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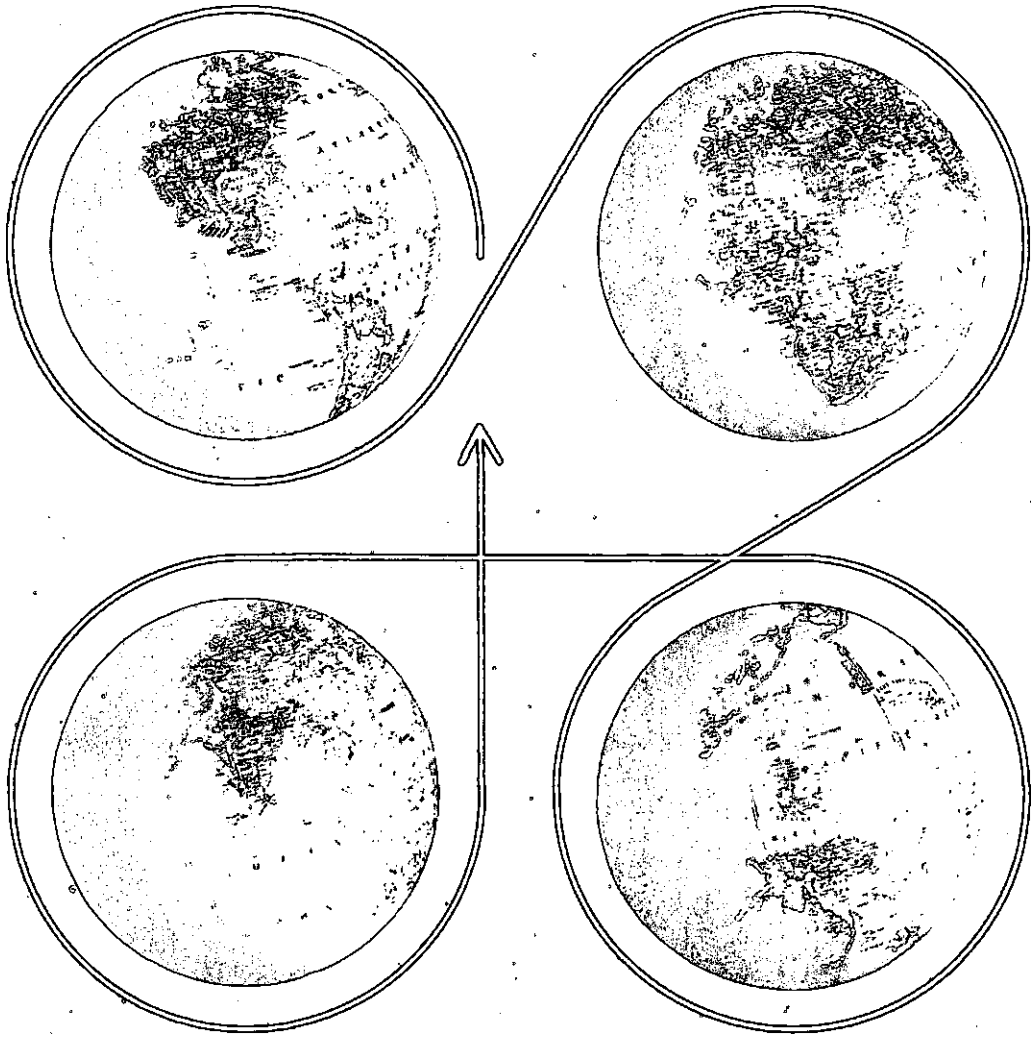

A Method of Watershed Land Classification and Assessment for the Tropics: A Case Study of Rio Guanare, Venezuela

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DEPARTMENT OF NATURAL RESOURCES

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A METHOD OF WATERSHED LAND CLASSIFICATION AND ASSESSMENT FOR THE TROPICS: A CASE STUDY OF RIO GUANARE, VENEZUELA

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INTRODUCTION

The development of effective policies and plans for regional development in the tropics would be enhanced if planning were carried out on a basis of adequate appraisal of the land resource. "Adequate appraisal" would involve a technically sound but simple and rapid assessment of the major environmental components (vegetation, soil, climate, fauna, water resources, topography, etc.), delineation of relatively homogeneous environmental units which tend to respond more or less uniformly to a given treatment, and information about local prevailing or likely land use practices. Given enough money and technology, a land owner or manager can do virtually anything with any piece of the environment. What is sought, however, is to promote viable, sustainable uses without major ecological degradation or harmful off-site impacts to neighbors or public "property," such as streams, reservoirs or settlements (as is the case with flooding or sedimentation). Such suitable, sustainable uses should be the goal of on-the-ground management and political policy decisions, avoiding the disastrous consequences of unsustainable land development which have often occurred in the tropics.

The basic assumption is that a segment of the natural environment -- a functioning ecosystem -- which is under planning scrutiny, has something "to say" about how it may be used efficiently, safely and pleasantly for human well-being; i.e., that it is more suited to certain uses over the long run than to others. Areas of land within a given climatic regime and having similar vegetation, topography, parent material and soil conditions are thought to have similar performance characteristics for such uses as forestry, agriculture, grazing, wildlife production and outdoor recreation and even certain kinds of man-made structures such as roads. The task at hand, is

first of all to have a method of delineating these landscape units in time and space (on a map, on an air photo, on the ground) and then to assess their capability or suitability to sustain an array of potential uses, given certain levels of management/technology/culture, without unacceptable degradation. The choice of which of the suitable uses, is a socio-economic; one, made by the landowner, manager or governmental planner.

The authors discuss a method that was developed in and found useful for regional planning in Venezuela. The study was carried out in a mountain watershed of forested and open land in western Venezuela near Guanare. The, method illustrates the effectiveness of such a rapid, low cost approach to land assessment, and how decisions about land use can be made for a range of different alternatives (5 selected agricultural crops, grazing, timber harvesting, firewood cutting, plantations for three different tree species, and a rating for watershed protection value). The field study was carried out by Hawes (1978).

The Study Area

The area is located in western Venezuela (Figure 1) consisting of the upper and mid watershed of Rio Guanare in the Andes and High Llanos (approximately 157,000 hectares). Rio Guanare is a major drainage in the Guanare-Masparro Integrated Development Project, a major project in Venezuela, and one expected to serve in part as a model for development of other regions of the country. In 1974, by Presidential decree, the mid and upper watershed of Rio Guanare was declared a Zone of Protection whose purpose was to maintain the quality and quantity of water resources for downstream development and to protect the fauna, flora and natural beauty and to enhance recreation. Because land use changes under this decree seemed to be a likelihood, a land evaluation for land use planning seemed particularly appropriate.

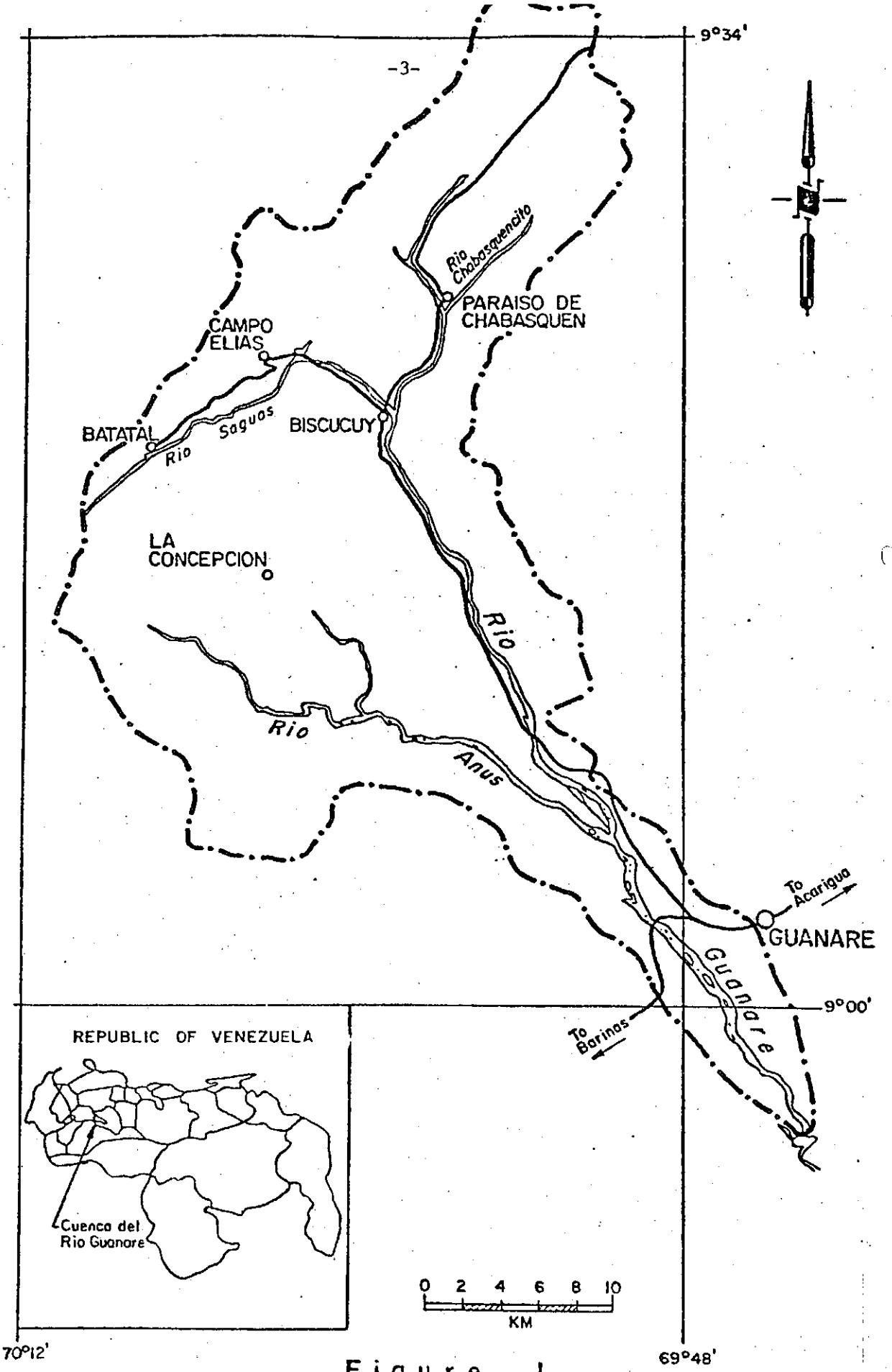

Figure 1
LOCATION OF THE STUDY AREA

The study area contains three physiographic zones: the llanos or plains (recent alluvium) from about 150 to 175 meters in elevation; the piedmont (eroding old alluvium) from about 175 to 400 meters; and the bedrock-controlled mountains from about 400 to 3000 meters. Rio Guanare is formed by the confluence of Rio Chabasquen and Rio Saguas, and has as its major tributary Rio Anus joining it in the lower piedmont zone (Fig. 1).

Climate-vegetation was classified using the Holdridge (1967) life-zone system, as developed for Venezuela by Ewel and Madriz (1968).[1] Under this system the watershed was classified into five major units: tropical dry forest, tropical moist forest, tropical premontane moist forest, tropical premontane wet forest and tropical lower montane wet forest. Smaller areas of tropical lower montane moist forest, tropical montane rain forest and tropical sub-alpine rain paramo also occur. These terms are roughly descriptive of the natural vegetative cover which would exist without man's intervention.

Soils in the watershed are complex due to the wide variations in climate, topography and geologic materials. Based on data from soil profiles and laboratory analysis, 8 Great Groups were identified: Ustorthents, Dystropepts, Tropaquepts, Haplustults, Tropudults, Paleustults, Hapustolls and Tropohemists.

[1] The life zone classification, developed by Holdridge (1967), provides a sound framework for classifying climate and vegetation in the mountain watersheds. The system is adapted to areas with little information, provides relevant climatic units for natural resource evaluation, is reproducable by other workers, and is widely used and understood so that the terms are meaningful.

Present Land Use

Agriculture is the main activity in the watershed. It is made up of the large farmer and campesino sectors. The Urge farmers normally have about 50 to 300 hectares, and farm about 40% of the territory (FUDECO, 1975). The campesino sector is less modern, using low levels of technology and having low production levels.

Coffee is the main crop. It constitutes essentially permanent agriculture and occurs throughout the watershed, especially in the upper valleys of Rio Anus, and also the valleys of Rio Saguas and Chabasquen. The total number of hectares in coffee is estimated to be over 20,000 (FUDECO, 1975).

The major horticultural region is near Anzoategui (potatoes, peppers, tomatoes and cabbages). There are some tomatoes grown in the plains, but crops are mostly corn, sorghum, cotton and sugar cane. Horticultural agriculture is usually mechanized with the use of irrigation and fertilizers.

Subsistence conuco (slash-and-burn shifting) agriculture is found throughout the watershed particularly in the valley of Rio Anus, the valley of Rio Guanare between 300 and 800 meters, and higher mountain slopes between 1,500 and 1,700 meters. It is a low technology, high labor input land use, with machetes, fire and rotation of the land used as management tools. The main crops are corn, beans, bananas, cassava and some cattle.

Commercial cattle production occurs in the piedmont and plains, and also around Chabasquen (on soils too dry for coffee production). It is generally of low quality (poor cattle stock and unimproved pastures), and does not have a major economic impact on the region (FUDECO, 1975). Fire is often a part of the regime.

Presently, there is little commercial timber harvesting in the area. This activity would temporarily increase with the construction of a reservoir because of tree removal for the reservoir site.

More detailed descriptions of present land uses were provided in the 46 land type descriptions which were done in this study.

The population of the mid and upper watershed has been estimated at 60,000 people (FUDECO, 1975). More than 80% is rural in small isolated settlements (FUDECO, 1975). The City of Guanare, which lies just outside the study area to the southeast, has a population of between 40 and 50,000 people (Comision Asesora del ejecutivo para El Programa Guanare-Masparro, 1976). A percentage of these people live in the watershed, but probably less than 25%. Using this estimate, and allowing for population increases since the 1971 census, the estimated population in the watershed in approximately 80,000.

The population is young, about 50% being less than 18 years old. The overall rate of population increase was about 50% from 1961 to 1971. While this increase is high, it has not been evenly distributed in the watershed. There is a general migration of people (mostly younger people) from the mountains into the plains (Comision Asesora del ejecutivo para El Programa Guanare-Masparro, 1976).

Transportation is fairly good with a paved 2 lane highway from Guanare to Biscucuy, and from Biscucuy to Bocono. From Biscucuy there is a partially paved secondary highway (poorly maintained) to Anzoategui. There are many tertiary roads penetrating the watershed to serve agricultural producers. However, these roads are not well maintained, especially during the rainy season, and often become impassable following heavy rains.

Vegetation

The life zones of Ewel and Madriz (1968) were used to classify the vegetation. More detailed information on present vegetative cover was provided in the land type descriptions. (See Appendix 1)

The tropical dry forest, except for poorly drained areas, has generally been cleared (logged or burned) for cultivation and grazing. The tropical moist forest has mostly been cleared for permanent agriculture, or, has secondary vegetation (shrubs, trees and grasses) associated with conuco agriculture. Small areas, generally steep and stony, remain in forest cover but are susceptible to deforestation by fires associated with cattle grazing.

The tropical premontane moist forest has largely been cleared of forest for permanent cultivation or is burned for grazing. The tropical premontane wet forest has a diverse vegetative cover. On very steep, often inacessible areas, the cover is mature forest. More gentle slopes (less than 45%)are usually cultivated with coffee and shade trees. Steep slopes (45-60%) tend to be used for conuco agriculture and grazing, and often have secondary vegetation of grasses and shrubs.

The tropical lower montane moist forest is a mixture of mature forest and grassland. The lower slopes are generally kept cleared for grazing by fires. The tropical lower montane wet forest generally has a cover of mature forest. Lower slopes may have some clearing for grazing and conuco agriculture.

The tropical montane rain forest has a cover of mature forest (possibly cloud forest). The tropical subalpine rain paramo has a cover of low shrubs and grasses.

Method of Identifying Landscape Units

The study area was classified into a series of land types.[1] Land types are defined as a recurring pattern of landforms with associated soil and

[1] The land classification methodology was developed in Venezuela following an analysis of the biophysical parameters in the region, the available data and the available manpower, time and financial resources to carry out the study.

geologic materials within an area of relatively homogeneous macroclimate (life zone).[1] A land type is a relatively permanent, homogeneous environmental unit (with a geomorphological base) thought to have similar performance characteristics.[2] The class limits for the land types were made "with an eye on" land performance characteristics, particularly for agriculture and forestry.

The first step in forming the land types was to stratify the area into broad life zones. The life zones (bioclimate zones) provide a framework for assessing biotic performance capabilities. This was done using the classification of Ewe and Madriz (1968). A second broad stratification was made based on different geological materials as determined from geological maps and air photo interpretation. From the combination of life zone and geological stratifications, a number of broad land zones were determined to aid the land type analysis.

Preliminary land types were then mapped on black and white aerial photographs at a scale of 1:60,000. Identification was made of repeating patterns of landforms (guided by the life zone and geological stratifications) based on slope steepness (flat, gentle, steep, very steep), slope shape (concave, linear or convex), slope regularity (regular, irregular), and relative relief. Approximately 38 preliminary land types were identified as homogenous, repeating landscape units having similar landforms in areas of similar macroclimate and geology.[3]

[1] This is similar in concept to units defined by Lacate (1969) and Christian (1958), for Canada and Australia respectively.

[2] That is, it offers similar opportunities and constraints for various kinds of land use.

[3] Land types as taxonomic classes do not include more than one major life zone and one major geological material. Thus, areas with similar landforms but different macroclimate (or less likely, geological materials) were classified as different land types.

Preliminary mapping was then field checked to test the significance of the land types, in terms of relative homogeneity of land features and for estimating similarities in performance capabilities. At this time soil pedons were selected, described and sampled for the land types. Boundaries were checked, and data were collected on the kind and variability of slopes, surficial and geologic materials, soil drainage and textures, vegetation cover, elevation, water resources, present land use, and significant landscape processes (e.g., earth flows). As the field work progressed and data were collected and analyzed, it was possible to form a broad conceptual model of the landscape features and processes. This was used to guide investigations of environmental parameters (for example the soils and surficial deposits), to assist in determining important land performance characteristics (such as slopes), and to evaluate the significance of the land types. Some new land types were added (and other land types were modified) by clarifying the central concept and variability of land parameters.

Forty-six land types were finally described in the study area. Each land type (within limits due to scale) has similar land features and performance characteristics, and differs significantly from other land types in these parameters.[1] Two examples of land type descriptions are given in Appendix 1. (Concepcion and Vertiente)

The second stage was to relate biophysical land attributes of each land type with the ecological requirements and management practices for an array of likely uses. Five crop types (coffee, bananas, maize, citrus and cassava), extensive grazing, timber production, firewood production, commercial forest

[1] For regional planning there has to be a compromise between level of detail (number of units) and variability in the classes (i.e., the level of taxonomic generalization). Probably 46 land types is near the maximum number of units which can reasonably be understood, remembered, and used at this level of regional planning.

tree plantations (Pinus caribaea, Pinus oocarpa and Tabebuia rosea) and watershed protection were the major land use options considered for the suitability ratings. In addition some work was carried out on recreation suitability in connection with the streams of the watershed, and a scenic classification carried out for the principal road through the watershed. Due to the absence of any information on wild fauna, no suitability assessment was attempted for wildlife.

For the crops, including the trees for reforestation, information was collected on the ecological plant requirements through a review of available literature, available local knowledge and field observations. Information was also collected on the kinds of management practices used, and where possible, the production expected under these practices. The suitability ratings assess the capacity of the land type in its present condition to respond to management techniques. Three suitable and two non-suitable classes were used, taken from guidelines suggested by F.A.O. (1976). These classes are:

Class S_1 Highly suitable -- land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S_2 Moderately suitable -- land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S_1 land.

Class S_3 Marginally suitable -- land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Class N_1 Currently not suitable -- land having limitations which may be surmountable in time, but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land type in the given manner.

Class N_2 Permanently not suitable -- land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Of three likely levels of management, - traditional, improved management and advanced technology, the middle level was selected as being most appropriate for a watershed whose lower portions were in the Guanara-Masparao Integrated Development Project.

Land Suitability for Agriculture

Suitability interpretations provide an assessment of the "fitness" of the land for a defined sustainable use under a specified level of management. The land units are analysed for their relative performance potential or for the degree of limitation the land has for a particular use (to accommodate the "non degradation constraint").[1] Table 1 illustrates the methodology for

[1] The suitability interpreations are necessarily tentative. Ratings can be expected to change with significant changes in crop prices, costs of management inputs, and changes in the alternative opportunities available to people in the area. For example, an activity such as the cultivation of maize on steep mountain slopes requires a high level of management inputs to overcome the severe topographic limitation. The decision on whether this activity is marginally suitable, or currently not suitable, will depend in part on the alternative opportunities available to the people in the area. A new technology may change suitability ratings, i.e., the adoption of terracing.

Land Types[a]		Environmental Parameters Considered for Coffee Production: Temperature (°C)	Precipitation (mm)	Topography (slopes)	Elevation (m)	Drainage	Soil Depth (m)	Soil Texture	Yield Potential (kg/hectare)	Suitability Rating
	Optimal:	16-22°	2,000-2,500	<45%	1,200	Well drained	2m, or >	Heavy	3,000-4,000	
	Marginal:	<13°;>25°	<1,800;>3,000	60-80%	600-800; >1,500	Excessive, or poor	1-2m	Medium to light	1,000-1,200	
Caña Degree of limitation		Very severe	Very severe	Slight	Very severe	Very severe	Slight	Moderate	Extremely low	N_2[b]
Concepción Degree of limitation		Slight	Slight/ moderate	Slight	Slight	Slight	Slight	Slight	Good	S_1[c]
Las Cruces Degree of limitation		Moderate	Slight	Slight	Severe	Slight	Slight	Severe/ moderate	Low	S_3[d]
Morgan Degree of limitation		Slight	Severe	Very severe	Slight	Severe	Severe/very severe	Severe	Very low	N_1[e]

[a] See the land type descriptions for a discussion of the environmental parameters.

[b] A rating of N_2 (permanently not suitable) was given to Caña land type. The limitations are in aggregate extremely severe, and because they are mostly climatic, they will be virtually impossible to overcome at this level of management (that is, without irrigation and drainage) in the foreseeable future.

[c] A rating of S_1 (highly suitable) was given to Concepción land type, for the limitations are in aggregate generally slight for the production of coffee.

[d] A rating of S_3 (marginal) was given to Las Cruces land type. Elevations and soil textures provide severe limitations, but not severe enough to preclude the use of this land type for coffee production at this level of management.

[e] A rating of N_1 (presently not suitable) was given to Morgan land type. The limitations are in aggregate very severe for sustained production of coffee, but may be surmountable in time if the high levels of inputs required for sustainable production were considered worthwhile (for example, terracing of the slopes).

making a suitability rating for coffee production on four selected land types.

Estimates are made of potential crop yields under specified levels of management for the suitability classes. Thus, in Miraflores land type which has a high suitability for coffee and a marginal suitability for maize, it is expected that under improved management, yields of between 3,000 and 4,000 kilograms per hectare of coffee, or 1,200 or 1,500 kilograms per hectare of maize, are possible.

From the land suitability analysis the amount of land in each suitability class for each crop can be determined. Approximately 36% of the land has a moderate or high suitability for some kind of agriculture; 40% is marginal or poor agricultural land; and 24% is nonagricultural land.

An analysis of the suitability of land areas for various crops (Table 2) shows that some 25,000 hectares are rated as prime land for coffee. Only about 300 hectares are rated as prime land for grazing, and no land areas are rated as prime for citrus, maize, bananas or cassava. From Table 2, it would appear that bananas are generally poorly suited to the study area, and cassava, maize, citrus and grazing are at best, only moderately suitable.

Table 2. Land area by suitability classes for various agricultural crops (in hectares).

Suitability	Coffee	Bananas	Cassava	Citrus	Maize	Grazing
High	24,860	-	-	-	-	330
Moderate	8,635	3,575	20,630	21,700	20,535	15,070 .
Marginal (Poor)	23,165	63,770	65,020	51,140	66,935	81,345
Not suitable	100,560	89,975	71,570	84,380	69,750	60,475

A comparison was made between the ratings developed by applying the systems of Strebin (1975), and Arrias and Comerma (1971), using the same land type data base. It was found that both the systems of Strebin and Arrias and Comerma consistently gave lower land suitability ratings. The Strebin system resulted in no land in the high suitability class, only 12% as moderate, 49% as marginal, and 39% as not suitable. The Arrias and Comerma approach rated land even more severely, with no land having a high suitability, only 2% with a moderate suitability, 52% as marginal, and 46% as not suitable.

The methodologies of Strebin and Arrias and Comerma are based implicitly on concepts of the Land Capability Classification of the U.S.D.A. That is, they seek to determine the soil erosion hazard of the land units (based on high technology agriculture) with topography playing a dominant role in determining the capability classes. Both methodologies seem better developed for evaluating areas of high input mechanized agriculture, such as in the flat-lands, rather than evaluation of steepland agriculture with specialized crops, less technology and intermediate management techniques.

The 24 to 34% disagreement in land suitability ratings between the proposed system and that of Strebin and Arrias and Comerma is very significant for agriculture assessment and regional planning. Many areas that would be classified as marginal by the other methods can be shown to be prime coffee producing areas under improved management (for example, the Concepcion, Miraflores, Esperanza and Cascadad land types). While more detailed information is needed on soil, climate, diseases and pests for these areas, initial indications show that these are prime lands for coffee production in Venezuela.[1] On the other hand, one area given the rating of

[1] The Rio Guanare watershed, because of its climatic and topographic conditions, is one of two major coffee producing areas in Venezuela.

moderate by the Strebin system (Cavacas land type) was rated in the proposed system as marginal, due to the severe soil and climatic conditions. This difference of 24 or 34% between marginal and high to moderate suitability ratings is critical for resource assessment of the watershed.

The classification used should provide a clear distinction between land highly suited for grazing, and land highly suited for cultivation. Generally, the land use capability approaches do not do this. Class 5 is used to indicate grazing land, but in a negative way. It is used to indicate land too low of quality for cultivation, but could be used for grazing. In some cases (for example Anzoategui land type) the land may be highly suitable for grazing.

In summary, the agricultural land classification used in this report provides greater detail and flexibility for regional land use planning than the two systems presently used in Venezuela. Detail is provided on land suitabilities for specific crops. It is an open-ended approach, with as many crops being considered as deemed relevant for planning. The classification is not static, as new crops can be added at a later time, or, the ratings can be reassessed for different levels of technology or management practices. For more general planning purposes, the crop suitability ratings can be simplified into one suitability class (as shown in Table 2). The suitability ratings consider the level of technology and economic inputs for production. This provides greater adaptation of local socio-economic conditions than the present systems. The classification is ecologically based, considering an integration of land performance characteristics. It requires more information about land parameters than the Strebin system (e.g., that is, precipitation, altitude, geomorphology), but requires less detailed soils information than is required to apply the Arrias and Comerma system.

Land Suitability for Forestry

A methodology is required, based on ecological land parameters, for evaluating the range of forest land capabilities for integrated development planning of tropical river basins (Lanly, 1976; Bene et al., 1977). The methodology should analyze a number of forest values (timber as well as conservation values) and be adapted to local socio-economic and environmental conditions (Hamilton, 1976).

The methodology proposed in this paper is a forest suitability classification based on the ecological parameters of the land types. It is designed for determining preliminary, baseline forestry interpretations important for integrated development planning and conservation of the watershed. The interpretations considered most important are for: watershed conservation values; the suitability for commercial timber production of natural forests; the suitability for fuelwood production; and the suitability for commercial plantations of Pinus caribaea, Pinus oocarpa, and the hardwood species Tabebuia rosea.[1]

The suitability ratings consider the fitness of the land type for a given, sustainable use. The ratings assess the capacity of the land type in its present condition to respond to management techniques (including consideration of the expense or inputs required) for a specific kind and intensity of use. Three suitable and two not suitable classes were used, as previously outlined for agriculture.

It must be emphasized that the forestry interpretations are preliminary. They are based on limited information and are designed only to

[1] Due to the lack of data on the type and frequency of species present, diseases, pests, and optimal environmental conditions for plantations, the interpretations are necessarily preliminary and need further investigation. They do, however, provide a framework and a reference for designing further research, as well as providing initial forest interpretations for planning in the watershed.

provide general, initial interpretations for planning. Further research is required on species requirements, management techniques, diseases, pests, etc. While basic forestry interpretations are necessary for comprehensive resource analysis and integrated planning of these mountain watersheds, at the present time existing information is insufficient to allow for confident predictions on land performance for forestry.

The user should be aware that land performance results from a combination and interaction of environmental factors. Thus, the limits described here are not absolute. What are important are land qualities which directly influence performance (e.g., soil moisture, soil stability) which result from a combination and interaction of the separate characteristics (i.e., rainfall amount and intensity, soil texture, soil depth, slope, evapotranspiration, etc.). Land qualities cannot normally be measured directly, but rather are evaluated qualitively from known land characteristics (Young, 1976).

Watershed Value Index

Tropical watersheds have an important value for soil and water conservation (Hamilton, 1976). Certain areas may be critical for regulating water flow and quality, and for conservation of soil resources. The land value in conservation may be much higher when preserved rather than used for extraction of timber or agriculture. Rarely, however, is the conservation value analyzed and made explicit in evaluating tropical forest land.

This study adapts the methodology of Wadsworth (1969) to the study area. Only a slight modification was made to emphasize the Urge areas of earth flow materials (on gentle slopes).[1] The watershed value index was developed as illustrated in Table 3. A watershed value index greater than

[1] A fourth class was added under the soil condition to include those gently sloping land types with earth flows.

Table 3. Calculation of preliminary watershed value indices.

	Weight
1. erosion hazard	
a. slope 60%+	10
b. slope 45-60% and clayey texture	10
c. slope 45-60% and fine loamy texture, or shallow	3
d. slope less than 45%, but frequent soil movement	6
2. unsuited to continuous non-forest cropping[a]	5
3. neither 1 nor 2	1
Sum = SC	

	Weight
1. annual precipitation	
a. 2,500 mm+	8
b. 2,000-2,499 mm	3
2. downstream storage	
a. existing reservoir	10
b. planned reservoir	5
c. important aquifer	4
3. neither 1 nor 2	1
Sum = WV	

SC X WV = Watershed value index

critical =100+

high = 70-99

moderate = 35-69

low = less than 35

[a] based on climate (cold temperature, high precipitation, and cloud cover)

100 is critical; 70 to 100 is high; 35 to 70 is moderate; and less than 35 is low. Critical values indicate areas that should be unmodified from the natural state. High values indicate areas that should only be modified with careful conservation practices, or, where possible, left undisturbed. Areas of moderate or low value indicate areas that can be used with decreasing levels of conservation practices.

The watershed value index ratings provide a semi-quantitative evaluation of important areas in the watershed requiring conservation. The technique appears to give realistic values, and due to its simplicity can be widely applied. At present the values must be tentative, and further research is required to validate the methodology.

It is calculated that 16% of the watershed has a critical watershed value index. Approximately 25% of the area has a high rating, and 59% a moderate or low rating. Areas rated as critical should remain in forest and not be used for timber harvesting or cultivated agriculture. Areas rated as high will need good management and conservation practices to prevent land degradation.

Suitability of Natural Forests for Timber Harvesting

Forest productivity: no detailed information exists in the study area about present forest composition, nor about land productivity for forestry or regeneration potentials. The most complete information is contained in the national life zone classification of Ewel and Madriz (1968). Their descriptions of each life zone and humidity province includes a general discussion of the vegetation composition, structure, succession and special edaphic associations. Included is a short interpretive description of the

general life zone suitability for forestry based on concepts of productivity, tree species, soil, and regeneration potential. Based on an interpretation of the work of Ewel and Madriz, the following guideline was developed by the authors, and has been judged to be reasonable by Ewel (1978).[1]

Table 4. Life zone suitability for sustainable timber harvesting.

Not Suitable		Suitable		
permanently not	presently not	marginal	moderate	high
			tropical dry forest	tropical moist forest
			tropical pre-montane moist forest	tropical pre-montane wet forest
			tropical lower montane wet forest	
tropical sub-alpine rain paramo	tropical montane rain forest			

Table 4 is only a general guide, and does not consider disease, pest or soil conditions.

Access: accessibility to the forest resource is of high priority. Accessibility is directly related to the cost of timber harvesting (Lanly, 1976). The availability and distance required to construct access roads for

[1] Ewel has suggested that the tropical dry forest be rated as marginal. However, in the study area much of what is technically tropical dry forest is more similar, in terms of vegetation composition and growth, to tropical moist forest. This is due in Urge part to the high soil moisture holding capacity of the soils and to a relatively high ground water table from Rio Guanare (for example, Fundo land type).

mechanized logging equipment was considered in the suitability ratings. Very steep, irregular broken terrain (greater than 60% slopes) is generally not suited for forest harvesting, and steep, irregular slopes (45 to 60%) will be marginal. Helicopter or balloon logging could change this.

Available forest cover: the availability of permanent primary or secondary forest was considered in the suitability ratings.[1] Land taken out of forest for permanent agriculture is considered to be not suitable for sustained natural forest harvesting. Areas now in shifting cultivation, or in grazing, will likely be marginally or poorly suited for commercial production.

Watershed value index: the watershed value index measures the importance of the land type for hydrological resources and soil conservation. Areas having a value of "critical" will generally not be suitable, or will be marginal, for sustained timber harvesting.

Management: more work needs to be done to define the appropriate levels of management for economic forestry, while maintaining the areas for sustainable use. In the present and immediately foreseeable stage of forestry development, management will likely be extensive, with stress placed on natural regeneration. Labor will be fairly intensive, with a moderate level of mechanization mainly in transport. Access roads should be designed with a low grade, and with adequate protection (buffer zones) given to stream banks and drainage channels. Timber harvesting will be selective cutting of desired species, not large scale clear cutting.

Using the above criteria, including the level of management, each of the 46 land types was rated as to suitability for sustained timber harvesting.

[1] It is assumed that the pressure for agricultural land will increase in the area. Hence, areas presently cleared for agriculture will probably remain in some type of agricultural use.

Suitability of the Natural Forest for Fuelwood Production

Available natural forest: the availability of permanent forest is the most important consideration. Areas permanently taken for agriculture or residential use are not suited for sustained fuelwood production. Areas under frequent or continuous burning, associated with grazing or conuco agriculture, will be marginal or not suitable.

Forest productivity: the productivity and regeneration potential of the natural forests were determined from Table 4.

Management: fuelwood production is considered an extensive, low technology, high labor input land use. It is considered a controlled use of the land, where no major change in the forest cover should take place. Access by road is not considered important (being mostly by mule or on foot), nor were the watershed value indices used, as clearing of the forest cover will be restricted as currently practiced in Venezuela.[1]

Using the above criteria, the suitability for fuelwood production on each land type was assessed.

Suitability for Forest Plantations

Forestry plantations are becoming increasingly important in tropical forestry. Plantations allow for high production of valuable species on limited land areas. In Venezuela, plantations of forests are increasing in importance. They are deemed necessary to meet the national demand for pulp and paper, lumber, and wood for furniture and industry. It is estimated that a secure demand will exist for plantations in Venezuela in the foreseeable future (Carrero and Bluhm, 1976). Hamilton (1976) points out that

[1] Due to the availability of cheap fossil fuels.

their establishment on already cleared and even degraded land can shift the pressure away from logging more native tropical forest until we know more about its management and values.

Plantations are relatively new to Venezuela with less than 20 years experience with high-growth exotic species (Smith, 1976). At the present time there is a lack of organized information on the suitability of exotic or native species for plantations. There are very few data on the productivity of species in plantation conditions, on the tolerable or optimal site conditions, and little information on diseases or pest problems, or on the availability of seedlings. At present, the minimal information required for confidently evaluating the suitability of the land for plantations is not available (Rodriguez, 1976; Luna, 1975 and pers. comm.). Nevertheless, even with the present data limitations, it is desirable to develop a preliminary analysis of the potential suitability of the land types for plantation forestry. At a later time, with more complete information, the suitability interpretations can be re-evaluated. Although the interpretations must be preliminary, the methodology will hopefully be important in regional analysis and the values obtained will assist in resource evaluation and planning of the study area.

The three species selected for study were: Pinus caribaea Morelet, Pinus oocarpa Schiede, and Tabebuia rosea. The pine species are important for pulp and paper production and Tabebuia (apamate) is high quality furniture and finishing wood.

Forest Land Use

In Venezuela information on forest productivity, species habitat requirements and appropriate management techniques is in a preliminary stage. The minimum information necessary for accurate predictions of land potentials and limitations for forestry use is not available. It is

however, important to initiate methodologies for making forestry interpretations, even though the interpretations may not be as accurate as desirable. The methodology developed in this paper will assist in resource assessments for integrating forestry considerations in land use planning of tropical mountain watersheds.

No areas have a high suitability for harvesting of natural forests, due mainly to steep topography and lack of permanent forest cover. Only 2% has a moderate suitability. Approximately 44% of the area is marginally suitable and 54% not suitable for sustained timber harvesting. As only 2% of the land has a rating as high as moderate, it can be concluded that harvesting of natural forest land will be unsuited to the study area..

The use of fuelwood can be important to meet domestic energy needs. In Venezuela, due to the availability of cheap petroleum products, fuelwood supplies will probably remain a low priority in the immediate future being restricted to marginal areas with subsistence agriculture. Approximately 10% of the study area is highly suitable for fuelwood production, 23% is moderately suitable, 50% is marginal and 17% is not suitable.

Development of forest plantations is at an early stage in Venezuela. Data on species requirements, species productivity, and appropriate management techniques are rudimentary. Nevertheless, to meet the increasing national requirements for wood products, plantation forestry can be expected to increase.

Pinus caribaea has been the most widely planted exotic species in Venezuela. However, in the study area, only about 2% of the area has a high suitability for Pinus caribaea due mainly to the high fire hazard and poor soil conditions. Approximately 34% of the area is moderately

suitable, 37% is marginal and 27% of the area is not suitable. The results, indicate that based on economic criteria, plantations of Pinus caribaea would not be highly suited to the study area. Plantations would probably be best undertaken for land conservation as well as for economic reasons. Large areas could be planted to help restore degraded land, yet still yield a moderately high level of income.

Pinus oocarpa has a similar tolerance range to Pinus caribaea. but appears better suited to areas of degraded soils, and areas subject to infrequent or light fires. Only about 2% of the area has a high suitability for Pinus oocarpa. Approximately33% is moderately suitable, 38% is marginal and 27% of the area is not suitable. The results indicate that plantations of Pinus oocarpa would not be well suited to the study area for primarily economic reasons. This species could be important for conservation of degraded land, particularly steep, dry areas, and areas with a moderate fire hazard. Further work is required to evaluate this species.

Tabebuia rosea is a native hardwood species found in the region. However, under plantation conditions it appears that less than 2% of the area would be highly suited for Tabebuia. Approximately 23% would be moderately suitable, 34% marginal and 41% not suited. Tabebuia appears to be poorly adapted to reforestation of degraded sites and its fire tolerance is low. It appears, based on very limited information, that Tabebuia is less well suited to plantation forestry in the study area than either of the pine species.

Plantation forestry can provide an important alternative land use - important not only for conservation, but also providing moderate economic returns on more marginal agriculture land. Further research should be undertaken to determine appropriate species for the area.

Overview

As an example of the complete rating which shows the alternatives available to land planners, managers and policy makers, three land types have been selected for presentation in Table 5.

It must again be emphasized in presenting suitability ratings, that no judgement is being made as to which one use is "best" or most appropriate for a given planning unit. No master plan for land use is produced. Rather, there may be several uses which can be sustained on a given unit of the landscape. The decision as to which use will depend on land tenure, needs, skills, available input resources, political plan for development, etc. In the case of the Zona Protectora of the Guanare Masparo Project, an over-riding consideration is the maintenance of water delivery and water quality. A change in technology (an easily adopted method of making terraces, a new availability of fertilizer) may alter the suitability rating, as would the development of a market where none existed before. The land suitability rating is specific to the area under planning scrutiny, and might be quite different for a similar land type in a different watershed with a different set of socio-economic circumstances.

Of particular importance in land use planning are those uses designated "permanently not suitable" (N2). In attempting to adjust land uses in a protected zone or other critical area in mountain watersheds, these "red flags" should give warning of needed change if the existing land use is one which is unsuited. Where land use regulations are being employed, these "red flag" areas may form the basis for guidelines or controls.

The method herein described offers a valuable tool to planners and policy makers of the tropics, particularly as the remaining tropical forest land comes under scrutiny for development. The need for such planning

TABLE 5. SUITABILITY RATINGS FOR COMPLETE ARRAY OF LAND USES FOR THREE LAND TYPES.

Land Type	Agricultural Crops of								Plantations of			Watershed Value Index
	Coffee	Bananas	Cassava	Citrus	Maize	Grazing	Timber Harvest	Firewood	Pinus caribaea	Pinus oocarpa	Tabebuia rosea	
Batatal	S_3	S_3	S_3	N_1	S_3	S_3	S_3	S_2	N_1	N_1	N_1	Low
Miraflores	S_1	S_3	S_3	S_2	S_3	S_3	N_1	S_3	S_2	S_3	N_1	Moderate
Vertiente	N_1	N_2	N_1	N_1	N_1	S_3	N_1	S_3	S_3	S_2	S_3	High

Suitability Symbols: S_1 - Highly suitable; S_2 - Moderately suitable; S_3 - Marginally suitable.
N_1 - Currently not suitable; N_2 - Permanently not suitable.

Watershed Value Index: Critical - Areas should be retained in natural state.

High - Modified only with careful conservation practices or retained undisturbed.

Moderate - Can be used with moderate level of conservation.

Low - Lowest level of conservation required.

based on adequate land resource assessment was highlighted at a Pacific-Asian international conference on "Forest Land Assessment and Management for Sustainable Uses" held in June 1979 at the East-West Center in Hawaii (Qureshi, et al., 1980). Ill-advised tropical forest clearing has also been a focus of concern by the United States State Department, and as a follow-up to a U.S. Strategy Conference on Tropical Deforestation (June, 1978) a federal inter-agency task force is currently drafting a U.S. Policy Strategy and Program. Each of these groups or conferences have emphasized the need for governments and international organizations to give "high priority" to "land use survey, inventory and classification activities as well as land-use planning at national and local levels". (Shane, 1978).

The methodology of biophysical land classification developed in this study for Rio Guanare was to provide a technically sound, but simple, rapid and relatively low cost inventory and assessment of the natural resources for regional planning. The original study was accomplished primarily by one person over a period of 20 months. Additional assistance was provided for the soil inventory (approximately 2.5 man months) and in collecting information on the ecological crop requirements (approximately 1 man month) The total manpower requirement including time to develop the methodology, conducting the inventory and assessment, is estimated to be approximately 24 man months of effort. An experienced team should be able to accomplish a similar study in a shorter period of time and at a lower cost based upon the methodology presented in this paper. The study area of the watershed was 157,000 hectares.

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Appendix 1

Land Type Vertiente (Vt)

Landforms and Materials: This land type consists of steep to very steep, convex to linear, often irregular, dissected mountain slopes. Materials are mostly deep colluvium, with a minor inclusion of shallow colluvium over bedrock.

Life Zone: The life zone is tropical premontane wet forest. Average precipitation is estimated at between 1,800 and 2,500 mm, with a dry period of about 3 months. Present cover is mostly grasses and shrubs, with trees in the gully areas and higher slopes.

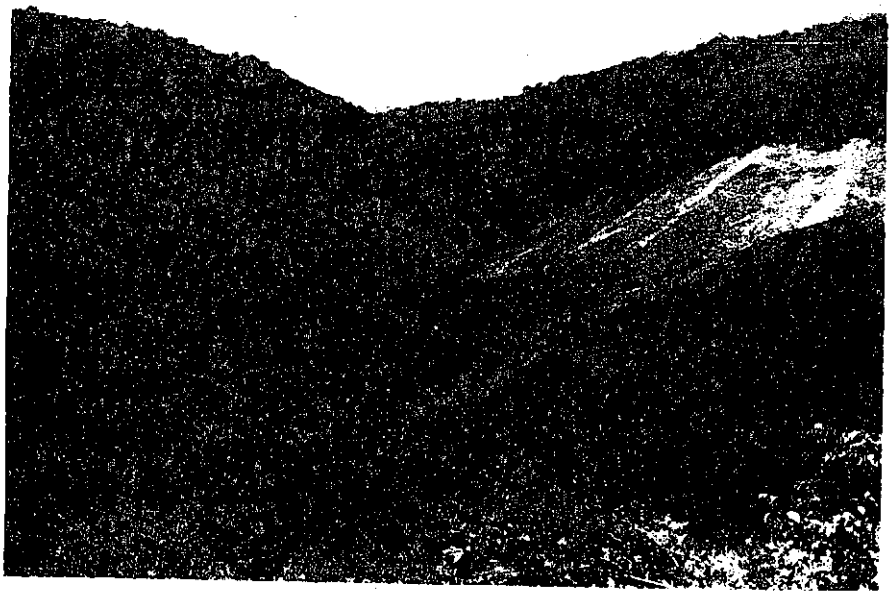
Geology: Primarily undifferentiated metamorphics with inclusions of sedimentary bedrock.

Soils: The selected soil pedon is somewhat excessively drained, has a coarse-loamy particle size class, and is classified as a Dystropept.

Hydrological Resources: Contains stream orders +1, of steep, bouldery channels.

Present Land Use: Present use is primarily for grazing, with some shifting cultivation of maize on the less steep slopes.

Landscape Features: Elevations are from 800 to 1,500 meters. Slopes are mostly 45 to 80% and greater. This land type is burned as frequently as every three years to maintain the grass cover.



Land Type Concepcion (Cn)

Landforms and Materials: This land type consists of gently to steeply sloping mostly regular, concave to linear low mountain slopes. Materials are primarily deep colluvium and earth flow deposits, with a minor inclusion of shallow colluvium.

Life Zone: The life zone is tropical premontane wet forest. Average precipitation is from 2,600 to 3,000 mm, with a dry period of 2 to 3 months. Cover is a mixture of natural forest and coffee with shade trees.

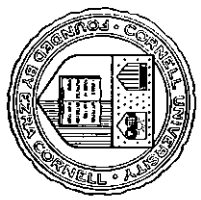
Geology: Fine to medium textured sedimentaries (Trujillo Formation).

Soils: The selected soil pedon is moderately well drained, has a fine particle size class and is classified as a Tropudult.

Hydrological Resources: Stream order is +1. Channels are frequent, and steep sided with stony bottoms.

Present Land Use: Present use is mostly coffee and bananas in wetter or more, accessible areas, and conuco agriculture in the areas of poorer access. Ridge tops are important areas for roads, housing and small farms.

Landscape Features: Elevations are from 700 to 1,400 meters. Slopes are mostly 15 to 60%. This land type is similar to Miraflores and Esperanza l.t., but occurs in the high precipitation area around La Concepcion.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