debate on international agricultural research. The paper will present a case study of the Tropical Pastures Program (TPP) of the Centro Internacional de Agricultura Tropical (CIAT). In this particular case we will be examining sustainability in connection with the expansion of agricultural into new environments. As we shall see, this issue involves conflicts between the expansion agricultural lands versus the maintanence of biodiversity, between the provision of livelihoods to growing numbers of people versus the preservation of the "service functions" of non-agricultural ecosystems (clean air and water, climatic regulation) and the desire to foment economic growth and development versus that of protecting wild lands from the negative impacts of human intervention. These questions lead us to the crux of the sustainability debate: how to balance human needs and ecological concerns.

**Sustainable agriculture: what is it?** The concept of sustainable agriculture remains rather "fuzzy" and depends to a certain extent on the context in which it is used. According to Douglass (1984:5-6) there are three principal definitions of sustainable agriculture:

(1) the ability of food production systems to produce the amount of food necessary to sustain world population, with food supply seen as expandable indefinitely subject only to economic rather than ecological or natural constraints;

(2) food production systems that provide a sustained yield over an unspecified long run without degrading the environment through erosion, pollution, salinization or other processes;

(3) food production systems that sustain a particular value system based on stewardship of resources and certain moral values of self-reliance, humility and holism.

In this paper the term "sustainable agriculture" conforms to definition (2) above: sustained yield over an undefined long run. The definition of sustainability generated by the Technical Advisory Committee (TAC) of the Consultative Group for International Agricultural Research attempts to blend aspects of definition one and two above. Under the TAC definition:

> **Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation. (CGIAR 1987:x)**

The TAC definition has the disadvantage of introducing the variable of intensification ("meeting changing human needs") in the definition of sustainable agriculture. Presumably the capacity of a system to respond to intensification depends on a number of ecological and economic variables which should be considered apart from the system's sustainability.

Neither of these definitions is very useful in operationalizing the concept of sustainability (see Herdt and Lynam, this volume) or in helping us visualize what sustainable agricultural systems should look like. There has developed in concert with sustainability concerns a vision of alternative agricultural systems less reliant on external inputs that can provide some guidelines as to the nature of sustainable agricultural systems. A recent article by Altieri, et al. (1983) outlines the "ecological and socioeconomic aspects of alternative, self-sustained, energy efficient, less-resource intensive agroecosystems." The authors suggest the following as characteristics of sustainable agroecosystems (Altieri, et al. 1983:46-47):

1. primary production: the crop or crops that replace a natural ecosystem should approximate the biomass of the natural climax community, e.g. "if a natural grassland needs to be transformed into an agricultural system it should be replaced by cereals rather than by orchards."

2. land use capability: major land qualities related to plant growth such as availability of water, nutrients, soil texture, resistance to erosion, etc should be used to determine the type of agricultural system for a given tract of land.

3. vegetational patterns: "the natural vegetation of an ecosystem should be used as an architectural and botanical model for designing and structuring as agroecosystem to replace it."

4. polyculture: traditional agricultural systems often employ polycultures, multiple and relay cropping which in theory are more stable, avoid risk and are more resistant to outbreaks of pests and diseases than monocultures.

5. low input, energy efficiency: sustainable agriculture relies on a variety of strategies to minimize external energy inputs to the system such as enhancing photosynthetic efficiency through modifying plant architecture and use of C-4 plants, improved soil management through minimum tillage, use of legumes for biological nitrogen fixation and "managing pests in an ecologically sound manner."

6. nutrient recycling: sustainable systems endeavor to maximize nutrient recycling through use of polycultures, incorporating legumes and agronomic practices that maintain vegetational cover, organic matter and healthy microbial populations in soils.

The main problem with this concept of sustainable agriculture is its disregard for the productivity advances permitted by the use of modern petroleum-based technology. At current and projected levels of population, it would be difficult to withdraw these external inputs from many highly productive farming systems. A more realistic goal in many cases is to reduce "chemical dependency" through more efficient use of more benign yield-enhancing agrochemicals complemented with changes in management where necessary. The guidelines produced by Altieri, et al. are perhaps most relevant to resource-poor farmers on marginal lands who are frequently far from the infrastructure and markets that provision external inputs. These are precisely the circumstances of many of the production systems where CIAT's Tropical Pastures Program works.

## Sustainable agriculture: the institutional response

The network of international agricultural research centers has expanded significantly over the past decade. In many cases sustainability concerns were incorporated early on in the research goals of these centers depending on their particular mix of commodities and research mandates. For example the Centro Internacional de la Papa (CIP) was immediately confronted with sustainability concerns and the farming of fragile lands as potatoes are frequently grown on steep slopes. The International Institute of Tropical Agriculture (IITA) has as one of its principal research foci the generation of low cost, low input alternatives to systems of shifting cultivation. And the International Center for Research in the Semi-Arid Tropics (ICRISAT) works with resource-poor farmers located on marginal lands with a high potential for natural resource degradation.

CIAT represents a different case. At CIAT the research focus is on four commodities -- beans, cassava, rice and tropical pastures -- which are produced in a wide variety of environments in diverse farming systems. This particular mix of commodities does not lend itself easily to a center-wide approach to sustainability. The responsibility for incorporating sustainability concerns instead has been confronted at the individual program level. For example the Cassava Program has had to devote research resources to the issue of soil nutrient depletion and erosion -- with consequent environmental degradation -- as cassava is often grown in marginal environments of low fertility. Research has been carried out on farming systems and cropping practices associated with cassava and in designing agronomic practices to reduce erosion in cassava-producing areas.

However, of the four commodities researched at CIAT, the Tropical Pastures Program is probably the most affected by sustainability concerns principally due to its work on pastures in the humid tropics. The balance of this paper will present an in-depth look at the nature of the sustainability debate and how concern over sustainability has affected research strategies and priorities in this program.

Tropical Pastures: a brief overview.

The Tropical Pastures Program (TPP), which evolved out of a beef production program, aims to increase beef and milk production through improved cattle nutrition based on grass-legume pastures well-adapted to acid, infertile soils primarily in the American tropics. This is expected to benefit producers through improved productivity and animal performance and consumers through an increased supply of beef and milk in urban areas (see CIAT 1985 for a statement of program goals). The research focus of the program is the collection and agronomic evaluation of improved tropical forage species as well as the development of appropriate management strategies for the integration of these forage crops in a variety of production systems.

The TPP is unique among programs at CIAT in several respects. For example, the TPP's research is focused on non-domesticated forage species -- often wild species little-known genetically or taxonomically. This leads to an intensive effort at collecting wild species in order to search for genetic variability and desirable traits with a corresponding reduced effort on plant breeding. Another distinctive aspect of the TPP is its research focus on acid, infertile soils. This research mandate encompasses the vast geographic area underlain by Oxisols and Ultisols including the Llanos of Colombia and Venezuela, the Cerrados of Brazil and forested areas of the humid tropics, primarily the Amazon Basin. Thus, in contrast to many other programs which endeavor to improve the productivity of domesticated crops grown on intensively used agricultural lands, the TPP is attempting to use new species to open a vast agricultural frontier presently characterized by low productivity. In agronomic terms, and in the eyes of development planners, these are "underutilized" lands. The working hypothesis of the TPP is that unlocking the productive potential of these lands through overcoming the natural environmental constraints that have restricted their use, will have a potentially tremendous impact on the agricultural economy of the American tropics.

The geographic focus of the program from the mid-70's through early 80's was the savannah ecosystem of South America (the Llanos of Colombia and Venezuela and to a lesser extent the Brazilian Cerrado). This region of almost 250 million hectares is one of the most sparsely inhabited regions of South America. Farming systems in the llanos are generally large, extensive cattle operations. The native grasses of the South American savannahs are of low productivity and nutrient content, severely limiting

the productivity of cattle raising in this ecosystem. Working in the llanos among extensive cattle ranches far from major population centers raised equity concerns regarding the TPP's research and limited its economic impact.

Partially in response to these concerns the program has in recent years expanded activities in the humid tropics, e.g. Amazonia. In expanding research efforts in the Amazon the TPP stays within mandate of working in areas of acid, infertile soils while at the same time opening up opportunities to work among a variety of production systems including those of the small to medium sized farmers actively colonizing the region. Small farmers also tend to operate more intensively managed "dual purpose" production systems -- raising cattle for beef and milk. Milk production creates more employment on farms than extensive cattle ranching and provides an important source of cash income for farmers. Milk is an item in great demand in urban markets, consumed preferentially by infants and children often at risk nutritionally. These aspects of the TPP's research directly address important equity concerns.

Amazonia: issues in agricultural development.

Expansion of research efforts by the TPP in the humid tropics and especially in the Amazon basin, provides not only a major technical challenge in the effort to develop sustainable systems in a very difficult agricultural environment, it also thrusts the program into the controversy over appropriate land uses in the Amazon basin. The past decade has seen an enormous increase in scholarly interest in Amazonia which is reflected in a burgeoning literature on Amazonian ecology much of it focused on the negative impacts of agricultural development (see Davis 1977, Goodland and Irwin 1975, Moran 1983, Smith 1983, Prance and Elias 1977, Barbiri-Sccazzchio 1980 and Schminck and Wood 1984). As pasture-based ranching has been a prominent form of development in the Amazon, the sustainability and productivity of this form of land use is coming under increasing scrutiny (see Hecht 1982a,b, Goodland 1980, Sanchez and Tergas 1979, Buschbacher 1986, 1987).

Agricultural expansion in the Amazon is particularly controversial due to this region's unique characteristics. The Amazon basin represents the largest remaining stand of tropical forest in the world, estimated to cover over 450 million hectares, about two-thirds of the existing tropical rainforest world-wide (see Table 1). Over half of this area, about 280 million hectares, is found in Brazil. Tropical forests are characterized by high species diversity: though they cover only 6% of the earth's land surface they are estimated to contain 50-90% of the world's species (World Resources Institute, 1988:5) The forests of the Amazon Basin contain about 2,500 tree species compared with only twelve to fifteen in northern temperate forests (Marden dos Santos 1988). Botanists and ecologists express alarm that this diversity will be reduced or eliminated before it is properly studied including description of the species involved and possible

medicinal or other economic uses of these species (Prance 1985, Janzen 1986). The tragedy of species extinction is compounded by the threat of cultural extinction as well as indigenous groups come into contact with settlers and state level societies anxious to usurp their lands. The disappearance of indigenous groups, in addition to its incalculable human costs, would contribute to the loss of indigenous knowledge of potentially valuable plant and animal species. Preservation of the tropical rainforest is therefore an urgent international concern.

Table 1. World Distribution of "Intact" Tropical Rainforest Ecosystems (Approximate figures)

| Country | Area of Tropical Rainforest (sq kms) |
|---|---|
| Brazil | 2,800,000 |
| Peru | 500,000 |
| Colombia | 400,000 |
| Venezuela | 300,000 |
| Guyanas (three together) | 300,000 |
| Bolivia | 162,000 |
| Ecuador | 100,000 |
| Africa (mainly Zaire & Gabon) | 1,600,000 |
| S.E. Asia (mainly Malaysia & Indonesia) | 900,000 |
| Total | 7,062,000 |

From: Goodland (1980:10)

Efforts to develop the Amazon are complicated by the difficult environmental constraints on agricultural productivity. The acid, infertile soils that place the area within the mandate of the TPP have been the principal constraint to the development of productive, sustainable agricultural systems. Aside from seasonally inundated alluvial soils and those with the influence of relatively recent vulcanism (estimated to cover about 31 million has or 6% of the basin, according to Cochrane and Sanchez 1982:163-164) most soils in the Amazon are characterized by high acidity (pH $<$ 5.3), high levels of aluminum saturation ($>$ 59%), low levels of phosphorus ($<$ 7 ppm), low levels of organic matter ($<$ 4.5%) and low cation exchange capacity ($<$ 8 meq/100mg) (see Table 2 for chemical characteristics of Amazonian soils). Soil nutrients are subject to rapid leaching and volatization due to high rainfall and continuously warm temperatures. It is widely recognized that the high biomass of the native forest is only maintained through extremely tight and efficient nutrient cycling, a subject which has been widely studied over the past decade (Jordan 1985, Salati and Vose 1984). Removal of the natural

vegetation interrupts this system of nutrient cycling resulting in nutrients loss through leaching and erosion, a process slowly reversed through colonization by secondary vegetation (Uhl 1987).

Table 2. Summary of selected parameters of soil fertility of Amazonian soils

| Parameter/ (0-20 cms) | Surface soil (20-40 cms) | | Subsoil Range | |
|---|---|---|---|---|
| | millions ha | % | millions of ha | % |
| pH | | | | |
| < 5.3 | 392.2 | 81 | 398.9 | 82 |
| 5.3 -7.3 | 91.2 | 19 | 84.7 | 18 |
| % organic matter | | | | |
| < 1.5 | 43.9 | 9 | 405.2 | 84 |
| 1.5 - 4.5 | 357.8 | 74 | 77.8 | 16 |
| > 4.5 | 81.9 | 17 | 0.4 | -- |
| % Al saturation | | | | |
| 0 - 10 | 81.8 | 17 | 96.2 | 20 |
| 10 - 40 | 37.9 | 8 | 49.8 | 10 |
| 40 - 70 | 78.4 | 16 | 39.4 | 8 |
| > 70 | 285.3 | 59 | 298.0 | 61 |
| Exchangeable Ca (meq/100 g) | | | | |
| < 0.4 | 222.5 | 46 | 349.4 | 72 |
| 0.4 - 4.0 | 159.7 | 33 | 81.3 | 17 |
| > 4.0 | 101.2 | 21 | 52.8 | 11 |
| Exchangeable K (meq/100 g) | | | | |
| < 0.15 | 298.8 | 62 | 439.1 | 91 |
| 0.15 - 0.30 | 113.7 | 24 | 37.9 | 8 |
| > 0.30 | 71.1 | 15 | 6.5 | 1 |
| Available P (ppm) | | | | |
| < 3 | 276.9 | 57 | 414.6 | 86 |
| 3 - 7 | 159.1 | 33 | 54.6 | 11 |
| > 7 | 47.7 | 10 | 14.4 | 3 |

Source: Cochrane and Sanchez 1982:172

A high percentage of exchangeable cations (Ca, K, Na, Mg) and sulphur are stored in aboveground vegetation rather than in the soil in tropical forests (Salati and Vose 1984:131). Stocks of P, which are generally limiting in the Amazon, are generally divided equally between above ground biomass and in soil (Lal 1986:201, Salati and Vose 1984:131). In contrast most N is located in soil, roots and litter. Clearing and burning the forest for agriculture makes nutrients locked up in the biomass

available to cultivated plants as numerous studies have shown (Nye and Greenland 1960, Ewel, et al. 1981, Lal 1986). Figures 1 and 2 present results from Peru on the effect of burning secondary forest on soil nutrient levels. Nutrient levels were measured before and after burning on ten experimental plots located on farmers fields. Figure 1 indicates whether the level of various nutrients increased, decreased or stayed the same in the upper stratum of the soil (0-20 cms) while Figure 2 presents the same data from the 20-40 cm level. The tables clearly indicate an increase in P, Ca, Mg and a decrease in Aluminum saturation and Iron with all effects more pronounced in the near surface layer of the soil. At the same time that nutrients become available for plant uptake after burning, they are also subject to leaching with the first heavy rains of the planting season.

Traditional slash and burn agriculture is based on the capture of these nutrients released from the burned vegetation. But as is well-known production declines with the loss of nutrients through leaching and erosion and through removal of harvested produce. Agriculturalists face other problems in Amazonia as well. Biotic pressures in the form of pests and diseases are extremely high. An especially difficult problem in plots cultivated for more than two years in succession is weed invasion. Data from the Peruvian Amazon indicate that weed control is the single most labor demanding activity in cattle raising for small farmers (Hernandez, personal communication) a statement corroborated for eastern Amazonia by Hecht (1982a:162).

The principal challenge facing agricultural development of the Amazon is to promote systems of production that are able to maintain reasonable levels of productivity on soils of low native fertility, in an environment of high biotic stresses in a region where the intensive use of chemical inputs is impractical due to inadequate infrastructure. This lack of infrastrucutre also inhibits the marketing of agricultural products, particularly perishable produce.

**Pasture development in Amazonia: a sustainable land use option?** In an oft-cited article ranking the environmental soundness of development alternatives stated that, "Conversion of tropical rain-forest ecosystems into pastures rates the worst, environmentally, of all the conceivable [development] alternatives." (Goodland 1980:18). While there exists some controversy in the agronomic literature on the exact dynamic of soil chemistry when an area is converted from forest to pasture (compare studies by Hecht 1982a, Falesi 1976, Toledo and Serrao 1982), there is widespread consensus that commonly used cultivars and management practices fail to maintain initial high levels of pasture productivity. The TPP has stated that, "Pastures are not, at present, a stable land use alternative due to the lack of germplasm adapted to the edaphic, climatic and biotic conditions of the [humid tropics] ecosystem." (CIAT 1985:70).

Therefore the question is not whether cattle ranching as currently practiced is a sustainable land use system -- clearly it is not. The question is whether sustainable pasture-based systems can be developed for the humid tropics. Can germplasm be found among the more than 10,000 accessions grasses and legumes collected by the TPP that is adapted to "edaphic, climatic and biotic conditions" of the humid tropics? Can these species be combined into productive, sustainable pastures capable of withstanding pests and diseases and grazing pressure by cattle? And can these species be managed by the producers that the TPP wishes to serve?

## Program Responses: Pastures and Sustainability

Given the controversy over the sustainability of pastures in Amazonia (and the program's recognition of this fact) one could argue that the entire research thrust of the TPP in the humid tropics is driven by the sustainability issue. The TPP has chosen some specific research strategies and emphases to make its research sensitive to the issue of sustainability.

### Geographic emphasis

The Pastures Program has focused its work more in what can be termed the "Andean Amazon" of Peru, Ecuador and Colombia (and to a lesser extent Venezuela and Bolivia) where agricultural development is significantly different than Brazilian Amazon. Pastures development in the Brazilian Amazon has been criticized as much for its social effects as its environmental effects. According to Hecht (1982a) pasture development in the Brazilian Amazon, at least since the mid-1960s, has been dominated by wealthy industrialists and multinational corporations clearing immense tracts of lands using subsidized credit mainly for speculative purposes. Along with this expansion came conflict with small settlers who had often spontaneously colonized the land. The ensuing title disputes usually left small settlers on the loosing end of an often violent confrontation (Schminck 1982).

In contrast the Andean Amazon is characterized by spontaneous and directed colonization schemes, involving migrants from the overcrowded highlands seeking land and often fleeing oppression and political violence. Aramburu comments on the Peruvian case that,

> **The expansion of the agricultural and demographic frontier in the Peruvian selva alta is primarily due to spontaneous migration of Andean peasants. . . . This process . . . generally distinguishes the case of the Andean countries with zones in the selva alta from the countries of the Amazon plain such as Brazil. (1984:174)**

Ortiz (1984) has likewise linked colonization in the Colombian Amazon to cycles of political violence in that country.

Colonization may also be linked to the discovery and development of resources such as petroleum in Ecuador (Uquillas 1984). The predominance of peasants among the migrants does not guarantee the success of the settlement nor that the process is free of conflict. Initial colonization by smallholders is often followed by land speculation and buy-outs by large landowners. Still it remains true that the colonization of the Andean Amazon follows a pattern distinct from the Brazilian case in being led by peasant migrants seeking family farms rather than being fueled by corporations and wealthy individuals interested in land speculation and tax write-off schemes.

Livestock raising forms an integral part of these family farms (20-150 hectares) that have production systems distinct from the extensive ranches of the Brazilian Amazon. Family farms involve a mix of annual and perennial crops, and dual purpose livestock production. Milk may be converted into cheese or sold fresh if the farmer is close to market or transportation link, or may be for home consumption -- a significant source of protein for infants and young children. Dual purpose production implies more intensive management of cattle herds which favors the introduction of improved pastures which often require more skilled cultivation in their establishment and maintenance. Inadequate attention has been paid to the role of cattle among small-to-medium producers in the Amazon. Misguided proposals to declare the Amazon a "cattle free zone" (Ledec, personal communication, 1988) besides being unworkable for logistical reasons, fail to recognize the role that cattle play in the survival strategies of peasant colonos.

Though Brazil has the largest portion of the Amazon Basin (refer to Table 1) significant portions of the national territories of the Andean countries are located in the lowlands. Table 3 lists the proportion national territory located in Amazonia of selected countries bordering the basin. The relative priority of development of the Amazonian portions of these countries should depend on three interrelated factors: one, the portion of national territory in the Amazon basin; two, alternative agricultural development options open to each country, and; three, population pressure on existing lands, especially those adjacent to Amazonia. If we use these criteria it becomes apparent that, in general, there is more pressure on the Andean countries to develop the Amazon than in Brazil, which has extensive agricultural resources located outside the Amazon Basin. Indeed, Brazilian colonization efforts in the Amazon have often been attributed to geopolitical motives rather than economic necessity (Wagley 1984 and other contributors to the same volume edited by Schminck and Wood 1984). Using these criteria probably no country needs the Amazon as much as Peru followed by Bolivia, Ecuador and Colombia. In fact, Peru provides an interesting case of development of the Amazon which may represent the extreme in terms of current urgency but may become more representative over time as other development options are closed out in other countries.

Table 3. Amount and proportion of land in Amazonia among selected countries

| Country | Total size (Kms Sq) | Territory in Amazonia (Kms Sq) | % Territory in Amazonia |
|---|---|---|---|
| Bolivia (1) | 1,098,581 | 360,000 | 33% |
| Brazil (2) | 8,511,960 | 3,000,000 | 38% |
| Colombia (3)) | 1,138,890 | 405,685 | 35% |
| Ecuador (4) | 270,670 | 134,706 | 48% |
| Peru (5) | 1,285,216 | 785,649 | 60% |
| Venezuela (6)) | 912,050 | 178,095 | 20% |

Sources: (1) Pereira & Salinas 1982
(2) Goodland 1980 & author's information
(3) Navas Alvarado 1982
(4) de la Torre F. 1982
(5) Gazzo 1982
(6) Benacchio 1982

**Agricultural ecology and the Peruvian selva: a brief overview.** The agricultural ecology of Peru is shaped by its highly contrasting geographic endowment. Geographically the country is divided into three broad ecological zones: coast, sierra and selva. Table 4 shows the approximate areal extent of these regions. The coast is extremely arid with agriculture only possible in widely irrigated river valleys widely separated by barren lands. The sierra also presents a difficult agricultural environment with steep slopes, very high altitudes and extreme parcelization of agricultural land among small producers with only limited areas appropriate for mechanization or other large scale agricultural development options. The selva covers approximately 60% of Peru and can be further divided into selva alta and selva baja. Selva alta consists of lands along the eastern versant of the Andes mountains between about 2,000 and 500 meters a.s.l. This region is characterized by extremely rugged topography, narrow river valleys, high variability in geology, soils, and climate. (This is the principal coca producing region of Peru.) Selva baja is the region under 500 mts a.s.l. and is characterized by undulating to flat terrain, large, slow-moving rivers, acid soils, uniformly hot temperatures, and abundant rainfall. While soil endowment is variable (particularly in selva alta), in general soils are acid and infertile, aside from limited alluvial soils. Natural vegetation in both areas is exuberant with high species diversity and can be classified as cloud forest, montane and pre-montane rain forest (selva alta) and tropical rainforest and semi-evergreen seasonal rainforest (selva baja).

| Table 4. Area of Geographic Regions of Peru | | |
|---|---|---|
| Region | Millions of hectares | % Total Area |
| Coast | 13.7 | 11 |
| Sierra | 39.2 | 30 |
| Selva Alta | 19.4 | 15 |
| Selva Baja | 56.2 | 44 |
| TOTAL | 128.5 | 100 |

Source: Sanchez & Benites 1985

At the middle of the present century, the Peruvian selva was a sparsely populated largely undeveloped expanse of territory inhabited by tropical forest tribal groups and settlers left over from the rubber boom -- awaiting the next economic bonanza. This pattern is repeated, with minor variation, for most of the Andean countries bordering the Amazon. This panorama began to change in Peru around mid-century. Key factors in this change were the construction of a road from Lima to the jungle town of Pucallpa (completed in 1947), spontaneous colonization from the overcrowded and economically depressed highlands (particularly to adjacent areas in the selva alta), and the initiation of planned colonization schemes also concentrated in the selva alta (e.g. the Alta Huallaga settlement of the 1950s-70s).

This development is reflected in the demographic figures presented in Tables 5 and 6, and Figures 3 through 5. Starting with Table 5 we note that total population in Peru roughly doubled from 1961 to 1981. As Table 5 indicates (see Figures 3 and 4 as well), this has been accompanied by a major shift in population distribution by region. The sierra, historically the cultural heartland of Peru, contained 65% of Peru's population in 1941 (approximately 4 million inhabitants) while the coast had about 28% (1.7 million with .654 million in Lima). By 1981 the coast had 50% of the population, with 27% of the total population of Peru in Lima (8.5 million with 4.6 million of those in Lima). Over that same time period the relative proportion of Peruvians living in the sierra declined to 39%. Population growth in the sierra was about 1.2% in the period 1940-1981, while the overall average for Peru was about 2.6% (see Table 6). At the same time the percentage of Peruvians living in the selva increased from 7% to 11%. The number of inhabitants of the selva increased from less than half a million in 1941 to nearly 2 million in 1981. Current estimates place the population of the Peruvian selva at about 2.3 million (INE 1987:28).

Table 5. Population Distribution by Geographic Region, Peru

| Region | 1940 | % | 1961 | % | 1972 | % | 1981 | % |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Coast | 1,759.5 | 28 | 3,859.4 | 39 | 6,242.9 | 46 | 8,512.9 | 50 |
| (*Lima | 654.1 | 10 | 1,845.9 | 19 | 3,302.5 | 24 | 4,600.8 | 27) |
| Sierra | 4,033.9 | 65 | 5,182.0 | 52 | 5,953.2 | 44 | 6,704.3 | 39 |
| Selva | 414.9 | 7 | 865.2 | 9 | 1,341.9 | 10 | 1,813.8 | 11 |
| PERU | 6,207.9 | | 9,906.7 | | 13,538.2 | | 17,031.2 | |

Population in thousands
* Figures for Coast include Lima.
Source: Moran 1984

Table 6. Population Growth by Geographic Region

| Region | Annual Growth Rate 1940-61 | 1961-72 | 1972-81 |
| --- | --- | --- | --- |
| *Costa | 3.8% | 4.5% | 3.5% |
| Lima | 5.1% | 5.5% | 3.7% |
| Sierra | 1.2% | 1.2% | 1.3% |
| Selva | 3.6% | 4.1% | 3.4% |
| PERU | 2.2% | 2.9% | 2.6% |

Source: Moran, 1984

Over the last forty years Peru has changed from predominantly rural (65% rural, 35% urban) to the reverse (68% urban, 32% rural). The key factors behind this change are the massive migrations triggered by depressed economic conditions in the sierra and the stagnation of the Peruvian agricultural sector. Between 1970-84, the Peruvian agricultural sector's growth rate was only 1% per year (INE 1987). (The economy as a whole grew at 2.3% per year during the same time period.) When combined with a population growth rate of 2.5% this indicates a 16% per capita decline in agricultural production. For the wave of migrants leaving the sierra the preferred destination is the city: Lima in particular, but increasingly to provincial cities as well. However substantial numbers of migrants, perhaps one of every five, according to Aramburu (1984:163) migrate to the selva. As Figure 5 illustrates, over 20% of rural households in Peru are located in the selva.

The selva already plays an important role in the agricultural economy of Peru. Figures 6 through 9 illustrate the respective contribution of coast, sierra and selva in the production of four staple crops: rice, maize, beans and yuca (cassava). The selva produces about 30% of the total national rice production and is the leading producer of corn with over 50% of national production (INE 1986:LV-LVI). The selva produces about 40% of the nation's dried beans and over 90 % of Peru's yuca. Thus in Peru it is no longer a question of integrating the region into the agricultural economy of the country -- the selva is already indispensable to Peruvian agricultural production.

Large areas of the selva consist of acid infertile soils only marginally suited to the production of basic grains (without extensive chemical inputs). According to Sanchez and Benites (1985), approximately 50% of the Peruvian selva (38 million hectares) is covered with acid infertile soils (see Table 7). If we add to this highly erodible soils on steep slopes (31%) and poorly drained soils (14%) we see that 95% of the soils of the selva have severe limitations to sustainable agricultural production. One option for bringing a portion of the acid infertile soils under production is cattle raising as forage species are generally less demanding of soil nutrients than annual crops. Sanchez and Benites (1985:413) calculate that less than 10% of the area apt for pasture in the selva is currently in this land use.

Table 7. Distribution of soils in the Peruvian Selva

| Type of Soil | Millions of Has | Percent |
|---|---|---|
| Acid infertile soils on flat to undulating terrain | 38.0 | 50 |
| Soils on steep slopes with high erosion potential | 23.4 | 31 |
| Poorly drained soils | 10.1 | 14 |
| Soils of high to moderate fertility on flat to undulating terrain | 4.1 | 5 |
| TOTAL | 75.6 | 100 |

Source: Sanchez and Benites, 1985

## Low Input Systems

The TPP's efforts have consistently been geared to a low input philosophy in germplasm selection and pasture management research. This approach has been fostered by the necessity to develop technology for extensive systems where application of fertilizer and other agrochemicals is unlikely. In situations where extensive ranching predominates (such as the Colombian llanos or the Brazilian Amazon), producers rarely fertilize pastures and are even less likely to attempt chemical control of pests and diseases. It is equally true of mixed production systems of the Amazon; if farmers use fertilizers at all, it will be applied to crops, not to pastures. Thus from the outset the TPP has had to focus on germplasm selection as the key to solving critical production constraints. This has led the program to assemble extensive germplasm collections and to focus selection on adaptation to edaphic and biotic constraints.

Moreover the TPP has attempted to integrate forage legumes into improved pasture systems as a means of ameliorating nitrogen deficiencies in acid infertile soils. Instead of relying on purchased nitrogenous fertilizers (which farmers are unlikely to apply anyway) the TPP has been experimenting with different species of forage legumes to provide needed nitrogen. This is a difficult challenge as the goal is to virtually create a new ecosystem composed of various grass and legume species. The species involved must be compatible biologically, palatable and nutritious for the cattle and sufficiently aggressive to withstand competition from weeds and to persist under the somewhat negligent management of most farmers. This is an extremely difficult task given the complex relationship between plant and soil, among plants and between plants and animals.

The Tropical Pastures Program's low input approach can be contrasted with the so-called "Yurimaguas technology" generated by Sanchez and collaborators (see Nicholaides, et al. 1984) for continuous cropping of annual crops in Amazonian soils. Table 9 lists the fertilizer requirements for the Yurimaguas technology which, in addition, requires intensive soil testing to identify site specific nutrient deficiencies (Fearnside 1987:210). While the Yurimaguas technology may be applicable to certain areas with favorable location in relation to markets and infrastructure, very low input pasture technology clearly has advantages in more typical frontier situations.

The ultimate goal of this research is to create highly productive swards that are efficient at capturing and recycling the limited nutrients available in these systems. This challenge is made all the more difficult by the program's focus on the reclamation of degraded sites where nutrient stocks are already depleted.

Another question that has received scant attention in the debate over cattle ranching in the selva is the context of cattle production within the national economies of the countries involved. Turning to livestock production data from Peru (see Figures 10 through 12) we can note that the milk and beef production in Peru are characterized by low to no growth over the last twelve years. In fact, the size of the country's beef herd has actually declined significantly in the last four years (Figure 10). According to Jarvis (1985) from 1970-1981 demand for beef in Peru grew 3.0% per year, while production declined 1.3% per year. Demand for milk products increased 3.1% and production declined 0.5%. As a result of this decline in production, Peru ranks 17th among 19 Latin American countries in terms of per capita fresh milk consumption (only Bolivia and Panama are lower) and 18th in per capita beef consumption (only El Salvador is lower). Another result is that Peru is one of the region's largest importers of dried milk -- approximately 30 thousand tons in 1981. Figure 11 illustrates the structure and magnitude of Peru's beef and milk imports from 1980-86. These imports peaked at nearly US $100 million in 1982 and were approximately US $40 million in 1986.

Clearly the livestock sector in Peru is failing to meet the needs of the country's growing population. The contribution of the selva to national beef production is low. Sere, Estrada and Toledo (1984) estimate that beef production in the selva from 1980-82 was approximately 11,000 metric tons per annum or about 12.5% of national production during this time period. Another indirect measure of the contribution of the selva to national beef production is the amount of beef from this region arriving at the market in Lima (see Figure 12). This has never exceeded 7% of the total. The selva produces about 4.5% of the total national milk production (INE 1986:LVIII).

In summary, the Peruvian agriculture cattle sectors are failing to grow at a rate that keeps pace with population growth. As a result imports are high, there is extreme pressure for prices to rise, and per capita beef and milk consumption have declined. To a certain extent, some of these conditions are unique to Peru, but of the countries bordering the Amazon basin, only Colombia has consistently been a net exporter of beef in recent years.

As a consequence, pressure to increase agricultural production in the Peruvian Amazon is likely to continue in the immediate future. Over time, given rates of population growth and alternative agricultural development strategies, other countries of the Andean Amazon may also need to look to the agricultural frontier of the Amazon basin for increased agricultural production. Distance from markets, difficulty of access, sparse population and environmental limits on annual crop production (acid infertile soils) all combine to make cattle raising an attractive development strategy for national governments and settlers.

Table 9. Lime and fertilizer requirements for continuous cropping of rice-maize-peanut-soybean rotation on an Ultisol of Yurimaguas, Peru

| Fertilizer | Amount per hectare | Frequency |
|---|---|---|
| Lime | 3 tons CaCO2 equivalent | Once per 3 years |
| Nitrogen | 80-100 kgs | Rice & maize only |
| Phosphorous | 25 kgs | Each crop |
| Potassium | 160 kgs | Each crop, split applied |
| Magnesium | 25 kgs | Each crop unless dolomitic lime is used |
| Copper | 1 kg | Once or twice per year |
| Zinc | 1 kg | Same as Copper |
| Boron | 1 kg | Once per year |
| Molybdenum | 20 g | Mixed with legume during inoculation |

Source: Nicholaides, et al. 1984:347

Reclamation of degraded lands

The research of the TPP designed to address sustainability concerns through its emphasis on the reclamation of degraded lands. The program is committed to generating technologies for the establishment of pastures in areas of moderately degraded (second growth/bush fallow forest) and severely degraded (weed-infested pastures) lands. It is more efficient and technically easier to generate germplasm for areas of secondary forest rather than intervening in the agroecosystem after it has already experienced a severe "crash" and reached an extremely degraded state.

The program's strategy is to focus germplasm screening among the forage crops that are least demanding in terms of nutrient requirements and thereby identify forage grasses and legumes adapted to the degraded soils of the Amazon. In the case of secondary forests ("capaoeira" in Brazil, "purmas" in Peru) the need is for species that will establish rapidly after forest clearing, capture the nutrients released by the burn and then set-up its own system of nutrient recycling. Here again, nitrogen fixing legumes play a critical role. These grass-legume associations must form stable, productive mixtures capable of establishment after relatively short fallows using the unsophisticated technology available to the small to medium

farmer. If species are found that can establish effectively after secondary forests, pressure to clear virgin forest would then be reduced. There are hundreds of thousands of hectares of secondary forest in the Amazon Basin and the development of agricultural options for these areas has been indicated as a priority by sustainability advocates (Goodland 1980:14).

The really difficult challenge is to establish improved grass-legume pastures in areas of highly degraded pasture, skipping the prolonged (10 + years) of fallow necessary for forest regeneration on these sites. Pasture establishment in these areas will probably require some mechanization to restore the physical structure of compacted soils and may require some minimal fertilizer input as well. Adding the dimension of mechanization obviously places this technology beyond the reach of most small to medium farmers. Yet if these areas can be reclaimed economically, investment in this research can be justified through reducing the need to deforest new areas. The large landowners who have been responsible for extensive deforestation -- the typical extensive rancher of the Brazilian Amazon, for example -- may find it more attractive to reclaim existing pastures, which are closer to established infrastructure and already fenced, rather than opening up new areas of forest. In any case the same philosophy applies of using well-adapted grass-legume pastures which utilize nitrogen fixation and effective nutrient recycling to maintain their productivity.

## Agroforestry: option for the future

The integration of trees in mixed land use systems is desirable from both an economic and ecological perspective. Trees can provide the farmer with benefits such as shade, living fences, forage, firewood, lumber or fruits, resins and other products depending on the species employed. Trees contribute to the sustainability of the system through their role in nutrient cycling either through nitrogen fixation, efficient uptake of nutrients in near surface levels of the soil and through tapping nutrient reserves in the subsoil unavailable to annual plants or forages and making these nutrients available through litter fall and other mechanisms. Trees can also help reduce wind and water erosion and contribute to watershed protection mitigating many of the negative effects of deforestation (for reviews of agroforestry see Huxley 1983, for reviews of agroforestry in the Amazon see Hecht 1982c, Peck 1982 and Bishop 1982.) Integrating trees into Amazonian farms would add to their economic stability through providing multiple products for consumption and/or marketing and augmenting the diversity of species cultivated.

The TPP is currently involved in an agroforestry project with a strong livestock component in the Ecuadorian Amazon under the direction of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) (see Bishop 1982 for a description of the project). The TPP is working closely with the project designers to evaluate both the technical and economic feasibility of the

system at the on-farm level. This system includes the use of grass-legume mixtures (Brachiaria humidicola and Desmodium ovalifolium) together with annual subsistence crops, coffee and trees utilized for shade (Cordia alliodora, a commercial timber species, Schizolobium amazonica, and others), living fences (Euphorbia sp., Erythrina ulei and others). Agroforestry systems are extremely complex and pose serious difficulties in research and investigation including the long time frame needed to evaluate species and systems of production, the scarcity of seed for expanding areas under investigation and production and the necessity for a cross-disciplinary approach to investigation and evaluation that often cross cuts ministerial and other bureaucratic boundaries within international and national development agencies. Many of these same factors impede rapid technology transfer and adoption as well.

The TPP plans to expand its investigation of agroforestry and the integration of tree species into livestock production systems in the future. Internal planning documents and personal discussions indicate that the program will be working closely with other international research centers with experience in agroforestry systems, such as International Council for Research in Agroforestry (ICRAF) and the International Institute for Tropical Agriculture (IITA). This collaborative effort will focus on appropriate tree species well-adapted to the abiotic and biotic conditions of the Amazon and appropriate to small and medium production systems.

Summary: Pastures Research and Sustainablity

If we look at the characteristics cited in Altieri, et al. 1983 (mentioned above) as typical of ecologically sustainable agroecosystems we see that the technology being generated by the TPP is in many ways congruent with these characteristics. The program's approach is to use polycultures (grass-legume mixtures) adapted to highly acid, infertile soils rather than modify the soil environment through costly amendments and chemical inputs. Through the use of nitrogen-fixing legumes, the program's strategy is again to minimize inputs (especially the use of expensive, petroleum-based nitrogenous fertilizers) and to set up an effective system of nutrient recycling within planted pastures. Considerable research effort is also expended in identifying accessions of tropical forages with resistance or tolerance to common pests and diseases and which establish rapidly and aggressively to minimize use of pesticides. The relatively recent involvement in agroforestry (which will expand in the future) will, if successful, succeed in further buffering the system against environmental perturbations and mimic architecture and biomass of the native forest.

Serious questions remain regarding the feasibility of this type of system from a technical, economic and social point of view. Can sustainable pastures be created for the humid tropics

that are agronomically sound? Will these systems be sufficiently superior in productivity to be attractive to farmers in the immediate, short term? Are the increasingly complex systems -- especially agroforestry systems -- capable of being managed by the migrants of relatively low educational and technical competence? These are only a few of the obvious barriers to the successful generation of productive, sustainable pastures in Amazonia.

The technical issues to some extent beg the question of whether cattle are ultimately an appropriate development option for the Amazon; a question that is beyond the scope of this paper. To a certain extent the type of systems that develop in the Amazon basin will be dependent as much on the policy and macroeconomic environments as on the agroecological environment and available technological options. Mahar (1988) has clearly analyzed how tax and credit policies encouraged the formation of unproductive and unsustainable extensive ranches in the Brazilian Amazon. The ultimate value of the TPP's technology is dependent on the presence of a pool of potential adaptors of the technology under development. Ill-managed, extensive cattle ranching enterprises which exist largely to capture tax and credit benefits and as gambles in land speculation are not likely adaptors of improved pasture technology. Small-to-medium producers may find the technology attractive, but their success and viability is contingent upon policies conducive to their survival.

## Social science input and research priorities

In expanding research activities in the humid tropics the TPP is faced with a production environment much more complex than that of the llanos or cerrado. There is a greater mix of small, medium and large farms with a greater variety of crop and livestock mixes in a heterogeneous natural and cultural environment. More data on production systems will be needed in order to target technology generation and transfer efforts in this ecosystem. The following is a partial list of research questions that demand further investigation with a strong social science input:

1. How prevalent is small to medium-scale cattle production in humid tropics (including dual purpose production systems)? What contribution do they make to regional economies? What impact will improved pasture technology make at the farm level and on regional/national economies?

2. Are migration trends of the 1960s and 70s continuing? Has the pace of migration to Amazonia increased, decreased or remained the same? And what is the relative weight of push vs. pull factors?

3. What are the actual and potential social conflicts arising from colonization? Is the process of land accumulation and concentration inevitable? What are

the constraints -- both technical and socioeconomic -- limiting the viability of a healthy small-to-medium farm sector in the Amazon?

4. What are actual and potential crop-livestock interactions in existing farming systems? What are the social and agroecological factors responsible for variable success in farming the Amazon? What is the relative importance of capital, management skills, and other factors? How do farmers choose among the range of productive activities available in the Amazon, e.g. annual crops, perennial crops, livestock, etc?

5. Why do farmers engage in activities that lead to resource degradation? What are the key factors that lead to resource degradation and where are the management interventions most likely to succeed in slowing or reversing degradation? How do farmers perceive resource degradation?

6. What are the principal barriers to the adoption of improved pasture technology by farmers? By what criteria do farmers evaluate and choose forage species? How does farmer management influence pasture productivity and persistence?

Concern over the sustainability of agriculture presents a stiff challenge to international agricultural research. There are tremendous difficulties in operationalizing the concept within the framework of traditional agronomic and economic research. The sustainability paradigm questions the success of high input, petroleum-based agriculture that has been the model for raising agricultural yields over much of the developing world. At present the advocates of sustainable agriculture have no alternative model that produces the same level of yields demanded by the earth's rapidly growing population without external chemical inputs. However concepts borrowed from alternative agriculture have much to teach us regarding complementary management techniques that can contribute to more efficient input use and in the design of low input agricultural systems for the many farmers for whom the adoption of chemical inputs remains economically and technically impossible.

Perhaps the greatest value of the sustainability concept is as a heuristic device that draws our attention to the conflicts inherent in the development process. Belief in the concept of "development" (including agricultural development) has been based on expanding the economic pie so that all share in its benefits. Sustainability in its wider sense reminds that development has a cost -- in this case an environmental cost. It forces us to examine more closely the trade-offs inherent in the transformation of natural resources; trade-offs between conservation and

exploitation, between short-term and long-term profitability. Awareness of these environmental costs allows us to examine more closely who benefits from the exploitation of a particular resource. When we realize that deforestation of the Amazon has an economic cost, in environmental services and future development options foregone, (however difficult these costs may be to quantify) we can then more legitimately raise the question of social and economic benefits. The resulting equation is quite different if these costs are incurred simply to benefit a reduced number of inefficient enterprises as opposed to fostering the development --perhaps slow and painful -- of a viable small-to-medium farm sector that generates social as well as economic benefits.

Technology generation has an important role in determining the productivity and sustainability of production systems. Technical solutions must be tailored to constraints prevailing in specific farming systems. Small farmers and large farmers face different problems. A menu of feasible technological options is a necessary condition for the existence and maintenance of viable production units at any scale. But technical solutions must be complemented by an economic and political environment conducive to generating agricultural production and incomes. Social science has a valuable contribution to make in more closely specifying the technical needs of various types and scales of farming systems and in determining appropriate agricultural policies to support them.

The international centers for agricultural research are largely technology-driven organizations. The "induced innovation" model of Ruttan (1977) that emphasizes the generation of new technology and the application of science to agriculture remain the main business at these centers. Yet experience shows that technology, far from being a panacea, is a relatively "blunt instrument" for achieving specific social and economic impacts (Sanders and Lynam 1982:476). If the centers are to evolve into more comprehensive agricultural development institutions (as suggested by Ruttan 1978), they must increasingly grapple with social and political issues they are currently ill-equipped to handle. Yet examining these issues may threaten the aura of scientific credibility and political neutrality essential to the successful conduct of their primary mission -- technology generation. How this dilemma is resolved in the coming years will strongly determine the success or failure of international agricultural research.

Fig. 1 Effect of Burn, 0-20 cms

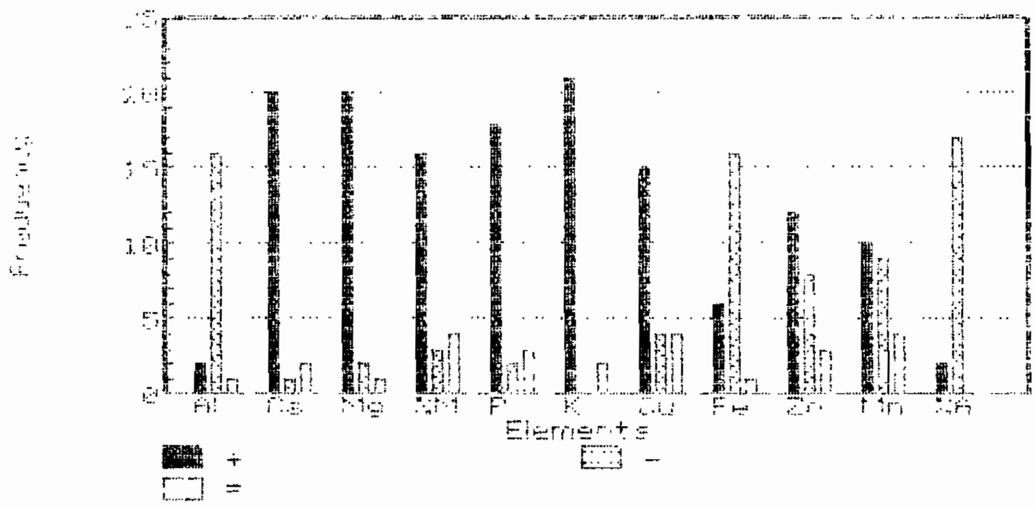



Fig. 2. Effect of Burn 20-40 cms

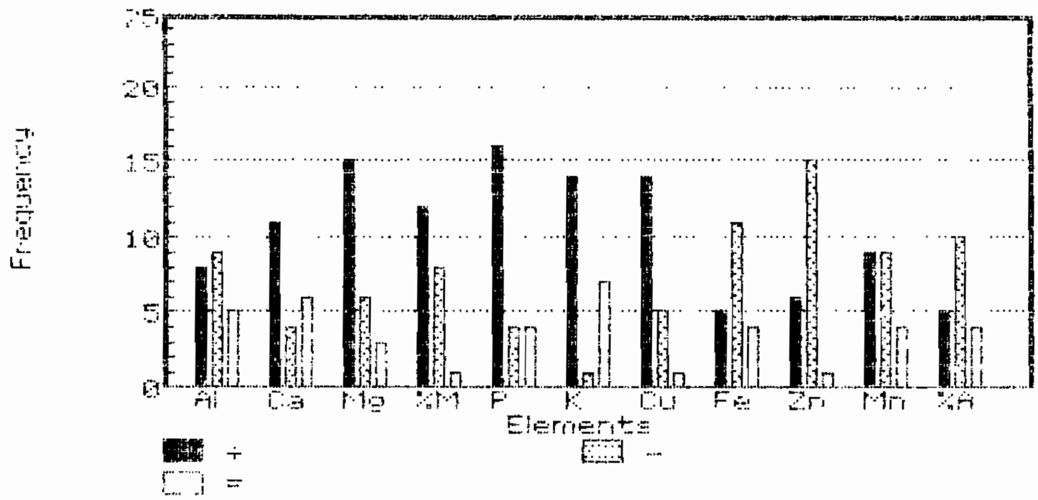
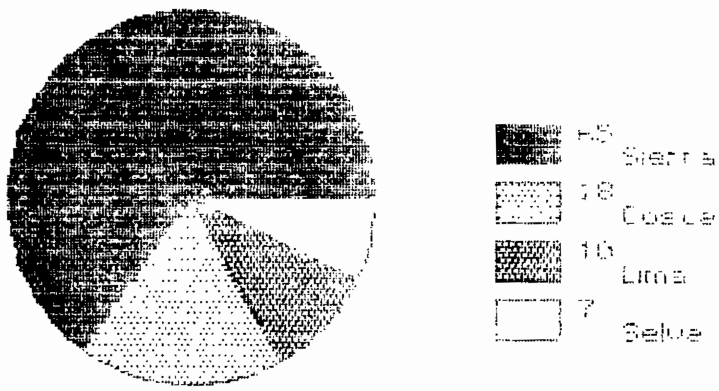


Fig. 3 Population Distribution by Region

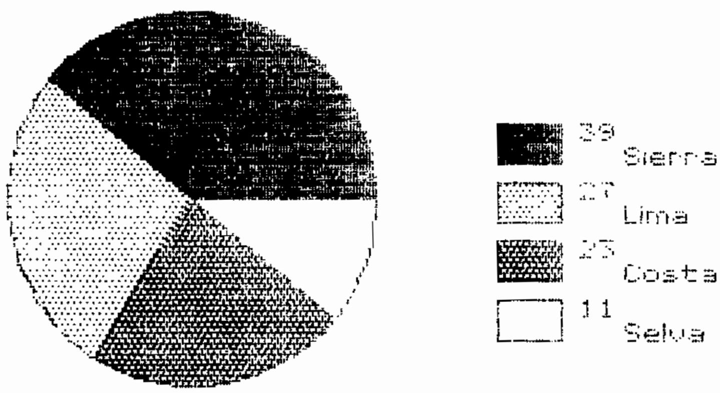
1940




Total Percent
100

Fig. 4 Population Distribution by Region

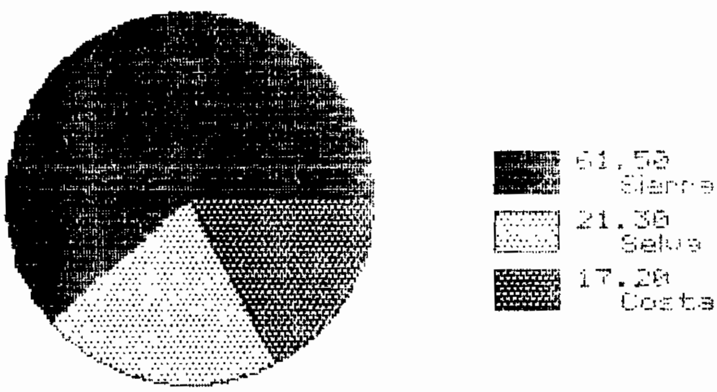
1981




Total Percent
100

Fig. 5 Distribution of Rural Households

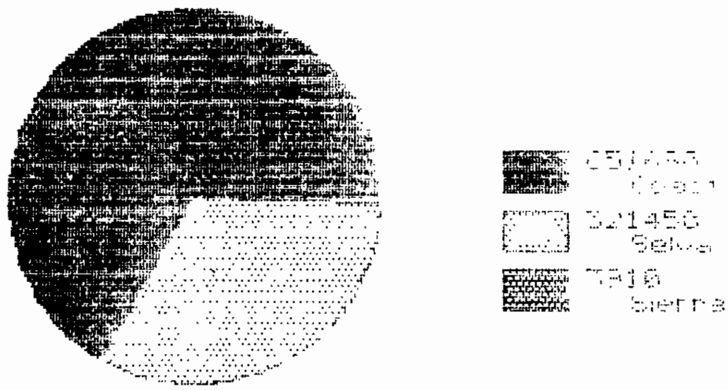
1984




Total Percent
100

Figure 6

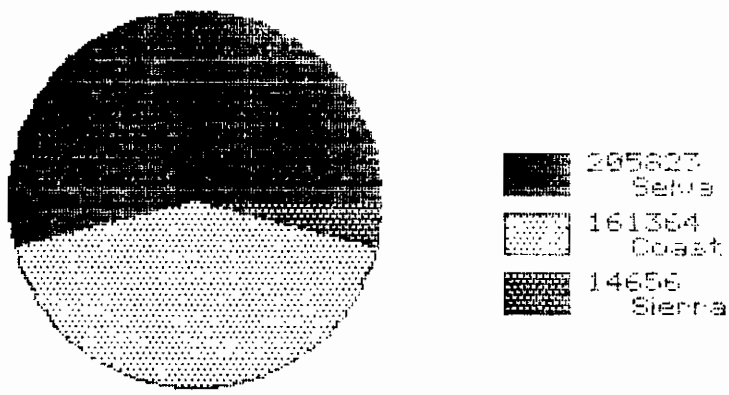
Rice Production by Region, 1984




Total Metric Tons
977.05 Thousand

Figure 7

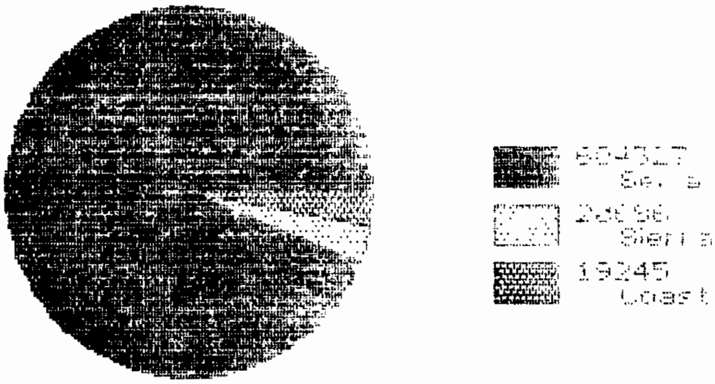
Maize Production by Region, 1984




Total Metric Tons
381.84 Thousand

Figure 8

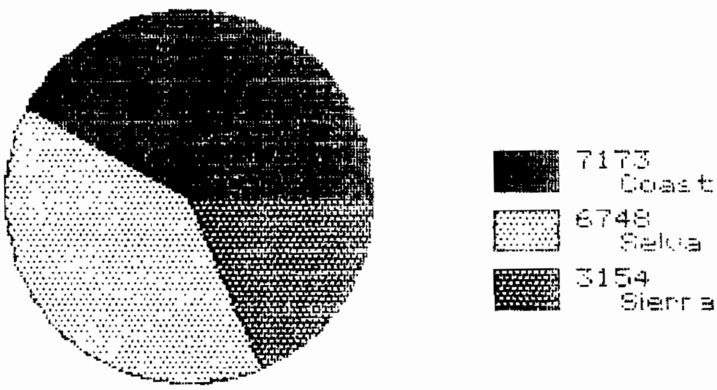
Yuca Production by Region, 1984




Total Metric tons
644.25 Thousand

Figure 9

Bean Production by Region, 1984




Total Metric tons
17.08 Thousand

Figure 10. Size of Cattle Herd

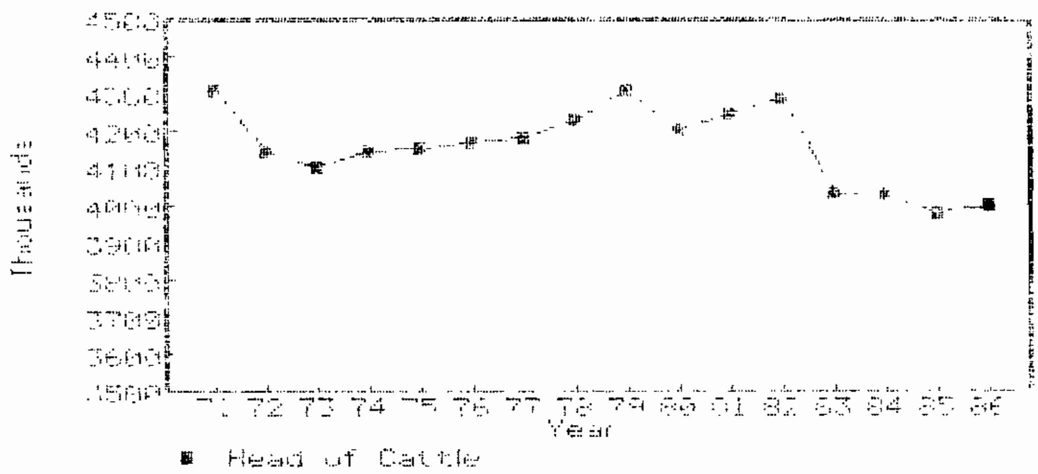



Fig. 11: Value of Beef & Dairy Imports

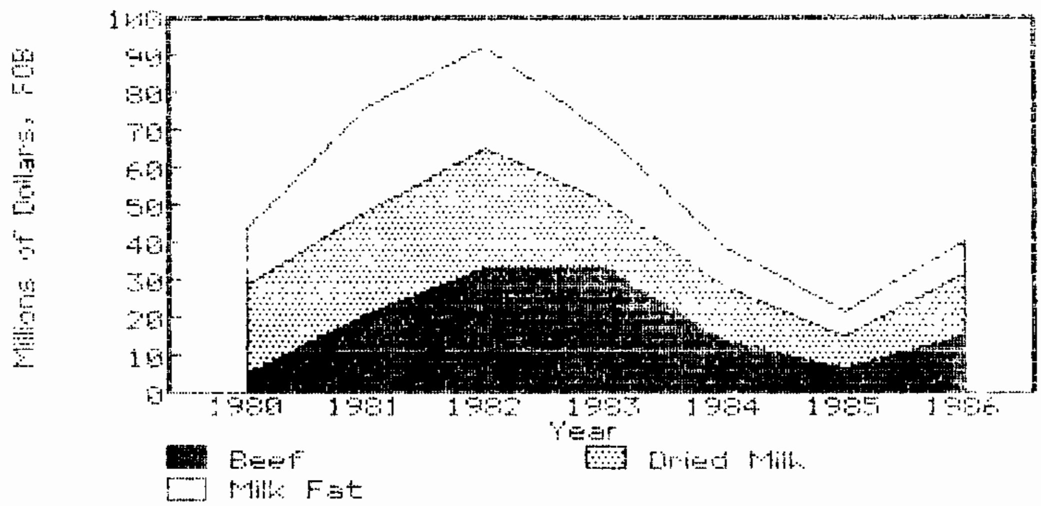
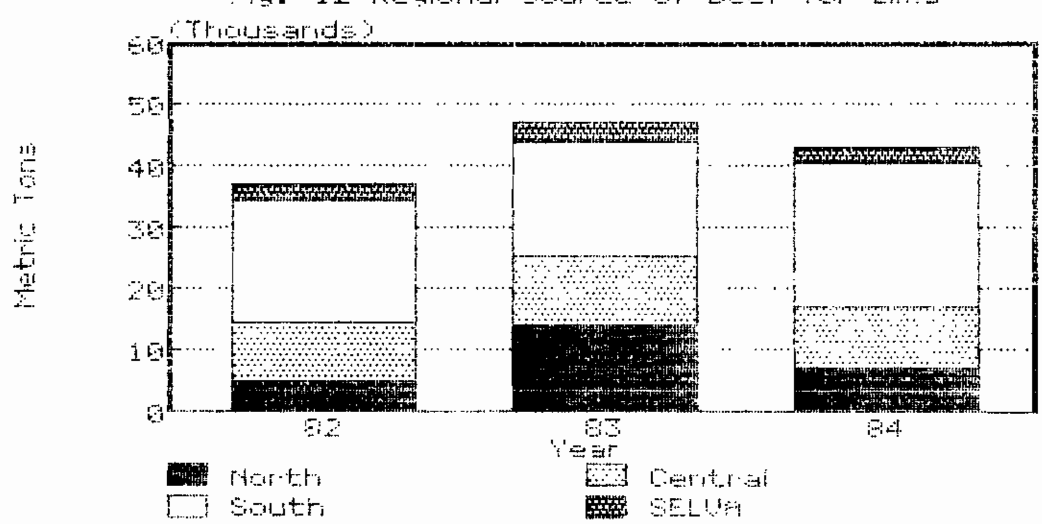



Fig. 12 Regional Source of Beef for Lima



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