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ECONOMIC TRENDS IN LATIN AMERICA AND THE CARIBBEAN:
IMPLICATIONS FOR AGRICULTURE AND AGRICULTURAL TECHNOLOGY GENERATION

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In this annex we investigate economic trends in Latin America and the Caribbean, drawing implications for agriculture and, more specifically, for agricultural technology generation.

THE CURRENT SITUATION

Latin America and the Caribbean underwent a deep economic crisis in the 1980s. As shown in Table 1, during the early years of the decade the region's debt burden took on enormous proportions. To overcome this crisis many countries cut their subsidies, curtailed their imports and attempted to stimulate their exports through drastic currency devaluations. The trade balance for the region turned positive towards the middle of the decade and as most countries made valiant efforts to repay their debts, the capital inflow of the early eighties was replaced by a capital outflow. Due to worsening terms of trade, the growth in the value of exports was less than expected. Also, domestic demand and the need for productive investment made it impossible to limit the imports to the level of the mid 1980s. The increase in the trade surplus petered out by the end of the decade. The region did not develop sufficient repayment capacity to reduce its outstanding debt, the nominal value of which increased throughout the decade.

The debt crisis had severe internal consequences. While most economies contracted with tax receipts falling accordingly, government spending was not sufficiently realigned. By the end of the decade, the average deficit in government budgets amounted to 10.2% (Table 2), leading to soaring inflation. This reduced the level of investment, further constrained the functioning of capital markets and stimulated capital flight into foreign exchange.

During the 1980s per caput income fell by 1% per year, so that by the end of the decade people were on average some 10% poorer than at the start. Nevertheless, at US$ 1780 in 1989 per caput income in the region remained higher than in Asia, where it was some US$ 700, and in Africa, where it was only US$ 470 (World Bank, 1989).

Population growth in Latin America and the Caribbean averaged 2.4% during the 1980s. This growth was almost entirely concentrated in the urban areas, which by the end of the decade accounted for 70% of the regions's 440 million inhabitants. During the 1990s, population growth is expected to fall to 1.9%, but if this remains concentrated in urban areas, the ratio of urban to rural population will increase with 2.5% per year.

The average figures hide considerable differences, both among and within countries. For example, birth rates in the Southern Cone are lower than in Tropical America. Moreover, the average income figure masks the sharp differences between poor and rich, characteristic of the region. CEPAL (1990) estimates that 37% of all Latin American and Caribbean households are poor, that is they have an income less than twice that needed to buy the basic food basket, while 17% of the households are destitute, that is their income is lower than the cost of the basic food basket. Table 3 shows that the patterns of poverty in the region have been changing. During the 1980s, both types of poverty increased in the urban environment. In the rural areas, destitution increased, but the total percentage of poor households decreased.

FAO (1990a) estimates that in the mid 1980s some 55 million people suffered from malnutrition The three countries were malnutrition was most prevalent were Haiti, Honduras and Peru, where the daily per caput supply of calories was 1902, 2078 and 2192 respectively per day (FAO, 1989). Low income urban dwellers are particularly at risk.

Will the debt crisis continue to influence the domestic economies as much as it has done? Decision makers in financial circles are becoming increasingly aware that the region is unlikely to repay its debt in full and debt has recently become the subject of negotiation. The price of debt certificates as a percentage of their nominal value halved between 1986 and 1989 (Table 4). This would suggest that the negative impact of repayment on growth will slowly diminish during the 1990s and that debt will be less and less of a millstone around the necks of Latin American countries. Nevertheless, a revival of international loans to the region should not be expected for many years. Financial institutions have long memories. For the coming decade Latin America will be largely dependent on internal financing.

Will Latin America succeed in increasing its export earnings to finance those imports that are vital for economic growth? During the 1980s, capitalism has established itself worldwide as the dominant economic system, and the theory of free trade and international division of labor has received strong support. Before the Iraq crisis broke out, the chances for a period of international peace that would allow the development of international trade looked good. The pressure to reduce protectionist policies in the Uruguay round of the GATT has been strong, but has not yet been translated in concrete measures. Although there are some indications that trade will increase, this will often be within economic blocks such as the EEC or NAFTA, instead of in a truly international fashion. In such an environment the ability to increase exports rapidly depends strongly on negotiating power and it is difficult to see Latin America's advantages here.

In summary, Latin America's debt crisis is slowly easing but will constrain future international financing; its governments are experiencing severe difficulties in managing this crisis and in maintaining their role; its export orientation, which initially paid off, has become less effective with diminishing terms of trade, increased import requirements and a weak bargaining position. In consequence, poverty has increased, especially in the cities and the region faces more welfare problems than at the start of the 1980s.

In response to the crisis, macro-economic policies have been modified. More than before, the economic environment of Latin American and Caribbean countries resembles free market conditions. If inflation can be controlled and solutions for the remaining debt problems could be negotiated, the conditions for renewed economic growth will be better than they were at the start of the decade.

ECONOMIC DEVELOPMENTS IN THE 1990s

Latin America in the 1990's will face great challenges. Most of the region's countries will have to pursue economic growth under conditions of foreign capital scarcity and high real interest rates. At the same time the ability of governments to stimulate capital intensive development will be severely hampered by lack of international financing. Monetary policies will have to be conservative in order to restrain inflation. Little money will be available for spending on equity problems, which will have to be addressed instead through growth oriented strategies. At the same time, resource conservation issues will become more important. Governments will thus have little room for manoeuvre and the role of non-governmental organizations in development may well increase.

Countries will need to look for new export markets to improve their balance of payments. For oil producing countries, the oil price increases as seen in the summer of 1990 might provide extra foreign exchange. For oil importing countries, higher costs of energy would require even more export growth. In addition, production costs might be increased and domestic inflation be fueled. Given the reduced room for the use of policy instruments, countries will have to adhere more and more to the principle of comparative advantage. To develop new markets, cost-reducing technologies that enhance comparative advantage will play a key role.

The small farmer and the informal sector are often seen as subjects of redistributive government policies. In the coming decade there are no resources available for such an approach and the only way to address their poverty is by linking them to growing markets (de Janvry and Sadoulet, 1990). Small farmers and informal sector entrepreneurs are used to earn a living in conditions of capital scarsity. In the financial conditions that the region faces, they might well be better able to pursue progress than the capital intensive enterprises that formed the traditional basis of growth.

The revival of the small farm as a business unit does not imply that the end of the equity problems is in sight. In the urban environment food availability for the poor people will remain a large issue. In the rural areas, not so much food but access to basic services is likely to become the basic equity issue.

Where investment capital is constrained and where governments have to reduce their activities, the key to economic development will not lie in a small number of large-scale, national initiatives, but in a large number of small-scale, local initiatives. The major contribution to economic development will come from new entrepreneurs, rather than from the already established ones. If this scenario is realized, modest economic growth, of around 1.5% per caput per year may be expected.

BEYOND THE YEAR 2000

Technology generation is a slow process. Considerable lead times are required, both for research and for the dissemination of its results. For properly focused research long-term forecasts have to complement short-term forecasts. This urges the consideration of economic trends beyond the year 2000. In the long run the extrapolation of trends is less reliable and the analysis has to shift to the basic mechanisms behind the trends.Three long term issues will be considered here.

INTERNATIONAL LABOR DISTRIBUTION

The principle of comparative advantage is key to the international distribution of labor. Comparative advantages depend strongly on factor endowments. For the world's developing regions and for one developed region factor endowments have been compared in Table 5.

Latin America has ample land, but not of such good quality as that of North America. Labor availability is not as high as in Asia, but compares favorably with that of North America. The educational level of the Latin American labor force is below that of both Asia and North America. The capital endowment of Latin America is assessed as rather poor, for two reasons: first savings rates are considerably higher in Asia; secondly there will be little willingness to lend to Latin America for a long time. Also, the quality of capital, as expressed by the flexibility and the transparency of financial markets, is inferior to that of both North America and Asia.

This assessment of factor endowments suggests that agriculture is the sector in which Latin America will have the most opportunities for international trade, but that North America with its ample availability of good land will be a strong competitor, most so in grains and oil seeds. Export strategies based on industry, which require a plentiful supply of skilled labor and substantial investment, are more feasible for Asian countries. The advantage in international services, which normally require very highly qualified labor, will stay with the developed world for some time.

What kind of agricultural exports should the continent aim for? Two issues affect the answer to this question. The first is the issue of food security versus food self-reliance. The concept of food self-reliance has gained considerable support in development circles, but the willingness of countries to rely on international markets for their basic food supply remains to be seen. Countries that cannot be self-sufficient will probably concentrate on producing as much as they can of their most basic staples, in order to ensure food availability to the poor and to reduce dependence on external supplies. They would rely on international markets for the supply of higher value products.

The second issue is international transport costs. At present a ton of wheat can be shipped from the Gulf to Egypt for only US$ 30 per ton (FAO, 1990b), but the expectation is that international oil prices, and therefore transport costs will be considerably higher at the beginning of the next century than they are now. This would suggest that it is best to concentrate on products with a low ratio of transport costs to value of produce. Again, this would point to high value crops.

Investment in agriculture and in the generation of agricultural technology appear good bets for Latin America and the Caribbean. The focus should be on enhancing the labor cost advantage that the continent has in producing high value products and on increasing the productive capacity of the region's plentiful but relatively infertile land. The resulting boost to agricultural development might well trigger off agro-industrial growth, in both the input and processing sectors.

EXPECTED GROWTH AND ENGINES OF GROWTH IN LATIN AMERICA

The long-term economic growth prospects for Latin American countries are strongly linked to three factors. First, political stability. This is crucial for the investment climate within a country, because it influences labor relations, investment risk and the stability of government policies. Secondly, a steady supply of foreign exchange. As we have seen, the prospects for international borrowing are bad, and countries will have to rely on other ways of obtaining foreign exchange. For Mexico, Venezuela or Ecuador, oil guarantees the supply of foreign exchange and reduces the vulnerability of the economy to the fluctuations of the world energy markets. In a few cases minerals may fulfil a similar function. Thirdly, the degree of outward orientation of a country. An outward orientation helps a country to develop export markets and to remain or become competitive.

The agricultural sector will be less disadvantaged than during the 1970's or 1980's. Instead of being sacrificed to industrial growth and being a source of government income, it may become an engine of economic growth. The role of agriculture as an engine of growth will be country specific. Countries like Brazil, Colombia, Bolivia, Uruguay and Argentina have ample land and can develop considerable comparative advantages in agriculture. In countries, such as Mexico and the Caribbean countries, land is scarce. They may develop some specialized agricultural exports but the potential for agriculture to promote overall economic growth will be somewhat limited.

In summary, some Latin American countries, such as Mexico, may experience healthy economic growth, but with a minor role for agriculture; others such as the Caribbean countries, will face low growth with, at the most, an intermediate role for agriculture; the countries in Central America are likely to face rather slow growth, but with an important role for agriculture; a few countries such as Brazil and Colombia might grow quite fast with agriculture in a vital role. The agricultural technologies to address these conditions need to cover a wide spectrum of options to take into account the differences that will occur in labor costs or input use. Depending on the importance of agriculture, the willingness to invest in agricultural technology will differ strongly among Latin American countries.

Countries experiencing rapid growth with a large role for agriculture will probably recognize the importance of sustainable agricultural land use. They will try to enhance the productive use of their agricultural resources. When growth is rapid, but the role of agriculture is small, countries may take a more "romantic" attitude towards sustainable agriculture, since their future does not depend on it. They might choose to set natural resources apart in nature reserves, or to adopt legislation which restricts unsustainable practices. Countries experiencing slow growth but with an important role for agriculture, may tend to exploit the natural resource base until growth has accelerated. They will disinvest on their natural capital. In countries that achieve slow growth with a small role for agriculture, sustainable agriculture may well be a non-issue.

AGRICULTURE VERSUS OTHER SECTORS

Table 6 provides some key data on the three principal production sectors of the region. Agriculture contributes 11% to the total Latin American Gross Domestic Product (GDP), but provides employment to 32% of the active population. Industry provides 37% of GDP but employs only 26% of the active population. The service sector provides 52% of GDP and employs 42% of the people. The per caput income in the sectors differs strongly. In the agricultural sector it is only US$ 640, while in industry and services it is US$ 2530 and US$ 2200 respectively. During the 1980s, when the overall economy contracted, agriculture grew more rapidly than the other sectors, but not at the rate of population growth.

Employment. Agriculture still provides considerable employment, but contrary to Asia or Africa, it is not any more the sector that absorbs most labor. Its average income is less than a third than that in the other sectors. In Asia agriculture is seen as the employment buffer of society, but this is no longer so in Latin America and the Caribbean. Here the service sector has become the principal source of employment.

Employment policies for Latin America cannot be based on the same premises as for Asia. In Latin America it is more useful to look at the urban informal service sector as the mirror image of the small farm sector in Asia; and to focus employment strategies at the informal sector.

If the employment buffer has shifted from the agricultural to the service sector, then the principal challenge for agriculture in the coming decades will be to raise income per caput. Increased labor productivity will be a key objective for agricultural development and will set some of the technological challenges. Yield increasing technologies will contribute to increased labor productivity, but will need to be complemented with appropriate mechanization.

The opportunities for increasing labor productivity are not equal across the different ecosystems of the continent. For example in many hilly areas,the potential for higher labor productivity is very limited. To avoid further outmigration from these regions, it will be necessary to create new income generating opportunities. This will urge the design of rural employment policies, that include agriculture as well rural industries and services.

Sectorial linkages. As shown by Pineiro (1988) and Mandler (1987), the Latin American agricultural sector is becoming increasingly integrated with the rest of the economy. Pineiro (1988) writes that the intermediate consumption of the agricultural sector amounts to 29% of the gross value of its output, while 34% of the gross agricultural output is input in another productive process. Janssen et al. (1990) estimate that technical change in agricultural production causes substantial welfare gains both within the agricultural sector and in the rest of the economy. For rice and beans, the income effects in the rest of the economy, as caused by the linkage effect, equal 78% and 41% respectively of the direct gains to producers and consumers.

Although the role of agriculture in the total economy is relatively small, agricultural development will nevertheless trigger substantial growth in other sectors. The ability of the sector to induce agro-industrial growth and rural development should be taken into account in national planning. An important issue is how to link the small farm sector to expanding markets.

IMPLICATIONS FOR AGRICULTURAL TECHNOLOGY GENERATION

The economic conditions of the countries of Latin America will vary substantially towards and beyond the year 2000. This will influence their attitude to agricultural technology generation. For some countries technologies oriented towards sustainable land use will be key to growth; for others short-term productivity increases will be most urgent. Technology generation will have to be specific to the conditions of the target country.

The role of the public sector in technology generation and diffusion will probably be reduced, due to budgetary problems. NGO's may step in, to fill the vacuum. Such organizations have good local knowledge, but little access to policy makers.

The fiscal and financial constraints faced by governments will force them to select their interventions on behalf of growth with great care. Price supports or credit subsidies will be difficult to afford and will cause concern for new distortions in the economic environment. Instead technology generation and diffusion, which enhance rather than obfuscate comparative advantages will be emphasized as a source of growth.

Agricultural technology generation should address two principal objectives. First, it should allow cost reductions of high value products, such as vegetables and animal protein products. These are the products for which the region has a long-term comparative advantage and an opportunity to increase its foreign exchange earnings. To reduce production costs successfully for these agricultural exports, a two-pronged stategy should be pursued: it is vital that the suitability of presently low-productive land resources will be improved; at the same time agricultural labor productivity will have to be enhanced drastically, to allow labor cost reductions while agricultural wages increase.

The second objective of agricultural technology generation should be to reduce the cost of staple foods to the urban poor. The traditional income disparities of Latin America persist but the locus of poverty is shifting from the rural to the urban areas. There will be a major need for increased production of those commodities that make up the food basket of the urban poor, to reduce the incidence of food in the expenses of the poor and to diminish malnutrition. To further alleviate poverty, more emphasis on the development of the informal sector will be required.

The extent to which agricultural technology can address the equity issue in the agricultural sector should be reassessed for various reasons. First, rural poverty has stopped increasing, despite the bleak conditions of the last decade. Secondly, the feasibility of poverty alleviating strategies is severely constrained by limited government resources. Thirdly, the ability of poor farmers to make productive use of small amounts of capital is now seen as an asset. Finally the role of the agricultural sector as the employment buffer of society is being transferred to the service sector.

The time is ripe to pursue strategies that speed up the transformation of subsistence based farmers in small scale entrepreneurs; that will increase labor productivity and that will create rural employment outside agriculture. For some small farmers this transformation might take place by increasing the productivity and market orientation of their farms. For others, it might imply a move out of agriculture into another type of economic activity. One of the technological challenges of the 1990's will be to integrate small-scale agriculture within more comprehensive rural development, for example by means of post-harvest processing, small-scale agro-industries and rural service activities.

Structural adjustment policies are creating a tough environment, but one in which the economic incentives are real. Such an environment will allow technology to perform on its own merit, rather than at the mercy of support measures. It is imperative that this opportunity is successfully used, and that technological improvements contribute significantly to economic growth. If technology generation and diffusion are unsuccessful, pressures to revert to policy interventions might arise. In such a case the influence exerted by special interest groups might once again distort economic incentives, decrease export competitiveness and reduce growth, thereby increasing the distance with the developed countries.

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Management of Natural Resources

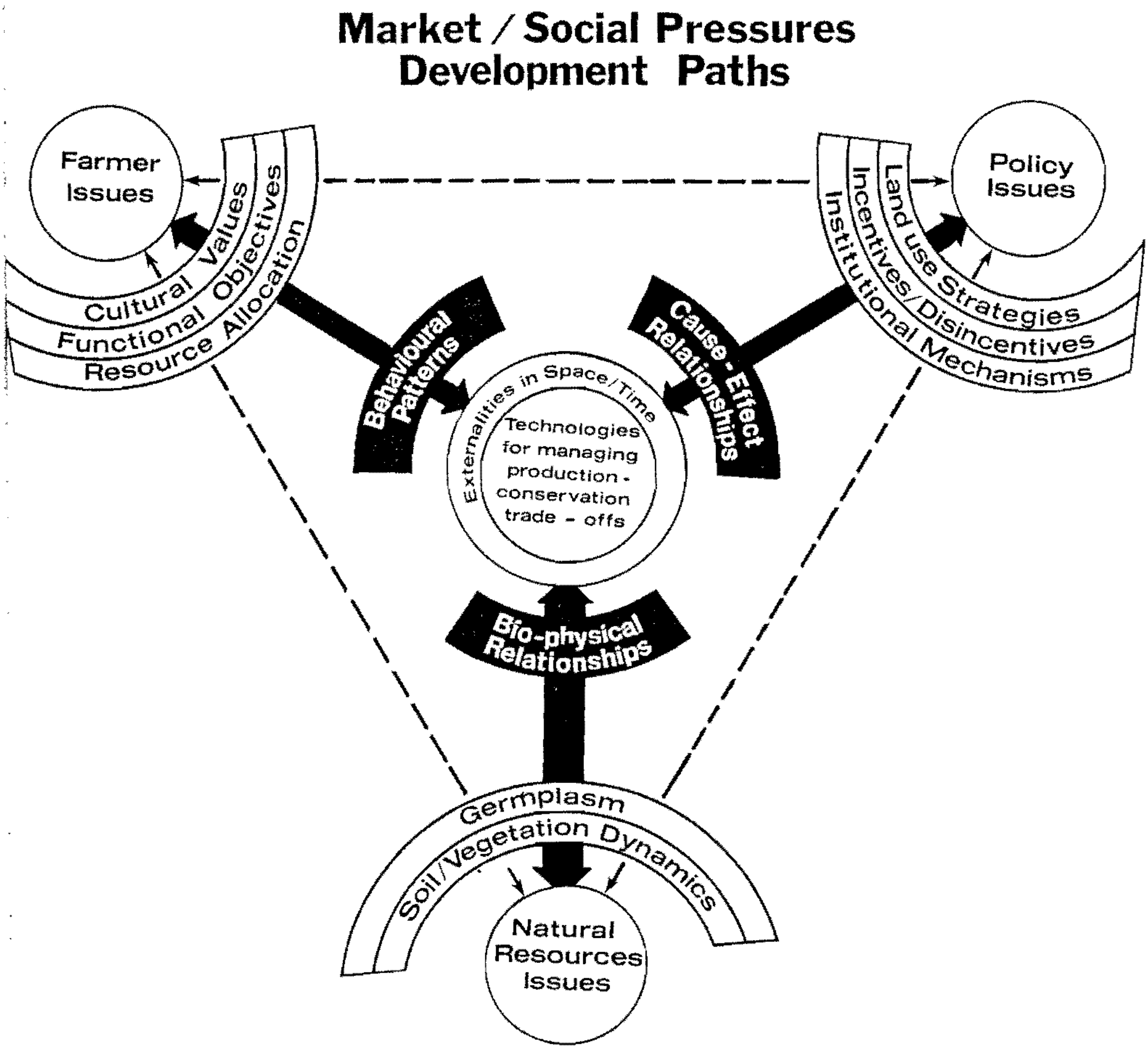

Table 1: Some macro-economic indicators for Latin America in the eighties

	1981	1985	1987/1989 1/
1. Outstanding debt (US$-billions)	290	377	415
2. Real effective exchange rate	94	125	151
3. Trade balance (US$-billions)	-12	+29	+22
4. Capital transfer (US$-billions)	+10	-33	-25
5. Inflation (%)	58	275	994

Sources: 1, 3, 4 and 5: CEPAL, 1989
2: de Janvry and Sadoulet, 1990

1/: For 1,3,4 and 5: 1989
For 2: 1987

Table 2: Government spending and deficits in Latin America, 1987.

	Government spending as % of GNP (1987)	Deficit as % of GNP (1987)
Brazil	26.1	13.3
Mexico	22.7	9.5
Venezuela	22.0	2.1
Colombia	14.7	-0.7
Costa Rica	28.3	4.8
Average L.A.	n.a.	10.2
OECD-members	28.4	4.4

Source: World Bank, 1989

Table 3: The presence of poverty in Latin America.

Year		1970	1980	1986
% Poor households:	Total	40	35	37
	Urban	26	25	30
	Rural	62	54	53
% Households in absolute poverty:	Total	19	15	17
	Urban	10	9	11
	Rural	34	28	30

Source: CEPAL, 1990

Table 4: Latin America: Price of debt certificates as a % of nominal value.

Year	1986	1987	1988	1989
Argentina	65	52	25	13
Brazil	74	62	51	31
Mexico	59	57	51	40
Colombia	81	85	65	57
Average L.A.	65	59	45	32

Source: CEPAL, 1989.

Table 5: A subjective assessment of factor endowments of different continents.

		Latin America	Asia	Africa	North America
Land:	availability	+	-	+	+
	quality	±	±	-	+
Labor:	availability	±	+	±	-
	quality	±	+	-	+
Capital:	availability	-	+	-	±
	quality	±	+	-	+

Source: Estimations by the author.

Table 6: The average importance of production sectors in Latin America.

	% of PIB (1987)	Annual growth 80-87 (%)	% of Employment	Average sectorial income per capita (1987)
Agriculture	11	2.2	32	640
Industry + mining	37	1.0	26	2530
Services	52	2.1	42	2200
Total	100	1.7	100	1780

Source: World Bank, 1987 and 1989.

CIAT's COMMODITY PORT-FOLIO REVISITED: INDICATORS OF PRESENT AND FUTURE IMPORTANCE

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INTRODUCTION

Since the second half of the 1970s CIAT's research has concentrated on beans, cassava, rice and tropical pastures. These commodities were chosen for good reasons. The principal objective of the CG-system in those days was increasing food availability; beans, cassava, rice and beef/milk (the end products of the tropical pastures) were essential ingredients of the Latin American diet. A second objective was to improve the living conditions of the poor; beans and cassava contributed to this objective for both producers and consumers, rice and beef mainly for consumers.

Are these commodities still the best ones for CIAT to work on? To address this question two issues have to be resolved. One of them is a policy issue and concerns the changes in the objectives of CIAT as part of the CG-system, as well as of its donors and clients. The present objectives of international agricultural research have evolved considerably from the ones that guided CIAT's choices in the seventies and the subsequent elaboration of those choices in research programs. Whereas food availability and equity where the focal points in the seventies, economic growth, equity, sustainability and institutional constraints are the principal considerations of the moment.

The thinking on economic growth versus equity has changed considerably. In the seventies the common opinion was that poverty had to be addressed by focusing research on the deprived people of the society and that one could not rely on the secondary effects of the trickle down principle. There was major attention for increasing food availability as a strategy to improve poor people's nutrition. Now the pendulum has swung back to income creation as the basic mechanism for poverty and malnutrition reduction. So commodities should not only be considered for their importance as food crops in small farms but also for their potential in economic development.

Sustainability has arisen as a research focus. Within the donor communities of the developed world the awareness about the negative impacts of intensive farming and of ruthless agricultural frontier development has grown. This has led to attention for more rational land use systems, for more durable crop productivity gains and for the value of natural resources outside agricultural use. The commodities that are being researched at CIAT should be building blocks of a more sustainable agriculture, and need to be reviewed in that light.

Another change in research policy considerations is the increased importance of the institutional setting. Partly because of the CG-system, partly autonomously, an intricate web of interacting institutions has been formed, at the international, the regional as well the country level. The room for starting new initiatives has been reduced, the potential of contributing to scientific progress depends on effective interaction as much as on individual research. Efforts in new commodities should make a significant difference to what is already being done and should not duplicate efforts of others.

A final remark with regard to the objectives of CIAT concerns its geographical coverage. Within the CG-system regional responsibilities and commodity responsibilities have traditionally been mixed. For example, CIAT at its foundation was envisaged as a center with Latin American responsibilities. Nevertheless, in the first 20 years of its existence it evolved towards a commodity approach. Now there is a feeling that CIAT should re-emphasize its regional responsibilities. New commodities options should thus be considered in a Latin American more than a global context.

The second issue that defines the attractiveness of commodities for CIAT's research port-folio is the extent to which they contribute to the Center's objective set. In light of fifteen years of research experience, expectations on the type and size of benefits for research on different commodities have changed. The rather optimistic estimates as expressed in "CIAT in the Eighties" might have made place for more conservative benefit assessments.

The role of commodities within the agricultural sector has been affected by the overall development trends. Whereas commodities such as poultry and eggs experienced very rapid growth, crops such as rubber or sisal faced decreasing demands. Consequently commodities with formerly outstanding importance might have been surpassed by others, that now reclaim their share of research resources.

Finally, the nature of the commodity might have changed. Commodities which were traditionally being grown by the small farm sector, might now be important in the large farm sector. Or, commodities that traditionally used little inputs (besides labor), currently are highly input dependant.

In addition, commodities with previously low demand expectations might now face large potentials. Commodities that traditionally are grown on prime land might have a role in marginal production environments. The potential impact of commodity research depends on how the commodity fits into the expected agricultural development trends, for example as regards intensification versus frontier expansion. The nature of the commodity defines its relative contribution to each of the Center's objectives and strongly influences its overall attractiveness.

As part of CIAT's strategic planning exercise, a group of CIAT mandate as well as other commodities has been submitted to an analysis of their relative contribution to the Center's objectives. In this paper we will explain the methodological procedures used for the commodity analysis and we will discuss the principal outcomes. This will help people to form an idea on what CIAT's best commodity choices would be, from a growth, equity, sustainability or institutional point of view. Although it will be impossible to avoid all value judgments, we have tried to present and analyze the data in an objective way. We hope that the reader will be able to form his own opinion based on the results.

RESEARCH PRIORITIZATION METHODS AND THEIR IMPLICATIONS FOR CIAT

Since the CG-system seriously started to apply strategic planning, a number of reviews of research prioritization methods have been made. TAC wrote one in 1988 (TAC, 1988), ISNAR made another one in 1988 (Norton and Pardey, 1988), ICRISAT developed its own ideas in 1989 (Mueller, 1989). Another important contribution has been made by Davis, Oram and Ryan (1987) in their paper on ACIAR research priorities. We feel that yet another literature review is unnecessary. Thus, we refer the interested reader to the cited documents. Nevertheless, we would like to summarize some major findings of these reviews, that will set the stage for the methodology that we have used at CIAT.

First of all we should distinguish between single and multiple criteria models. In the first group belongs congruency analysis, as also applied by Janssen, Sanint and Sere (1989) for the 1989 CIAT internal annual review. Precedence, the principle of increasing or reducing the budget according to the previous allocation is also a single criterion method. Single criterion methods can provide very rough first indications on the relative magnitudes of priorities or resource allocation. Generally, a single criterion does not allow to express the different components of the objective set of the institution under scrutiny. They do not provide sufficient detail for any more sophisticated analysis.

The focus thus turns to the multiple criteria models. Within the multiple criteria models, an important distinction is between models with built-in criteria weighing, and models without criteria weighing. In the first case, the model considers different criteria and already weighs them in order to come to a priority order. Mathematical programming models (see Romero and Rehman, 1989) or hierarchical prioritization (Saaty, 1986) belong in this group. In the second case the value of the different options with respect to the criteria are obtained, but the actual prioritization takes place outside the model, through the interpretation of the model results by the decision makers. Scoring models are an example of this methodology. The relevance of built-in criteria weighing versus interpretation outside the model depends on the precise understanding of the importance of the different criteria to the decision makers, and on the understanding of their preferred decision process.

In much of the literature a distinction is made between the value of production (in congruency analysis) or the expected benefits of research (in producer and consumer surplus analysis). The expected benefit of research is a more relevant criterion than the value of production, but the assumptions that are needed to obtain it are more susceptible to mistakes. This problem is partly obviated by the consultation of experts, for example in a Delphi-type questionnaire (see for example Herdt and Riely, 1987). Still, the number of assumptions easily reduces the credibility of the second type of analysis, or shifts the discussions from the outcomes to the assumptions and procedures.

Another issue is the relationship between research costs and research benefits. Ideally, for all commodities included in a prioritization analysis the relationship between research costs and research benefits should be established throughout a continuum from low to high costs (the research production function). This would then allow to determine the optimum size of the programs. Such an analysis is theoretically possible, but practically tedious to execute for more than a few crops. Consequently, it is difficult to apply a true cost-benefit framework, and normally the analysis will be constrained to the comparison of expected benefits at a certain level of funding. In that situation a comparison of expected benefits satisfies the benefit-cost criterion.

The three literature reviews cited earlier distinguish benefit-costs models from multiple scoring models. The distinction seems to be based on the greater use of economic and mathematical concepts in the reported cost-benefit analyses than in the multiple scoring analyses. This distinction, however, is rather confusing. Within a multiple scoring framework, there is no reason why the expected benefit-cost ratio cannot be included as one of the criteria.

Where do the previous observations lead CIAT's commodity analysis? First of all to the realization that a multiple criteria framework is preferable above any single criterion. Secondly, that there is no reason to consider cost-benefit analysis and a multiple scoring model as mutually exclusive, but that the first method can be absorbed in the second. Thirdly, to the awareness that the credibility of the commodity analysis depends on the effective involvement of commodity experts, even though the economists stay responsible for the final results.

Finally, they lead to the conclusion that it is more important to supply clearly interpretable information to the decision makers than to elicit their judgments and include these in the evaluation approach. In its analysis of priority assessment methods, TAC stated that: "no model will ever be a substitute for [our] collective judgement." Apparently the time of the economists is more efficiently used in obtaining the relevant information and presenting this in a clear framework than in pre-emptying the decision process that might follow.

CIAT's COMMODITY EVALUATION APPROACH

In response to the review of research prioritization methods, two major decisions were taken. First of all we decided that the economist's interventions should center on data collection and presentation and not so much on the interpretation with respect to the objectives of CIAT. In the design of the commodity evaluation procedure, value judgements could be avoided in all except two cases, which will be discussed later on. With respect to the interpretation of the outcomes of the analysis, we will try to expose our values as clearly as possible whenever this is needed.

Secondly we decided that not any single method was sufficiently versatile to be used alone, but we recognized that most methods might have some role to play in the commodity analysis. We therefore decided to blend different methods into the CIAT approach.

Although we had restricted ourselves to a Latin American context, the number of commodity options remained large. We took the decision to apply a two stage analysis (Figure 1). In the first stage, we scored the commodities on a small number of simple criteria and in a hierarchical prioritization process we discarded some of them from further study. The other commodities were submitted to an in-depth analysis. Naturally the criteria to discard certain commodities involves a policy judgement, be it of a rather simple and straightforward nature.

In the second stage, a restricted group of commodities was studied with more attention. A single cost-benefit criterion, as favored by Ryan (personal communication) or a single congruency analysis as applied my McIntire (1985) appeared too restrictive to express the roles of the different commodities, or to address the questions of CIAT's board and management. Rather we decided to develop criteria for each of the four principle objectives of growth, equity, sustainability and institutional complementarity. The selection of the final evaluation criteria implies another policy judgement, but since it was done in close collaboration with CIAT management we feel confident about it.

Although we decided against a single criterion, we do agree that agricultural research should be considered as a long term investment, and therefore that benefit-cost assessments should form the backbone of the analysis. With respect to economic growth and equity, there were no conceptual problems in developing a benefit-cost framework of analysis, but we did feel that some considerations such as nutrition, employment, and expected future value of the commodity were not sufficiently included. In case of sustainability and institutional considerations, the investment concept is not equally clear or not that easily applicable and here we looked for other criteria.

The scores for the commodities on some of the criteria could be obtained directly from original data sources. To obtain scores on some other criteria, we used a partial equilibrium model as well as a simple general equilibrium model. Most of the data needed to feed these models were gathered by the economists.

Nevertheless, a number of critical parameters of an essentially subjective nature, such as the expected supply shift in case of successful research, the lead time of research, the speed of adoption of improved technology, were obtained in consultation with experts on the specific commodities. These consultations took two forms: whenever possible, the economic and technical prospects of the commodity were discussed with an expert. Additionally, a questionnaire was developed to elicit judgements on the type and rate of technical change that could be expected in a certain commodity as the result of CIAT research. The questionnaire was accompanied by a commodity profile to orientate the expert with respect to the socio-economic details of the commodity. The questionnaire was sent to several specialists for each commodity. The response was only 19% (up to this date). In the case of sorghum, soy beans and cotton the results formed the base for subsequent adjustments. In most cases, we feel confident that our collected information provided us with as good an estimate as anything. However in the case of bananas and plantains the data should be viewed with care, since little specific information could be provided on technical changes.

The methodology applied can thus be summarized as a initial hierarchical screening process, followed by the application of a multiple criteria model, built around a benefit-cost analysis and estimated by means of an expert consultation procedure. The methodology tries to provide clearly interpretable data on the expected benefits of research in total and to different target groups, but it reinforces or challenges the outcomes from the benefit-cost analysis with a number of additional criteria. No effort was made to weigh the different criteria or to include them in a formal decision procedure.

Before discussing the application of the methodology to present and potential CIAT mandate commodities, a final remark should be made about the time available for this study. Methodology and model development, data collection, data processing and reporting has taken place in a time frame of three months. This is obviously very short and has led to the necessity of cutting corners on some of the more tricky issues. From a Center's management and planning perspective, however, such a time frame is favorable. The procedure is rapid and agile, and misconceptions by the data analysts can be corrected at a low cost of time invested. The acid test for the methodology is how data, assumptions and results stand up to a critical outside review.

COMMODITY SCREENING

On the basis of communication between CIAT management and CIAT economists 18 commodities were selected for initial screening. In alphabetic order, these commodities were: bananas, beans, beef, cassava, coffee, citrus (oranges + lemon), cocoa, coffee, cotton, ground nuts, milk, oil palm, pineapple, plantains, rice, rubber, sorghum, soy beans, sugar, vegetables (onions, snap beans and tomatoes) and wood products. These commodities are agricultural products, in the sense that land is a principal factor in their production. Marine products, eggs, poultry and pork were excluded for this reason. Beef and milk production can also be divorced from the land, but in Latin America this is normally land dependent.

These commodities were screened for three criteria. First of all we looked to the value of production within Latin America, as a proxy for the significance of the commodity. Then we looked to the share of Latin America in total developing world production, to understand whether research in Latin America would truly contribute to scientific progress. Finally we assessed the merit for international research, basically by reviewing the existing strength of research by national programs or producer organizations.

To assess the value of production and the share of Latin America in total developing world production, we used the data set developed by Davis, Oram and Ryan (1989) for the use of TAC. As the authors admit, this data set is amenable to improvements, but nevertheless we considered it an adequate source for the initial screening. The assessment on the merit of international research was made on the basis of our existing knowledge of research strength, without further consultation of sources.

Table 1 shows the outcome of the screening process. Because of their low value of production, cocoa, ground nuts, oil palm, pineapple and rubber were discarded. Coffee and sugar both have strong research programs by producer organizations and were discarded because of an apparent lack of merit for international research. Wood products were not discarded as such, but the relevance of (agro)forestry research was considered to depend more on the importance that CIAT would give to land use than on the value of this mixed bag of products. The share of Latin America in total developing world production turned out to be a redundant criterion.

COMMODITY EVALUATION IN A MULTIPLE CRITERIA FRAMEWORK

Eleven commodities remained after the initial screening. Apart from the CIAT-commodities (beans, beef, cassava, milk and rice) these were banana, citrus, cotton, plantain, sorghum, soy beans and a group of vegetable products.These commodities were evaluated for the potential contribution that research could make to economic growth, equity, sustainability and institutional complementarity. For the evaluation of these commodities, data were obtained from a large number of sources. These are reported in Appendix 4.

ECONOMIC GROWTH

Criteria. Technology development aims to contribute to economic growth through the more efficient use of scarce resources. In the context of agricultural research this has normally been interpreted as increasing production per unit land or per unit labor. In the history of agricultural economics research, the estimation of technological benefits has normally been restricted to the direct effects on the supply and demand of the commodity in question.

Recently, there has been increasing awareness of the indirect effects of technological change. When the supply of a certain commodity increases, this triggers off demand for other products. For example, if more rice is produced, more combines are needed, more rice mills will be built and more fertilizer will be requested. At the same time, the income of producers may increase, and they will expand their consumption. The resulting demand for goods and services allows other people to earn an income. The extra value added in this way, outside the commodity sector, is referred to as the linkage effect (Mellor and Lele, 1973). The relative size of the linkage effect, differs among commodities, according to input intensity and the share of the extra income spent on domestic products (Hazell and Roell, 1983). For a proper comparison of technological change in different commodities, both the direct effect on supply and demand and the indirect effect outside the commodity sector have to be considered.

The direct and indirect technology effects provide monetary estimations of the contribution to economic growth and they are logical, rational and discriminatory criteria. Nevertheless, both are rather susceptible to the assumptions and the model structure applied, as will be explained later on. To support or challenge the consistency of the previous estimates, some proxy-variables were included as additional economic growth criteria. These were the present value of production, the expected demand growth and the potential for foreign exchange earnings.

Measurement. How were the different criteria measured? For the value of production, the average from the FAO production yearbooks for the three ultimate available years was multiplied with the average world market price during the last decade, as supplied in IMF or FAO price statistics. The expected demand growth was assessed by analyzing commodity demand with respect to income and urbanization and by reviewing the supply of substituting products. The potential foreign exchange earnings were assessed in a qualitative way by considering the tradeability of the commodity, the present volume of trade, the expected world market demand growth, and the potential for import substitution.

For the direct effect on supply and demand of the commodity in question the technological impact was estimated in a partial equilibrium framework. See Table 2 for the assumptions and Appendix 1 for the model applied. For those interested in the model, a technical summary can be obtained from the authors. A brief discussion on some of the peculiarities of our model will follow.

In the analysis of technological impact over time one wonders whether the the proper parameters of the partial equilibrium model would not change, such as the elasticities, or the size of demand and supply. Therefore we simulated the effect of technological change as influenced by autonomous shifts in demand and supply. This does not deal with possible changes in elasticities, but it does assess the technology impact in a dynamic fashion. We applied a 10% discount rate and aggregated the research benefits as simulated from 1990 to 2025 to arrive at a net present value (NPV).

Supply and demand functions are normally only known close to the observed market equilibrium. The extrapolation to prices that are higher or lower than observed is rather speculative and, in case of linear functions often produces substantial supplies at negative prices. We have used the specification of Lynam and Jones (1986) which states that supply is only possible at positive prices. For further discussion of this specification see the papers of Pachico, Lynam and Jones (1987) and Antony, Anderson and Kauzi (1988).

Lindner and Jarrett (1978) show that the size and distribution of research benefits depends strongly on the type of supply shift. In all cases, we have applied a pivotal demand shift. This shift provides a conservative approximation of the total expected benefits of research and avoids exaggerated estimates. Nevertheless, a pivotal supply shift tends to depress very much the expected producer benefits. In the analysis of equity contributions, this has necessitated some adjustments.

A partial equilibrium model has the shortcoming that the effect on supply or demand of other products is not included. This has some consequences in the estimation of the equity contributions. As well, the linkage effects outside the commodity sector cannot be estimated in a partial equilibrium framework. This turns the attention to the measurement of the indirect technology effects.

For the measurement of indirect technology effects the general equilibrium model by Haggblade and Hazell (1989) was expanded. Our model consists of a tradeable sector, a non-tradeable agricultural sector and a non-tradeable non-agricultural sector. Apart from these three sectors it contains a sector where supply and demand parameters for the commodity under evaluation can be imputed, both in case of a tradeable or a non-tradeable commodity.

The model allows to evaluate different types of technological change. For purposes of this paper we have evaluated the effect of a 10% shift in the slope of the supply function, coupled with a 10% reduction in the tradeable input to output ratio. This roughly reflects technology that increases yields per hectare at equal input levels per hectare.

By varying the tradeable and non-tradeable input coefficients and the income elasticity of domestic demand according to the commodity under evaluation (see Table 3),the ratio of the expected income change outside the agricultural sector to the expected supply change because of new technology can be calculated. By applying this ratio to the net present value of the expected supply change, as obtained in the partial equilibrium model, the NPV of the linkage effect is obtained. A brief description of the model is provided in Appendix 2.

Results. The values of the commodities on the different criteria are given in Table 4. The NPV of research benefits varies considerably, from almost US$ 3 billion in case of beef and rice to only US$ 107 million in case of plantain. Three CIAT mandate commodities have rather high expected values of research within a Latin American context. These are beef, rice and milk. For the other two CIAT mandate commodities, beans and cassava, the

NPV's of research benefits within Latin America are considerably lower. They are more comparable to vegetables, cotton, bananas or sorghum.

If we consider that for both beans and cassava, CIAT has a global and not a regional mandate, the expected values of research on these crops change considerably. For both crops the NPV doubles by considering the other continents where CIAT has an operational mandate. In case of beans the NPV improves even further in case the snap bean, the vegetable brother of the dry bean, is included in the analysis. While in a Latin American context the usefulness of a bean or cassava program is not equivalent to a soy bean or sorghum program, the mixed geographic responsibilities of CIAT suggest continued attention to the first two crops.

Technology that would allow sorghum and soybeans to be grown on the acid savannas of the lowland tropics would have a considerable pay-off. In case of soybeans the direct benefits are more than a billion dollars. In case of sorghum, in a Latin American context these benefits are higher than for beans and cassava. The NPV of research benefits for vegetables are lower than expected beforehand. Although vegetable demand will grow rapidly, it will do so from a rather small basis. For cotton and citrus, the NPV of research benefits was also small. In case of cotton, this is caused by the limited room for technological improvement. In case of citrus, the importance of the commodity resulted smaller than estimated in the first stage.

For all commodities, the inclusion of the linkage effect increases considerably the impact of research. The value of the linkage effect changes remarkably among commodities. In beans and beef, it is less than 40% of the NPV of direct research benefits, but in citrus or bananas it is larger than the direct research benefits. In case agriculture should be used as the motor of agricultural change, commodities such as citrus or soybeans would appear more instrumental than commodities such as beef or beans. In general the relative linkage effect is higher for tradeable than for non-tradeable commodities.

The potential foreign exchange earnings for Latin America are high in commodities such as soy beans, cotton, citrus and banana. The expected foreign exchange earnings from dried cassava exports in Asia remain high. Beef takes an intermediate position while for rice, cassava in L.A., beans, plantains and vegetables the export potential is low.

Future demand growth is low only for cotton, because of substitution by artificial fibers, and plantains, where urbanization is expected to decrease effective demand. Future demand growth is high for animal proteins (beef and milk), animal feed raw materials (soy bean cake, sorghum) and vegetables. For the other commodities we expect future demand growth to be roughly equal to population growth.

Not all commodities have secondary products, but for those commodities that do, this does influence future prospects. For cassava there is high future demand in the animal feed sector. For citrus, the expectations in the juice market are very favorable. For soy bean oil high urban demand is expected.

The current value of production of the CIAT commodities compares favorable with that of the newly considered options. CIAT's choices were well founded twenty years ago. Although the CIAT commodities might have faced more reduced growth than some others, their growth started from a large initial value. Soy beans, cotton and bananas have comparable values of production. For the other products, these are considerably lower.

EQUITY

Equity Criteria: As was alluded to earlier, the current focus on equity relates to the improvement of incomes as the basic mechanism to reduce poverty and malnutrition. As such, commodities play a dual role as a food crop for the small farmer, at the same time generating economic development.

In Latin America poverty has become worse. Although the share of poverty is higher in rural areas, in urban areas poverty increased from 31% to 45% during the last decade (United Nations, 1990). Consequently, nutritional aspects need to receive major emphasis for the future.

Latin development has shown intensive use of capital with low labor absorption and often labor displacement. Larger producers are benefitting more from public policies, farm mechanization and input subsidies than smaller ones (FAO, 1988). This has been one of the reasons behind further urbanization and more landless agricultural labor. In addition small farmers have been pushed to the less fertile or marginal lands.

As such, when different commodities are evaluated with respect to equity issues, one has to focus on poor consumers, small producers, generation of labor, and the direct nutritional contribution. The decision making criteria used in this exercise are: (B1) Technology derived benefits to poor consumers. The latter were defined as the consumers of the lowest two (40%) income quintiles; (B2) The percentage small farmers benefitting from new technology; (B3) Technology derived employment effect: (B4) Total calories for human consumption; (B5) Total proteins for human consumption. It should be noted that the poor consumers of B1 and the small producers of B2 were defined in such a way that on the basis of income they are quite comparable.

Measurement: Generating B1 proved quite straight forward. Total research benefits were already calculated in the previous section. Hence, for our measurement, consumer surplus was multiplied with the percentage of poor consumers as given in Table 2.

Measurement of B2 has lead to major discussions. Welfare theory tells us that for non-export commodities in general, (in a partial equilibrium framework) consumer surplus is positive, while producer benefits might be negative. Our model subsequently showed similar results. In the case for consumer benefits this seems quite realistic. However, negative producer benefits seem counter intuitive and might have been caused by the use of a pivotal shift in order to obtain conservative expected benefits. As a consequence, MODEXC's first results were rejected. Then, the total producer surplus, including exogenous impact, was discussed. However, although positive, this measurement confounds the true impact from technology with interactions from different origins. As such, this measure was rejected as well. An alternative is to argue that in the long run the equilibrium price of the commodity may be equal to the price before technology impact, due to substitution effects. Subsequently the producer benefits can be calculated as $P_1(Q_1-Q_0)$ (price after impact times the additional quantity). However, this is quite a heroic assumption, and hard to substantiate. As a Salomon's solution, more than as a theoretically derived judgement, B2 gives the percentage of small farmers benefitting from new technology. As such this measure should be evaluated in light of total benefits.

The measurement of the employment effect resulting from technology impact was calculated using the general equilibrium model, described earlier (See also Appendix 3). The effect is made up of (a). The direct effect, which measures the change in employment within the commodity sub-sector, influenced by the technological change; and (b) the indirect effect, which captures the change in employment outside the sub-sector and is calculated through the linkage effect of the model. For a treatise of the mechanics of the calculation, see Appendix 3.

The measurement of total calories and proteins are rather straight forward. They were calculated from FAO - Food Balance Sheets.

Results: The results for equity criteria are summarized in Table 5. The results from the poor consumer benefit criteria (B1), are quite similar to those of total benefits. Among the CIAT commodities rice stands out, with a high estimate of approximately 2.6 billion US$. This seems quite acceptable, given that rice is the most common and popular carbohydrate in Latin American diets. The results again show that the inclusion of Africa and Asia for beans and cassava respectively, greatly increases the importance of this criteria. Most other commodity estimates are average to low.

When looking at the share of poor farmers receiving benefits (B2), it becomes very obvious that rice and beef & milk are produced by larger farmers relative to beans and cassava. Subsequently, relatively more benefits will accrue to small farmers of the latter two crops. A similar trend is distinguishable for bananas, sorghum, soybeans and cotton. For these crops in general, large farmers are the main producers. Thus, only few small farmers will reap benefits from new technology.

From the results of the employment effect criterion, it can be shown, that typically crops with high labor use in harvesting and processing, i.e. cassava and bananas, have the highest scores. Inversely, crops like beans in L.A. even show a loss of employment due to technology impact. Extra employment in harvesting and marketing cannot compensate for employment reduction in production.

The results for criteria B4 and B5 are intuitively obvious. Total calories for rice, and cassava (including Asia) stand out. The scores for bananas, plantains, citrus, sorghum, cotton and vegetables are relatively low. The remaining crops show intermediate values. In the case of total proteins, beans, rice, milk and beef show high scores, with the other crops having low to intermediate values. It should be noted here that with this criterion, only direct intake for human consumption is measured. As such, this discriminates against cassava, soybeans and cotton seed (meal) where a considerable share of production is being utilized for animal production. Subsequently, these crops would show higher values if indirect protein consumption would have been measured.

SUSTAINABILITY

Criteria: As mentioned earlier, sustainability aspects have increasingly received more emphasis as key components of the objective functions in international agricultural research as envisioned by the donor world. It isn't accepted anymore to pay "lip service" to environmental dangers that surround most agricultural production systems. Sustainability has deserved a place as an objective in itself.

It is important to realize that sustainability does not only imply sustaining the environment over time. Better, it implies to sustain an interacting system of biological, social and economical actors, over time. Consequently, one has to talk about multi-objective functions for the improvement of agricultural production systems.

Given the above, for this exercise several alternative criteria were discussed. One set of criteria tried to capture different aspects of sustainability i.e. soil erosion, fertility losses, methane emissions, pesticide usage, and contribution to deforestation. These criteria were evaluated for each of the proposed commodities. However, one of the major problems was, that hardly any data exist to substantiate estimates. In addition, how can one evaluate a specific crop with respect to one of the criteria for the whole of LA/C?.

Also the scores of these criteria are very technology dependent. As such, a new approach had to be found.

The problem with respect to the generalization for the whole of LA/C was solved by CIAT's Agroecological Unit (AEU) who suggested three priority agro-eco zones i.e. hillside zone, savanna zone, and seasonal forest transition zone for CIAT intervention. For these zones an assessment was made to the relative contribution of commodity research for the conservation of the natural resource base in LA/C.

Results: In consultation with several resource persons and based on the scarce available data, a qualitative assessment was made for the priority zones. Estimates were captured as small, medium and large contributions (*, **, ***).

For the hillside zone the underlying argument was, that perennial crops will contribute relatively more to conservation of the natural resource base, than annual crops. Hence, as Table 6 demonstrates, milk (improved pastures) and citrus have the highest scores. It was viewed that rice, sorghum, soybeans, and cotton can contribute little. The remaining crops show a medium score.

For the savanna zone the hypothesis was offered; that a crop/pasture system would have a relatively high contribution. Preliminary results from experiments in the Colombian Llanos on rice/pasture systems seem very promising. From a land-use perspective the emphasis should be placed on an integrated systems approach. As a consequence, rice, beef (improved pastures) and soybeans are visualized to score highest. The remaining crops show low to medium contributions.

In the case of the seasonal forest transition zone, both current seasonal forests and zones that used to be forested, are included. As such, the major influence with respect to the former, is a political one. Government policies are required to alleviate the pressure on the forests. We see little contribution of commodity technology to this end. With respect to zones that used to be forested we don't foresee large commodity technology contributions. Yet, the majority of current CIAT commodities can make a medium positive impact. For sorghum, soybeans, cotton or vegetables, only a low score can be given.

INSTITUTIONAL CONSIDERATIONS

Criteria: National agricultural research institutions are CIAT's first and foremost important partners in the fulfillment of our objectives.

They are the recipients of new technology on the one hand, and in the long run have to adopt certain responsibilities of CIAT. Hence, it is of vital importance to assess the capacity of the national institutions when considering the basket of commodities to be researched. Basically two criteria are proposed that can shed some light on our assessment: (D1) What is the current level/capacity of investigation of the National Program for a specific commodity? and (D2). Is there any investigation done on a specific crop by another international centre, and which centres are these?

Results: For the current CIAT commodities, sufficient information exists on the level and capacity of national research. Yet for the other commodities, we had to rely on sketchy data and country experience of CIAT scientists that had worked with different crops previously.

In evaluating the results, the old dilemma arises again if one should work with a national program which is weak, or inversely, if one should work with a national program that is already relatively strong? Some voices argue that therefore, CIAT should work with the intermediate programs. Nevertheless, in Table 7 the results on institutional considerations are shown. We leave the dilemma to be solved by the appropriate decision makers. However, given the dilemma, we have assigned one star (*) for both weak and strong programs. Two stars (**) were given for intermediate national investigation.

Current investigation of national programs for beans (LA) and rice are appropriate for successful collaboration. It should be noted here that producer organizations may play a vital role in national research as is the case for rice. As such, total national research estimates can differ with that respect. The remaining commodities invariably show weak national program investigation in LA/C.

When looking at current investigation of other international centres, a deficit can be seen for citrus, soybeans and cotton. However, one should take into account that considerable research on these crops is being done by commercial entities in the developing world.

In the case of cassava and milk/beef, although other international research is being conducted, this is not directly related to LA/C. In the case of bananas, considerable research is conducted by commercial entities in addition to international centres. For bananas/plantains a research network (INIBAP) exists for LA/C.

SUMMARY AND CONCLUSIONS.

The dynamic setting in which CIAT technologies are demanded has shifted somehow from the early objectives of the 1970's characterized by warranting food self-sufficiency and equity of poor farmers, to the more complex objectives of today based on achieving food self-reliance, equity (with a broader perspective beyond the small farmer to accommodate effects on the poor urban dweller) and sustainability, all of this within the recognized need to strengthen the institutional framework. Additionally, the trend towards geographical specialization within the CG-system created the feeling that CIAT should re-emphasize its Latin American responsibilities.

The increased awareness of the need to focus on land use and production systems to adequately address development issues in this new political context poses some complexities to the selection of priorities within the strategic planning exercise. At CIAT, it was decided to undertake two parallel tasks that will later be crossed to establish the optimal mix in program structure and activities. The two tasks were (i) to revisit the CIAT current commodity portfolio of beans, cassava, rice and tropical pastures (beef and milk) in the realm of other plausible commodity choices and (ii) to identify agroecological zones susceptible of being the research subject of a land use program.

This report focused on the first of those two tasks: the CIAT's commodity portfolio, revisited. The problem of identifying priorities at the commodity level was approached from the perspective of a multiple objective decision making (or lexicographic) process in which objectives are weighed according to some preferences expressed by the decision makers. Under this framework, it is recognized that such weights are not known; rather, they are assigned by decision makers in a process of "collective judgement". Therefore, the role of the economists involved in this part of the process focused on obtaining the relevant information and presenting it in a clear framework that can be assimilated by the decision makers afterwards. Such information is presented here. No effort was made to weigh the different criteria or to include them in a formal decision procedure.

The approach blends several methods, from quantitative to qualitative, and has two stages. First, 18 plausible agricultural products were included, and after scoring them on some simple criteria, the number was reduced to 12 products that were to be the subject of an in-depth analysis. Those were the 5 CIAT commodities (beans, cassava, rice, milk and beef) plus bananas, plantains, citrus, sorghum, soybeans, cotton and vegetables (tomatoes, onions, snap beans). Wood products were not discarded as such, but the relevance of (agro)forestry research was considered to depend more on the importance that CIAT would give to land use than on the value of this mixed bag of products; their evaluation must take place at a later stage.

The methodology applied can be summarized as an initial hierarchical screening process, followed by the application of a multiple criteria decision making model, built around a benefit-cost analysis and estimated by means of an expert consultation process.

The in-depth analysis of the second stage was guided by four basic groups of criteria related to growth, equity, sustainability and institutional complementarity with CIAT.

In Table 8, each of the groups of criteria was summarized in an attempt to synthesize the multiple criteria; this table includes some judgement of the kind required from decision makers: an attempt is made to synthesize several indicators for each of the four groups of criteria into one indicator that summarizes the group. In that sense, our own particular group judgement was incorporated. However, the scorings are relatively well differentiated so that such a summary will be agreeable within small discrepancies.

From Table 8 it is quite clear that the current CIAT commodity portfolio emerges as being quite relevant, given the set of criteria imposed by the Center. Two other commodities appear attractive: sorghum and soybeans, which have a low score only in the set of equity considerations and which can be addressed in very specific areas. Citrus is quite important from the point of view of sustainability.

Let us look at each one of the groups, to obtain an idea of the relative ranking of the commodity options by category.

From the point of view of growth, the commodities with the high scores are rice, milk and beef. Although they all rank low in one of the criteria: potential foreign exchange earnings, they outrank the rest in growth related aspects and in the current value of production.

The second group of criteria, equity, has two clear winners: beans and cassava, specially when the global area of the mandate is considered (L.A.+). Rice has very high scores for equity among poor consumers (B1, B4, B5) but does not have an important equity component for producers. Milk and beef are somewhat less important than rice in this criterion. None of the commodities considered outside the CIAT current portfolio appears as being relevant from the point of view of equity.

From the point of view of sustainability, the tropical pastures program clearly has an important contribution to make; both beef and milk production rank high. Cassava and beans find a major thrust outside Latin

America. Citrus has particularly an important role in the hillsides. In the savanna zone, where there is a shortage of germplasm to be used in crop-pastures sustainable rotations, both soybeans and sorghum for acid soils may have much to contribute towards this criterion of sustainability.

Finally, with respect to institutional aspects, tropical pastures, beans and sorghum have relatively short lead times for research and there is a propitious environment to complement national and international efforts in those commodities. Rice, cassava and soybeans are also good in that respect, to a lesser extent.

As a basis for future planning, this document examined a wide set of commodity options including the current portfolio of CIAT plus others that were identified as having good potential for entering into the CG-system and/or into CIAT's future activities. As mentioned earlier, the exercise runs parallel to the identification of agro-ecozones, and the integration of the two exercises has not been done at this point. Such crossing of information corresponds to the next stage of the strategic planning process. The results of this stage help to reduce the set to more manageable size. Other considerations, like the role of multipurpose tree species will be better handled at that stage.

Besides the relative weights, that are clearly subjective in nature, there are other considerations like the quality of the data. Some quantitative indicators are much more reliable than others; the current value of production is easier to measure then the expected benefits from research to society, for example. Some qualitative indicators are also better founded than others.

The bottom line conclusion is that the spirit of this document is founded on the premise that "no model will ever be a substitute by our collective judgement" (TAC). The data presented here are supposed to guide the strategic planning process rather than trap it.

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Table 1: Summary data for initial screening of commodity options.

	Value of production (million US$) (L.A.)	% 1/	Decision 2/
Beans (Phaseolus) 3/	4131	61.30	I
Beef	10023	61.94	I
Cassava 3/	6209	21.76	I
Citrus (oranges + lemon)	7302	61.95	I
Cotton	2700	14.13	I
Milk	11845	30.40	I
Plantain/Banana	9530	39.53	I
Rice	4.070	6.59	I
Sorghum	1716	33.21	I
Soy beans	6214	64.34	I
Vegetables 4/	1887	21.68	I
Cocoa	1443	35.08	V
Coffee	11930	65.81	M
Ground nuts	340	4.73	V
Oilpalm	118	4.48	V
Pineapple	417	24.15	V
Rubber	70	1.38	V
Sugar	3701	50.46	M
Wood	24815	20.80	L

1/: Share of L.A. in total developing world production.

2/: I = included for further analysis.
V = discarded because of low value of production.
M = discarded because of apparent lack of merit of international research.
L = decision depends on CIAT's position with respect to land use research.

3/: For beans and cassava, value in other target regions included (respectively Africa + WANA and Asia).

4/: Snap beans + tomatoes + onions.

Sources: Data prepared by Davis, Oram and Ryan (DOR) for TAC decision making.

For Beans: DOR-data do not distinguish phaseolus and non-phaseolus. Data presented are farm gate value as estimated by Janssen, Sanint and Sere (JSS) for last years presentation in the Annual Review.

Snap Beans: Estimates made by Henry and Janssen for Snap Bean Economic Study.

Rice: Value for L.A. corrected with JSS-calculations.

Table 2: Data used in the partial equilibrium model to estimate research benefits

Product	Region	Value of production (million US$)	Supply elasticity	Demand elasticity	K 3/	Supply growth	Demand growth	Consumption share of 40% poorest consumers (%)	Share of small producers in production (%)	Lead time of research
Banana	L.A.	7.504	0.4	- 2.0	1.17	1.5	2.2	-	12	6
Bean	L.A.	2.459	0.6	-0.5	1.28	1.6	1.7	39	55	4
	Africa + Wana	1.672	0.4	-0.4	1.26	2.2	3.0	85	90	4
	Snap beans 1/	1.470	0.8	-0.6	1.31	2.5	3.1	74	95	4
Beef	Tropical L.A.	8.580	0.5	-0.4	1.46	1.0	1.5	25	26	4
Cassava	L.A. - fresh	628	0.5	-0.8	1.09	0.8	1.0	19	58	8
	- processed	2.103	0.5	-0.8	1.24	1.6	2.0	60	50	6
	Asia - processed	1.767	0.5	-2.2	1.23	1.2	4.0	-	90	6
Citrus	L.A.	1.341	0.3	-2.0	1.20	2.0	2.0	19 5/	53	6
Cotton	L.A.	3.388	0.5	- 5.0	1.12	0.8	1.4	25	25	6
Milk	Tropical L.A.	10.325	0.7	-0.8	1.25	1.4	1.6	26	50	4
Plantain	L.A.	514	0.5	-1.2	1.28	0.8	1.7	33	52	6
Rice 2/	L.A.	4.070	0.5	-0.5	2.8	1.8	2.0	36	18	2
Sorghum	L.A.	1.232	0.5	- 5.0	1.34	2.0	3.0	25 5/	13	6
Soy bean	Tropical L.A.	4.782	0.5	-5.0	1.50	2.0	3.0	25 5/	3	6
Vegetables 4/	L.A.	1.887	0.8	-0.7	1.31	2.5	3.0	25	80	6

1/ : Weighted average for L.A., Asia and Africa.

2/ : In rice very significant technology adoption has occurred over the last 20 years. In light of this fact future rice research benefits are estimated in a somewhat different way than for the other commodities. The Rice Economist has a note available that can be requested in his office, to explain the estimation procedure.

3/ : K = The factor which expresses the shift in supply. Defined as: $\frac{\text{Initial supply + Expected extra supply because of technological change}}{\text{Initial supply}}$

4/ : Includes tomatoes and onions.

5/ : Considered as fully tradeable commodities.

Table 3: Assumptions for evaluation of linkage effects.

A: Commodity data for multiplier and linkage analysis

	Type		Input use			Inc. effect
	Non tradeable	Tradeable	Tradeable inputs	Ag. Non tradeable inputs	Other non tradeable inputs	Exp. elast
Rice	x	x	0.16	0.01	0.20	0.5
Soy beans		x	0.12	0.01	0.25	0.5
Cotton		x	0.10	0.01	0.20	0.7
Sorghum		x	0.24	0.01	0.04	0.5
Citrus		x	0.05	0.01	0.25	0.7
Banana		x	0.10	0.01	0.08	0.5
Plantain	x		0.05	0.01	0.04	0.9
Tomato	x		0.15	0.01	0.30	0.8
Onions	x		0.15	0.01	0.04	0.8
Milk	x	x	0.05	0.05	0.30	0.7
Beef	x	x	0.03	0.05	0.25	0.5
Beans	x	x	0.10	0.01	0.04	0.9
Cassava	x		0.05	0.01	0.20	0.9

B: Input/Output matrix

Intermediate demand from:	To: 1/	2/	3/	4/	5/
1. CIAT tradeable	*	*	*	*	*
2. Other tradeables	-	0.11	-	0.02	0.18
3. CIAT non-tradeable	*	*	*	*	*
4. Ag. non-tradeable	-	0.09	-	0.02	0.17
5. Other non-tradeable	-	0.10	-	0.025	0.20

* To be filled with data of the commodity under evaluation.

Data sources: Due to time limitations, the input use estimations are based on subjective assessments of CIAT-economists.

Table 4. Decision-making criteria for CIAT's commodity options (beans, rice, cassava, milk, beef, banana, plantain, citrus, sorghum, soybean, cotton, vegetables).
Objective: <u>ECONOMIC GROWTH</u>

CRITERIA	BE		RI	CA		MI 2/	BF 2/	BAN	PL	CIT	SOR 2/	SOY 2/	COT	VEG
	LA	LA+	LA	LA	LA+	LA	LA	LA	LA	LA	LA	LA	LA	LA
A1 NPV of research benefits at 10 % (million US$)	594	1,418	2,957	419	1,495	1,910	3,230	1,040	107	226	619	1,248	336	499
A2 NPV of multiplier effect (million US$)	241	523	2,319	319	1,221	1,219	1,621	358	29	258	454	1,050	375	214
A3 Potential foreign exchange earnings from new technology 1/ (high, medium, low)	*	*	*	*	***	**	**	***	-	***	***	***	***	*
A4 Future demand growth (<=> pop. growth)	=	≥	=	≤	≥	≥	>	=	<	=	>	>	<	>
A5 Current value of production (million US$)	2,459	5,601	4,070	1,461	3,228	8,714	6,852	7,504	514	1,300	1,237	2,362	3,393	1,887

Note: LA denotes (tropical) Latin America.
LA + denotes (tropical) Latin America plus Asia for cassava, and includes Africa and snap beans for beans.
It should be noted that especially for the future, semi-arid Africa will receive cassava resources.

1/ Includes import substitution.
2/ Tropical lowlands of Latin America.

Table 5. Decision making criteria for CIAT's commodity options (beans, rice, cassava, milk, beef, banana, plantain, citrus, sorghum, soybean, cotton, vegetables).
Objective: EQUITY

CRITERIA	BE		RI	CA		MI 3/	BF 3/	BAN	PL	CIT	SOR	SOY	COT	VEG
	LA	LA+	LA	LA	LA+	LA	LA	LA	LA	LA	LA	LA	LA	LA
B1 Technology derived benefits to poor consumers (million US$) 2/	415	1,903	2,595	846.8	1,127	742	1,498	43	40	75	62	134	21	137
B2 Percentage small farmers benefiting from new technology (%) 1/	55	76	18	58	90	50	26	12	52	53	13	3	25	80
B3 Technology derived employment effect (000 man years)	-63	53	98	-60	171	110	67	224	5	103	59	156	37	33
B4 Total calories for human nutrition (million kcal/day)	38.8	63.1	106	29.8	86.5	48.5	26.4	16.8	9.6	5.8	2.3	23.4	6.6	4.7
B5 Total proteins for human nutrition (000 kg/day)	2,393	3,979	2,100	187	542	2,818	1,746	223	87	0	60	0	0	185

1/ For farmers with income < US$3,000.
2/ For consumers of lowest two income quintiles (lowest 40%).
3/ Tropical Latin America.

Table 6. Assessment of the relative contribution of commodity technology for the conservation of the natural resource base in specific ecozones in LA/C. 1/ (beans, rice, cassava, milk, beef, banana, plantain, citrus, sorghum, soybean, cotton, vegetables).
Objective: SUSTAINABILITY

CRITERIA/ZONES	BE	RI	CA	MI	BF	BAN	PL	CIT	SOR	SOY	COT	VET
Hillside zone	**	*	**	***	**	**	**	***	*	*	*	**
Savanna zone	**	***	**	**	***	*	*	**	**	***	*	*
Seasonal forest transition zone	*	**	**	*	**	*	*	**	*	*	*	*

1/ Ecozones as determined by AEU-CIAT\

* = small contribution
** = medium contribution
*** = large contribution

Table 7. Decision making criteria for CIAT's commodity options (beans, rice, cassava, milk, beef, banana, plantain, citrus, sorghum, soybean, cotton, vegetables).
Objective: INSTITUTIONAL CONSIDERATIONS

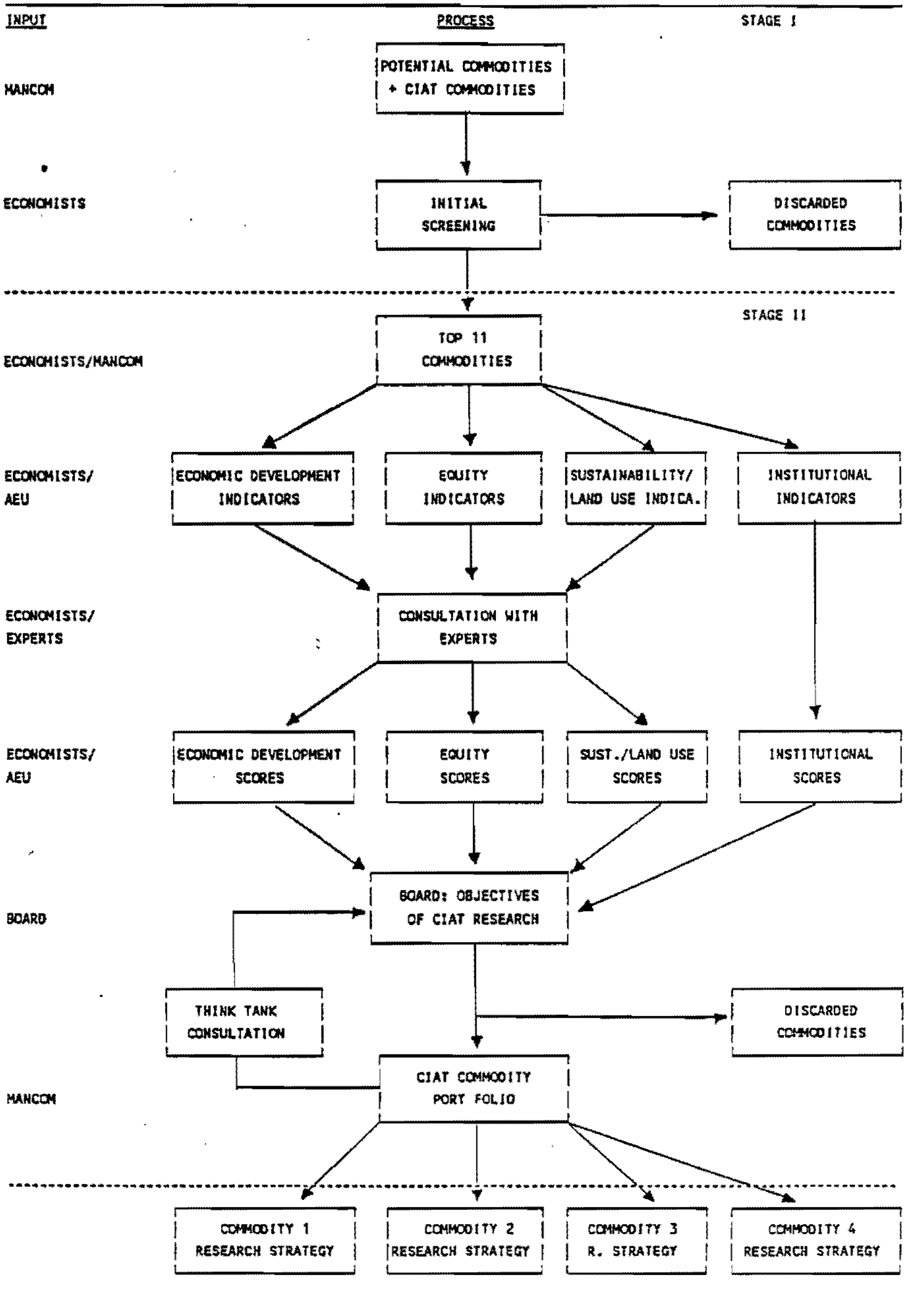
CRITERIA	BE		RI	CA		MI	BF	BAN	PL	CIT	SOR	SOY	COT	VEG
	LA	LA+	LA	LA	LA+	LA	LA	LA	LA	LA	LA	LA	LA	LA
D1 Current investigation of National programs (strong, intermediate, weak) 1/	**	**	**	*	*	*	**	*	**	*	**	*	*	**
D2 Current investigation of other International Research	CRSP		IRRI WARDA	IITA		ILCA ILRAD		INIBAP IRFA IITA CATIE		-	INTSORMIL ICRISAT	-	-	AVRDC
D3 Lead time of research (years)	4	4	4	8	6	4	4	6	6	8	7	4	4	4

1/ weak and strong: *
intermediate : **

Table 8: A summary of the contribution of commodity options to CIAT objectives.

		Economic growth	Equity	Sustainability	Institutional considerations
Beans	L.A.	*	**	*	***
	L.A.+	**	***	**	**
Rice		***	**	**	**
Cassava	L.A.	*	**	**	**
	L.A.+	**	***	***	**
Milk		***	**	**	**
Beef		***	**	***	***
Bananas		**	*	*	*
Plantain		*	*	*	*
Citrus		*	*	***	*
Sorghum		*	*	**	***
Soya beans		**	*	**	**
Cotton		*	*	*	*
Vegetables		*	*	*	***

FIGURE 1: A FLOW CHART TO SUMMARIZE CIAT COMMODITY SELECTION PROCESS



APPENDIX 1: MODEXC
A MODEL TO CALCULATE ECONOMIC SURPLUSES

MODEXC is a user-friendly, menu-driven model prepared to be run under LOTUS-123, that calculates consumer and producer surpluses associated with technological change, within a partial equilibrium framework. MODEXC is based on the technology evaluation method proposed by Lynam and Jones (1985) and applied among others by Pachico, Lynam and Jones (1987) and Antony, Anderson and Kanzi (1988).

MODECX simulates the evolution in market equilibrium, as both supply and demand shifts. Supply shifts in the model occur from two sources: (1) the technological change under evaluation (the objective of the analysis) and (2) other technological changes and supply shifts associated with the autonomous growth in the producer's sector. From the demand side, the autonomous shifts that take place are associated with population growth, higher incomes and variations in prices of substitutes. The model performs annual calculations of consumer, producer and total benefits emerging from the technological change being evaluated, as well as from those changes associated with autonomous supply shifts.

MODEXC uses three criteria to determine the economic benefits associated with agricultural research investments:

1) Net Present Value of economic surpluses
2) Internal Rate of Return (IRR) of research investments
3) Benefit/Cost ratio analysis

<u>The Mathematical Model</u>

[1] $S_0 = C\ (P-M)^d$ Initial Supply Function

The model considers three alternative scenarios for the supply shift, depending upon the type of technological change, as follows:

1. When $K_1>1$ and $K_2=K_3=1$, a pivotal divergent shift is assumed.

2. When $K_2>1$ and $K_1=K_3=1$, a non-pivotal and divergent supply shift is assumed.

3. When $K_3>1$ and $K_2=K_1=1$, a non-pivotal and convergent supply shift is assumed.

Results

MODEXC calculates, for each year of evaluation, quantity and equilibrium prices time, in two stages. In the first stage, it calculates quantities and prices provided that there are only autonomous changes in the system. In the second stage, it calculates the quantities and prices considering the autonomous changes in the system and the changes brought by the technological innovation under evaluation. Three types of economic surpluses are estimated by the model: those caused by the autonomous changes, those associated with the technological change under evaluation and the sum of the previous two.

MODEXC has the option of measuring the economic surpluses in closed or in open economies. In the latter case, the model estimates the total production, as well as domestic consumption and trade (imports or exports).

To calculate Benefit/Cost ratios and the Internal Rate of Return on research investments, the model allows for the incorporation of research expenditures that take place from ten years before to 20 years after the implementation of the new technology.

The MODEXC computer program and the manual for operation can be obtained from the authors of this paper.

[2] $S_1 = CK_aK_1\ (PK_2 - M/K_3)^d$ Total Supply Function, including both the technological and the autonomous shifts in supply

[3] $D_0 = \beta\ P^{\eta p}$ Initial Demand Function

[4] $D_1 = \beta K_D\ P^{\eta p}$ Shifted Demand Function

where:

P = Commodity price

M = Minimum supply price

$$d = \frac{E_p\ (P_0 - M)}{P_0}$$ where: E_p price elasticity of supply

P_0 = initial market equilibrium price

$$C = \frac{Q_0}{(P_0 - M)^d}$$

Q_0 = initial market equilibrium quantity

K_a = $(1+\delta)^t$ = autonomous supply shift

δ = annual rate of growth in supply due to autonomous forces

t = time

β = intercept of the demand function

ηp = price elasticity of demand

K_d = $(1+W)^t$ = demand function shifter, where: W is the net annual growth in demand.

K_1, K_2, K_3 = supply shifters due to technological change

APPENDIX 2: THE ESTIMATION OF LINKAGE EFFECTS

A simple general equilibrium model was developed to estimate the linkage effects of technological change.

The model distinguishes 5 supply sectors:

Sector 1 includes the data on the tradeable commodity to be evaluated. If a non-tradeable commodity is evaluated, sector 1 stays empty.

Sector 2 includes the supply of all other tradeable commodities. For sector 1 and 2 a fixed (world market) price is supplied to the model.

Sector 3 includes the data on the non-tradeable commodity to be evaluated. In case a tradeable CIAT commodity is evaluated, sector 3 stays empty.

Sector 4 includes the supply of all other agricultural non-tradeable goods.

Sector 5 includes the supply of all non-agricultural goods and services that are non-tradeable.

For sector 3, 4 and 5 intermediate and final demand is defined. Demand and supply of sector 3, 4 and 5 need to be balanced in the model.

Income is defined as the difference of the total value of production and the value of intermediate demand. In case of non-tradeables a term is included, that defines the income increase to consumers because of the price effect of the technical change.

The model has linear supply and demand equations. It is written in a micro-computer spreadsheet and is solved by an iterative procedure.

MODEL STRUCTURE

Supply:

$$S_i = a_i + b_i * P_i \qquad (1)$$

For i = 1 to 5.

Where,

S = supply

P = price

a,b = supply equation coefficients

Final Demand:

$$D_i = c_i + d_i \cdot P_i + e_i \cdot Y_i * (1-s) \qquad (2)$$

For i = 3 to 5

Where,

d = final demand

s = savings quota.

Y = income

c,d,e = demand equation coefficients

For the tradeable sectors (segment 1 and 2) all supply is cleared at a fixed price.

Intermediate Demand:

$$ID_i = \Sigma^5 \; f_{ij} \cdot S_j \qquad (3)$$

Where,

f_{ij} = intermediate demand fraction from sector j to sector i.

IDi = intermediate demand for production of sector i.

Total Demand:

$$TD_i = D_i + ID_i \qquad (4)$$

Where TD = total demand.

Income:

$$Y = \Sigma^5 \ S_j * P_j - \Sigma^5 \ \Sigma^5 \ fij \ . \ S_j \ . \ P_i + (D_3 \ . \ P_3 - D_3 \ . \ P_3) \qquad (5)$$

The first term after the equal sign expresses total supply, the second term expresses the input use by the different sectors; the third term expresses the income increase to consumers because of the possible price effect of technical change in a non-tradeable commodity. The superfix indicates that technological change has occurred, superfix o that it has not occurred.

Equilibrium:

$$S_i = TD_i \qquad (6)$$

For $i = 3$ to 5

Parameter values:

a_i, b_i, c_i, d_i and e_i are calculated on the basis of expected supply and demand elasticities, price levels and equilibrium quantities. For the assumptions on the parameters, see table 3.

The commodity under evaluation has a price elasticity of supply of 0.8. Agr. non-tradeables and other non-tradeables are considered to have perfectly elastic supply.

Price elasticities of demand where put at -0.5 for all non-tradeable sectors. Income elasticities change with the product under evaluation. This reflects to what extent extra income is spent on domestic non-tradeables.

All prices have been arbitrarily put at 1000, to facilitate model interpretation.

The equilibrium quantities reflect somewhat the Colombia economy. Total income is close to 50 billion, contribution of the agricultural sector is 25%. The share of the non-agricultural non-tradeable sector is some 40%.

The share of the CIAT-tradeable or non-tradeable commodity does not reflect its real contribution to GNP. In all cases the initial value was put at one billion. In case the other non-tradeable sectors have fully elastic supply, the relative size of the different sectors does not influence the size of the multipliers, that will be obtained. These only depends on the relative input use and on the income elasticity of domestic demand.

Evaluation of technical change:

By inputting into the model the input use and income elasticity for the individual commodities and by simulating a supply shift in sector 1 or 3, the impact of technical change on the production of the commodity itself as well as in other sectors can be evaluated. By dividing the income change outside the commodity with the production increase as caused by the technological change, the multiplier, discused in the economic growth section of the paper is obtained. This figure is multiplied with the NPV of production increases as obtained in the partial equilibrium model (see appendix 2) to obtain the NPV of the linkage effect.

The model allows to evaluate technical changes of different nature. In the present case we have evaluated a pivotal change of 10% in b1 or b3 (see equation 1) combined with a reduction of tradeable input use per unit output of 10%. This roughly reflects technology that increases yield per hectare at equal input levels.

The spreadsheet programs to execute the linkage effects and a more extensive evaluation of the general equilibrium model can be requested from the authors.

APPENDIX 3: ESTIMATION OF THE EMPLOYMENT EFFECT OF NEW TECHNOLOGY

The employment effect of new technology was estimated for the final year of analysis, 2025.

To estimate the employment effect of new technology, we distinguished two subeffects:

1. The change in employment within the commodity sub-sector influenced by technological change (the direct effect).

2. The change in employment outside the sub-sector (the indirect effect).

ESTIMATION OF THE INDIRECT EFFECT

We assume constant labor productivity outside the sub-sector that is influenced by technological change. Therefore we can estimate the indirect effect as a linear relationship with the extra production in the rest of the economy, as generated through the linkage effect. We use the general equilibrium model, exposed in Appendix 2, to calculate the expected extra production.

The relationship between employment and production is expressed by the average labor productivity. At the conservative assumption of 1.5% GDP growth per year from now to the year 2025, at a constant participation rate of the total population of 57%, and at a ratio of 1.46 between total production and total value added (as observed in the general equilibrium model), we can estimate the expected labor productivity in the year 2025 as:

$$US\$1812 \times 1/0.57 \times 1.46 \times (1.015)^{38} = US\$\ 8172 \text{ per year.}$$

where:

US$ 1812 = PIB/head in 1987 (source: World Development Report, 1989),
and the other terms are as expressed above.

The extra production outside the sub-sector as caused by the linkage effect can be calculated in the general equilibrium model. By dividing this with the production change because of technical change in the sub-sector, we calculate a production to production multiplier for each commodity. This last multiplier was applied to the extra production as estimated in the partial equilibrium model for the year 2025. The value obtained in this way was divided by the expected labor productivity per person in the year 2025, to find the years of employment as caused by the indirect effect.

THE DIRECT EFFECT

At the assumption that CIAT technology normally aims to increase yields per hectare without major changes in the use of labor per hectare we can estimate the direct employment effect if we know the following data:

1. Total production in tons with and without technical change (P_o and P_t).

2. Yields in tons/ha with and without technical change (Y_o and Y_t).

3. Estimated labor use in days per ha in land related activities in the year 2025 (L).

4. Estimated labor use in days per ton in volume of production related activities (T).

5. Labor days per year (LD)

At the assumption that the labor use per ha and per ton stay the same before and after technical change, the number of years of direct employment within the commodity sub-sector before technical change is calculated as:

6. $(P_o/Y_o*L + P_o*T)/LD$

and after technical change as:

7. $(P_t/Y_t*L + P_t*T)/LD$

By subtracting (6) from (7) the effect of technical change on employment in the commodity sub-sector is found.

ESTIMATION OF THE TOTAL EFFECT

By summing the indirect and the direct effect, the total employment effect for the year 2025 is obtained.

A more elaborate note on the employment effect, with an example, is available from the authors.

APPENDIX 4: DATA SOURCES
(A: PRICES)

SOURCE \ VARIABLE	Po Inicial price	Pmin Minimum price of supply	Pi International price	Eo Price elasticity of supply	Ed Price elasticity of demand
Precos recibidos pelos agricultores. Fundacao Getulio Vargas 1988, Brazil.	CAL				
FAO production yearbook.	CAA, BAN		BAN		
Lynam, J.K. (1).					CAA
Economics section of cassava, bean, rice and tropical pastures.	BF, MI(5), RI, SOY, CIT	CAL, CAA, BEA, BEL, BF, MI(5), RI	CAA, BF, MI(6)	CAL, CAA, PL, BAN, BEA, MI, BEL(7), SO(11), RI, SOY, CIT	CO, BEL(10), RI, SOY, CIT
FAO. Economía mundial del banano 1970-84		BAN			BAN
World Bank. Commodity trade and price trends, Washington, D.C. 1988 Edition.			RI, SOY		
FAO. Monthly Bulletin of Statistics.	BEA, BEL, SO		BEA, BEL, SO		
IMF. International financial statistics, prices of basic commodities	CO, SO		SO, CO		
CVC. Manual de costos de producción agropecuaria, 1988, Cali, Valle, Colombia.		SO, CO			
Project FAO-RLAC/CIAT (2)					BF
Andersen P.P. et.al. (3)					MI
Valdez, A. (4)				BF	
Janssen, W. (8)					SO
Askary, H. and Cummings, J.T. (9)				SO, CO	

Continuation

VARIABLE / SOURCE	Po Inicial price	Pmin Minimum price of supply	Pi International price	Eo Price elasticity of supply	Ed Price elasticity of demand
FAO. Review of food consumption surveys 1977, vol.2, Rome 1979.					BEA
Lynam, J.; Sanint, L.R.; Saez, C.; Ibañez-Meier, C.; Gontijo, A.; and Janssen, W.(12)					CAL
Ministerio de agricultura. Anuario de estadísticas del sector agropecuario. Colombia, 1989.	PL				
Federación Nacional de Cafeteros de Colombia (13).		PL			
Sanint, L.R.; Rivas, L.; Duque, M.C. y Seré, C. (14)					PL
Instituto de Economía Agrícola. Informacoes Economicas. Gov de Estado de Sao Paulo, Sao Paulo, Brazil.		SOY, CIT			
Fundacao Getulio Vargas. Agroanálisis. Several Issues. Rio de Janeiro, Brazil.			CIT		

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In addition to: Konjing Chaiwat and Issariyanukula Apisith. Output Demand and Marketing of Rice and upland Crops in 7 Thailand. In: Food Policy Analysis in Thailand edited by Theodore Panayotou. Agricultural Development Council. Bangkok 1985.

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2)

BEL = Beans, LA	CO = Cotton
BEA = Beans, Africa	MI = Milk
BAN = Banana	PL = Plantains
BF = Beef	RI = Rice
CAA = Cassava, Asia	SO = Sorghum
CAL = Cassava, LA	SOY= Soybeans

APPENDIX 4: DATA SOURCES
(B: VOLUMES AND QUANTITY)

SOURCE \ VARIABLE	Qo Initial quantity	D Demand growth	P Supply growth	Production distribution	Consumption distribution
FAO production yearbook and F) trade year book	PL, BAN, CAA, CAL BEL, BEA, CO, SO, RI, SOY, MI, BF	SO, CO	PL, BAN, SO, CO		
Economic section of cassava, bean, rice and tropical pastures		CAL, PL, BAN(15), RI, SOY, CIT, BF, MI(19)	CAL, RI, SOY, BF, MI(19)	CAA, BEA, PL(17), BAN(16)	CAL
Trends in CIAT commodities (tables)			CAA, BEL, BEA		
Censo Agropecuario. Fundacao Instituto Brasileiro de Greografia e Estadistica (IBGE). Brazil, 1980.				CAL, BEL, SO, CO, BF	
Estudo nacional de despesa familiar. Fundacao Instituto Brasileiro de Geografia e Estadistica (IBGE), Brazil, 1980					BAN, BEL(10), SO, CO
FAO. Commodity Review and Outlook. 1988		CAA			
FAO. Review of Food Consumption Surveys, 1977, vol.2, Rome, 1979.					BEA
Sanint, L.R.; Rivas, L.; Duque, M.C. y Seré, C. (14)					PL, SO, CO, CIT, BF, MI
Fundacao Getulio Vargas. Agroanalisis. Several issues. Rio Janeiro, Brazil.				RI, SOY, CIT	RI, SOY
USDA World Citrus S. and O.	CIT	CIT			
Janssen, W. (18)	BEL, BEA	BEL, BEA			
Rivas, L. (20)			MI		

(15) BAN: average of: a) George and King. Consumer demand for food commodities in the United States with projections for 1980. Giannini foundation monographs No.26, March 1971. b) FAO: Trade yearbook.

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(19) BF and MI: Estimated using data from:
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- FAO production yearbook. Several years.
- Trends in CIAT Commodities. Several years.

(20) Rivas, L. Some aspects of the cattle industry on the North Coast plains, CIAT, Technical Bulletin No. 3, December 1974.

Notes: 1. Food Balance Sheets (1979-81) were used as calories and proteins in all commodities.

2. For snap bean data sources, see: Henry, G. and Janssen, W. (eds.). Snap beans in the developing world, proceedings of an internal conference, CIAT, Cali, Colombia, 1990.

3. The "k-shifts" and the percentage of adoption for the initial and the final year, as were used in the partial equilibrium model, have been derived from information collected from the "Expert Consultation Survey" (may 1990). In several cases these values were adjusted as to reflect additional data from the Economics Sections at CIAT.

A GEOGRAPHICAL INFORMATION APPROACH FOR STRATIFYING TROPICAL LATIN AMERICA TO IDENTIFY RESEARCH PROBLEMS AND OPPORTUNITIES IN NATURAL RESOURCE MANAGEMENT FOR SUSTAINABLE AGRICULTURE IN CIAT

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SUMMARY

The Agroecological Studies Section of CIAT was asked to assist in the process of planning new natural resource management initiatives for CIAT. The aims of these initiatives were to be growth in agricultural production, increased equity for the urban and rural poor and maintaining and conserving the natural resource base of soils, water and vegetation for future generations; in other words working towards sustainable agricultural systems.

Previous studies in resource allocation within the centre had been made on the basis of the individual commodity programs and this estimates of volume of production and potential impact could be made at a macro level. The geographic complexity of a natural resource management approach obliged us to devise a radically different method. This paper describes the information processing stages and decision points used to narrow the broad range of environmental and agricultural situations to those where CIAT has the greatest potential of impact on growth, equity and sustainability. Agroecological Studies provided the information, many members of CIAT were involved in the decision making.

Stage 1 - Environmental description of the continent.

Stage 2 - Selection of likely candidates for environmental classes.

Stage 3 - Characterisation of land use within each class.

Stage 4 - Selection of agroecosystem groups as possible entry points for research.

This process identified three agroecosystem groups.

1. Tropical savannas including lowland and Brasilian upland savannas.
2. Well watered tropical hillsides with predominantly less fertile soils.
3. Forest margins in the seasonally moist forest zones where deforestation is already advanced.

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INTRODUCTION

In past decades international agricultural research centres such as the Centro Internacional de Agricultura Tropical (CIAT) had clear mandates for attempting to increase total food production to offset growing population and urban poverty. However, there is a consensus is appearing that rural poverty and other agricultural problems in tropical countries cannot be solved solely by producing more food. Solutions must include technology that produces food in a manner that protects the natural resource base and is compatible with the given social conditions. Though total food production has increased, other problems have largely been ignored or ill-addressed in the past by mainstream agricultural research. These are currently vaguely referred to as 'sustainability' problems, and are known to be influenced by both socio-economic and environmental factors (Douglas, 1984). That is, such problems result not only from the nature of the resources but also the given land use and the social factors that drive them. The non-resolution or aggravation of these problmes have long term implications for social welfare, environmental quality and food production itself.

A problem that CIAT faces in attempting to broaden its research is that it operates in a wide range of environments, both physical and social. For example, though different areas nominally might suffer erosion, the causes and effects differ considerably from country to country and from ecosystem to ecosystem. This supposed site specificity has been seen as an obstacle which impedes technological solutions to problems at a scale larger than that of the individual crop.

It would seem that site specific complexity would preclude an international approach. However, over the past eight years the Agroecological Studies Unit (AEU) has been conducting crop-specific agroecological analysis in a variety of environments. Fieldwork in similar ecosystems, with similar land use, but in different countries led to the hypothesis that where climate, soils and land use were similar then the types of problems tended to be similar. The method described below is an attempt to investigate this relationship systematically, and to make a working estimate of the most important sustainability problems across Latin America.

The approach taken by the AEU was to classify the continental area in a two phase process, both including analysis and then decisions process stages. In Stage I all of Latin America and the Caribbean were mapped in broad environmental classes. Then, based on predetermined criteria, a short list of environmental classes was chosen in Stage II. Stage III was the systematic description of actual land use in the selected environmental classes. The most important agroecological clusters (areas with similar environments and land use patterns) and their respective problems were then evaluated for relevance to CIAT's current and future research in the decision process of Stage IV.

STAGE I - CONTINENTAL ENVIRONMENT DESCRIPTION

The scope of this first Phase was vast. It included all of Latin America in which CIAT could support a reasonable role in natural resource management. This forced us to make certain assumptions and choose criteria for the environmental classification. First, it had to be simple enough to be mapped using available data. Second, it had to be consistent with the data from which it was drawn. Third, it had to reflect the environmental requirements of actual or potential commodity crops for a center of tropical agriculture. Finally, environmental criteria had to reflect the experience of scientists working in the center.

The AEU has detailed data for parts of the continent, however, as the scope of this study was broader than these specialized data we opted for more general information consistent across the continent. As the climate database is the most complete database available for Latin America, the first step was to classify climate and discard logistically unfeasible classes thus reducing the total area under consideration.

ENVIRONMENTAL CLASSIFICATION

The analysis used files of regularly gridded data (METGRID) on climate, soils and elevation. These files were interpolated from the climate database, developed in the AEU, which contains mean monthly information from over 7500 stations across Latin America. The interpolation used as a basis the 10 minute grid of a digital terrain model (NOAA, 1984) and the central pixel from a raster version of the FAO Soil Map of the World (UNEP/ GEMS/GRID, 1988). From these files we constructed a point quadrat approximation of rainfall, temperature, soils and elevation for the continent at a spatial resolution of approximately 18.5 km.

Interpolation of the climate data was done by weighted inverse squared distance from the nearest 4 stations in the database, corrected for altitude to the NOAA elevation using a standard tropical atmosphere lapse rate model based on data from Riehl (1979). The spatial spread of climate stations is highly variable but tends to be more dense in areas where there is a high variation in altitude and slope and where the majority of the population are often found.

Five environmental criteria were decided upon based on many years of consultation with CIAT commodity scientists.

Season Length. This was calculated as the number of wet months where rainfall exceeds 60% of potential evapotranspiration, calculated by the method of Linacre (1977).

1.	Humid	over 9 months wet
2.	Seasonal wet	9 to 6 months wet
3.	Seasonal dry	6 to 3 months wet
4.	Arid	2 or less - REJECTED

The truly arid classes were excluded at this step because CIAT has had relatively little experience with rainfed crops or natural resources in these areas.

Temperature during the growing season. The growing season was defined as that season with wet months as defined above. The cutoffs were:

1. Lowland tropics, temperatures greater than $23.5^{\circ}C$.
2. Mid-altitude, 18 to $23.5^{\circ}C$.
3. Highlands 13 to $18^{\circ}C$.
4. Cold less than $13^{\circ}C$ - REJECTED.

These temperature cutoffs were selected based on commonly accepted figures that have proved useful for classifying CIAT's crops in the past. The cold areas were rejected because they represent an area in which CIAT has not worked, and in which other organizations have a comparative advantage.

Diurnal Temperature Range. Based on the experience of CIAT scientists this variable was added to distinguish areas with large diurnal temperature ranges from those with small diurnal ranges. It is similar to dividing between continental climates and maritime climates but does not indicate relative distance from the sea in South America, given that the Amazon basin has an oceanic influence on climate. The variable is important for pest and disease (particularly fungal) incidence.

1. Maritime - Less than $10^{\circ}C$ mean diurnal rane
2. Continental - Greater than $10^{\circ}C$ mean diurnal range

Annual Temperature Range. To distinguish between tropical and sub-tropical areas, we set the annual temperature range cutoff at $10^{\circ}C$.

1. Tropical - Less than $10^{\circ}C$ annual range
2. Subtropical - More than $10^{\circ}C$ annual range

Soil Acidity. This was used to divide soils into those likely to have serious acidity problems, and those that area unlikely to have such problems. A commonly used cutoff for tropical soils is the pH of 5.5 (Landon, 1984). Below this level the chemistry of many elements changes significantly in terms of toxicity and deficiency.

1. Acid soils. pH less than 5.5 → Al Saturation
2. Less acid and neutral soils pH above 5.5.

Summary

These variables in theory produced 128 possible environmental classes. On the one hand this was an unmanageable number of environmental classes. On the other hand, conditions within each class still varied considerably. By eliminating the very dry and very cold areas the theoretically possible number was reduced to 72 classes. Of these, 9 combinations did not exist in reality, and a further 12 were discarded because they were too small for consideration or they were cool subtropical areas with a strong frost risk precluding crops within CIAT's experience.

STRATIFICATION

The next step was to stratify the remaining environmental classes in terms of their relevance for future CIAT work. Three broad criteria for choosing environmental classes were given. 1. The class should be significant for positively affecting rural poverty ("equity"). 2. The classes should be important for positively affecting natural resource ("environment") 3. The classes should have potential for increasing food production thereby favoring the urban poor ("growth"). To make the stratification possible using these criteria, four independent kinds of information were combined with the environmental classes using the image overlaying capacity of a geographical analysis package, IDRISI (Eastman, 1988).

Access: As the relative area of a class might be a criterion for choosing between classes, the figure used was an estimate of the area that is accessible with current infrastructure. Our calculation was to include the area within each class that was within 30 km of either side of an all weather road, navigable river or sea coast. all-weather roads were digitized for each country. For Brazil this meant digitizing the entire 1989 road Atlas. The 60 km corridor along each road is a generous estimate for the increase in access that might occur over the next few years. This analysis can be extended to future development of infrastructure in more detailed studies.

For many of the 51 classes this exercise did not reduce effective area by much. However, for the humid and seasonally moist classes it excluded areas such as the Darien Straits, upper Rio Negro and mid Xingú which are truly inaccessible, but not legally protected (Figure 1).

Legally Restricted Areas: The areas in each country in Latin America that are legally restricted from conventional agricultural use were digitized from available maps collected by the AEU. These are mostly national parks, forest reserves, Indian reservations, ecological preserves or protected catchment areas. Some countries report no such areas and in others the protection is only on paper. However, these areas represent a signigicant proportion of some environmental classes, therefore we excluded them from our calculation of potential agricultural area of an environmental class (Table 1).

Rural Population Density: Both rural and urban population are unevenly distributed in Latin America. We felt it was fundamental to know the absolute size and relative distribution of the rural population in each environmental class. The nature of most problems and opportunities in agriculture are related to population density and associated infrastructure.

As a first approximation we digitized a population map that was transposed from a published population map (Times Atlas, 1985). The actual population represented by this map was calculated by computer and a new map plotted to represent 1986 rural population. This information was overlaid on the map of environmental classes to provide an estimate of rural and urban population in each class.

Access in tropical Latin America

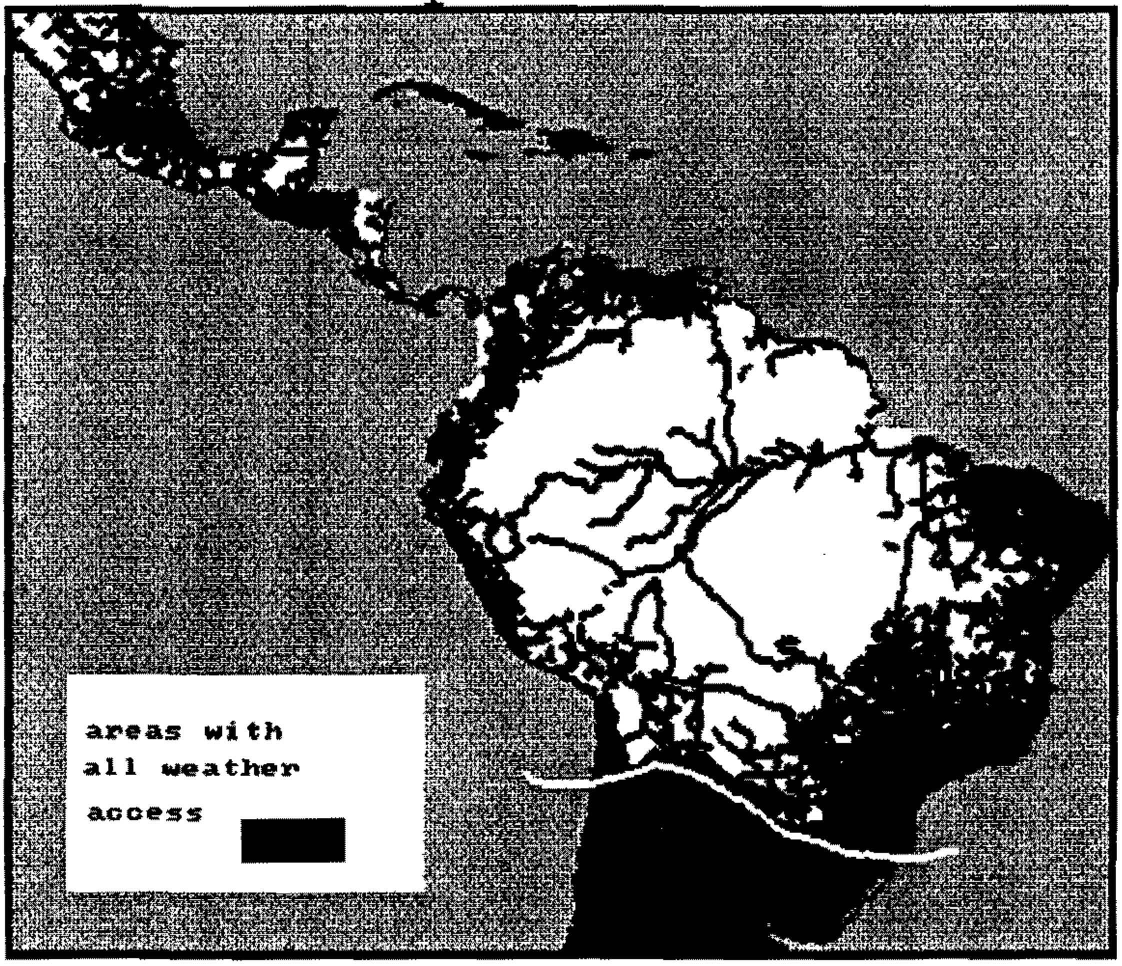

FIGURE 1.

Rural Income per capita: We included this variable as a crude measure of the magnitude of rural poverty at the level of country or in Brazil at the state level. Despite its generality, even within Brazil the rural income per capite by state varied from around 150 $US (Maranhao and Piauí) to over 2000 $US (Mato Grosso do Sul) (World Bank, 1987; IBGE, 1984).

Results

The above socio-economic information was overlaid onto the map of environmental classes. To achieve a crude assessment of an equity index

TABLE 1. The effect of subtracting legally protected and/or inaccesible land from the area of an environmental class.

Class Number	Class Designation*	Sum Prod. Index	Number of countries	Accessible Area not Protected Km^2	Total Area not Protected Km^2
2	T L S M A	3242757	24	810689	2431409
5	T L S C A	1936433	18	484108	1433703
17	T M S C A	1847765	18	615922	846215
8	T L S M W	1819042	23	303174	493803
12	T L D C W	1503994	13	375999	708777
9	T L D M W	1364902	12	341225	391260
11	T L S C W	1085185	17	180864	344035
6	T L D C A	1061534	12	530767	784066
1	T L H M A	976925	18	325642	1157602
3	T L D M A	853181	13	426590	514077

*

Col.			
1	T = Tropical	S = Subtropical	
2	L = Lowland	M = Mid altitude	H = Highland
3	H = Humid	S = Seasonally wet	D = Dry
4	M = Maritime	C = Continental	
5	A = Acid Soil	W = Weakly acid to good soils.	

the mean rural income was extracted for each class. The importance of a class for the equity issue increases with number of people involved, but it decreases as rural income rises. We therefore divided total population by rural income to obtain an index which increased with increasing rural population and/or with increasing poverty. Table 2 shows the classes that ranked the highest for equity.

An effort to rank classes in terms of environmental degradation or risk was more complex, even at this scale, because of the very different types of degradation that exist.

Areas of high risk to problems of an abusive nature such as excessive pesticide use are to be found in the areas with access to markets and hence purchased inputs. They are likely to be the higher population areas within each class.

TABLE 2. Environment Classes ordered by Rural Poverly Index.

Class Nunmber	Class Designation*	Rural Pop.	Rural Poverty Index	Rural Pop/km2	Rural PCI[1] mean
2	T L S M A	7462384	16480	3	453
9	T L D M W	6264550	11988	16	523
8	T L S M W	5860458	9304	12	630
3	T L D M A	4122772	7619	8	541
17	T M S C A	7133114	6912	8	1032
21	T M D M W	2544063	6674	18	381
5	T L D C A	4496741	6663	3	675
14	T M S M A	4810238	6553	14	734
1	T L H M A	2234896	5677	2	394
11	T L S C W	4577921	5396	13	848

* See Table 1.
1/ Per capita income.

A second type of degradation occurs when virgin land is converted to agriculture. Areas with relatively untouched native vegetation, be it forest, savanna or other are likely to be those with low rural populations. A ranking was made of the area of each class with population less than 2 per km2. This can be interpreted as either the areas available for expansion of agriculture, or as native vegetation for protection.

A third important type of degradation results from nutrient depletion and erosion through insufficient inputs or decreasing fallow time. We have made the assumption that this will occur most frequently in settled areas, but far from markets where there is less incentive to use inputs. The index we used was the area of each class with moderate to low population density (2 to 20 km^{-2}) divided by rural income. Table 3 shows the classes ordered by this index.

A subjective productivity index was constructed to rank the environment classes in terms of potential economic impact or growth. This index was given values from 1 to 7 per unit area, the calculations are shown in Table 4. The potential growth index was calculated by multiplying the area of accessible, legally available land by its productivity index. The top ten classes ranked by this index are shown in Table 5.

TABLE 3. Area by class with likely degradation by nutrient depletion (erosion or nutrient leaching, weed infestation, etc)

Class Number	Class Designation	Nutrient Depletion Degradation Index	Rural Pop.	Rural Pop/km2	Rural PCI[1] mean	Accessible area
2	T L S M A	792	7462384	3	453	810689
3	T L D M A	517	4122772	8	541	426590
9	T L D M W	473	6264550	16	523	341225
5	T L D C A	449	4496741	3	675	484108
17	T M S C A	427	7133114	8	1032	615922
6	T L D C A	386	3471035	4	882	530767
21	T M D M W	308	2544063	18	381	130436
18	T M D C A	292	3379676	7	826	362535
12	T L D C W	283	4704845	7	954	375999
1	T L H M A	235	2234896	2	394	325642

* See Table 1.
1/ Per Capita Income.

TABLE 4. Relative productivity per unit area calculations

		Dry Season (months) < 2	3-6	7-9
Temperature	Lowland	3	4	2
	Medium	4	4	2
	Highland	4	3	1

2 points were added for non-acid soils and 1 point for sub-tropical areas. To form an index of potential economic impact this index was multiplied by the accessible area of each class.

TABLE 5. Environment classes ordered by production potential index.

Class Number	Class Designation*	Subjtv. Prod. Index	Sum. Prod. Index	Rural Pop.	Accessible Area Km^2
2	T L S M A	4	3242757	7462384	810689
5	T L S C A	4	1936433	4496741	484108
17	T M S C A	3	1847765	7133114	615922
8	T L S M W	6	1819042	5860458	303174
12	T L D C W	4	1503994	4704845	375999
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1	T L H M A	3	976925	2234896	325642
3	T L D M A	2	853181	4122772	426590

* See Table 1.

STAGE II. SELECTION OF LIKELY CANDIDATE ENVIRONMENTAL CLASSES

This stage included the participation of the CIAT management committee, economists and the Agroecological Studies Section.

A summary Table was calculated which included all environmental classes that appeared in the top 5 of the five rankings: one for equity, one for growth and three for sustainability (Table 6). An additional column indicates whether or not the class was in the top five in terms of CIAT's current commodity responsibilities. Given our described method and the criteria we were given, the most relevant classes were 2, 17, 5, 8, 9 and 12. A surprise finding was the importance of class 2 for all the criteria. As a class that is mainly seasonal moist forest one would not expect it to rank highly in terms of rural poverty because the general impression is that it is sparsely populated. In fact it has a high population, mainly in coastal areas, and the rural per capita income is very low, suggesting a large poverty problem.

TABLE 6. Occurrences of classes in the first 5 rows of the subject rankings.

Class	Growth	Equity	<__Sustainability__> 1	2	3	CIAT Crops
2	*	*	*	*	*	*
17	*	*	*		*	*
5	*			*	*	*
8	*	*	*			
9		*	*		*	
12	*		*	*		
3		*			*	
1				*		
6				*		
18						*

The original indices extracted from the GIS images could have been weighted strongly towards total area. A sensitivity analysis was* made which varied the weights according to Growth, Equity and Environment and also included factors for:

1. Internationality - the number of countries that the class was found.
2. CIAT advantage - the percentage of area planted to CIAT commodities.
3. The importance to the Andean, Central American and the Caribbean; the area outside Brazil.

The <u>growth</u> variable was divided into two separate components:

1. The production potential index as previously defined.
2. A growth potential index. This included population. The idea being that currently populated areas have more inherent growth potential than those beyond the frontier.

* The authors wish to acknowledge the assistance of Drs. L. Sanint and W. Janssen in the sensitivity analysis.

The equity (rural poverty) index was redefined to exclude the size of the zone by defining it as rural population density divided by rural income.

Environmental indices were modified to include the production potential index in the cases of high risk of an abusive nature and those of degradation from nutrient depletion and erosion. The second environmental index which weighted the the amount of virgin lands was consciously set low because the utility for agriculture depends very strongly on the value and quality of the virgin lands.

The indices were standardised to zero mean and unit variance and were combined in an additive index with weights assigned according to the following 5 scenarios. (Table 7).

TABLE 7. Weighting Scenarios.

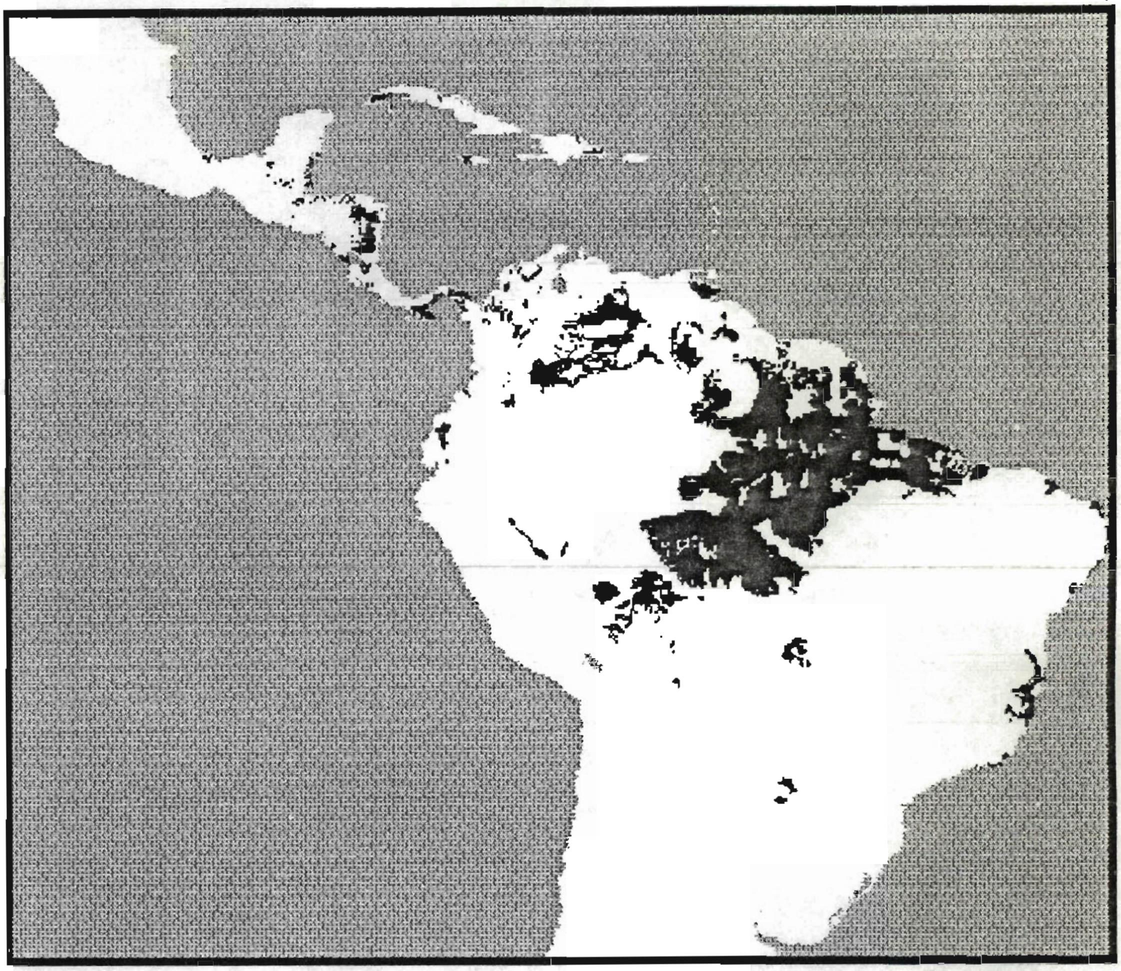
Scenario	1	2	3	4	5
Prod. Potential	4	4	8	4	4
Growth Potential	6	6	12	6	6
Rural Equity	10	10	10	10	10
Environment					
1	5	5	5	5	5
2	1	1	1	1	1
3	4	4	4	4	4
Internationality	3	0	3	3	3
CIAT Commodity	5	0	5	5	5
Area outside Brazil	5	0	[illegible]	0	10

TABLE 8. Results of sensitivity analysis on the environmental classes, using five different weighting scenarios (Sanint and Janssen, 1990).

SCENARIO	1	2	3	4	5
	8	9	8	2	8
TOP	2	2	2	9	2
5	9	8	9	8	9
	17	17	17	17	17
	20	20	11	20	11
	11	21	20	21	12
SECOND	12	11	12	11	20
5	21	12	21	12	5
	5	5	5	5	21
	14	34	14	23	14

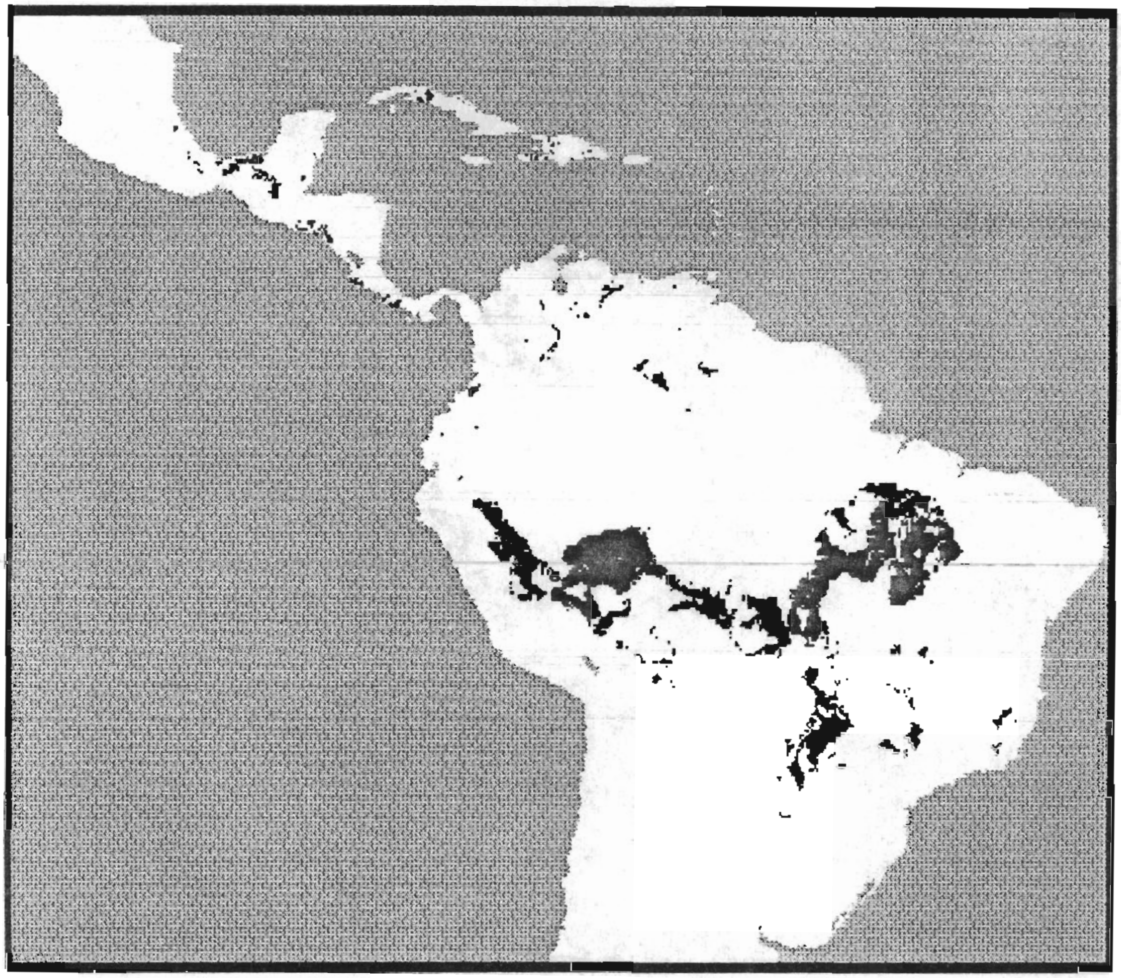
Table 8 shows the ordering of environment classes under each of the weight scenarios. The order appears to be remarkably stable under the various weightings. Classes 2, 5, 8, 9, 11, 17 and 20 were selected for further study. Maps of their distribution and brief descriptions follow.

Class 2 Seasonally wet lowland maritime tropics on acid soils



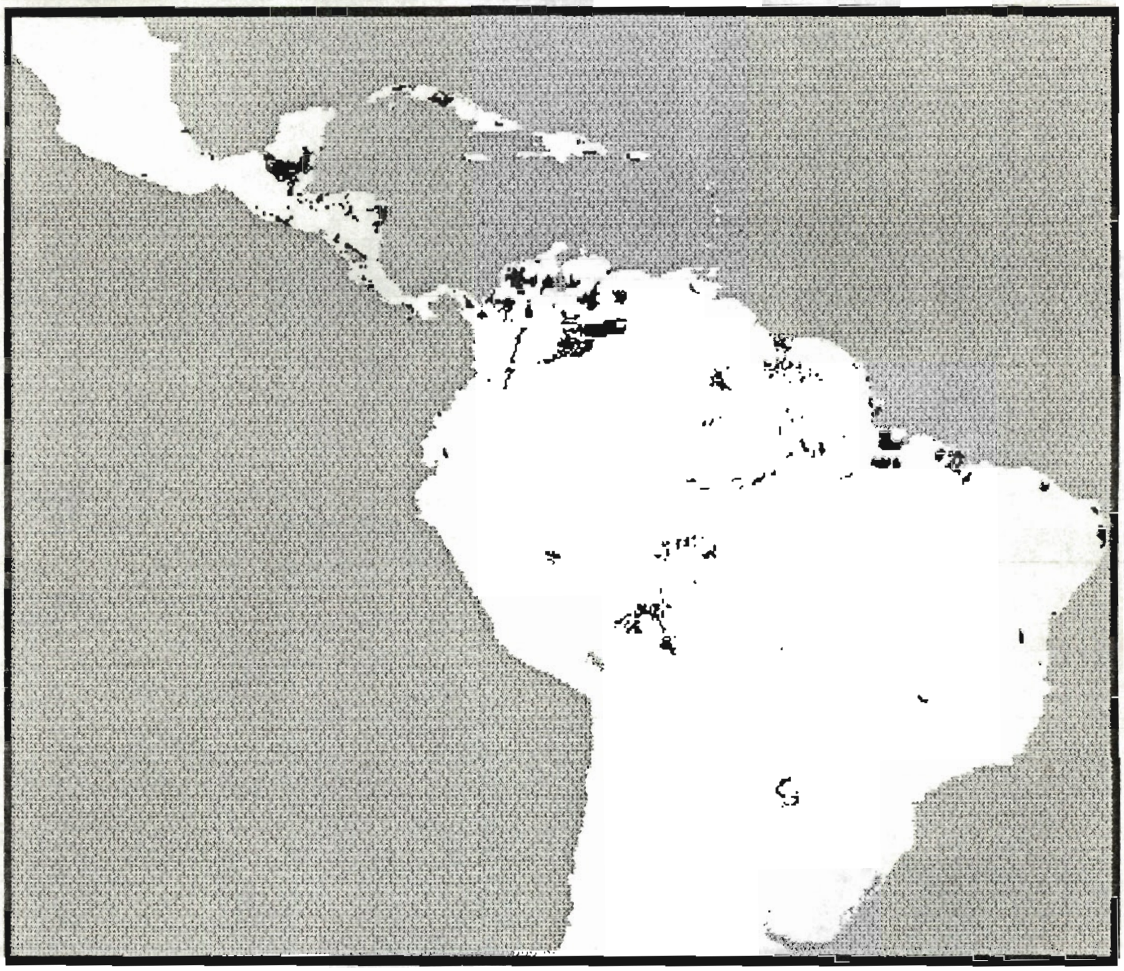
This Class is heterogeneous. It includes highly populated areas of coastal Brazil under sugar cane and cacao with some similar areas in the Caribbean and Central America. Large areas of semi-evergreen seasonal forest in Brazil, Peru, Colombia, Bolivia and Central American countries. It also includes the savannas of the Colombian Llanos and in Venezuela, and areas of the northern Cerrados of Brazil.

Class 5 Seasonally wet lowland continental tropics on acid soils



This class is the continental counterpart of Class 2. Much of the area is seasonal forest although some areas are lowland savannas. Large extents are inaccessible and lightly populated. This would be an area for forest conservation except where already deforested and degraded.

Class 8 Seasonally wet lowland maritime tropics on good soils



Includes heavily populated coastal areas throughout the regions, apart from Peru. An anomaly in this region as mapped is that it includes poorly drained areas in Bolivia, Arauca Colombia and some regions of the Amazon basin. Apart from these anomalous regions it is generally highly productive.

Class 9 dry lowland tropics maritime on good soils

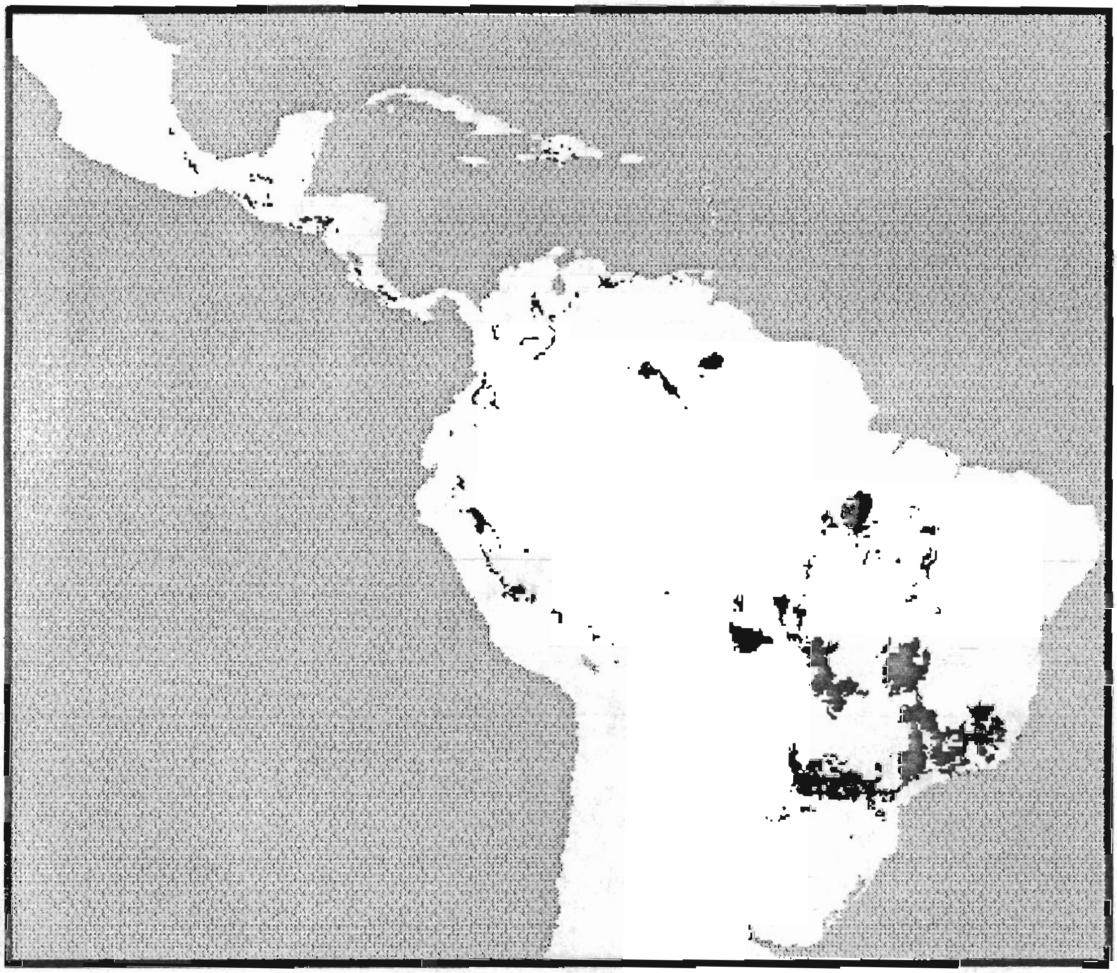
Although limited in extent this class includes heavily populated coastal areas of N.E. Brazil, Venezuela, Colombia, Ecuador, Costa Rica and Mexico. It contains lower populated areas of the Yucatan, Honduras and Bolivia. It is an important class for Mexico outside of the atypical Yucatan areas.

Much of the area is hilly, containing much cotton and various annual crops. It is also an important sugar cane region.

Class 11 Seasonally wet lowland continental tropics on good soil

The continental counterpart of class 8. Although some areas have truly good soils, are highly productive and well populated, significant areas of this class are remote poorly accessible areas in the continental interior. This is maybe due to their designation as non-acid where they are poorly drained.

Class 17 Seasonally wet mid altitude continental tropics on acid soils



This is a highly heterogeneous class but closely allied to the coffee areas. These are the poorer coffee areas throughout Central America and the Andes. Large areas in Brazil include the high cerrados around Brazilia but also the more broken terrain of the coffee areas to the south. Apart from the savannas of Roraima and Guyana and the northern extent of the cerrados all these areas are moderately to highly populated.

Class 20 Seasonally wet mid altitude maritime tropics on good soil

Although of very small geographic extent these hill slope areas have high population. They are coffee zones throughout Central America and the Northern Andes. The good soil companion to Class 17. Also good soil areas in the hill lands behind the coast of Brazil.

STAGE III. THE DETERMINATION OF LAND-USE CLUSTERS

The selection of environmental classes within which to concentrate research efforts does not suffice to identify and characterize researchable problems. Problems with the sustainable management of land resources depend as much on the nature of the land use as on the nature of the present resources. The purpose of Stage III, therefore, was to assess the actual land use in the selected environmental classes. The most prominent combinations of land use and environment were then identified. The nature of problems resulting from the respective land uses, and their relative importance is the kind of information that CIAT needs to plan its research at this scale.

METHOD

The approach used was to map each contiguous area of a selected environmental class (referred to as a subzone) and determine a number of variables relating to its actual land use. Figure 2 is an example of the worksheet that was filled for each subzone with an area of over 600 km2. The cutoff size of 600 km2 reduced the number of subzones in the selected classes from over 500 to just over 300, yet accounted for over 98% of the area.

Using maps, censuses, atlases and reports, simple variables were noted for physical, biological and agricultural characteristics. Socio-economic variables were also included such as principal farming systems, population density, urban dependence on agriculture, land distribution, percent of area readily accessible to transport and relative distance to market. Parallel to this, interviews were conducted with visitors to CIAT from different countries, and recent first hand information was obtained about as many subzones as possible. This helped check against the secondary information that we were using for our descriptions.

Once the worksheets had been filled, the variables were used to determine generic production systems for each of the 300 subzones e.g. extensive cattle ranching or intensive irrigation of annual crops. It is important to note that virtually all of the subzones had at least two modal production systems practised by different people within the same

PAIS: HOJA ONC: SUBZONA:
TITULO: AREA:

DESCRIPCION:

TOPOGRAFIA < 8: $8 < 30$: > 30:

SUELOS

PROFUNDIDAD: TEXTURA:
DRENAJE:
PROB. QUIMICA:
PROB. FISICA:

CLIMA

BIMODAL: MESES > 200 mm.:

USO DE LA TIERRA

VEGETACION NAT.: %:
RIEGO %: ANUALES:
PERENNE: PASTURAS %:
BOSQUE MAN.: RASTROJO LARGO:

ANUALES (en orden):

PERENNE (en orden):

SISTEMAS

1.- P1:

2.- P2:

3.- P3:

4.- P4:

DEN. POB.: DEP. URB.:
LANDLESS: IPCR:
% EXP. < 10 Ha.: % AREA < 10 Ha.:
ACCESO: AISLAMIENTO:

FIGURE 2. Worksheet Filled for each of the 300 subzones.

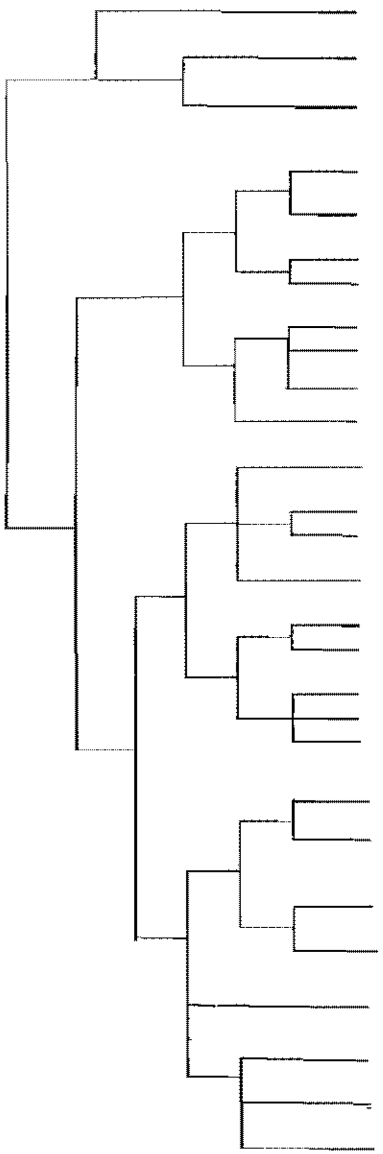
environmental subzone eg. extensive cattle ranching by large landholders and shifting cultivation by small landholders. The land use patterns were assigned to each of the 300 subzones along with the environment class. Table 9 shows all of the land use patterns identified.

RESULTS

Where repeating land use patterns occurred within an environmental class these were termed agroecological clusters: groups of areas where climate, soil and land use were similar. This process resembles classical regional geography that would divide a country into production zones. Production zones obviously bear a relationship to the environment. What is happening within them is dependent on people and what they want to do about their livelyhoods in the environments that they inhabit. Modern attempts at agroecozoning have by and large ignored the people.

Comparisons of Figure 3 and Table 9 shows that just over one third of the potential combinations of land use patterns and the 6 environmental classes exist. There are land uses which are not significant in some environmental classes. Amongst those cells which are recorded, it is relatively straightforward to identify the agroecological clusters which have the greater relative importance in terms of area and population.

The question then becomes, why are some land use patterns more important than others within the environmental classes we examined? They are expressions of the relationships between the landscape, the natural environment, and the social and political conditions under which agriculture is practised. For example, where good soils, good rainfall, good access, and good markets are combined, the predominant land use is intensive sugar cane and intensive cattle. Where mid-altitude temperatures, good access, acid soils, and steep slope are found together, the land use is predominatly coffee and intensive cattle with some horticulture. A third example is where poor access, large distance from market, and forest occur together, the land use is predominantly shifting cultivation and extensive cattle grazing (eg. the forest frontier).



LAND USE CLUSTERS	2	5	8	9	11	17	20
				Environment Class			
UNUSED FOREST LANDS	1.68	0.17					
RUBBER-NUTS	2.58	1.88			0.77		
FLUVIAL & VARSEA SYSTEMS	6.11	0.18	1.62		1.77		0.46
INTENSIVE CANE POOR LANDS	7.51						
INTENSIVE CANE GOOD LANDS			15.57	5.34	1.73		
INTENSIVE IRRIGATION			1.27		0.24		0.72
BRASIL MECHANIZED COFFEE AREAS	3.17	4.09			0.23	19.73	
MECHANIZED MEDIUM SCALE			1.24			0.18	
CERRADOS TYPE PASTURES MECH CROPPING						31.07	
POOR LOWLAND PASTURES MECH CROPPING	11.27	29.22					
LOWLAND EXTENSIVE GRAZING POOR SOILS	3.35	1.06					
GOOD LOWLAND PASTURES MECH CROPPING			3.39		2.10		
POORLY DRAINED PASTURES	4.49	1.60	0.11		8.42		
GOOD LOWLAND PASTURES ALONE					0.54		
HIGHLAND PASTURES ALONE						0.35	0.52
LOWLAND EXTENSIVE GRAZING POOR SOILS	3.35	1.06					
POOR LOWLAND PASTURES MANUAL CROPPING	37.42	7.25					
GOOD LOWLAND PASTURES MANUAL CROPPING			4.98		1.73		
DRY LOWLAND PASTURES MAN/MECH CROPS				5.10			
DRY LOWLAND PASTURES MANUAL CROPPING			0.79	13.92			
GOAT GRAZING				4.44			
LADERAS CATTLE COFFEE POOR SOIL						3.02	
LADERAS GRAZING. SHIFT CULT POOR SOIL					0.08	6.78	0.22
LADERAS CATTLE COFFEE GOOD SOIL							3.51
LADERAS GRAZING SHIFT CULT GOOD SOIL							2.89
LOWLAND CATTLE COFFEE	2.05		0.15	1.62	0.17		
SHIFTING CULTIVATION			0.84	0.56			0.13
SMALL SCALE CANE & MANUAL CULTIVATION	0.26		0.05	1.47	0.23	0.42	0.26
LOWLAND GRAZING. SHIFT CULT ON SLOPE	1.11	2.92	0.26	1.62			

FIGURE 3. Area of the Agrocological Clusters inthe 7 Environmental Classes.

TABLE 9. Principal land use patterns identified.

Extensive Cattle/Shifting cultivation/Forest	XC-SC-F
Extensive Cattle/Mechanized Annual Crops/Shifting Cultivation	XC-MA-SC
Hillside Cattle/Coffee/Horticulture	HC-CO-HO
Hillside Cattle/Coffee/Shifting Cultivation	HC-CO-SC
Intensive Sugar Cane/Intensive Cattle/Mechanized Annual Crops	IS-IC-MA
Intensive Irrigated Crops/Extensive Cattle	II-XC
Rubber and Brazil Nut Extraction/Forest	RN-F
Traditional Riverine Systems on Flooded Land	TR-F
Extensive Goat Grazing	XG
Mechanized Coffee/Mechanized Annual Crops/Intensive Cattle	MC-MA-IC
Extensive Cattle/Forest	XC-F
Extensive Cattle/Mechanized Annual Crop/Forest	XC-MA-F
Small Scale Sugar Cane and Annual Cropping	SS-SA
Intensive Irrigation/Medium Scale Annuals	II-MM
Medium Scale Mechanized Annual/Medium Scale Cattle	MM-IC
Extensive Cattle on Poorly Drained Soils	XCP
Shifting Cultivation/Managed Forest/Small Scale Cattle	SG-SC-BA
Small Scale Cattle/Shifting Cultivation/Commercial Bananas	SG-SC-BA

* The order of the abbreviations does not always represent the relative predominance of the individual systems.

Land use patterns are repeated to the extent that geographically separate subzones have similar physical and human environments. Not only do the individual farming systems interact with the environment, but different systems within an area also interact and compete with each other for resources thus forming part of the overall environment. From the knowledge gained in describing the agriculture in each subzone, we might assume that the types of problems faced (environmental, social, economic) are similar for different subzones with the same land use patterns and environment. This is a useful hypothesis but needs much further study. Nevertheless we use it for the purpose of planning in CIAT.

Application

Figure 3 provides an information base, for CIAT or any potential user, from which to make decisions about the relative importance of different land uses and their problems. At CIAT, the criteria of growth, equity and environmental maintenance were used to indicate areas where it would be logical to begin research on sustainable agriculture and its relationship with environmental and socio-economic conditions.

When sorted by predominant patterns, a series of groupings appeared which seemed to be logical. These were inspected and clustered according to a consensus of subjective estimates of similarity among those working in the AEU. Since much of the information was non numeric and not ordered this was considered more appropriate than a numeric clustering algorithm. Figure 3 shows the areas and population respectively for these land use pattern groups within the six environmental classes selected in Stage I.

DESCRIPTIONS OF MAJOR AGROECOSYSTEM CLUSTERS

Class 8 and 9. Intensive cane, mechanized cultivation.

These areas are characterised by intensive estate managed sugar cane, large farm grazing of cultivated or induced pastures and mechanized cultivation of sorghum, soybean, cotton and often irrigated rice. A small farm sector generally concentrates on fruit and horticultural products. Tobacco is grown in some areas along with beans, maize and some cassava. Often irrigated, the climatic difference between the dry class 9 and seasonally wet class 8 is diminished.

Soils are good and topography flat and easily mechanizable. There is little or no remaining natural vegetation except in places where this was a native grassland suitable for grazing. Fallowing is rarely practiced.

Growth potential is low in terms of area expansion, there being little land unused. Movement to intensified mechanized cultivation may diminish the importance of grazing. The small farm sector may account for up to 80 percent of the rural population but only about 5-10 percent of the land.

Increased profitability of broad scale mechanized crops might lead to "intensification" and absorption of small farmer areas, but this is less likely than in some other areas because the small farmer sector concentrates on higher value crops for the urban markets.

The small farm sector may provide labour for the estate and larger farms but this is also supplied from nearly urban populations.

Problems

1. Erosion risk is generally low but compaction by heavy machinery may occur in some areas.
2. While these areas are not the typical arid irrigation areas, salt buildup due to poor irrigation practices is a risk in many places.
3. Excessive use of pesticides and herbicides occurs frequently on the commercial cropping lands especially on rice, cotton and soybeans.

Spillover: Shift from grazing to cultivation will push cattle to less easily managed areas.

Lowland Extensive Grazing Poor Soils Classes 2 and 5 (Carimagua)

These areas are found in the altillanura of Colombia, in Mexico and Venezuela and have an accessible area of 4.41 Mha. Soils are highly acid and natural vegetation is savanna and semievergreen forest. Topography is flat with only 5-20% on slopes from 8 to 30 percent.

The land use pattern is differentiated from a further 29.2 million hectares of Class 2 and 5 savannas by having insignificant cultivation either perennial or annual, manual or mechanized.

Population is low and average farm size is almost 1000 ha but decreasing. The principal production system is presently cow/calf operation on native pastures. Markets are relatively distant but isolation is not extreme.

Growth potential is high for acid tolerant crops on mechanizable land.

Problems

1. Erosion is little risk under native pasture but could become severe on even moderate slopes under inappropriate cultivation.
2. Destruction of the gallery forest.

Spillover: Intensification may increase the demand for rural labour or enhance the reduction of farm size.

Technology developed here should be applicable to the Class 2 and 5 poor lowland pastures where mechanized cropping already exists. However it may also be feasible to use it in the cleared forest areas where large numbers of small farmers at present using manual methods might be prejudiced, possibly increasing deforestation.

Class 2 and 5. Poor Lowland Pastures, Manual Cropping

This is a very widespread frontier area of 44.7 million hectares. It has varying degrees of access but generally moderate to high distance to markets. Land and income distribution are highly skewed. An average of 51% of the farmers have less than 10 hectares but control an average less than 10% of the land.

Natural vegetation is semievergreen forest. In some cases this has completely disappeared, but overall about 40% of the original forest remains. This is usually located on the steep or inaccessible lands.

About 4% of the land is under perennial crops 11% in annual cropping and 30% under extensive grazing. In some areas up to 30% is under bush fallow. Topography is heterogeneous but over half the area is flat and inherently mechanizable. One third is undulating and the remainder mountainous.

Population density is low to medium with a few areas of high population in coastal Brasil and the Caribbean. 30% to 70% of farmers have between 1 to 10 hectares. Access is moderate to good, with moderate distance to markets.

Problems. Most areas show a marked contrast between small farmers practising shifting cultivation or long fallowing, and extensive graziers.

Competition for land is reducing fallow periods and inducing small farmers to extend the forest clearance.

Soil depletion is a problem where fallow periods are cut due to land shortage. This is due mainly to insecure tenure for smallholders.

Spillover: It may be that technology developed for the lowland savannas might be applicable by the larger landowners, although they are not generally at present pursuing much mechanized cropping. This would increase competition for land, and result in serious disadvantages for small-holders. This would seriously increase forest clearance.

Well Watered Mid Altitude Hillsides. Classes 17 and 20.

There are the following:

Laderas Cattle Coffee	Poor Soil	3.02 Mha
Laderas Cattle Coffee	Good Soil	3.52 Mha
High Grazing Shift. Cult.	Poor soil	7.01 Mha
High Grazing Shift. Cult.	Good Soil	2.90 Mha
	Total	15.43

There are found throughout Central America the Caribbean and the Andes. The cluster also includes areas from Classes 14 and 23 which were not analysed in this study but are judged to be similar.

Even at this level of classification these areas are highly heterogeneous. Natural vegetation is mostly seasonal forest although in some cases humid or pre-montane forest. A small proportion, about 10%, of this remains.

Access is generally good but is least in the shifting cultivation poor soil areas. Population is highest in the coffee areas and quite low in the non coffee poor soil region. Land distribution is uniformly skewed with approximately 80% of the farmers holding roughly 20% of the land. Isolation is generally low to moderate although poor mountain roads give long travel times in some areas.

Perennial crops account for up to 30% of the area, even in the better non coffee areas. Annual crops, beans maize cassava etc. are grown on 5% to 20% and between 20% to 60% of the land is in pastures.

Bush fallow accounts for the remaining lands and may be from 10% to 30% depending on the area.

Approximately 50% of the area can be classed as rolling with up to 40-50% steep nevertheless there is generally about 10% of the area which is flat.

Problems

1. Erosion is a serious problem almost everywhere due to:
    a) Overgrazing on steep pastures
    b) Fire fallow clearance
    c) Poorly managed cultivation
    d) In some cases poorly managed coffee.

2. Pesticide overuse is prevalent in the coffee crop.

3. Although most of the remaining forest is on steep lands, there is still pressure for felling.

4. Coffee washings are a frequent pollutant of streams and rivers.

Extensive grazing and small-scale manual cultivation, in the dry, lowland areas of non-acid soils. Class 9.

This land-use pattern occupies about 14 million hectares, most of which is accessible. The type includes an important portion of the Sertao in N.E. Brazil, the middle Sinú on Colombia's north coast, and the Acapulco and Cancún areas of Mexico. The rural population density is moderate to high, and the total rural population is estimated at 2,700,000.

Between 30 and 50 percent of farms are less than 10 ha. and control less than five percent of the land.

The natural vegetation, scrub, dry forest and wooded savanna, is extant in approximately half or the area.

Agricultural land use is dominated by pastures, about 30% of the total area, and bush fallow. The latter varies in importance, in some places it reaches 40% of the area. Annual crops occupy about ten percent of land, and perennial crops are generally absent. Exceptions to the latter are found in parts of N.E. Brasil, where cashews and tree cotton can occupy upto 15% of the land.

Topography is predominantly flat (70%) with the remainder mostly rolling.

Problems. Problems associated with the area's climate are important, that is, the unreliability of rainfall and risk of drought. These affect humans, crops and animals. Adaptation to drought is most difficult for smallholders who rely on annual crops rather than extensive grazing. Declining soil fertility is a significant problem for many of these people, due to overcultivation.

Extensive Pastures and Small-Scale Manual Cultivation on non-acid Soils in the Seasonal Lowlands. Class 8 and 11.

This type occupies about 6.7 million hectares, in northern Colombia, Venezuela, Guatemala, Belize, Mexico, Paraguay and Brazil (the litoral in Ceará). The natural vegetation is seasonal and humid forest, on average half of the area retains this cover. Land holding patterns vary greatly. These areas are not densely populated, although the total rural population is around two million. Access varies a great deal.

A small percentage of the land, less than five percent, is under perennials, and annual crops cover 5-40%. Pastures cover about 40% of the area; the proportion rises to 70% in some places. Bush fallow is unimportant.

Forty to ninety percent of the area has flat topography, with ten to fifty percent rolling. Steep topography is generally absent and does not usually exceed 30% of those regions where it is found.

Problems: Forest clearance is an important aspect of the agricultural dynamics of these areas. Frequently land is cleared by colonists and smallholders, only for these to be displaced soon after by ranching. Concentration of land ownership is particularly notable in accessible areas and where the quality of land is particularly good.

As a result of insecure tenure and land concentration, fragmentation and social conflict affect sedentary agriculture in numerous ways. Many farms are too small to permit sustainable systems to be implemented by their owners, and soil degradation is to be expected. The social instability of these areas prevents consensual resource management amongst all land users. This also contributes to inefficient, absentees, management of pastures, with the emphasis on area rather than pasture and animal quality.

Like most new or recent frontier areas, social infrastructure (health care, education, roads) is often absent.

Class 2 and 5. Poor lowland pastures mecahnized cropping, some manual crops.

A large area of 40.5 million hectares in Brasil, Colombia, Panama, Mexico and Paraguay, 29.2 million hectares of this are lowland savannas environmentally similar to the Altillanuras of Colombia, the rest is seasonal forest. The reason for separate classification from the Carimagua type is the existence of significant areas of mechanized cropping, sometimes up to 30% of the land area.

The area accounts for a population of 2.7 million. Access is variable but over half the area has 100% accessibility. Isolation from markets is mainly moderate, a few cases being highly isolated.

50% to 90% of the area is still in natural vegetation but where this is savanna it is grazed. Virtually no perennial crops are grown but little of the land is left as fallow.

The proportion of flat land is relatively low but can reach 25%, the rest is classed as rolling with steep lands less than 5% of the area.

Up to 50% of the farmers use less than 8% of the land.

Crops include upland rice, sorghum and some soybeans.

Problems

1. Erosion. A maximum of a third of the land is suitable for mechanized cropping and small farmer crops are often relegated to sloping lands.

2. Compaction by heavy machinery.
3. Soil depletion - soils are poor and not suitable for continual cropping.

Cerrados Type Pastures and Mechanized Cropping. Class 17

The area of 31 million hectares is almost exclusively in Brazil. Access is moderate and distance to market to medium.

Depending on the distance to population centers the rural population varies from low to medium. At one extreme these are essentially no farmers with less than 10 ha, but in the south east up to 50% of farmers farm less.

Generally over 50% of the area is still natural vegetation which is campo cerrado, cerradao and seasonal forest. There are almost no perennial crops or managed forest. On the average 13% the area is under annual cropping but the proportion is higher closer to markets, just under half the area is declared as pasture, as a significant proportion of the area is in some form of natural forest.

Only 54% of the total area is less than 8% and fully 13% is over 30%, or very steep land.

Problems

Erosion

Compaction

Water Table modification under cropping.

Class 9. Extensive Pastures, Medium or Large Scale Mechanized and Small Scale Manual Cropping, on Good Soils in the Dry Lowlands

This type covers some 5.1 million hectares, in north east Brazil and Mato Grosso, the savanas de Bolivar on Colombia's north coast, and small areas in Nicaragua and Bolivia. Together they have a moderately dense rural population. Between thirty and seventy percent of farms are smaller than 10 ha, and account for no more than five percent of the land.

Natural vegetation, which ranges from wooded savanna and Sertao to seasonal forest, covers appproximately one quarter of the total area. Perennial crops are unimportant. Annual crops account for five to ten percent of the area. The proportion of the area under pastures varies from 30 to 70%, and fallow from 10 to 30%. Topography is mostly flat to rolling. Most of the areas are accessible, moderately isolated from urban market centres.

Problems: Availability of water for crops and livestock is a significant problem as is unreliability of rainfall for upland cultivation. Well-watered land is such a critical resource for agriculture that competition is important. The land-holding pattern is often extremely skewed, with large landholders dominating well-watered bottomlands, conflict over both land and water is therefore common.

Smallholdings are too small for traditional fallow-based systems to remain effective, shortened fallows have led to soil nutrient depletion. Soil erosion is common, both for small-scale and mechanized agriculture.

Access to markets is usually most difficult just as smallholder crops are being harveted, at the end of the rainy season. There are few opportunities for employment during the dry season, therefore, labour migration is high. Labour shortages for land preparation, and a high incidence of female-headed families often result from all male seasonal migration.

PHASE IV. SELECTION OF AGROECOSYSTEM CLUSTERS

AREAS EVALUATED

Within the environmental classes selected in the CIAT decision process, land use was found to be highly patterned. A hierarchy of land use patterns was identified based on the structure and intensity of associated farming systems. The patterns were quite strongly concentrated in certain environmental classes. Henceforth, we refer to a particular combination of land use pattern and environmental class as an agroecosystem cluster.

A considerable database has been compiled as a result of the process of agricultural characterization of environment classes. We were able to calculate the total area of each land use pattern within each class, and to estimate rural population. These two variables gave us an initial indication of the relative importance of the different agroecosystems. A number of land use patterns, some spreading across different environmental classes, clearly stood out as worthy of further evaluation, whilst others could be rejected as insignificant. We had evaluated the most important land use patterns (and in cases where these were largely confined to a single environmental class, agroecosystem cluster) as potential areas for natural resource management research to focus. These were as follows:

1. Areas of intensive agriculture, particularly sugar cane, mostly in lowland areas and on non-acid soils.

2. Areas of mechanized crop production, for instance coffee, and found exclusively in Brazil. These were most extensive in the highlands, but some lowland systems contained a significantly large population.

3. Lowland and highland areas of extensive grazing and mechanized agriculture on acid soils. The Colombian Altillanura was also included in this group, although mechanized crop production is not yet important there. These land use patterns occupy some 76 million ha., and are by far the most extensive of all those identified. They also have large absolute populations, despite low overall densities.

4. Areas of extensive grazing and manual small holder cultivation on acid soils. These are also very large (45 M ha.) with large populations. They are mostly forest frontier areas or areas where seasonal forest once existed.

5. Areas of extensive grazing and manual cultivation by smallholders in the dry lowlands.

6. Highland areas of extensive grazing, shifting or smallholder cultivation, and perennial crops (notably coffee) on acid soils.

The only other significant land use patterns not evaluated was that dominated by extensive grazing on poorly drained pastures. This has a smaller spatial extent, but possibly a higher total rural population, than the highland cattle-coffee systems.

Selection Criteria and Procedure

To evaluate the different land use patterns and environmental class combinations we devised a set of criteria, as follows:

Group 1 Economic potential	
Market demand	: Demand for agricultural production is significant.
Area or volume of total production	: Spatial extent, and/or overall importance for agricultural production is high.
Intensification potential	: Existing production systems could be intensified significantly.
Infrastructure	: Physical communications and support services are good.
Group 2 Resource potential	
Productivity Index	: Climatic and edaphic conditions are favourable for agriculture.
Expansion of agricultural land	: There is scope for area expansion of agriculture.
Natural vegetation	: A strong value is attached to conserving natural vegetation and significant areas remain.
Spillovers	: Intervention will have a positive impact elsewhere, or non-intervention will have a negative impact elsewhere.
Group 3 Resource Problems	
Ecological fragility	: The area is ecologically fragile for agriculture.
Sustainability	: Existing systems are not sustainable.

Deforestation	:	Deforestation is a concern over a large area.
Soil degradation	:	Soil resources are suffering significant degradation and/or erosion.

Group 4 Equity

Rural poverty	:	There are a large number of poor rural inhabitants.
Employment opportunities	:	Significant employment opportunities can be generated through agriculture.
Food supply for the urban poor	:	The area supplies or could supply basic urban foodstuffs to urban areas.
Land distribution	:	Uneven land distribution is a major source of inequity.

Group 5 Technological considerations.

Lack of appropriate or exogeneous technology	:	Appropriate technology is not currently employed/available.
Problems can be addressed through technology generation	:	New technology can significantly contribute to finding a solution.
Probability of generation	:	It is likely that new technology can be generated to solve identified problems.
Time frame	:	New technology can be generated quickly.

Group 6 Institutional considerations.

Institutional strength	:	Potential collaborators exist.
CIAT's comparative advantage	:	Previous or current CIAT research can contribute to finding solutions.
Internationality	:	The agroecosystem is found in a sufficient number of countries.
Site availability	:	It is feasible to begin research soon at CIAT test sites or other known locations for a given agroecosystem.

Each land use pattern or agroecosystem cluster was then scored for each criterion on a three point scale from -1 to +1. Zero implied neutrality or irrelevance. For technical considerations, if there was no real lack of appropriate technology, giving a score of -1, then the remaining criteria were automatically scored as zero, since they became irrelevant.

The members of the working group did this scoring individually. The scores for each group of criteria were then summed to give an overall score, for the six agroecosystems. An average score was then computed. Where a strong difference of opinion arose, scores were discussed in detail for each criterion to resolve the disagreement.

We summed the scores for each group of criteria. We envisaged the need to apply different weights to these scores, in accordance with different views on the relative importance of growth, equity and sustainability as final selection criteria. We therefore grouped economic and resource potential to give a single indicator of growth. Resource problems indicated the magnitude of sustainability as an issue in each agroecosystem, with equity untouched. As a fourth factor, we combined technological and institutional considerations to indicate feasibility.

Results

The results are given in Table 10, which suggest where resource management will fit best with CIAT's various goals, and where research is most feasible. Giving different weights to the issues of growth, equity, sustainability and feasibility would have little effect on the ordering of agroecosystems in Table 10. Only if we doubled the weights for equity and sustainability, and halved those for growth and feasibility, would the semi-arid pasture and manual cultivation systems rank higher than the conglomerate of savanna agroecosystems,for example.

Based on these decision criteria and scores the working group arrived at three groups of agroecological clusters (see Figure 4). The first consists of lowland areas of manual cultivation and extensive grazing, with a seasonally wet climate. Continental and maritime instances of this land use pattern were combined to define the foci for research. The areas in question have very large expanses of degraded pasture. The rehabilitation of these has long been a concern of CIAT's Tropical Pastures Programme. A significant amount of upland rice and cassava is grown in these areas particularly in Brazil.

TABLE 10: Means scores and totals for the selection criteria.

Agroecosystem	Growth	Equity	Sust.	Feasibil.	Total
1. Intensive cane, etc.	2	1	-3	1	1
2. Mechanized coffee, etc.	2	2	-1	-1	2
3. Pastures and mechanized cultivation	4	1	0	6	11
4. Pastures and manual cultivation (forest margin)	3	2	4	2	11
5. Semi-arid pastures and crops	0	3	2	0	5
6. Hillsides: pastures, coffee, manual cultivation.	3	2	4	6	15

The second group is composed of the seasonally wet hillsides of the northern and central Andes, Central America and the Caribbean, where we find similar land use patterns. Intensive coffee production and cultivation of annuals, in association with extensive pastures, is very important. Cassava and beans are important staples in this area, and cattle are common as a source of milk, meat and cash on both small and large farms.

The third group of agroecosystems is that which exploits extensive grazing and/or large scale mechanized agriculture, on the natural savannas of the Llanos and Cerrados. Lowland and mid-altitude, seasonally wet, environments have been combined to define the area on which to focus. Research at CIAT into intensification of these extensive grazing systems through the incorporation of annual crop rotations has become increasingly important.

Similar use patterns are found in dissimilar environments and vice versa. For an institution such as CIAT, which wishes to generate new agricultural technology this is critical. Innovations which modify land use systems may have applicability across different environments. An understanding of environmental conditions can provide a rational frame for evaluating innovations in areas which are environmentally distinct from those where adoption has occurred.

Selected Agroecosystems

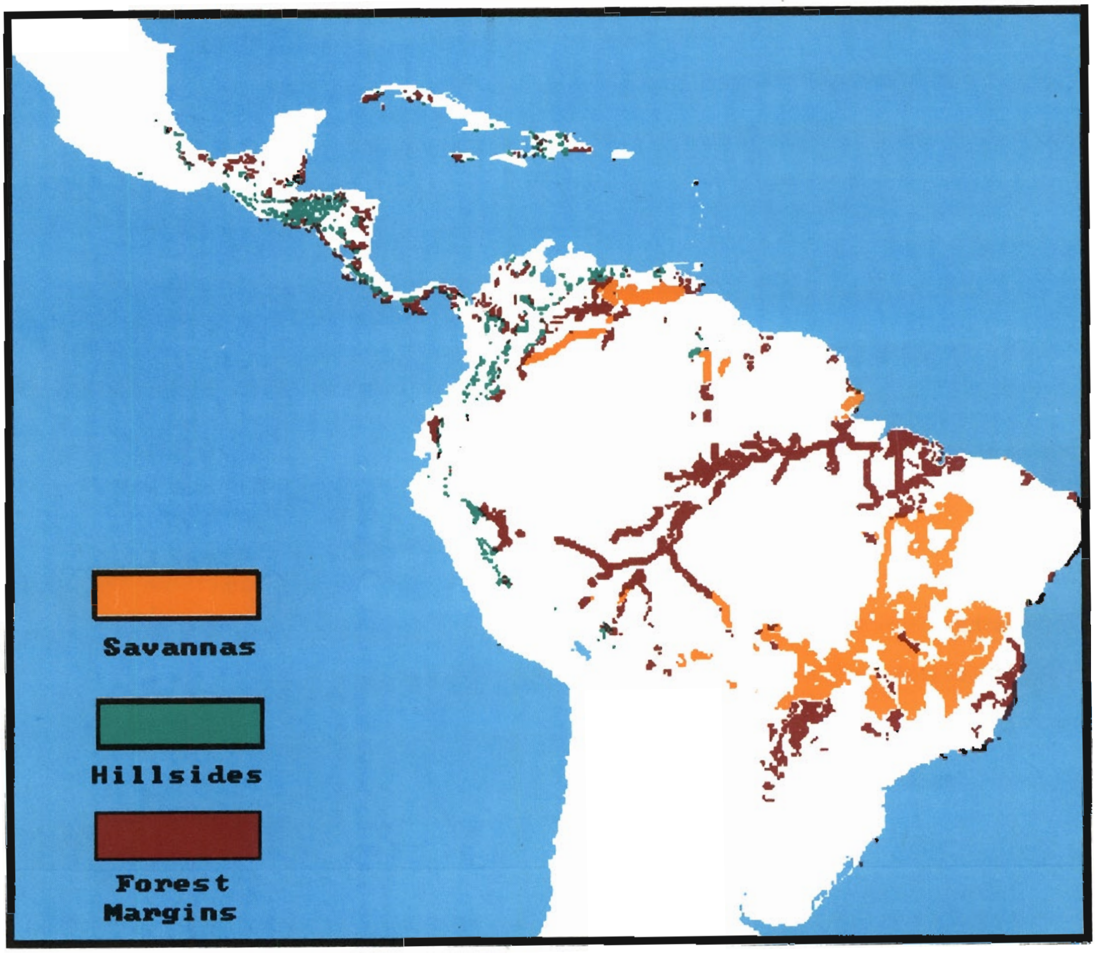


FIGURE 4.

Within a single environment class, it is vital that researchers understand the Human aspect of agriculture, reflected in land use patterns, if they are to increase their understanding of the farmers' needs for new technology.

CONCLUSION

It was impossible to consider all land use problems in the entire continent. However, by the above method the AEU was able to systematically arrive at widespread specific land use problems. Our approach offers a distinct advantage over more subjective attempts to identify areas in which to conduct research, whether for agricultural development, environmental protection, or the conflict between these two goals. Agroecological zonification based on physiological requirements of single crops (FAO, 1978) alone cannot help in understanding sustainability problems. Similarly, studies to determine the ideal or potential uses of land, without studying the limitations imposed by actual land use, are of limited utility. A system that includes both environmental and social variables provides a means to select locations and agrarian systems systematically, and hence to relate the results of research systematically to other places and systems.

By tentatively defining a series of relationships between man's activities and environmental conditions, expressed as agroecological clusters, the work has provided the basis for systematic study of agricultural systems and their environmental consequences. What are needed now are comparative studies of interaction between the different systems which make up the land use patterns. This is vital if we are to understand the way in which the actions of certain groups within agrarian societies, our intended beneficiaries, are conditioned by the aspirations of others, and how the results affect productivity and the environment.

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1984	Quinindé.	Mapa morfo-pedológico.
1983	Santo Domingo.	Mapa morfo-pedológico.
1983	Quevedo.	Mapa morfo-pedológico.
1983	Muisne.	Mapa morfo-pedológico.
1984	Guayaquil.	Mapa morfo-pedológico.
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