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A STUDY OF THE ECOSYSTEMS OF CENTRAL-WEST BRAZIL

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RESUME

The land systems survey of Central-West Brazil based on satellite imagery with infield checking as a part of CIAT's beef cattle project's Impact Area Survey has virtually been completed. Some highlights of the survey were:

1. The use of the total wet season estimated potential evapotranspiration provided a climatic criteria for the zonation of native vegetation.

2. Of the 245 million ha studied, 60% or 146 million ha were savannas. These fell into completely different categories for beef cattle production; 126 million ha were well drained savannas, and 20 million ha were seasonally flooded savannas.

3. Whilst one soil type often predominated in any one land system, there were invariably significant minor soil intrusions with defferences both in terms of moisture relationships and native fertility.

4. The lack of soil moisture during the dry season on the well drained lands would indicate a need for a more vigorous search for drought tolerant forages.

5. Al toxicity was common in the savanna soils. A new equation was developed to enable farmers apply lime more scientifically to overcome this problem. This should save farmers many millions of dollars in the years to come.

6. Soil mineral deficiencies were common throughout the region, especially phosphorus. Relatively small applications of P appear to be sufficient to the satisfactory growth of many currently used forages.

7. The computerization of the survey data as a data bank, should provide an ongoing facility for both scientists and economists alike.

INTRODUCTION

The region referred to as the central-west of Brazil is shown on Figure 1. This was the first area chosen for study as a part of CIAT's beef cattle project's Impact Area survey, as the generalized vegetation maps of the FAO-UNESCO Soil Maps of the World (1971, 1975) indicated that about 60% of the Oxisol and Ultisol savannas where cattle production was taking place were found in this region. It extends over 245 million ha of land. The published information relating to the climate, landscape, vegetation and soils of these lands was far from comprehensive, and had not been reduced to a common base.

The objectives of the survey were:

1. To classify and map the land resources of the Oxisol and and Ultisol lands as a basis for CIAT's beef cattle program's technological development and transfer strategy.
2. To identify geographical priority areas for technological innovation through economic appraisal.

The products of the survey were specified as:

1. The compilation of a data bank containing:
   a) Maps at a scale of 1:1,000,000 showing land systems.
   b) Climatic, landscape and soil information of individual land systems.
   c) Information on selected grasses and legumes suitable for cultivation.
   d) Information on animal management and disease problems.
   e) Bibliographical references and abstracts.
2. Reports summarizing the land information and the geographically oriented appraisal of priority areas for beef cattle work according to the economic studies.

METHODOLOGY

In order to provide a geographic summary of the land resources, it was decided to modify the land systems approach developed by Christian and Stewart(1953) in their study of the land resources of the Katherine-Darwin region of Northern Australia.

For this study, a land system was defined as "an area or group of areas throughout which there is a recurring pattern of climate, landscape and soil". These environmental parameters classify in the following categorical order to form a true <u>land classification</u>:

1. Climate
   - a) Radiant energy received
   - b) Temperature
   - c) Potential evapotranspiration
   - d) Water balance
   - e) Other climatic factors
2. Landscape
   - f) Land-form
   - g) Hydrology
3. Soil
   - h) Soil physical characteristics
   - i) Soil fertility characteristics

The water balance analysis was carried out using Hargreaves' (1977) method. Utah State University, (Drs. Geoge Hargreaves and Karl Hancock), was subcontracted to carry out this work. An example is shown in Table 1.

Satellite imagery, ERTS and LANDSAT, with aerial and land reconnaissance was used in the definition of landscape patterns.

Soil physical properties were categorized using a modification of the technique described by Mansfield(1977) to facilitate computer comparison of data.

Soil chemical characteristics likewise were categorized to enable their description in terms such as The Soil Fertility Capability Classification system developed by Buol and his co-workers(1975) in North Carolina.

All the above information was recorded on formats prior to storage in the computer data bank.

The Data Bank.

The collated data for the land systems has been recorded on magnetic tape to provide a facility for potential users of the study. Apart from making detailed information available for any part of the region, selected data may be compared and correlated. Additionally, a map print-out system has been devised to enable the automatic compilation of maps according to given criteria. The system can be updated as new information comes to hand. Ing. Jorge Porras of CIAT's computer center was responsable for devising the system.

The Economic Studies.

Economic studies of the region are under way by Dr. G.A. Nores and his fellow economists to help define priorities in the development of beef cattle technology for the region. This work will be complemented by the field studies of managemental practices to help with the identification of production problems being carried out by Dr. Ingo Kleinheisterkamp and his co-workers.

The study was carried out as a joint venture with EMBRAPA (Empresa Brasilera de Pesquisas Agropecuarias),with Dr. Luis Azevedo as EMBRAPA's co-ordinator. It was started in June 1977, and the geographical aspects are now available to investigators via CIAT's computer center.

HIGHLIGHTS

Climate

Data from 83 meteorological stations east of the Bolivian border were analysed and mapped. It was noted that the well drained savanna regions are associated with a 4^{+} to 6 month dry season. Of particular interest was the observation that the total wet season (months with a Moisture Availability Index greater than 0.33) potential evapotranspiration throughout the savannas, is remarkably constant. The Moisture Availability Index (MAI) is a term defined by Hargreaves(1977) as a moisture adequacy index at the 75 percent probability level of precipitation occurrence (or dependable precipitation, PD). It is defined as dependable precipitation divided by potential evapotranspiration, ETP. The equation is:

$$MAI = \frac{PD}{ETP}$$

Table 2 summarizes this information for 25 meteorological stations found in the dry land savanna regions.

Potential evapotranspiration ranges from 923 to 1112mm, with a mean of 1001 mm and a standard deviation of 56 mm. It is logical that the potential evapotranspiration during the wet season of the year, which in effect is a measure of the energy available for plant growth or the multiplicant of solar radiation and temperature, should correlate with natural vegetation cover, providing other factors affecting the ecosystem such as soil fertility are relatively constant.

Landscape.

Central-west Brazil shows spectacular contrasts between flat tablelands, hills and valleys and lowland plains. These major formations within which the landsystems have been delineated have been summarized on a small scale physiographic.. (Fig.2).

A speedy flight throughout the region starting from Brazilia would show the following major formations:

a) The Pratinha surface highlands. Savanna or Cerrados covered hills and tablelands ranging from 1000 to 1200 mts in altitude.

b) Flighing northwards, the Tocantis Highlands. Broken, hilly terrain, still covered in savanna.

c) Continuing northwards, the Tocantis peniplains, lowland savannas.

d) Turning westwards,the lowland Xavantina complex, seasonally inundated savannas.

e) Continuing to the west, the Northern Matogrosso forested tablelands. Semi-evergreen Amazonian forests.

f) Swinging southwards, the Northern Matogrosso sandy savannas, at about 2000' altitude.

g) Eastwards to Caceres. Mainly forested alluvial plains.

h) Eastwards across the calcareous hills that form a great arch to the north and west of Cuiâba; mainly savannas.

i) Further eastwards and over the Alcantilados Tableland. A great plateau formed from sandstones, mainly covered by savannas.

j) Further eastwards still,as far as Goiania lying in the so-called (and probably misnamed Goiania Depression), savannas and forests.

k) Southwards to the Parana river as far as Tres Lagoas; mainly savannas.

l) Once again westwards across the sand-covered basaltic plateau with savannas, to

m) A little south of Campo Grande, savannas.

n) Due south to Dourados and forested lands.

o) And finally northwards and westwards to the pantanal, an area of seasonally flooded savannas.

Clearly, there are two completely different land circumstances for cattle production on the Oxisol and Ultisol savannas mapped.

The first is characterized by cattle production on well drained lands, principally Oxisols, where the major limiting factor to production is lack of palatable fodder during the dry season. These are acid soils with an oxic subsoil horizon or a horizon containing significant proportions of Fe and Al sesquioxides.

The second land circumstance is characterized by cattle production on poorly drained lands with mainly Ultisols on flat topography. These are acid soils with a heavy textured subsoil horizon that impedes drainage under a lighter textured topsoil. With the onset of the wet season, the topsoil very quickly becomes saturated with water and the land generally inundates to the extent that cattle must be shifted to higher lands. Often the availability of higher lands within reasonable walking distance is limited and a shortage of wet season fodder results. Nevertheless, at the present time, such lands appear to be carrying more stock per unit area than the well drained lands, and are well thought of by cattle producers.

In central-west Brazil, approximately 52% or 126 million ha would classify as well drained (mainly Oxisol) savannas, 8 % or 20 million ha as seasonally flooded (mainly Ultisol) savannas and the remaining lands as other formations including 21 million ha of Entisol (sandy) caatingas.

Vegetation

The literature review indicates that considerable time and effort has been spent studying the Brazilian savanna lands. Nevertheless, even recent vegetation maps have failed to depict the area of poorly drained savannas along the Araguaia river in central Brazil.

There is a varying vegetation gradient throughout the dry land savannas, or "cerrados". The locally recognized physiognomic forms are usually described as Campo Limpo (grassland), Campo Sujo (grassland with occasional shrubs), Campo Cerrado (open savanna), Cerrado (closed savanna with low, open tree forms) and Cerradao (closed savanna with higher, more closed tree forms).

Terminology and specific descriptions vary from author to author, and only a few workers such as Goodland (1969) have described the physiognomic types in quantitative terms such as percent canopy cover, component numbers and heights. Fig.3 shows the typically distorted semi-deciduous xeromorphic shrubs and small trees.

An excellent account of the Cerrado vegetation has been given by Eiten (1972) who summarized existing knowledge and notes "within its own climatic region, the Cerrado is adapted to poor, well drained, senile soils". Nothwithstanding, there is a considerable controvery as to the origin of cerrados vegetation, the background of ehich is provided by Goodland (1970). Hill (1965) summarized various authors' opinion according to their general bias in terms of climatic, pedologic or edaphic, geomorphic and biotic, and anthropic or combinations of these. The present study has clearly shown that the Cerrados vegetation is only found in the climatic zone where the total wet season evapotranspiration ranges from about 900 to 1050 mm. Within the Cerrados, the fertility gradient tends to follow the physiognomic form. This was first shown by Goodland (1969,1971) and is clearly illustrated by Table 3 which has been taken from Lopes and Cox (1977).

An important feature common to the Cerrados is that many tree and shrub species stay green even during the latter part of the dry season. Rawitsher et al (1943) and Ferri (1944), have shown that these plants transpire normally. However, neither they nor subsequent workers have made estimations of total leaf area transpiring as a percentage of complete vegetative cover; further, their findings on soil moisture and water table heights are clearly site specific. Certainly, the underbrush of grasses dries out soon after the start of the dry season, due to the first meter or so of the soil drying out almost completely.

It was interesting to observe that beef cattle actively browse cerrado shrubs and trees especially during the dry season. Neto et al(1976) have shown that at the height of the dry season (September) over 60% of animal intake comes from shrub and tree browsing. From a cattle production point of view, the supply of protein adequate forage during the dry season is critical on the well drained lands. Both Andropogon gayanus cultivars and Stylosanthes capitata cultivars were seen growing well in the Cerrados in September.

Soils.

Virtually all the land systems mapped contain areas of contrasting soils; these contrasts have been accounted for, at least in so far as major differences are concerned, by describing the soils of the several landscape facets within any one land system separately.

Water-table depths vary in the well drained savannas, but as indicated by Eiten(1972) are generally deep, ranging from 10 to 30 meters. The moisture holding capacities of the Oxisols as reported by the same author, are also quite low, in spite of relatively high clay contents. However, within any one land system, there are often significant areas of soil, such as that following along streams, with completely different physical (and chemical) characteristics that might be used to help alleviate dry season water stress. The opposite is true for the areas of poorly drained landscape.

The variability of soils within landscape units, in so far as chemical properties are concerned, has been illustrated by Lepsch et al(1977) in their study of the Occidental Plateau, Sao Paulo. A minor calcareous intrusion described was clearly very significant to cattle nutrition.

As a general trend, there is a fertility gradient between the savannas and adjacent forests. The same is true within the savannas; as already noted, Table 3, those with a higher biomass generally have a higher fertility status.

In assessing soil fertility, the approach followed was that of:

a) The identification of toxicity problems, particularly Al, Mn and Fe.

b) The subsequent identification of deficiency problems.

Throughout much of the savanna region, soil Al saturation levels were found to be high. Further, it was noted that many farmers were spending large sums of money an massive lime applications in attempting to overcome Al toxicity problems based on the neutralization of Al. However, crops and forages vary in their tolerance to Al, the degree of which may be expressed approximately in terms of the % Al saturation of the cation exchange capacity. Consequently, for many crops it is not necessary to neutralize all the exchangeable Al, but merely to apply enough lime to decrease the % Al saturation to levels that do not affect production. Therefore, to facilitate lime estimations an equation was developed with the help of the author's colleages Dr. Sanchez and Salinas, viz:

$$\text{meq Ca/100g soil required for liming} = 1.5\left[\text{Al} - \text{RAS}(\text{Al}+\text{Ca}+\text{Mg})/100\right]$$

The values for the elements on the right hand side of the equation are expressed in terms of meq/100g soil in the original complex of the unlimed soil. RAS = required % Al saturation. When the estimated lime requirement using the factor 1.5 is greater than the chemical lime equivalent of the exchangeable Al, a closer agreement to measured data is obtained by substituting the factor 1.5 by 2.

The equation can be used for estimating approximate field lime requirements by simply changing the expression meq Ca/100g soil to tons of lime/ha and multiplying the other side of the equation by the apparent specific gravity of the soil. The use of the equation requires no special soil analyses only a 1N KCl extraction for the determination of exchangeable Al, Ca and Mg. It could lead to considerable savings in the use of lime not only in the region of interest, but also in the rest of the world. It is a practical developement of CIAT's stated minimal input philosophy.

As seen from Table 3, the possibility of Mn and, or Fe toxicities can not be discounted. However, it was not possible to obtain sufficient geographically specific data to estimate the extent of these toxicities.

Apart from nitrogen, phosphorus was the most common mineral deficiency. However, for many of the forage species being cultivated in the region, relatively small applications of P_2O_5, 50kg or less, appear to give satisfactory responses once Al toxicity problems are overcome.

Zinc deficiency has been reported, but only in the context of over-liming, although soil levels are often low,as are Mg, K and S levels. McClung and de Freitas(1959) have reported a sulphur deficiency. B, Mo and even Mn levels may prove to be deficient in some soils for some crops. Soil Na levels are very low in the Cerrados soils, and this undoubtedly indicates the need for the use of common salt in helping to improve beef cattle nutrition in those regions.

The Land Systems Map and the Data Bank.

Fig. 4 provides an example of the Land Systems Map of Tocantis, one of 9 maps covering the region, which has been produced as an over-lay to the topographical maps of Brazil. These same maps have been stored on magnetic tape for computer reproduction. The computer print-out will enable not one, but many different maps to be made according to specific and requested criteria.

Finally, it should be emphasized that all the basic data collected for the survey has been collated and stored on magnetic tape, and is now available to facilitate a multitude of estimations relevant to any given factor, and to enable intelligent correlations to be made between characteristics both by scientists and economists alike.

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Table 1.

An example of Hargreaves Provisional Water Balance Analysis.

Metereological Station	Porto Nacional	Goias	Lat. 10°31'	Long. 48° 43' Alt. 237 mts.

	Temp Med	H.R. Med	PCT Sol	RS Med	Prec.	Et Pot	Def Prec.	Dep Prec.	MAI
Jan.	25.3	84.	42.	471.	274.	146.	-128.	182.	1.24
Feb.	25.3	85.	40.	452.	229.	127.	-103.	151.	1.19
Mar.	25.4	85.	40.	435.	272.	135.	-137.	181.	1.33
Apr.	26.0	81.	57.	474.	150.	145.	- 5.	95.	.66
May	25.8	75.	77.	497.	36.	156.	119.	15.	.10
Jun.	24.8	67.	85.	489.	1.	145.	144.	- 9.	-.05
Jul.	24.8	62.	89.	513.	2.	157.	155.	- 8.	-.04
Aug.	26.4	53.	87.	559.	3.	178.	175.	- 8.	-.04
Sept.	27.9	57.	66.	540.	35.	172.	137.	14.	.08
Oct.	27.0	73.	52.	510.	142.	164.	23.	39.	.54
Nov.	25.9	81.	42.	468.	233.	142.	- 91.	153.	1.08
Dec.	25.5	84.	38.	447.	284.	139.	-144.	189.	1.35
Annual	25.8	74.	60.	448.	1663.	1808.	145.		

K E Y

TEMP MED	Mean temperature in degrees Celcius.
H.R. MED	Mean relative humidity in percent.
PCT SOL	Mean percentage of possible sunshine.
RS MED	Incident solar radiation estimated from PCT SOL.
PRECIP	Mean precipitation in mm.
ET POT	Estimated potential evapotranspiration.
DEF PREC	ET POT Minus PREC.
DEP PREC	(0.70 x PREC) minus 10.
MAI	Moisture availability index (DEP PREC/ET POT)

Table 2. Potential evapotranspiration - Cerrado region, Brazil.

Stations	Latitude (S)	Longitude (W)	Potential Evapotranspiration
			mm.
Carolina	5°30'	43°21'	1058
Imperatriz	5°32'	47°30'	1110
Belo Horizonte	19°56'	43°56'	954
Curvelo	18°46'	44°26'	929
Frutal	20° 2'	48°56'	1098
Itabira	19°37'	43°13'	984
Monte Alegre	18°52'	48°52'	1024
Muriae	21° 8'	42°22'	1050
Oliveira	20°41'	44°49'	997
Paracatu	17°13'	46°52'	940
Pedra Azul	16° 0'	41°17'	952
Catalao	18°10'	47°58'	987
Formosa	15°32'	47°18'	935
Goiania	16°41'	49°17'	989
Luziania	16°15'	47°56'	995
Pirenopolis	15°51'	48°58'	934
Porto Nacional	10° 3'	48°43'	998
Taguatinga	12°16'	45°54'	1112
Caceres	16° 3'	57°41'	1028
Cuiaba	15°36'	56° 6'	1058
Meruri	15°43'	51°44'	1024
Pres. Murtinho	15°38'	53°55'	965
Goias	15°56'	50° 8'	989
Paraná	12°33'	47°47'	923
Franca	20°33'	47°26'	1002
Minimum			923
Maximum			1112
Mean			1001.4
Standard deviation			55.9

Table 3. Relationship between types of native cerrado vegetation in central Brazil and average topsoil characteristics. [a]

Soil Property	Campo limpo 64[b]	Campo cerrado 148[b]	Cerrado 255[b]	Cerradão 45[b]	Forest 16[b]
pH (H_2O)	4.87a	4.94ab	5.00b	5.14b	5.28c
pH (KCl)	4.16a	4.25b	4.25b	4.32b	4.35b
Δ pH	-0.71ab	-0.69a	-0.76bc	-0.82dc	-0.93d
Organic matter (%)	2.21a	2.33a	2.35a	2.32a	3.14b
Exch. Ca (meq/100 cc)	0.20a	0.33ab	0.45b	0.69c	1.50d
Exch. Mg (meq/100 cc)	0.06a	0.13a	0.21b	0.38c	0.55d
Extr. K[c] (meq/100 cc)	0.08a	0.10ab	0.11b	0.13b	0.17c
Exch. Al (meq/100 cc)	0.74a	0.63a	0.66a	0.61a	0.78a
Eff. CEC (meq/100 cc)	1.08a	1.19a	1.43b	1.81c	3.00d
Al saturation (%)	66a	58b	54b	44c	40c
Extr. P[c] (ppm)	0.5a	0.5a	0.9b	2.1c	1.4bc
Extr. Zn[c] (ppm)	0.58a	0.61a	0.66b	0.67b	1.11c
Extr. Cu[c] (ppm)	0.60a	0.79ab	0.94b	1.32c	0.95b
Extr. Mn[c] (ppm)	5.4a	10.3b	15.9c	22.9d	24.1d
Extr. Fe[c] (ppm)	35.7a	33.9a	33.0a	27.1b	37.2c
Clay (%)	33a	36a	34a	32a	37a
Silt (%)	20a	16b	15b	16b	16b
Sand (%)	46a	48a	51a	53a	47a
Hue	7.3YRa	6.7YRa	5.4YRb	4.4YRc	4.4YRc
Value	4.3a	4.2a	3.8b	3.5c	3.6bc
Chroma	4.5a	4.7a	4.9a	4.7a	5.7a

Source: Lopes and Cox (1977).

[a]Means for each line not followed by the same letter are significantly different at the 0.05 probability level.

[b]Number of samples.

[c]Extracted by 0.05 N HCl + 0.025 N H_2SO_4.

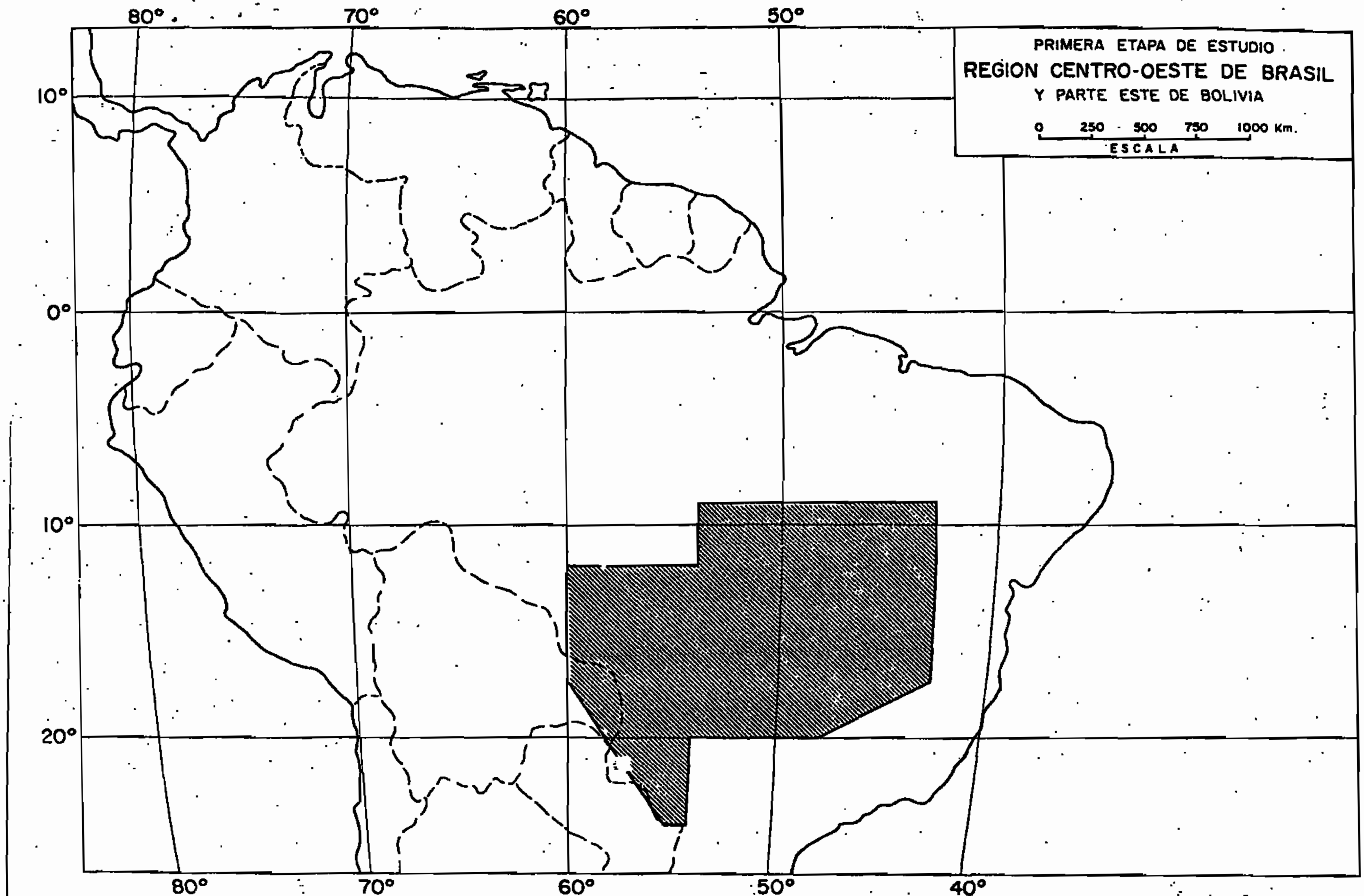

Figure 1. Region Centro-Oeste de Brasil

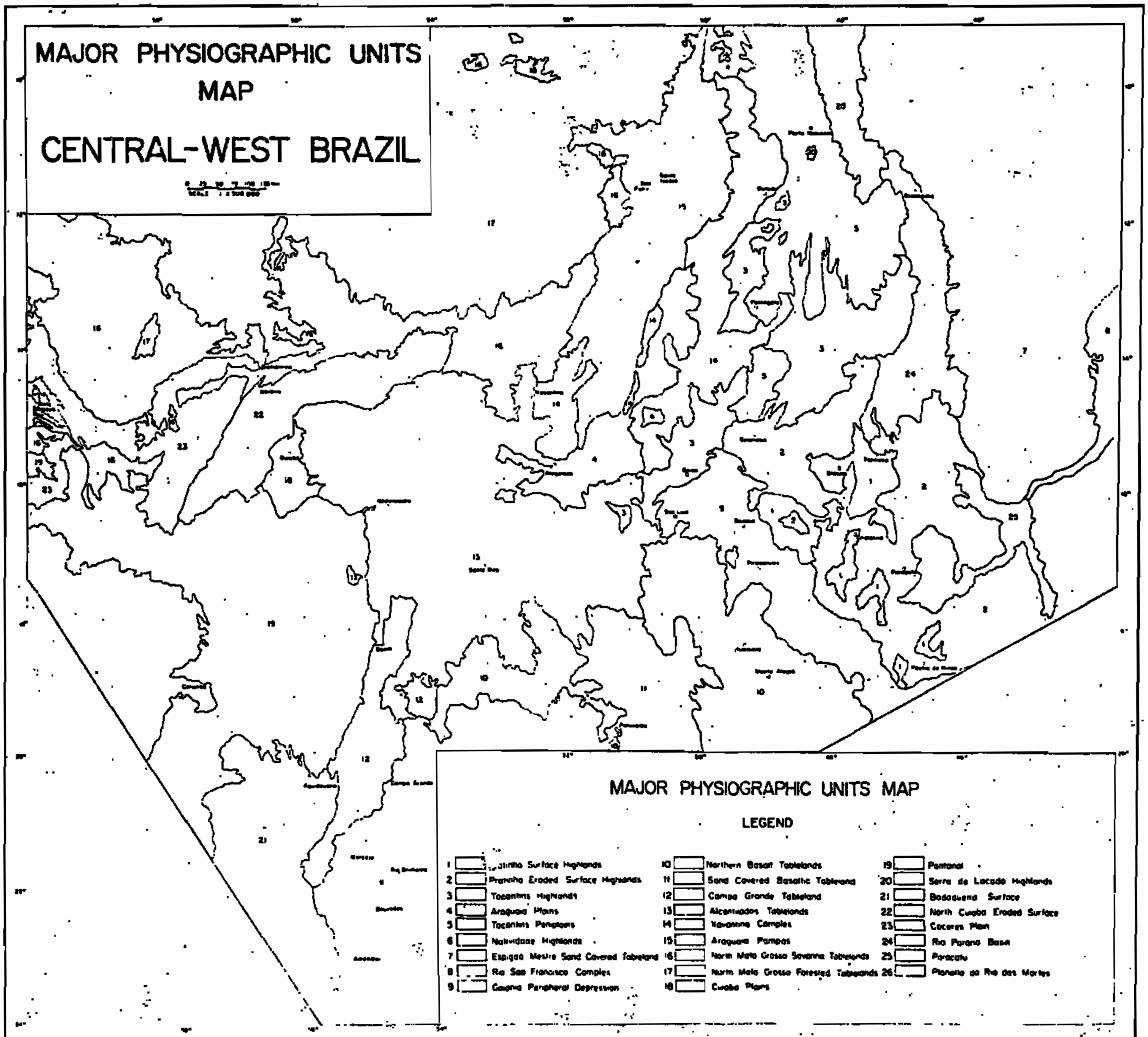

Figure 2. Central-West Brazil.

Fig. 3. The Campos Cerrados Vegetation.