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LAND USE ALTERNATIVES FOR THE HUMID AND SUBHUMID TROPICS OF LATIN AMERICA 1/

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The vast majority of the lowland American tropics receive over 1000 mm of rainfall annually and have ample moisture during at least six months of the year to support vigorous vegetative growth. Native vegetation ranges from open, treeless grass savannahs to tall, dense rain forest. Agriculture in this region is limited primarily to alluvial soils, steep mountain soils or soils which have been rejuvenated by volcanic ash deposits plus a few sites where soils have developed from basic parent rocks and have medium to high levels of native fertility.

The potential of this vast, largely untapped resource is the subject of much controversy but most observers agree that the rational use of the natural resource base demands many different kinds of land use, depending on climate, soil, topography, social, economic and cultural considerations.

The purpose of this paper is to review briefly the geology, soils, climate, vegetation and population distribution in the region, to discuss some of the alternative uses of the resource base and suggest some considerations which should be taken into account in planning for development of the region.

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THE RESOURCE BASE

Geology

The geology of South and Central America is dominated by three major land forms, as seen in Figure 1. The Guyana shield in the north and the Brazilian shield to the east are very old land surfaces on which have formed deeply weathered, generally extremely infertile and acid soils during millions of years of exposure to high temperature and high rainfall regimes. These surfaces are extremely stable and subject to very little geologic erosion.

Running the length of the western edge of the continent are Andean mountains which were formed during the Cretaceous period and have been subjected to strong tectonic activity in recent geological time. Because of the magnitude of the uplift and the very steep slopes, accelerated geologic erosion is common throughout the Andean region. The vast Sub-Andean depression separating the Andes and the two old shields is filled with sediments, largely derived from the Andes. It is drained by the Amazon, Orinoco, and Paraná rivers. The eastern slopes of the Andes are mostly composed of very poor rock formations giving rise to alluvium of low inherent fertility.

Soils

The soil landscape of the region is shown in figure 2 in a very generalized fashion, to indicate the predominant groups of soils found in the different regions. It is a landscape of extremely infertile and acid soils throughout the low, humid tropics east of the Andes. The old surfaces are covered by very deeply weathered soils formed in place and the Sub-Andean depression is filled with poor sediments. The well drained soils in the depression are subject to further leaching under a high rainfall, high temperature regime.

With few exceptions, the oxisols and the ultisols are strongly to very strongly acid and of low to extremely low fertility. The few exceptions are important in the regions where they occur, since these "islands" of fertility in a great "sea" of extreme infertility serve as stepping stones for the development of new regions. They determine to a large extent the location of towns and cities in the Brazilian Planalto, ocurring mainly along major drainage ways, where erosion has been sufficient to rejuvenate soils and on outcroppings of basalt which have given rise to fertile soils with high base saturation.

Climate

Figure 3 shows annual rainfall. Most of the region is characterized by rainfall of between 1000 and 2500 mm. (There are some areas where annual rainfall exceeds 10,000 mm.) In the wetter regions there may be no pronounced dry season at any time during the year; while in the dryer regions there is usually a period of extreme drouth of up to six months duration. Figure 4 shows representative rainfall distribution patterns for several key locations.

Vegetation

The major vegetation areas are shown in Figure 5. The three dominant types of vegetation are tropical wet evergreen forest and tropical seasonal forest plus tropical savannahs. Within each of these general areas one finds numerous land forms and drainage situations. On the old shield surfaces, most land-scapes are well drained. However in the Sub-Andean depression, large areas are imperfectly to very poorly drained and subject to seasonal flooding. They include low terraces along all three major rivers, large areas in the Venezuelan and Colombian llanos, the Bene plains of Bolivia, the Gran Pajonal of Peru and the Pantanal of Brazil. These areas are largely covered with savannahs, the major exceptions being the seasonally flooded and swamp forests along the major drainage ways.

Population

Population is concentrated along continental coastlines and in the Andean region throughout tropical Latin America. The major restraints to the development and settlement of new areas are low native soil fertility, extreme soil acidity, and lack of access routes. Because of lack of infrastructure, on farm costs for inputs such as lime and fertilizer to modify the unfavorable soil chemical environment are too high in most areas to be economically feasible. The area in question has sometimes been referred to as a great fertility desert, fertility being the single most limiting factor in the development of the area.

ALTERNATIVES FOR FUTURE USE

There are many alternatives for the future use of this great resource base, ranging from the maintenance of forest or savannah reserves to intensive agricultural development. A brief listing of the more likely alternative uses would include: forest or savannah reserves, lumber extraction, grazing of native savannah, perennial tree crops, grazing of seeded, perennial pastures, subsistence food crops, and commercial production of annual crops.

Factors influencing choice of land use

Among the more important factors which influence the choice of land use are included:

1) Accessibility or cost of developing access routes
2) Soil factors, including drainage, fertility, acidity, physical characteristics
3) Climate
4) Topography
5) Availability of technology needed for the particular land use choice
6) Availability of capital
7) Available management
8) Market for products
9) The availability of delivery systems for the technology, capital and other required inputs

Governments and development agencies are concerned with factors such as:

1) Potential for generation of employment
2) Improved income distribution
3) The likelihood that the systems will provide for sustained yields
4) Probability of resource conservation
5) Productivity of the system in terms of gross product, production of food or other commodities vital to region

Table 1 shows the kind of analysis that might be used in considering different land use alternatives from the stand point of input requirements and the likely output of the systems. The most favorable systems are those in which expected output is relatively high compared to input requirements. The priority placed on different output components will vary in space and time and will control to a large extent the choices made. For example, the input requirements for forest or savannah reserves are very low or nil but the output from these systems in terms of employment or food production is very low and for that reason this alternative may often have to be rejected. At the other extreme, the input requirements for annual crop production using high levels of technology are very high in this type of ecosystem but the output expected is also quite high and in some circumstances will indicate this as the preferred choice.

Specific case examples

To further examine factors which influence the choice of land use systems, some specific examples will be presented.

Resource base: Well drained savannahs, acid, infertile oxisols with high phosphorus fixation capacity, very low base saturation but with excellent physical properties, deep friable profiles, good moisture during eight months of the year and smooth to gently rolling topography. The biological potential of this type of ecosystem has been adequately proven and documented in a number of sites in Latin America. If sufficient lime and fertilizer are supplied, we know that we can produce very good yields of climatically adapted crops. However, rather heavy investments are required initially to modify soil chemical conditions in order to achieve acceptable yields, and a fairly high level of management, along with necessary technology and delivery systems for technology, capital and other inputs are required.

If adequate infrastructure exists, or if the site is close to markets and sources of lime and fertilizer (especially phosphorus); and if good technology and technical assistance are available, along with adequate capital and management, then the area should, and probably will, move rather rapidly to intensive, high technology, annual cropping systems.

If on the other hand, the area is distant from markets and/or lime and fertilizer sources and is lacking adequate infrastructure, what is the practical potential of the resource base? Most native savannahs in tropical Latin America are composed of species of very low palatability and nutritive value and their potential productivity is low under present management systems. Calving rates are characteristicly 50% or less.

Fattening is impossible and feeders are usually sold at three years or more of age, weighing 300-350 kilos. However, there are many forage species which are native or have evolved in similar ecosystems elsewhere which offer a much higher potential of productivity. These species are well adapted to the acid, infertile soil environment and require no lime and very little fertilizer for establishment and maintenance. A mere change in species can have dramatic impact on production performance, both in terms of calving rate and rates of gain, and may also make it possible to fatten cattle for market. Although the change appears to be simple it does imply much higher levels of capitalization and management for satisfactory performance.

Thus, largely depending on the availability of technology, capital, management and other required inputs, a remote area may remain in extensive native savannah with low levels of capital input and management and correspondingly low levels of output or it may move into improved pastures if capital and management, along with technology are available, with a corresponding increase in output.

Many restraints on land use alternative choices can be removed or altered but the economic feasibility of making such modifications will vary from region to region and in time. Other restraints are much less amenable to modification. For example, in the southern Colombian Llanos, (Meta and Vichada), 8 to 9 million hectares of savannah are found on very rolling, heavily dissected topography, interspersed with gravel capped hills and laterite outcroppings. This region is in sharp contrast to the smooth, non-dissected, well-drained plains along the right bank of the Meta immediately to the north. Both areas are presently used predominantly for extensive grazing of native savannah vegetation. The serrania, because of topographic limitations will probably remain in grass, either native or improved or a mixture of the two, for the foresceable future, whereas the smooth plains to the north will probably move progressively through mixed native range and improved pastures, with limited food crop production, to more intensive pasture management and eventually into intensive food crop production.

Like the "serrania" in the Colombian Llanos, there are hundreds of millions of hectares of land that should never be used for animal crops because of topography or other factors. Tables 2 and 3 present a broad picture of the extent of land which is marginal or unsuitable for cropping. However, much of this land is suitable for livestock production on a sustained basis. With introduced pasture species and adequate management, yields can reach 100-200 kg of live weight beef/ha/yr. Yields can be even higher with intensive management and use of appropriate fertilizers. The role of beef cattle in utilizing marginal lands in the American tropics is presently very important and will doubtless increase rapidly in the years to come. Technology is currently being developed to increase the productivity of tropical soils, notably through use of legume-grass pasture association and better animal health programs.

In addition to the large areas which are suitable only for permanent pastures, (or forests and other perennial tree crops), there is a vast expanse of land with good potential for annual cropping, but which cannot be economically farmed at present. Beef is often a logical first step in the evolutionary development of agriculture on this type of land, until adequate infrastructure can be developed to support more intensive agriculture which requires much higher levels of input.

An example of the intensive management on an extremely poor, acid soil resource base can be seen in the vicinity of Campinas in the state of Sao Paulo, Brasil. Extremely infertile and acid oxisols have been developed in recent years and are presently being used for intensive production of corn, soybeans, cotton, vegetables and cut flowers. Development has been based on extensive use of fertilizer and lime to modify soil conditions, and ready access to markets in the Campinas and Sao Paulo area. Similar, but unimproved campo cerrado land in this region is presently selling for as high as $1,500 U.S. per hectare. In contrast, similar land in the Colombian Llanos, with even more favorable topography and climate, sells commercially at less than $5 U.S. per hectare and is still being used almost exclusively for extensive grazing of native savannah.

One of the characteristics of the setting in which land use alternative choices are made is that it is often highly dynamic. What may be entirely uneconomical at present, in the absence of infrastructure or lack of fertilizer and lime for soil modification may become highly attractive with the development of infrastructure and new sources of phosphorus and lime along with new markets, or changing market conditions resulting from increased demand for given commodities. The development of new technology or perfection and application of technology already known, often has a profound impact on land use. Government policy relative to credit, marketing, road construction, imports and exports greatly influences development patterns.

The future of the humid tropics of Latin America depends on many complex factors. The biological potential of the region is great but the realization of this potential requires many inputs including new technology, vast amounts of capital, and the training of management at all levels. The results could mean increased employment, better income distribution, and more food for the people in the region.

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Table 1. Input requirements and expected output from different land use systems in the humid tropics. (O, L, M, H= nil, low, medium, high).

	Input requirements						Expected output						
	Infrastructure	Capital	Management	Technology	Maintenance costs	Fossil energy	Employment	Income distribution	Sustained yields (stability)	Resource conservation	Food production	Foreign exchange	Recreational value
Forest reserve	O	O	O	O	O	O	O	O	H	H	L	L	L-H
Savannah reserve	O	O	O	O	O	O	O	O	H	H	L	L	L-H
Lumber extraction	L	L	L	L	O	L	L	L	H	H	L	L-M	M
Grazing management native savannah	L	L	L-H	L	L	L	L	L	H	L-H	L	L	M-H
Perennial tree crops	M	H	H	M-H	H	L-M	M-H	L-H	H	H	L-M	M-H	M
Perennial seeded pastures	L	M	M	H	L-M	L	M-H	L-H	H	H	M	M-H	M
Subsistence food crops-long, wild fallows	L	L	L	L	L	L	M	M	M-H	M-H	L	O	L-H
Annual crops, intermediate technology	H	M	M	M	M	M	M-H	M-H	M	L-H	M	L	M
Annual crops, high technology	H	H	H	H	H	H	H	H	L-H	L-H	H	H	H
Combinations of above, dynamic in nature													

Table 2.- Broad soil regions of the humid tropics of Latin America, by country. From M. Nelson, The Development of Tropical Lands. Resources for the Future. (Johns Hopkins, 1973).

Soil region[a]	Mexico	Central America	Venezuela	Colombia	Ecuador	Peru	Bolivia	Brazil	Guianas	Paraguay	Argentina	Total
Lowlands												
Amazon basin	–	–	–	22.0	4.0	44.0	2.0	224.0	–	–	–	296.0
Bolivian plains	–	–	–	–	–	4.0	33.0	4.0	–	–	–	41.0
Orinoco basin	–	–	34.0	40.0	–	–	–	–	–	–	–	74.0
Atlantic coastal lowlands, northern South America	–	–	–	–	–	–	–	14.0	15.0	–	–	29.0
Pacific coastal lowlands, northern South America	–	–	–	18.0	7.0	–	–	–	–	–	–	25.0
Upper Paraná–Paraguay basin	–	–	–	–	–	–	6.0	18.0	–	16.0	6.0	46.0
Chaco	–	–	–	–	–	–	7.0	–	–	10.0	25.0	42.0
Mexican and Central American humid lowlands	18.0	27.0	–	–	–	–	–	–	–	–	–	45.0
Total lowlands	18.0	27.0	34.0	80.0	11.0	48.0	48.0	260.0	15.0	26.0	31.0	598.0
Uplands												
Guiana uplands	–	–	32.0	–	–	–	–	46.0	29.0	–	–	107.0
Forested Amazon uplands of the Brazilian Shield	–	–	–	–	–	–	16.0	78.0		2.0		95.0
Central Brazilian depression	–	–	–	–	–	–	–	48.0	–	–	–	48.0
Central Brazilian *cerrado* uplands	–	–	–	–	–	–	–	169.0	–	2.0	–	171.0
Brazilian Atlantic uplands	–	–	–	–	–	–	–	55.0	–	–	–	55.0
Central southern Brazilian uplands	–	–	–	–	–	–	–	30.0	–	9.0	–	39.0
Eastern Andean foothills and piedmont	–	–	–	6.0	5.0	22.0	6.0	–	–	–	–	39.0
Total uplands	–	–	32.0	6.0	5.0	22.0	22.0	426.0	29.0	13.0	–	555.0
Total humid tropics	18.0	27.0	66.0	86.0	16.0	70.0	70.0	686.0	44.0	39.0	31.0	1,153.0

Sources: A. C. S. Wright and J. Bennema, *The Soil Resources of Latin America*, FAO/UNESCO Project, World Soil Resources Report no. 18 (Rome: FAO, 1965); and K. J. Beck, *Soil Map of South America 1:5,000,000*, FAO/UNESCO Project, World Soil Resources Report no. 34 (Rome: FAO, November 1968).

Note: Dashes indicate "not applicable."

[a]See map 1.

Table 3.- Inventory of humid tropical land resources, by country, according to suitability for land use. From: M. Nelson. The Development of Tropical Lands. Resources for the Future (Johns Hopkins, 1973).

Country	Soil areas according to suitability: Cropping: Alluvial[a]	Hydromorphic[b]	Good upland[c]	Marginal-low fertility[d]	Marginal-shallow or steep[e]	Total	Pasture or plantations[f]	Forestry or reserve	Total
Mexico	← 6.7 →		← 11.4 →						18.1
Central America	-	-	-	-	-	2.3	5.2	18.5	26.0
South America									
Colombia	3.6	6.3	1.5	20.2	0.4	32.0	69.4		101.4
Ecuador	0.1	0.6	0.4	4.8	0.1	6.0	15.3		21.3
Peru	0.1	2.7	1.6	17.2	0.4	22.0	55.1		77.1
Bolivia	0.7	10.8	0.6	12.3	2.2	26.6	52.2		78.8
Argentina	2.7	2.3	3.1	5.7	1.7	15.5	15.2	6.5	37.2
Paraguay	0.7	2.8	4.2	7.1	0.7	15.5	14.8	10.4	40.7
Brazil	3.2	25.4	21.8	174.4	18.5	243.3	333.3	170.1	746.7
Venezuela	0.2	5.7	2.3	17.1	5.0	30.3	[illegible]	[illegible]	[illegible]
Total South America	11.3	56.6	35.5	258.8	29.0	391.2	767.1		1,158.3

Sources: A. C. S. Wright and J. Bennema, *The Soil Resources of Latin America*, FAO/UNESCO Project, World Soil Resources Report no. 18 (Rome: FAO, 1965); and K. J. Beek. *Soil Map of South America 1:5,000,000*, FAO/UNESCO Project, World Soil Resources Report no. 34 (Rome: FAO, November 1968).

Note: Dashes indicate "not available."

[a]Soils developed from recent deposits and located in floodplains or deltas. Characteristics of the soils depend on their parent material.

[b]These soils are found on flat or depressed landscapes with little or no runoff where drainage presents a problem.

[c]These soils occur on undulating or level topography, are well drained, are not susceptible to serious erosion, and have medium-high natural fertility.

[d]These soils are of the upland type but with very low natural fertility. With appropriate crops and fertilizer, reasonable yields may be expected.

[e]These soils pose special problems for agricultural use due to shallowness or slope, heavy texture or sandiness. They occur primarily in highland areas and are susceptible to severe erosion.

[f]These soils are unsuited to normal crop production because of major limiting factors such as steep topography, poor drainage, low fertility, sandiness, heavy texture, and rock outcrops or stones.

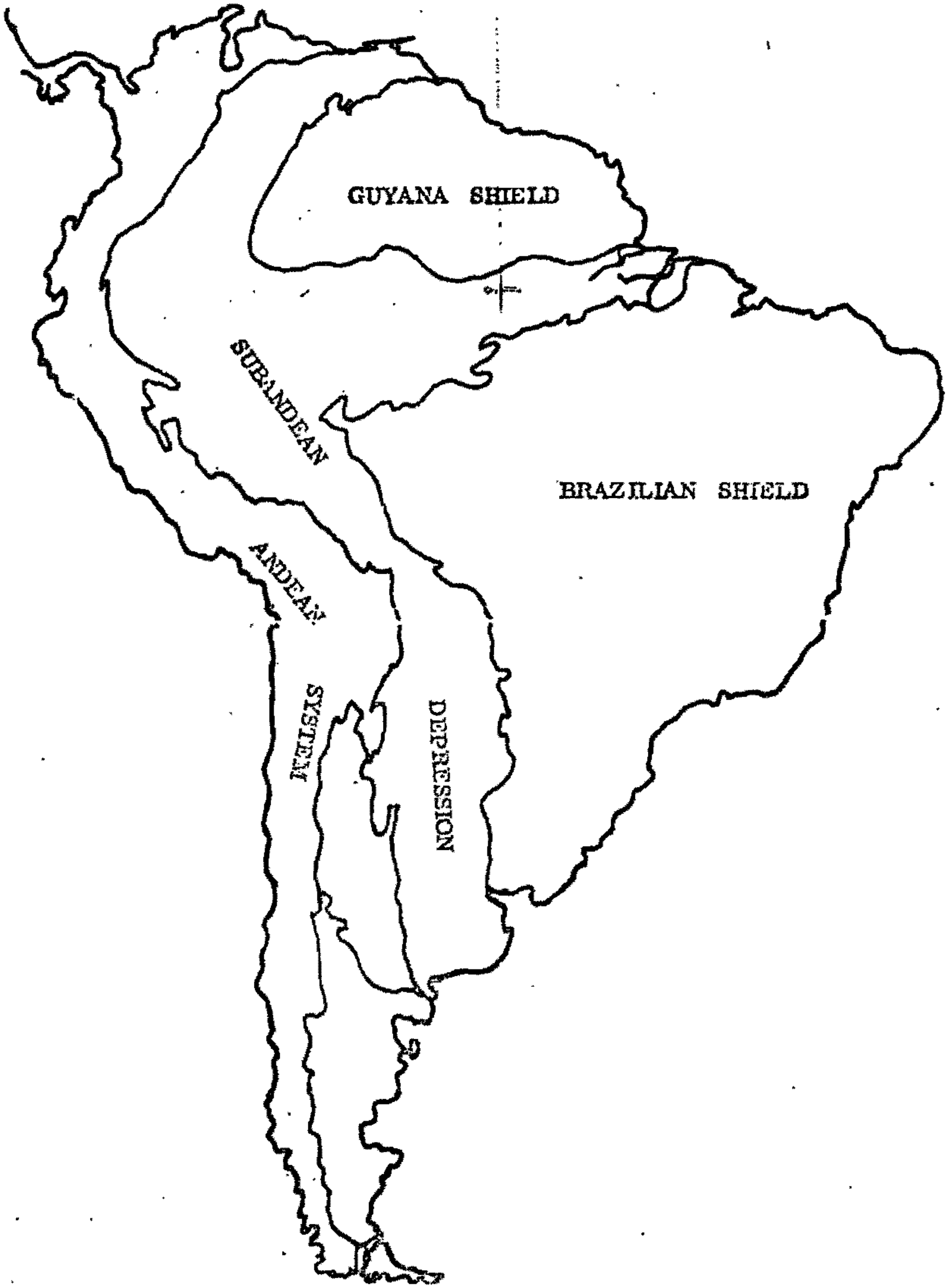

Fig. 1.- Major geotectonic regions of South America. (From: World Soil Resources Report No. 34: Soil map of South America. K. J. Beek. FAO, Rome 1968.

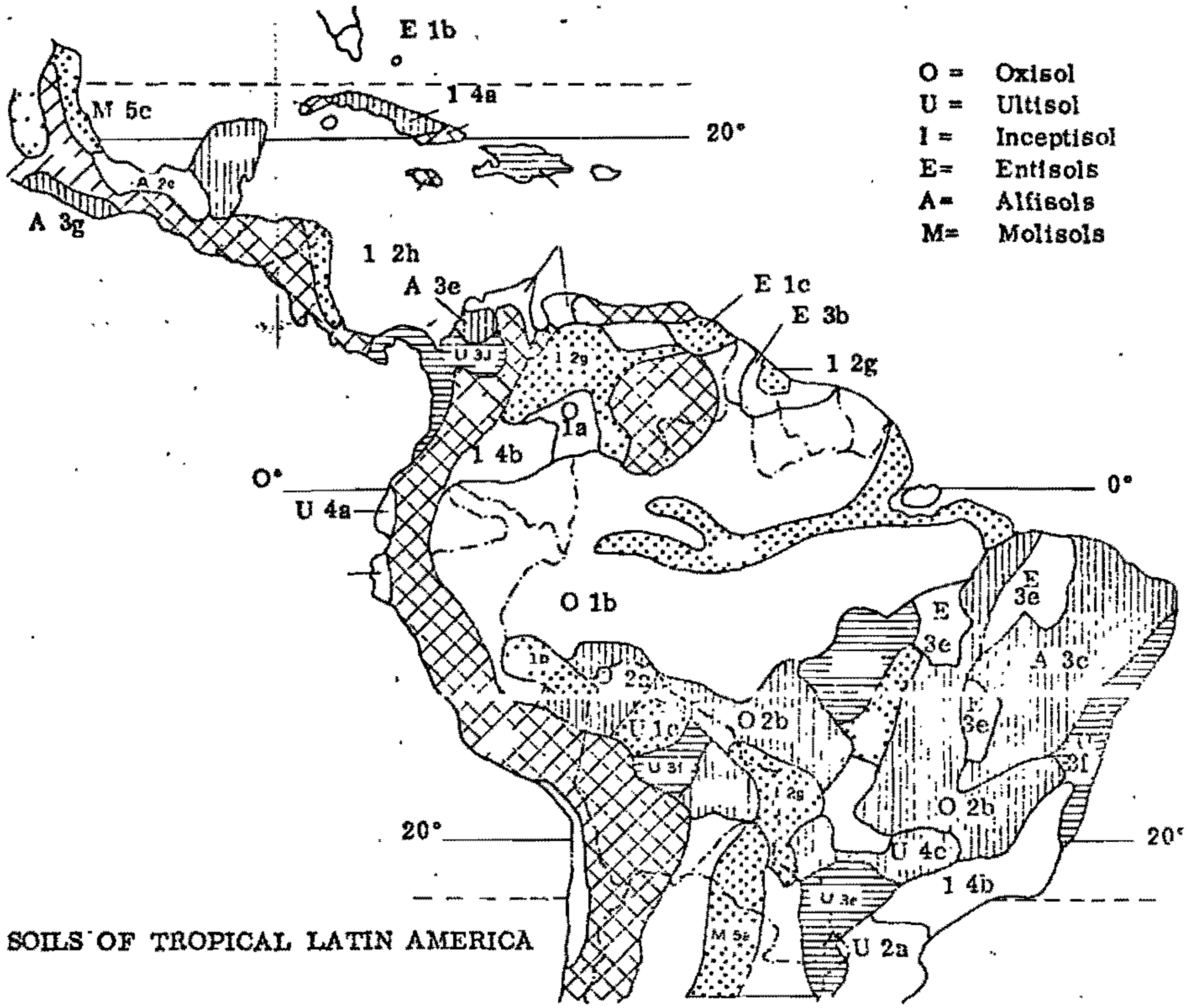

Fig. 2.- Major soil groups of Latin America. (Adapted from a 1971 manuscript soil map prepared by the Soil Geography Unit, Soil Conservation Service, USDA).

Fig. 3.- Rainfall distribution in South America. Annual Precipitation, mm. (Adapted from: Agricultural Geography of Latin America. 1958 Misc. Pub. No. 743, FAS, USDA Washington).

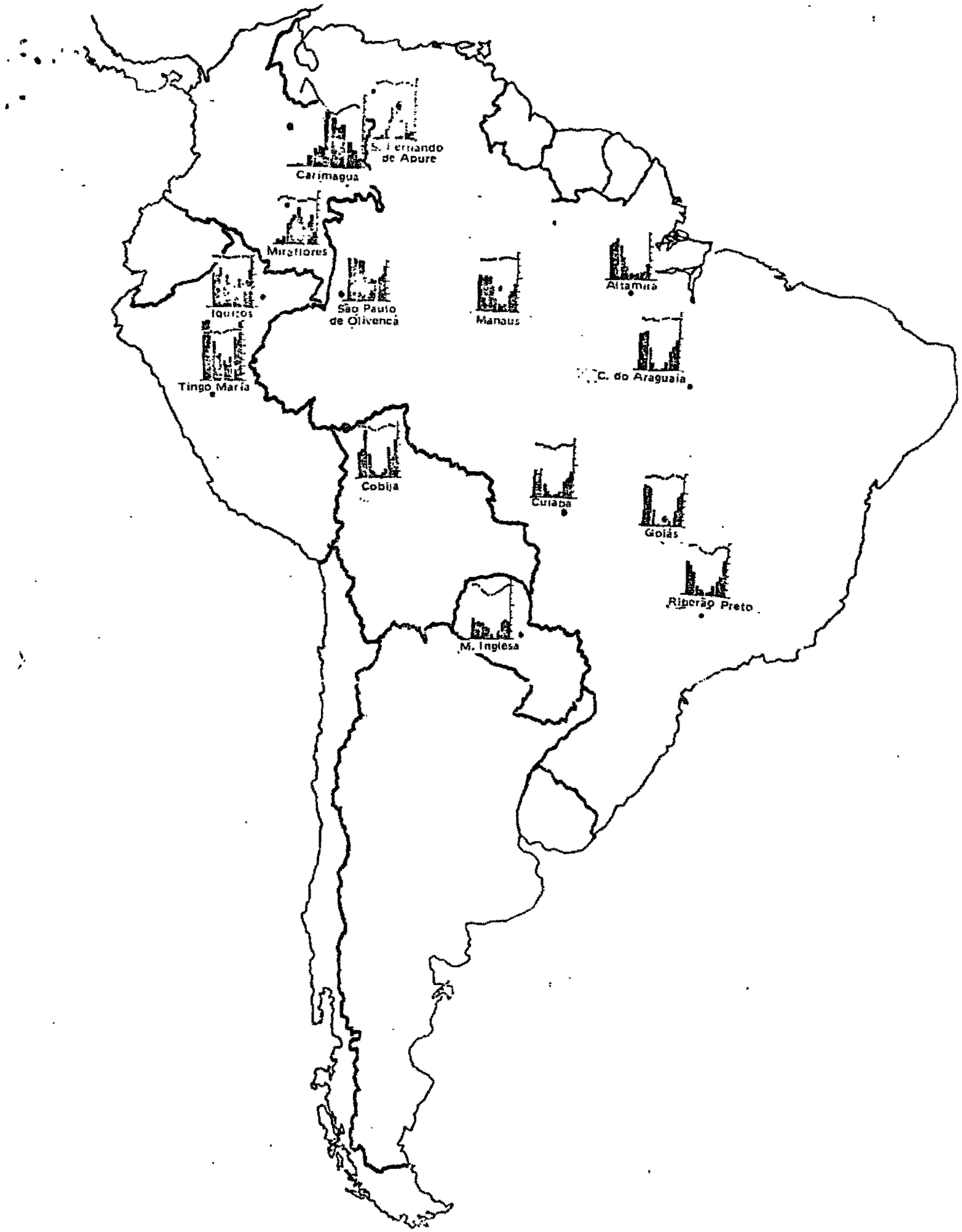

Fig. 4.- Rainfall distribution at selected sites in South America. (Adapted from: Agricultural Geography of Latin America. Misc. Pub. No. 743. 1958 FAS, USDA Washington.)