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

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ABSTRACT

Over the last 12 years a data base of climate, soils and crop distribution has been assembled for Latin America Recently, socio-economic variables such as access and population density and environmental variables such as the location of national parks, biological reserves and indian reserves have been added Formerly this information was used primarily to make decisions on commodity research Given the increasing awareness of long term agroecological and socio-economic problems this database was used to systematize the search for the effective, specific courses of research into more sustainable agriculture Given the premise that agroecological problems and solution vary with both the physical and social environments, the approach was divided in to phases Phase I divided the continent into 124 classes in simple climatic and edaphic terms The resulting classes were then overlaid with rural population density, rural income per capita, access and location of protected areas Based on pre determined criteria, a short list of environmental classes were chosen Phase II involved a systematic assessment of actual land use in each subzone of the six selected classes Subzones with similar environments and land uses were grouped in agroecological clusters These in turn were evaluated for relevance to current and future CIAT research By this method it was possible to quantify pre-determined aspects of sustainability problems based on both environmental and social variables This formed an immediate basis for deciding between research problems However, for the long term, it

allows systematic comparison between the problems or areas that have researched and other areas with similar environment or land use problems

Introduction

In the last few decades international agricultural research centers such as the Centro Internacional de Agricultura Tropical (CIAT) have had clear mandates to attempt to increase total food production to offset growing population and urban poverty However, there is a growing consensus that rural poverty and other social 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 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 problems 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 CIAT 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, the types of problems tended to be similar The method described below summarizes one attempt to subdivide climate, soils and land use to explore this relationship and target the most important sustainability problems across Latin America

Method

The approach taken by the AEU was to classify the continental area in a two phase process In Phase I all of Latin America and the Caribbean were mapped in broad environmental classes Then, based on pre determined criteria, a short list of environmental classes were chosen Phase II 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

Phase I

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 establish certain 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 should reflect the environmental requirements of actual or potential commodity crops for a center of tropical agriculture

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

The Metgrid files used are an interpolation from the climate database, developed in the AEU, which contains mean monthly information from over 7000 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

<u>Season Length</u> 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 7 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

<u>Temperature during the growing season</u> 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 °C

2 Mid-altitude, 18 to 23 5 °C

3 Highlands 13 to 18 °C

4 Cold less than 13 °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 the AEU on classifiers that are important for plant growth, an additional variable was added to distinguish areas with large diurnal temperature ranges from those will small diurnal ranges This is a proxy for 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

1 Maritime - Less than 10 °C mean diurnal range

2 Continental - Greater than 10 °C mean diurnal range

Annual Temperature Range To distinguish between tropical and sub-tropical areas, we set the annual temperature range cutoff at 10 °C

1 Tropical - Less than 10°C annual range

2 Subtropical - More than 10°C annual range

Soil Acidity One simple soil variable was used to divide soils into those likely to have serious acidity problems, and those that are 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 Therefore there were two more qualifiers

1 Acid Soils, pH less than 5 5

2 Less acid and neutral soils, pH above 5 5

Summary

These variables in theory provided for 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 these environmental classes in terms of their relevance for future CIAT work Three broad criteria for choosing environmental classes were given

1 That the classes be significant for positively affecting rural poverty (equity)

2 That the classes be important for positively affecting natural resources ("environment")

3 That the classes have potential for increasing food production thereby favoring 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 estimate used was a calculation of the area that is accessible with current infrastructure Our method 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 Xingu which are truly inaccessible, but not legally protected (Figure 1)

Legally Restricted Areas The areas in each country in Latin America that are presently legally restricted from conventional agricultural 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 significant proportion of some 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

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 capita (PCI) by state varied from around 150 $ US (Maranhao and Piaui) 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 the mean rural income was extracted in IDRISI for each class The importance of a class for the equity issue increases with the 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

A subjective productivity index was constructed to rank the environment classes in terms of potential economic impact or growth This index had values from 1 to 7 per unit area and the calculations are shown in Table 3 The potential growth index was calculated by multiplying the area of accessible, legally available land by its productivity index (Table 4)

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 An 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/km2) divided by rural income Table 5 shows the classes ordered by this index

A second form of degradation results from ill conceived intensification of an abusive nature such as excessive agrochemical use Areas of high risk to these problems will be the higher population areas within each class with easy access to markets and hence purchased inputs The top five classes, by this index, are indicated in the summary Table 6

A third type of degradation occurs when virgin land is converted to extractive agriculture Areas with relatively untouched native vegetation, be it forest, savanna or other type are likely to be those with low rural populations Another 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 The top 5 classes are indicated in Table 6

Conclusion Phase I

A summary table was calculated which included all of environmental classes that figured 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, 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 In effect, it has a high population, mainly along coastal areas, and the rural per capita income is very low, suggesting a large poverty problem It ranks high in environmental concerns because it contains much of the seasonal forest margin in Central America and the Amazon Basin

A group of economists at CIAT used our extracted data to conduct sensitivity analysis to check for biases towards variables such as class area or population They used five different scenarios with different factors and weights, independent of area, and essentially the same classes emerged, as is shown in Table 7 (Sanint and Janssen, 1990)

Phase II - The determination of Land use Clusters

The selection of environmental classes within which to concentrate does not suffice to identify and characterize relevant research 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 resources. The purpose of Phase II, therefore, was to systematize 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 needed by that CIAT 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. A 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.

The percent area in three topographic slope classes (0-8%,8-30%,>30%) was estimated from medium scale topographic maps. Soil depth, predominant texture, drainage and any obvious chemical or physical problems were noted from semi-detailed soil maps. The number of months with over 200 mm precipitation was calculated from the CIAT database. In the countries where relatively recent agricultural census were available, percent area under annual cropping, perennial cropping, pasture, forest or fallow was calculated. In other countries, this was estimated from land use maps. Socio economic variables were also estimated for each subzone, such as population density, urban dependence on agriculture, land distribution, percent of area readily accessible to transport and relative distance to market

Once the worksheets had been filled, the topographical, agricultural and social information was used to determine generic production systems for each of the 300 subzones such as 'extensive cattle grazing' or 'intensive irrigation of annual crops' It is important to note that virtually all of the subzones had at least two modal production systems practiced by different people within the same subzone eg extensive cattle ranching by large landholders and shifting cultivation by small landholders These interacting production systems together were termed land use patterns and assigned to each of the 300 subzones Table 8 shows all of the land use patterns identified Instances of repeating land use patterns within an environment class was termed an agroecological cluster Table 9 illustrates some differences between three agroecological clusters within one environmental class

Comparison of Figure 2 and Table 8 shows that just over one third of the potential combinations of land use patterns and the 7 environmental classes exist Some land use patterns are not significant in some environmental classes Land use patterns appear to be repeated to the extent that geographically separate subzones have similar physical and human environments They are expressions of the relationships between the landscape and the natural environment, and the social and economic conditions under which agriculture is practiced For example, where neutral soils, long growing seasons, good access, and close markets combined, the predominant land use in Latin America was intensive sugar cane and intensive cattle Where mid-altitude temperatures, good access, acid soils, and steep slope were found together, the land use was predominantly coffee and intensive cattle with some horticulture A third example was where poor access, large distance from market, and natural forest vegetation occurred together, the land use was predominantly shifting cultivation and extensive cattle grazing (e g the forest frontier) Not only do the individual production 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 may assume that the types of problems faced (environmental, social, economic) are similar for different subzones with the same land use patterns and environment 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 (Table 10)

Application

Figure 2 and Table 10 provide 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 former criteria 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 land use 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 2 shows the areas and population respectively for these land use pattern groups within the environmental classes selected in Phase I.

Once the AEU had provided the basic information on the different agroecological clusters, a multidisciplinary group of CIAT scientists selected the three most relevant (CIAT, 1990).

The first was termed the seasonal forest margin, and 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 which has long been a concern of CIAT's Tropical Pastures Programme. A significant amount of upland rice and cassava also occurs, particularly in Brazil. Current land use is not sustainable, in part contributing to further deforestation.

The second group of agroecological clusters was composed of the seasonally wet hillsides of the northern and central Andes, Central America and the Caribbean. 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. Deforestation, erosion, agrochemical abuse and fragmentation are among the problems encountered.

The third group of agroecological clusters chosen is that which contains 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 for research to focus on Research at CIAT into the intensification of these extensive grazing systems through the incorporation of annual crop rotations has become increasingly important over the last few years

The methodology and data were employed initially to select those agroecological clusters which were most important for a given agricultural activity or type of research However, in the future, they should primarily promote an understanding of the similarities and differences between individual agroecosystems Similar land use patterns are found in dissimilar environments and vice versa, but the degree of similarity can be assessed from Table 10, with a knowledge of the environmental classes 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 Similarly, within a single environment class, it is vital that researchers understand 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 identify and quantify 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 An approach that includes both environmental and social variables provides a means to select locations and agrarian problems systematically, and hence to relate the results of research rationally to other related places or problems

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 the interactions between the different production 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, the intended beneficiaries, affect productivity and the environment

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

Class	*	Rural Pop	Urban Pop	Total Area Km²	Number of countries	Total Area not Protected Km²	Accessible Area not Protected Km²
2	T L S M A	7462384	12830741	2800366	24	2431409	810689
5	T L S C A	4496741	8037021	1576880	18	1433703	484108
17	T M S C A	7133114	23632759	912817	18	846215	615922
8	T L S M W	5860458	8995565	540488	23	493803	303174
12	T L D C W	4704845	10728149	830303	13	708777	375999
9	T L D M W	6264550	11475161	398355	12	391260	341225
11	T L S C W	4577921	8229079	390481	17	344035	180864
6	T L D C A	3471035	8324097	879678	12	784066	530767
1	T L H M A	2234896	2798926	1624899	18	1157602	325642
3	T L D M A	4122772	7077859	557513	13	514077	426590

* T = Tropical, S= Subtropical, L= Lowland, M= Midaltitude,
H = Higher altitude, H= Humid, S= Seasonally wet, D= Seasonally dry,
C = Continental, M= Maritime, A= Acid Soils, W= Weakly acid soils

TABLE 2 Environment Classes ordered by Rural Poverty Index

Class	*	Rural Pop	Rural Poverty Index	Urban Pop	Rural Pop/km2	Rural PCI mean	Rural PCI std	Number of countries
2	T L S M A	7462384	16480	12830741	3	453	298	24
9	T L D M W	6264550	11988	11475161	16	523	492	12
8	T L S M W	5860458	9304	8995565	12	630	487	23
3	T L D M A	4122772	7619	7077859	8	541	460	13
17	T M S C A	7133114	6912	23632759	8	1032	547	18
21	T M D M W	2544063	6674	4134194	18	381	170	10
5	T L D C A	4496741	6663	8037021	3	675	588	18
14	T M S M A	4810238	6553	13620092	1[illegible]	734	438	21
1	T L H M A	2234896	5677	2798926	2	394	111	18
11	T L S C W	4577921	5396	8229079	13	848	708	17

* T = Tropical, S= Subtropical, L= Lowland, M= Midaltitude,
H = Higher altitude, H= Humid, S= Seasonally wet, D= Seasonally dry,
C = Continental, M= Maritime, A= Acid Soils, W= Weakly acid soils

TABLE 3 Relative productivity per unit area calculations Points were first determined for dry season temperature pairs Then, 2 points were added for non-acid soils and 1 point for subtropical areas

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

TABLE 4 Environment classes ordered by sum production potential index This was calculated by multiplying the relative productivity index by the accessible area of each class

Class	*	Subjtv Prod Index	Sum Prod Index	Rural Pop	Rural Pop/km2	Number of countries	Accessible area Km^2
2	T L S M A	4	3242757	7462384	3	24	810689
5	T L S C A	4	1936433	4496741	3	18	484108
17	T M S C A	3	1847765	7133114	8	18	615922
8	T L S M W	6	1819042	5860458	12	23	303174
12	T L D C W	4	1503994	4704845	7	13	375999
9	T L D M W	4	1364902	6264550	16	12	341225
11	T L S C W	6	1085185	4577921	13	17	180864
6	T L D C A	2	1061534	3471035	4	12	530767
1	T L H M A	3	976925	2234896	2	18	325642
3	T L D M A	2	853181	4122772	8	13	426590

* T = Tropical, S= Subtropical, L= Lowland, M= Midaltitude,
H = Higher altitude, H= Humid, S= Seasonally wet, D= Seasonally dry,
C = Continental, M= Maritime, A= Acid Soils, W= Weakly acid soils

TABLE 5 Environment classes ordered by nutrient depletion/environmental degradation index (erosion or nutrient leaching, weed infestation, etc)

Class	*	Nutrient Depletion Degradation Index	Rural Pop	Urban Pop	Rural Pop/km2	Rural PCI mean	Number of countries	Accessible area
2	T L S M A	792	7462384	12830741	3	453	24	810689
3	T L D M A	517	4122772	7077859	8	541	13	426590
9	T L D M W	473	6264550	11475161	16	523	12	341225
5	T L D C A	449	4496741	8037021	3	675	18	484108
17	T M S C A	427	7133114	23632759	8	1032	18	615922
6	T L D C A	386	3471035	8324097	4	882	12	530767
21	T M D M W	308	2544063	4134194	18	381	10	130436
18	T M D C A	292	3379676	8204852	7	826	12	362535
12	T L D C W	283	4704845	10728149	7	954	13	375999
1	T L H M A	235	2234896	2798926	2	394	18	325642

* T = Tropical, S= Subtropical, L= Lowland, M= Midaltitude,
H = Higher altitude, H= Humid, S= Seasonally wet, D= Seasonally dry,
C = Continental, M= Maritime, A= Acid Soils, W= Weakly acid soils

TABLE 6 Summary of Phase I The occurrences of classes in the first 5 rows of the subject rankings

			<—— Environment	—————>		
Class	Growth	Equity	Intensification Abuse	Protection	Nutrient Depletion	CIAT* Crops
2	*	*	*	*	*	*
17	*	*	*		*	*
5	*			*	*	*
8	*	*	*			
9		*	*		*	
12	*		*	*		
3		*			*	
1				*		
6				*		
18						*

* Rice, beans (Phaseolus vulgaris) and cassava

TABLE 7 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 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

TABLE 9 Example of some topography and land use variables for three different agroecological clusters within one environmental class, 17 (Tropical, mid-altitude, seasonally wet, continental, acid soil

	Total Area (000) Km2	No of countries	Slope Classes <8%	Slope Classes 8-30%	Land Use (% area) Annual Crops	Land Use (% area) Perennials Crops	Land Use (% area) Pastures	Access	% properties >10 Ha
1/ MC-MA-IC	197	1	15	67	13	6	64	100%	26
2/ HC-CO-HO	98	10	8 5	43 5	14	18	42	63%	65
3/ XC-MA	311	2	45	33	13	0 01	43	76%	2

1/ Mechanized coffee, mechanized annual crops, intensive cattle

2/ Hillside cattle, coffee, horticulture

3/ Extensive cattle, mechanized annuals

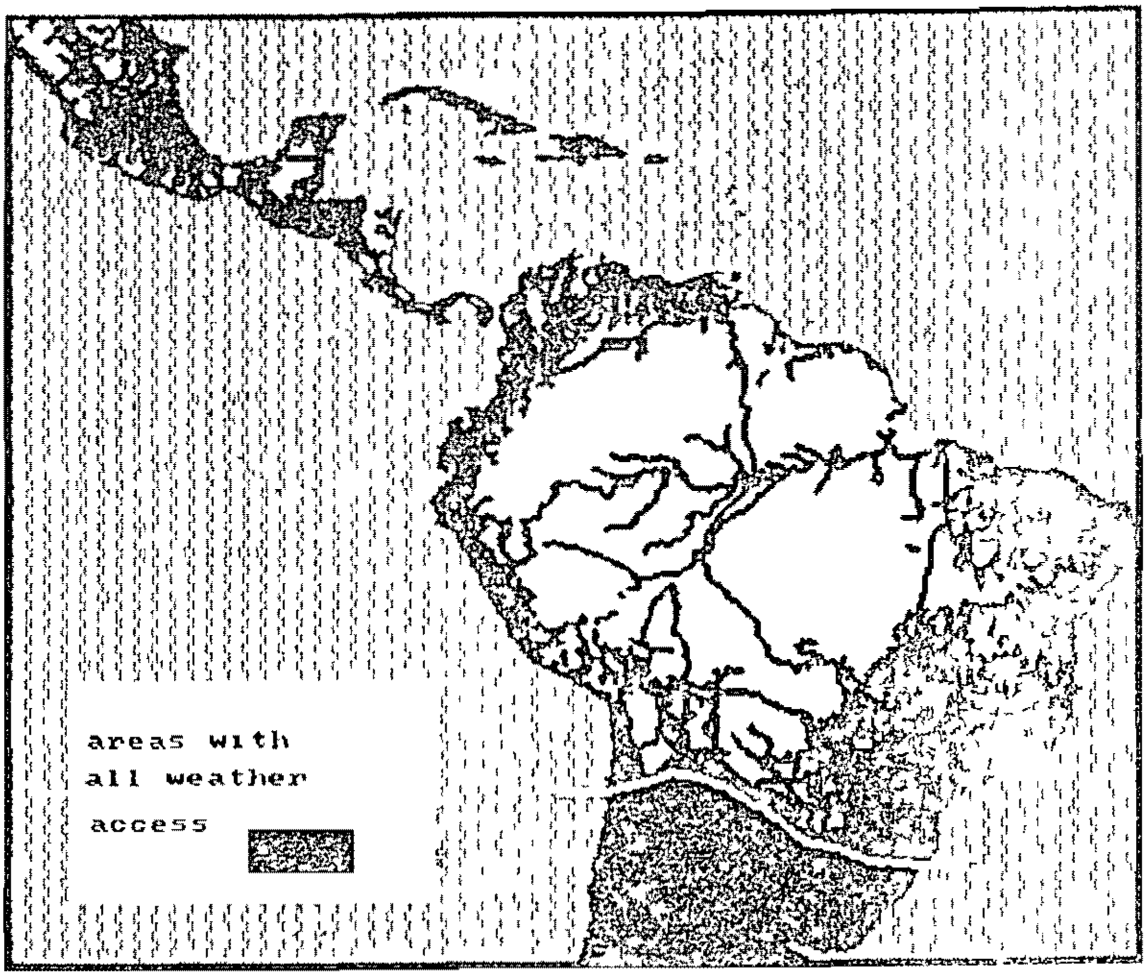
TABLE 10 Summary of the most important Agroecological clusters

Land Use Pattern	Selected Environmental Classes 2	5	8	9	17	20	Other Classes
Extensive Grazing/ Manual Cropping	XXXX	XX	XX	XXX			XX
Extensive Grazing/ Mechanized Cropping	XX	XXX			XXXX		XX
Hillside Grazing/ Coffee/Shifting Cultivation			X	X	XXXX	XX	XX
Mechanized Coffee/ Pasture/Mech Crops					XXXX		X

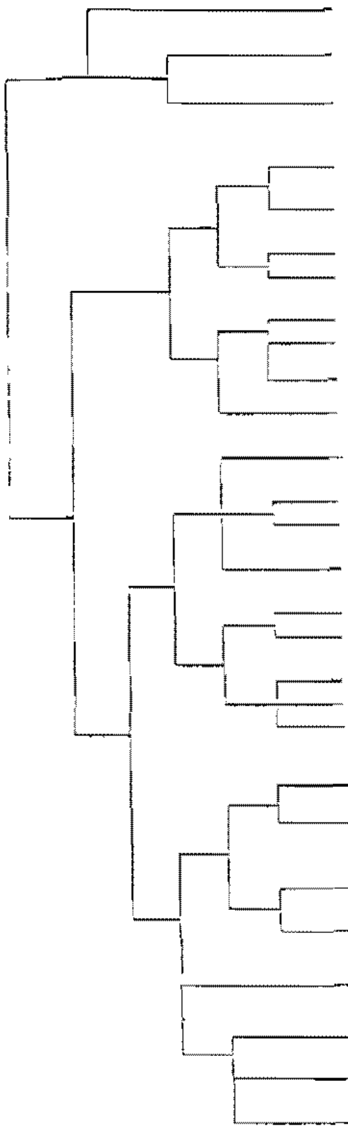
Figure Captions

Figure 1 All weather access in Latin America and the Caribbean The areas in white are more than 30 kms from an all weather road or navigable river

Figure 2 Area (km^2) of the main agroecological clusters in the seven environmental classes The cluster diagram at the left indicates relative resemblance of the different land use patterns


areas with
all weather
access

Environment Class



LAND USE CLUSTERS	2	5	8	9	11	17	20
UNUSED FOREST LANDS	1 68	0 17					
RUBBER NUTS	2 58	1 88			0 77		
FLUVIAL & VAPSEA 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 5		
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			[illegible] 96		1 [illegible]		
DRY LOWLAND PASTURES MAN/MECH CROPS				5 10			
DRY LOWLAND PASTURES MANUAL CROPPING			0 79	13 92			
GOAT GRAZING				4 4[illegible]			
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 04	0 56			0 10
SMALL SCALE CANE & ANNUAL 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			