1a MAKING RESOURCE MANAGEMENT PLANS OPERATIONAL

2a THE CIAT SAVANNA PROGRAM

1a. Production needs

Latin America is in the midst of a severe economic crisis. The debt burden has grown to enormous proportions, terms of trade have deteriorated, capital inflow has slowed, and inflation has soared further slowing economic growth. At the same time, an exodus of people from rural areas has pushed the proportion of city-dwellers from 49% in the early 1960s to 69% in 1986.[1] Many countries in Latin America are confronted by inadequate rates of growth in the production of staple foodstuffs. The low-income strata of the population, especially the urban poor, have been particularly affected and average caloric intake is below recommended levels in many countries.[2] Thus there is a critical need to increase food production. However, this will be possible only if production is substantially increased in an economically efficient and ecologically benign way.

1b. Production Strategies

There are essentially two options for increasing agricultural production in Latin America:

- the extensive approach of expansion on to previously uncultivated lands in frontier areas, and
- the intensive approach of increasing yields per unit area on currently cultivated land.

Production increases in the Amazon countries from 1960 to 1980 were based almost exclusively on area expansion.[3] As the more accessible lands have come into cultivation, expansion of agricultural frontiers has increasingly focused on the tropical rain forests and the acid soil savannas.

Deforestation

Deforestation of the Amazon is a major concern. Although agricultural production in deforested areas is initially satisfactory, it declines rapidly as loss of soil organic matter and fertility lead to the physical and chemical degradation of the soil resource base. The ecological and environmental costs of deforestation are also causes for concern.

The Acid-Soil Savannas — An Alternative

While some hold that deforestation is inevitable and that its increasing rate is a necessary cost of development,[4] a more optimistic view[5] advocates incentives to relieve migrant pressures on the Amazon by promoting better production opportunities elsewhere, particularly the acid soil savannas.

The obvious alternative to agricultural expansion into the Amazon rainforest is increased agricultural productivity on the acid soil savannas. Selection of the savannas (llanos in Venezuela and Colombia, and cerrados in Brazil) as the target land resource on which to promote economic growth is based on:

- Geographical proximity to the humid tropics and the fact that they represent a substantial land resource for the four countries that control 88% of the South American rain forests[6,7]

- Current use for agricultural production, albeit at different levels of intensity[8,9,10]

- Relative ease of access, requiring little additional infrastructure for the supply of inputs and the movement of production to markets.

The savannas are more attractive to production-oriented farmers, particularly if incentives to land speculation are curtailed in the Amazon.[11,12] However, the technological basis for this strategy requires the generation of sustainable cropping systems applicable to acid soil savanna environments.

Savanna Development — Constraints

Production systems in the Latin American savannas range from low through restricted to high inputs, and from native savanna through improved pastures to crop rotations and monocropping, and occasionally to integrated crop/pasture systems. Intensive annual cropping systems with high inputs in the Cerrados of

Brazil and the Llanos of Venezuela have been profitable in the short-term,[13] but there are indications that they are not sustainable as currently practiced and ultimately lead to soil degradation[14]. The degradation is characterized by:

- Nutrient deficiencies
- Soil compaction
- Soil loss (erosion)
- Loss of soil organic matter
- Pests and diseases, although information on the latter is scanty.

As their physical properties deteriorate, medium- to long-term productivity will decline. Therefore, to sustain intensified land use in the savannas, new technologies that maintain soil structure are required.

2a. Needs that can be met with current technology

While much remains to be done, CIAT's Savanna Program already has prototype technologies, using legume-based pastures in combination with crops, which reverse and recuperate these processes and lead to improved soil conditions. In collaboration with ICA and FEDEARROZ, these technologies are being evaluated with farmer collaborators in the Colombian llanos. EMBRAPA/CNPAF has developed the Barreirão system for the recuperation of degraded pastures using a rice crop, although a legume component is not included.

In this context, rice varieties developed by CIAT, which have at least double the yield potential of traditional varieties in commercial conditions, can play an important role in savanna cropping systems especially in pasture renovation and establishment[15].

There are more than 30 million hectares of improved pastures in the Brazilian cerrados many of them are degraded. If half the pastoralists renovated these pastures each six years with a crop of the new rice lines, at least 15 million tonnes extra of rice would be available in the global market. If this were to be done by the early part of the next century, it would provide all the increase estimated that Brazil will require each year[16].

Moreover, by making use of the fertility remaining after the crop, a regenerating legume-grass pasture produces at least four times as much animal liveweight gain as a degraded grass, which is maintained for a number of years. Again, if half of the graziers recuperated their pastures each six years, the present

... production of the Cerrados would increase by at least 70%, from 2.5Mt to more than 4.3Mt LWG.

2b. Research needs

The research needs of the savannas fall into three areas:

- ***Agro-ecological characterization***, to identify current land use patterns.
- ***Analysis within defined current land-use patterns*** to determine the relationships of predominant production systems with agricultural production, land degradation and socio-economic circumstances. These analyses are cross-sectional, that is, they simulate in space what happened in time.
- ***Develop sustainable agro-pastoral systems***, based on an understanding of the bio-physical and socio-economic processes that affect management of resources to optimize private benefits and social returns.

3a. The role of CIAT in meeting the research needs

NAR's in Brazil, Colombia, Venezuela, and Bolivia expect that CIAT's objectives in the Savannas should be in the areas of

- other components of agropastoral systems (soybean, sorghum, maize and peanut),
- strategic long-term research on soil processes, nutrient dynamics and crop adaptation in agro-pastoral systems,
- developing acid-soil-adapted germplasm,
- savanna management,
- international collaboration,
- exchange of germplasm and information,
- systems research, which is expensive for National Programs,
- bio-physical modelling of agro-pastoral systems.

3b. Research in which CIAT's Savanna Program has a comparative advantage, and in progress or planned

(i) ***Objectives.*** The overall goal of the Savanna Program is to develop and adapt technologies to increase the productivity of the infertile acid savanna soils of the tropical Americas.

(ii) ***Mechanisms.*** The Savanna Program focuses on developing alternative strategies of land use and understanding the relationship between those strategies and policy instruments. At the production level, emphasis is on generating management technologies and production systems that are agro-ecologically sound and economically viable.

Excessive use of fertilizer damages the environment. The goal is therefore to increase agricultural production while using fertilizer as efficiently as possible. Thus, agronomic research is focused on understanding nutrient loss and nutrient use efficiency so as to develop simulation models of crop and nutrient dynamics. When linked with geographic information, the models will provide powerful tools for extrapolating research results and performing cost, benefit and risk analyses for alternative technologies. Complementary linkages with NARS's in both on-station and on-farm research and with IFDC and CIAT's Tropical Forage Program will be key components of this work.

(iii) ***Scope of Work.*** The major limitations of the savannas are low pH, low fertility, and high levels of aluminum. There are therefore two options possible for prototype legume-based systems:

- aluminum-tolerant crop and pasture cultivars (upland rice, CIAT's adapted forage germplasm)
- less Al-tolerant crop and pasture cultivars (maize, soybean, less-adapted forage germplasm) with applications of lime.

Both systems are being studied in a multi-disciplinary team approach, as follows:

Agronomic research. Nutrient management studies to maximize fertilizer efficiency and minimize environmental impact.

Database development and modelling. Based on the agronomic data, models of rice, maize, soybean, mixed pasture, green manure and pasture-livestock that describe nutrient dynamics within their respective components. They will enable the agronomic, economic and environmental assessment of different configurations of the legume-based ley farming systems under different agro-climatic conditions and managerial alternatives.

Socio-economic and policy research. Micro-economic analysis of alternative cropping-livestock systems, ex-ante studies of the impact of new technologies and their implications in terms of equity, labor, nutrition, farm income, market development and rural settlement. Comparative analyses of country and regional agricultural policies to improve understanding of the conditions required for successful adoption of new components and systems.

(iv) ***Activities.*** The activities are outlined in the appendix.

(v) ***Expected Outputs.***

Sustainable legume-based ley cropping systems for the lowland acid soil regions of tropical savannas. Based on technology that is agronomically and environmentally sound, technologies will be developed for crop production that will balance nutrient exports and losses, and will preserve soil organic matter. Soil physical, chemical and biological properties and plant productivity will be maintained in the longer term.

Understanding of the effects of cropping systems and fertilizer on the environment (nutrient and soil losses). Monitoring and modelling of soil physical and chemical processes will determine the indirect costs and long-term effects on the environment and the natural resource base, and the trade-offs between costs and benefits in terms of both environmental and monetary parameters.

Recommendations on strategic use of fertilizers. Improved agronomic efficiency by farmers, by optimizing forms of fertilizer, rates and times of application, methods and placement.

Indicators of sustainability will be obtained both from on-farm monitoring and analysis of existing cropping systems, and from long-term, longitudinal studies.

3c. Research in which NAR's have a comparative advantage

Because of the variable strengths of the NARS's, there is no general strategy applicable to all countries. However, there is considerable research input in savannas research in EMBRAPA/CPAC on crop and pasture rotations, in which CIAT staff are actively collaborating, and which complements the Savannas Program's in-depth studies. PROCITROPICOS is planning a project on pasture renovation in which Savannas Program staff have participated, and which will complement the Program's in-depth studies being carried out in the Colombian llanos.

4. Opportunities for collaborative research with Institutions from developed countries

Areas in which both CIAT and its National counterparts seek to recruit institutions with expertise to complement their research are:

(i) *Soil physical processes.* At present, some soil physical parameters are being monitored in a few selected cropping systems and treatments in existing experiments to evaluate compaction. A great deal more pro-active research is required to understand the interaction of soil physical processes with sustained crop productivity.

(ii) *Soil hydrology.* In line with (i) above, crop management practices are likely to influence the hydrological cycle in alternative cropping systems, with possible carry-over effects into the dry season in terms of crop and system productivity.

(iii) *Soil mineralogy.* Knowledge exists on the mineralogy of some soils of the Cerrados, and to a lesser extent, on some soils of the Colombian llanos. More comparative studies are required to enable extrapolation between sites and soils, and to estimate the effects of mineralogy on soil nutrient dynamics and to evaluate the effects of alternate fertilizer sources on crop productivity and related sustainability issues.

(iv) *Environmental impact.* Different cropping systems for the savannas may have different impact on the quality of the environment, by their effect on processes such as micro- and macro-diversity and pollution by agrochemicals. There is virtually no research on this problem in the savannas.

(v) *Demographic and anthropological studies.* To a large extent, the rural population of the savannas has migrated to the region during the last 30-40 years, bringing with them diverse agricultural traditions. Because of the diversity, management practices applied by different sectors of the rural community vary widely. Because the development of sustainable agricultural practices is management-intensive, there is an urgent need to determine effects of culture and tradition on the development and adoption of alternative management practices directed towards sustained crop productivity and the conservation of natural resources.

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APPENDIX

Activities

The objectives are being addressed through a two-pronged approach involving both short-term perspectives of long-term trends (cross-sectional analysis in space of comparable systems of differing longevities) and long-term experimentation (longitudinal analysis of contrasting systems and factors in time).

Studies include not only types of nutrient sources, but also the timing and method of their application and the integration of inorganic and organic inputs. These are directly linked to studies of nutrient dynamics in selected cropping systems. These studies involve both the determination of gross changes in nutrient levels and the measurement of input/output balances, mineralization or immobilization rates, losses by leaching or gaseous pathways, and soil biological activity. A series of field experiments include 'best bet' options (rice, soybeans, maize and cowpea with ley legumes Vichada, Kudzu and Calopo and perennial soybean) supplemented by small plot and greenhouse studies to elucidate principles. Quantification of these processes is important for the modelling objectives of the project.

(i) ***Selection of strategic crops and inputs.*** Research focuses on determining the effects of selected ley and crop rotations, cultural practices including tillage, and fertilization regimes on harvestable yield and on the dynamics of soil physical and chemical characteristics.

(ii) ***Effects of sequential cultivation on food/feed crop yields and plant productivity.*** The influence of several soil tillage and crop management systems on the harvestable yield levels is being determined. Productivity of components and the agronomic and economic efficiency of each system is also being evaluated. Plant productivity parameters including above- and below-ground biomass and leaf area index are being determined in different systems.

(iii) ***Effect of agropastoral or sequential crop production on organic matter turnover and nutrient dynamics in the soil and crops.*** Conversion of native savanna to agro-pastoral or sequential cropping systems could result in accelerated organic matter mineralization due to tillage and disrupt the internal recycling of nutrients, thereby increasing the potential for their loss from the system. It is therefore essential to develop soil and crop management practices that result in improved synchrony of nutrient mineralization from organic pools and plant uptake, facilitating better conservation of nutrients that are not used by the food/feed crops. A greater understanding of nutrient dynamic processes, including organic C turnover and nutrient acquisitions, losses from and transfers among various system nutrient pools, is therefore required.

(iv) ***Effects of sequential crop production on the environment.*** Research activity is focused on the evaluation of changes in soil physical properties. Deterioration of these properties leads to environmental risk and may occur in crop production systems that require sensitive management of plant residues and strategic external inputs of fertilizers.

(v) ***Development of a crop production systems model based on nutrient and organic matter dynamics.*** As a means of integrating results from the foregoing activities, models will be developed to incorporate nutrient and organic matter dynamics into a comprehensive analysis of the functioning of different crop production systems for the acid soil savannas. The basis for this modelling activity will be the CERES (rice, maize) and SOYGRO (soybean) simulation models, which will be further adapted and validated for systems where nitrogen derived from the grass-legume phase will provide an increasing proportion of the rice crop's N requirements. Further refinement of the model to account for phosphorus, potassium and sulfur dynamics will require additional descriptions of P, K and S cycling from the pasture phase. The models will be validated and tested with a wide range of cropping systems and will serve as a research tool to assess the effects of agropastoral or sequential cropping on soil productivity, to help identify areas requiring further research, and to assist in the economic assessment of costs, benefits and risk associated with the new technologies.

(vi) ***Economic analyses.*** Economic analyses of the benefits of the proposed cropping systems under investigation in the project will be undertaken by the economists of CIAT's Natural Resource Division and IFDC's Economics and Policy Program. These include farm level economic analysis regarding profitability and viability of improved cropping systems and regional analysis of the likely implications if widespread adoption takes place. Cross-country policy comparisons will allow understanding of the macroeconomic conditions that contribute to shape new farming systems and their implications at farm level.