BRAZILIAN PROBLEM SOILS : DISTRIBUTION, CHARACTERISTICS AND UTILIZATION

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Summary

Five main ecological dominions were defined in Brazil. In those areas occurs a broad variety of soils which in their majority present some type of limitation to agricultural production. About 86% of the Brazilian surface is covered by what can be called problem soils. Among them Latosols (Oxisols), Dystrophic Red-Yellow Podzolics (Ultisols), Quartz Sands (Entisols) Lithosols (Inceptisols), Planosols (Ultisols, Alfisols, Mollisols) predominate. Maps showing the approximate distribution of these soils are presented. Low nutrient status, acidity, high aluminum saturation (Latosols, Dystrophic Red-Yellow Podzolics, Quartz Sands and some Cambisols, Lithosols, Planosols and Hydromorphic Soils); shallowness (Lithosols, Cambisols); low water retention capacity (Quartz Sands and some Latosols); excess of water (Hydromorphic Soils, and some Planosols) are some of the main natural constraints to crop production presented by these soils. In the last few years the expansion of the agricultural frontier has become strongly dependent on the use of stressed soils, where a great number of annual and perennial crops has been cultivated.

Introduction

Brazil is a continental size country. With an area of 8.5 million km^2 it extends from about 4° N to 33° S of latitude and from 36° to 72° of longitude. Within such limits it is understandable that there exists a broad variety of climate (Brazil, Escritório de Meteorologia, 1969), lithology, topography, vegetation and consequently, soil types.

Latosols, Red-Yellow Podzolics, Cambisols, Lithosols, Quartz Sands, Planosols, Ground-Water Laterites, Humic Gley, Low Humic Gley, Podzols, Brunizems, Terra Roxa Estruturada, Vertisols are some of the most important soil types found in Brazil. Among them prevail the ones which present some type of impairment for agricultural use. The limitations may include chemical, physical, mineralogical or any combination of these three soil properties. Soils which present such limitations are considered here as "Problem Soils".

In this paper, are presented some general comments about the different regions of Brazil, in terms of climate, lithology, geomorphology, vegetation and soils, with the objective of introducing the reader to the environmental conditions which may have affected the development of the soils. Then the most important soils, which were considered problem soils are described and their occurrence and most frequent use pointed out. We did not consider all problem soils which have been recognized in Brazil but only the ones, that due to the extent of their area are considered the most important. So, soils such as Solonchaks, Solonetz, Vertisols, Rendzinas, which occur in relatively small areas were not considered. The soils were labeled according to the Brazilian System of Soil Classification (Bennema and Camargo, 1964) and correlated to the Soil Taxonomy System (Table 1).

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Table 1 Approximate correlation of Brazilian system with soil taxonomy and FAO/UNESCO legend

Brazilian System	Soil Taxonomy	FAO/UNESCO
Latosols	Oxisols	Ferralsols
Yellow Latosol	Umbriorthox	Xanthic Ferralsol
	Plinthaquox	Plinthic Ferralsol
		Humic Ferralsol
Red-Yellow Latosol	Acrustox	Orthic Ferralsol
	Haplorthox	Acric Ferralsol
Dark-Red Latosol	Acrustox	Orthic Ferralsol
	Haplorthox	Acric Ferralsol
Dusky-Red Latosol	Acrothox	Rodhic Ferralsol
	Haplorthox	
Red-Yellow Podzolics	Ultisols	Acrisols
Dystrophic Red-Yellow Podzolic	Hapludult	Orthic Acrisol
	Paleustult	Ferric Acrisol
		Humic Acrisol
		Nitosols
		Dystric Nitosol
Eutrophic Red-Yellow Podzolics	Alfisols	Luvisols
	Rodoxeralf	Chromic Luvisol
	Haploxeralf	Orthic Luvisol
	Tropudalf	Ferric Luvisol
	Paleustalf	Nitosols
		Eutric Nitosol
Brunizems		
Brunizem	Mollisols	Phaeozems
	Haplustoll	
	Argiustoll	Haplic Phaeozem
		Luvic Phaeozem
Cambisols	Entisols	Cambisols
Dystrophic Cambisol	Tropofluvent	Dystric Cambisol
	Inceptisols	Ferric Cambisol
	Fragiaquept	Humic Cambisol
	Haplaquept	
Eutrophic Cambisol	Eutrochrept	Calcic Cambisol
Podzols	Spodosols	Podzols
Podzol	Cryohumod	Humic Podzol
	Tropaquod	Gleyic Podzol
Quartz Sands	Entisols	Arenosols
Grey Quartz Sand	Quartzipsamment	Albic Arenosol
Red-Yellow Quartz Sand	Udipsamment	Ferralic Arenosol
Regosols	Entisols	Regosols
Dystrophic Regosol	Cryopsamment	Dystric Regosol
Eutrophic Regosol		Eutric Regosol
Lithosols	Entisols	Lithosols
Lithosol	Ustorthent	Lithosol
		Ranker

Brazilian System	Soil Taxonomy	FAO/UNESCO
Planosols	Ultisols	Planosols
Planosol	Albaquult	Dystric Planosol
	Molissols	Eutric Planosol
	Paleustoll	Humic Planosol
		Mollic Planosol
		Solodic Planosol
Vertisols	Vertisols	Vertisols
Vertisol	Pelludert	Calcaric Vertisol
		Pelic Vertisol
Solonetz	Aridisols	Solonetz
Solonétz	Nadurargid	Orthic Solonetz
	Natrargid	Mollic Solonetz
	Mollisols	
	Natriboroll	
Solonchaks	Inceptisols	Solonchaks
Solonchak	Halaquept	Gleyic Solonchak
Ground-Water Laterites	Alfisols	Luvisols
Ground-Water Laterite	Plinthustalf	Plinthic Luvisol
	Inceptisols	Gleysols
	Plinthaquept	Plinthic Gleysol
		Acrisols
		Plinthic Acrisol
Gley	Inceptisols	Gleysols
Humic Gley	Fragiaquept	Dystric Gleysol
Low Humic Gley	Haplaquept	Eutric Gleysol
	Humaquept	Humic Gleysol
		Mollic Gleysol
Thiomorphic Gley	Entisols	Fluvisols
	Sulfaquent	Thionic Fluvisol
Grey Hydromorphic	Ultisols	Gleysols
Grey Hydromorphic	Albaquult	Calcaric Gleysol
Rendzinas	Mollisols	Rendzinas
Rendzinas	Calciustoll	Rendzina
Alluvial	Entisols	Fluvisols
	Udifluvent	Dystric Fluvisol
Organic	Histosols	Histosols

The main ecological dominions of Brazil

Five ecological dominions are (Ab'saber, 1971; 1977) identified in the Brazilian landscape: one located in the subtropical and four in the intertropical zone. They are the result of the interaction of many environmental conditions and correspond to the core area of well defined biomes: equatorial, tropical and subtropical forests; xerophilous formations and savannas. The contact between them is not always direct but through transitional areas, or inclusions..

The areal distribution of these units is shown on Fig. 1. Some of the climatic (Table 2), geological, geomorphological, vegetative cover and soil characteristics are briefly presented.

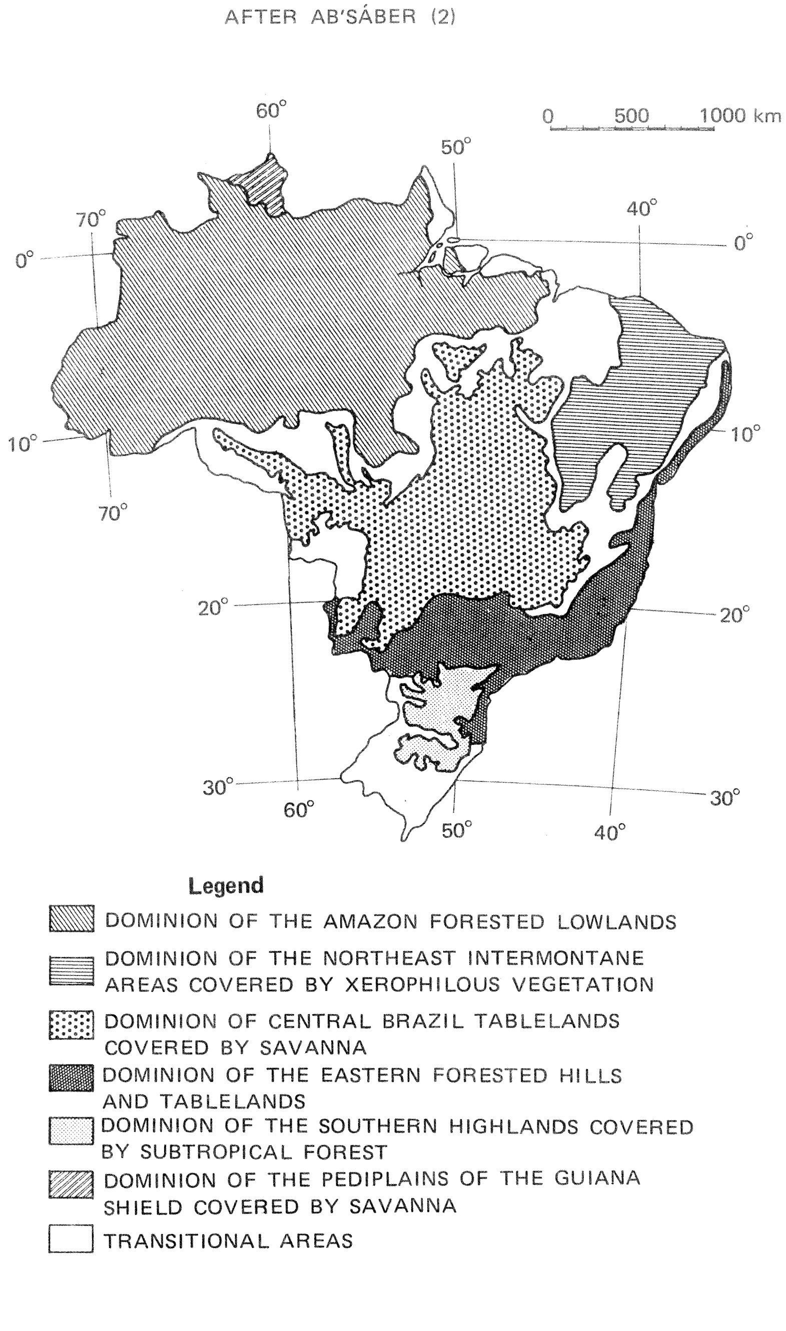

Fig. 1 Brazilian ecological dominions.

Table 2 Precipitation and temperature characteristics of the Brazilian ecological dominions

Brazilian Ecological Dominions	Annual mean Precipitation mm	Annual mean Temperature °C	Minimum mean Temperature °C	Minimum mean Temperature °C	Absolute minimum Temperature °C	Absolute maximum Temperature °C
DOMINIONS OF THE AMAZON FORESTED LOWLANDS						
Eastern sector	2.500–3.000	25	21	32	14	39
Central and western sectors	1.750–2.000	26	22	30	16	32
Northern sector	1.500–2.000	26	20	31	18	37
Southern sector	2.000–2.750	24	19	33	8	40
DOMINION OF THE NORTHEASTERN INTERMONTANE AREAS COVERED BY XEROPHILOUS VEGETATION						
Eastern sector	1.000–1.500	25	23	32	15	37
Central and western sectors	500– 750	25	22	30	16	39
Northern sector	1.500–1.750	26	24	30	14	38
Southern sector	750–1.000	25	19	29	10	39
DOMINION OF THE CENTRAL BRAZIL TABLELANDS COVERED BY SAVANNA						
Northern sector	1.750–2.000	24	20	34	8	40
Central sector	1.000–1.500	21	16	30	5	38
Southern sector	1.500–1.750	19	14	28	-2	29
DOMINION OF THE EASTERN FORESTED HILLS AND TABLELANDS						
Northern sector	1.250–1.750	25	20	28	12	36
Central sector						
– Coast	1.500–2.250	22	18	26	8	38
– Upland	1.000–1.250	18	14	25	0	39
Southern sector		21	12	28	2	40
DOMINION OF THE SOUTHERN UPLANDS COVERED BY SUBTROPICAL FOREST						
Northern sector	1.250–1.500	17	12	23	-5	35
Central sector	1.500–2.000	16	8	24	-8	36
Southern sector	1.750–2.000	15	10	22	-6	38
DOMINION OF THE PEDIPLAINS OF THE GUIANA SHIELD COVERED BY SAVANNA	1.500–1.750	25	21	30	18	38

1 Dominion of Amazon Forested Lowlands

The landscape of this unit is characterized by lowlands and flood plains in the central portion, bordered in the north and south by rougher relief of the Guiana and Brazilian Shields (Domingues *et al.* 1968). The lithology of the lowlands is represented mainly by Tertiary and Quaternary sediments, of clayey to sandy textures. In the shields predominate Precambrian crystalline rocks and sediments of the Paleozoic. The crystalline areas are pediplained and punctuated by inselbergs showing a hilly landscape. The drainage network is perennial and of great density.Here are located some of the largest rivers of the world.

This dominion corresponds approximately to the Brazilian Humid Tropics. The climate is typically equatorial with annual rainfall that may exceed in some areas 3500 mm. The dry season is more frequently of 3–4 months although in some areas there is no characterized dry period.

The vegetative cover is predominantly rain forest. This forest presents a different floristic composition and physiognomy whether it occurs on flood free, temporarily flooded, or permanently flooded areas. Other vegetative formations in this region include savannas, grasslands and "capinaranas"*.

In the areas with Tertiary and Quaternary sediments predominate Yellow Latosols and Dystrophic Red-Yellow Podzolic soils in the dry lands, and Gley and Ground-Water Laterite soils, in the floodplains. In the Guiana and Brazilian shields Dystrophic Red-Yellow Podzolics, Red-Yellow Latosols and Quartz Sands are the dominant soil types. Relatively small areas of "Terra Roxa" and Eutrophic Red-Yellow Podzolic soils occur on the southern and southeastern portions of the dominion.

2 Dominion of the Northeastern Intermontane Areas covered by xerophilous vegetation

This dominion is characterized by a semi-arid climate with annual precipitation ranging from 500 to 800 mm. There are two distinct seasons: a rainy one which is very irregular and sometimes inexistent, and another one which is very dry lasting for up to 8 months. It is not unusual however, to observe series of 2 to 3 years with precipitation well below the normal, causing severe drought.

The relief shows contrasting facets represented in the Precambrian areas (Crystalline shield) by pediplains, inselbergs, block mountains and steep ridge mountains. Mountains, plateaus of small to large amplitude are related to the Cretaceous sedimentation and pediplanation processes to the Tertiary-Quaternary. Quartz pebbles and blocks, covering the surface in many areas reveal the action of arid climate in this region. The São Francisco River is the only perennial water course in the dominion.

Vegetation is essentially of the xerophilous type, represented by deciduous trees, shrubs, annual forbs and Cactaceae.

Dominant soils are represented by the Non-Calcic-Browns followed by Litholics, Planosols and Vertisols. On the tablelands of the Cretaceous occur the Yellow Latosols and on the mountainous areas of the Precambrian, Litholic Soils and Red-Yellow Podzolics. In the Northwestern section of this dominion prevail the Eutrophic Red-Yellow Podzolics.

3 Dominion of the Central Brazil Tablelands covered by savanna

This is an area characterized by savanna-type vegetation (Cerrado). Variations of this formation include xeromorphic woodlands (Cerradão) and grasslands (Campos).

Climate is tropical continental with rainy summers and dry winters. Annual precipitation ranges between 1500 to 2000 mm but with an average dry season of 5 to 6 months (varying from 5–7 in the extreme north to 3–4 in the extreme south) (Domingues *et al.*, 1968).

The lithology of the dominion is represented by pediplained Precambrian crystalline rocks

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* A bush-type formation which occurs on Podzols in areas of high precipitation (2000 mm/year) in the western portion of the dominion.

of the Central Brazilian Plateau and by Mesozoic sediments in the northeast and southwest. Basaltic outflows significantly affected the sediments of the southwest. The relief in the sedimentary area is dominated by tablelands of varying dimensions and cuestas. In the crystalline area prevail plateaus, other highland shapes and intermontane basins with inselbergs. The most representative physiographic units of this dominion are the Central Brazilian Plateau with a mean altitude of 900 meter and the flat valleys of the São Francisco, Araguaia and Tocantins Rivers.

Red-Yellow and Dark-Red Latosols, and Quartz Sands are the dominant types of soils in the region. Other soils in the dominion include: Concretionary Latosols in the northeast, Humic and Low Humic Gley and Ground-Water Laterite soils on the valleys of the rivers draining to the Amazonic Basin; Lithosols and Dystrophic Cambisols in residual mountain formations consisting of quartzites and sericite quartzites. Also in the southwestern portion of this region, in the areas affected by basalt predominate Dark-Red and Dusky-Red Latosols, where a very intensive agriculture has developed. Finally, in relatively small but important agricultural areas (Mato Grosso Goiano), appear Dusky-Red Latosols and "Terra Roxa Estruturada" covered by seasonal forest.

4 Dominion of the Eastern Forested Hills and Tablelands

This is the western portion of the Brazilian Plateau extending from 6° of Latitude South to almost the northern border of Brazil. It is under the influence of an oceanic climate. Annual precipitation is between 1000 and 1750 mm, although in some places it may reach 4000 mm. This precipitation however, is not very well distributed along the year with dry periods that range from 1 to 4 months (Brazil, Escritó de Meteorologia, 1969). According to the extension of the dry season, vegetation varies from wet evergreen to seasonal forest (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissâo de Solos, 1958).

This dominion is characterized by three morpho-geological units: one corresponding to the Precambrian crystalline formations located on the coast border with predominant rolling to hilly topography, and mountain ranges rising over it. Here predominate Dystrophic Red-Yellow Podzolics, Red-Yellow Latosols and intergrades of those two soils. Other soils in this subunit include Eutrophic Red-Yellow Podzolics, and Eutrophic Cambisols in the northern section of the region and Dystrophic Cambisols and Lithosols in the south. The second unit is represented by a strip of sedimentary flatlands of the Tertiary with predominantly Yellow Latosols although Red-Yellow Latosols also occur in the Northeast. The third subunit consists of Cretaceous sandstones often cemented by calcium carbonate. Basic volcanic rocks may be underlying the exposed sandstones. The relief is composed of rolling uplands and cuestas. The sandstone cemented by calcium carbonate has generated sandy Eutrophic Podzolic while the sandstone without $CaCO_3$ generated Red-Yellow Latosol. From the exposed basaltic rocks, developed mainly Dusky-Red Latosols occurring also as "Terra Roxa Estruturada".

5 Dominion of the pediplained areas of the Guiana Shield covered by savanna

On the southern part of the dominion predominate pediplained areas on Precambrian rocks, covered by sandy detritic deposits. Towards the northeast the relief is mountainous, frequently showing the parent rock. On the pediplained areas appear isolated and blocky inselbergs, revealing the aridity of a period responsible for the actual landscape. In the north, table-like structures deepen toward the north where basaltic sills are present among the sediments. Basaltic inselbergs appear as residual massif on the plains.

Climate is semi-humid with annual precipitation of 1500 mm and dry periods of 4 to 5 months corresponding to the summer of the Northern Hemisphere.

Vegetation is represented by grasslands and gallery forests. Seasonal forests appear in some valleys and on the basaltic massif. Savannas occur on the Litholic Soils of the mountainous areas of the northeastern part of the dominion.

On the pediplains predominate Quartz Sand soils while on the mountainous parts of the north and northeast prevail Lithosols and rock outcrops. "Terra Roxa Estruturada" are present on the basaltic outflows.

6 Dominion of the Southern Plateaus covered by subtropical forest

A series of successive plateaus descending in a small gradient toward the Paraná river (west) characterizes this dominion. Those are Neo-Mesozoic and Tertiary planation surfaces carved on a basaltic formation. The topography varies from gently undulating to rolling. Toward the eastern border of the Plateau predominates a hilly topography in the Permo-Carboniferous areas.

The climate is humid temperate with a pronounced temperature decrease in the winter. Rains ar well distributed during the year with annual totals of 1500 – 2000 mm. Although there is no dry season, precipitation is lower in the north during the winter and in the south during the spring (Domingues *et al.*, 1968).

The vegetation in the dominion is characterized by a subtropical forest with *Araucaria angustifolia* which occurs predominantly on the valleys but appears also, on the undulating to rolling areas of the plateau associated with grasslands.

The soils developed on the basaltic surface are predominantly Dusky-Red Latosols with "Terra Roxa Estruturada" appearing on the younger surfaces.

Characteristics, occurrence and agricultural use of some of the Brazilian most important problem soils

1 Latosols

These are soils with an oxic B horizon corresponding to some type of Orthox, Ustox and Humox of the Soil Taxonomy (Estados Unidos, 1975). They are extremely weathered with kaolinite, gibbsite, amorphous minerals and iron oxide and hydroxide being the dominant clay minerals (Moniz and Jacson, 1967; Rodrigues, 1977; Souza, 1979; Weaver, 1974). Dessilication and cation leaching result in very low CEC (< 13 meq/100g of clay after correction for organic carbon) and extremely low concentration of calcium, magnesium, potassium and sodium (Table 3). Also, iron and aluminum rich Oxisols develop positively charged sites which strongly adsorb phosphates and sulfates (Hsu, 1964; Volkweiss, 1973).

The low water retention capacity, even for the clayey soils is another important characteristic of Latosols. The mineralogical composition of the clay fraction and the fact that kaolinitic particles are bound by iron oxides and hydroxides into very stable sandsize aggregates explain this behavior (Lopes, 1977).

Latosols have been mapped throughout the Brazilian territory. An estimated 40% of the country is covered with Latosols (Table 4, Fig. 2a).

Four major types of Latosols are recognized in Brazil: Yellow, Red-Yellow, Dark-Red and Dusky-Red.

Yellow Latosols occur mainly on the Amazonic Basin and on the tablelands of the humid coastal zone (Brasil, Departamento Nacional de Produçâo Mineral, Projeto RADAMBRASIL, 1973; 1974; 1975; 1976; 1977; 1978). Kaolinite, is the predominant clay mineral and molecular ratio "Ki" is usually between 1.7 and 2.1 (Jacomine, 1979a). These soils are very poor, strongly acid, usually allic and dystrophic (Table 2). The degree of agricultural use of these soils in the Amazon is very low where natural forest vegetation predominates although extensive areas of Yellow Latosols have been planted to pasture lately. Sugar cane, citrus, tobacco, corn and cassava are cultivated on these soils in Bahia coastal area. On the southeastern portion of the dominion of the eastern forested hills and tablelands, pasture has been the most common use (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1958; FAO/UNESCO, 1971).

Red-Yellow and Dark-Red Latosols occupy extensive areas in the Cerrado Region, Southeast and South regions of Brazil (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e

Table 3 Summary of selected data for some of the soils with largest occurrence in Brazil

No. of sites	Horizon	Sand %	Silt %	Clay %	pH H_2O	C %	S mg/100g	CTC of soil	V %	Al Saturation %	P ppm	SiO (Ki) Al_2O_3
Dark-Red Latosol, dystrophic, alic, clayey												
27	A	25±19	14±8	61±19	5.3±0.6	2.40±0.90	3.9±3.8	11.4±3.3	31±25	35±28	1±0	1.38±0.47
	B	23±18	12±6	65±20	5.1±1.1	0.63±0.32	0.8±0.6	4.3±1.8	17± 9	40±27	<1	1.32±0.49
Dark-Red Latosol, dystrophic, loamy												
22	A	80± 6	6±3	14± 4	5.0±0.5	0.90±0.30	1.65±1.60	5.4±1.6	28±18	42±24	3±2	1.98±0.13
	B	72± 6	8±3	20± 5	5.0±0.5	0.15±0.05	0.30±0.15	2.1±0.5	14± 5	73± 9	4±17	1.94±0.13
Red-Yellow Latosol, dystrophic, clayey												
30	A	43±15	16±9	41±11	4.0±0.5	1.40±0.50	0.6±0.6	8.5±2.6	7± 6	78±17	2±1	1.62±0.40
	B	34±13	14±7	52± 9	5.0±0.5	0.35±0.10	0.3±0.3	3.6±1.4	11± 8	68±32	<1	1.58±0.37
Red-Yellow Latosol, dystrophic, loamy												
42	A	68±10	12±8	21± 5	4.9±0.4	0.75±0.38	0.6±0.6	4.4±1.9	13± 9	60±23	1±1	1.50±0.50
	B	60±11	14±8	26± 5	5.0±0.4	0.25±0.15	0.4±0.4	2.4±0.8	15± 8	52±27	<1	1.40±0.55
Yellow Latosol, dystrophic, clayey												
15	A	44±11	20±7	36±10	4.4±0.4	1.21±0.54	0.5±0.4	8.3±3.3	7± 8	83±20	1±1	2.00±0.16
	B	40±15	18±6	42±12	4.8±0.3	0.36±24	0.3±0.4	5.2±2.1	8± 8	85±18	<1	1.91±0.08
Yellow Latosol, dystrophic, loamy												
13	A	68±74	14±4	18± 6	4.6±0.4	1.02±0.90	0.3±0.2	5.9±.43	7± 7	79±18	1±1	2.14±0.35
	B	54±10	16±3	28± 6	5.2±0.3	0.23±0.09	0.2±0.1	2.1±1.0	8± 5	77±13	<1	1.97±0.30
Dusky-Red Latosol, dystrophic, clayey												
8	A	17± 7	19±4	64± 5	5.2±0.5	2.28±0.75	6.2±5.0	13.9±4.4	40±22	26±21	2±2	1.88±0.11
	B	14± 7	15±5	71± 7	5.4±0.4	0.44±0.16	0.6±0.3	5.2±0.9	10± 4	73± 9	<1	1.77±0.10
Dystrophic Red-Yellow Podzolic, clayey												
25	A	50±13	23±12	27±80	4.1±0.5	1.60±0.75	0.9±0.9	8.9±3.4	10±10	80±13	2± 1	2.10±0.40
	B	36±12	19±10	45±10	4.5±0.5	0.38±0.17	0.5±0.5	5.4±1.9	8± 6	82±16	1± 0	1.80±0.50
Quartz Sand												
39	A	82±12	10± 8	8± 3	4.8±0.7	0.77±0.51	0.5±0.4	5.0±3.4	13±11	64±21	2± 3	1.68±0.91
	C	82± 8	10± 8	8± 4	5.0±0.5	0.21±0.14	0.2±0.2	2.1±2.7	17±14	58± 9	<1	1.41±0.80
Cambisol, dystrophic, clayey or loamy												
26	A	25±18	41±13	34±15	4.5±0.7	1.81±1.22	1.8±2.1	10.4±5.2	18±18	66±28	2± 2	2.36±0.83
	B	23±15	41±12	36±14	4.8±0.5	0.50±0.31	1.7±5.4	7.0±7.4	14±16	75±25	1± 0	2.32±0.31
Ground-Water Laterite												
16	A	34±29	41±22	25±15	4.8±0.6	1.50±1.81	0.7±0.4	7.4±5.8	12±10	69±26	2± 3	2.36±0.64
	B	26±23	34±19	40±17	5.1±0.4	0.35±0.26	0.4±0.6	5.1±4.9	7± 7	83±26	<1	2.07±0.47
Low Humic Clay, dystrophic												
18	A	21±25	47±20	32±14	4.1±0.4	3.18±3.86	3.1±3.7	18.7±12.9	14±13	76±20	2± 3	2.71±1.70
	C	18±22	40±16	41±18	4.5±0.4	0.46±0.42	1.5±2.1	11.6±8.6	10± 8	86±10	<1	2.11±0.43
Solodic Planosol, eutrophic												
24	A	70±22	20±19	10± 8	5.8±0.9	0.50±0.39	4.2±4.5	6.0± 4.7	63±17	13±17	2± 3	2.89±0.52
	B	48±18	21±19	33±12	6.2±0.9	0.29±0.17	12.9±9.7	4.6± 9.9	83±15	5± 7	1± 2	2.80±0.47
Eutrophic Planosol												
8	A	53±20	31±11	16± 9	5.7±0.8	0.90±0.36	6.8±6.3	9.7±6.7	58±29	17±25	5± 7	3.67±0.88
	B	34±17	22± 6	44±16	ȯ.0±0.7	0.51±0.36	15.1±5.1	17.1± 8.4	82±10	5± 6	1± 2	2.93±0.62

Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1958; 1971; EMBRAPA, Centro de Pesquisas Pedológicas, 1975a; 1975d; 1976; 1978b; Goiás, Secretaria da Agricultura, Projecto zoneamento Agricola, 1978). They are extremely weathered soils with Ki ratios usually lower than 2.0 (Table 2). Like the Yellow Latosols, they are also very poor and acid. Among those Latosols are found, allic, dystrophic, eutrophic, humic, intergrades to Podzolic

Table 4 Estimated area of Brazilian Soils based on FAO's "Soil map of the world"

	Area	
	1,000 ha	%
Acrisols	190,599	22.52
Cambisols	7,969	0.94
Rendzinas	442	0.05
Ferralsols	335,597	39.66
Gleysols	60,461	7.14
Phaeozems	7,012	0.83
Lithosols	33,592	4.25
Fluvisols	13,567	1.60
Luvisols	64,660	7.64
Nitosols	15,947	1.88
Histosols	148	0.02
Podzols	563	0.07
Arenosols	70,888	8.38
Regosols	6,010	0.71
Solonetz	3,893	0.46
Rankers	5,712	0.67
Vertisols	8,545	1.01
Solonchaks	2,312	0.27
Planosols	16,010	1.89

types. Most of the Red-Yellow and Dark-Red Latosols of the Cerrado Region still remain with their natural vegetation, even though the agriculture frontier has rapidly advanced in this area. Annual (upland rice, soybean, corn), as well as perennial crops (citrus, coffee, mangoes, Pinus, Eucalyptus) and pasture are found in this dominion. In the southern states these soils have been used mainly for annual crop production (soybean, corn, wheat, rice, beans) but are also used for coffee, citrus, sugar cane, cassava, forestry and pasture.

The Dusky-Red Latosols are derived from basic igneous rocks of high ferromanganese content. They may have a higher than normal cation exchange capacity and in some cases higher base status than other typical Latosols (Table 2). They occur mainly in the Central – South and South of Brazil and have been under very intensive use for crop production (Brasil, Ministerio de Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1960; FAO/UNESCO, 1971).

2 Dystrophic Red-Yellow Podzolic Soils

Soils with an argillic horizon, acid and low base saturation (V < 50%) (Bennema and Camargo, 1964; Jacomine, 1979). Acid rocks such as sandstones, schists, phyllites and some gneiss and granite are their parent materials. In the clay fraction predominates kaolinite although iron and aluminum oxides are also common (EMBRAPA, Centro de Pesquisas Pedológicas, 1975a). Varieties of this soil type include clayey, loamy/clayey, loamy, sandy/loamy, intergrades to Latosol and plinthic soils (Camargo and Falesi, 1975). They have been mapped almost everywhere in Brazil but concentrate in the upper Amazon basin (Brasil Departamento Nacional de Produçâo

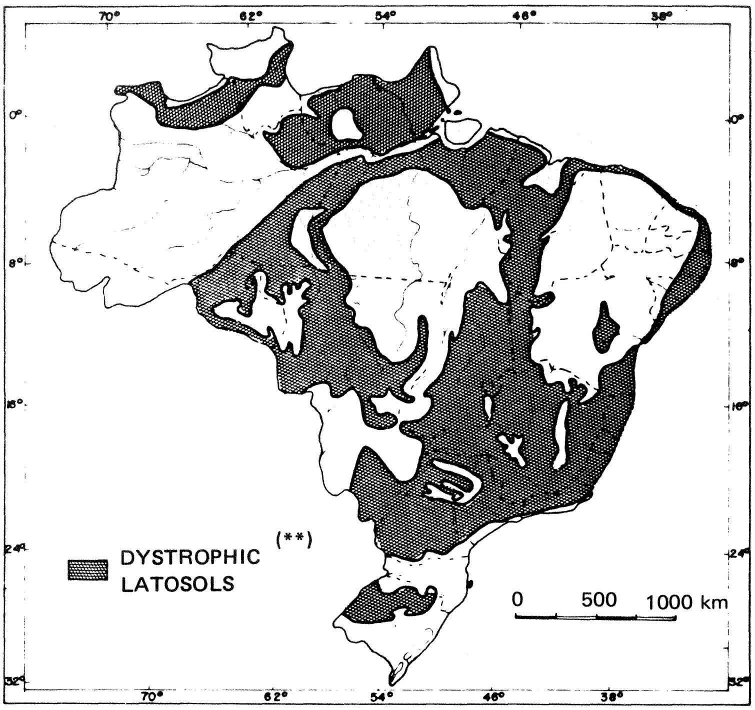

Fig. 2(a) Approximate distribution of the main Brazilian Problem Soils (Dystrophic Latosols).

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

Mineral, Projeto RADAMBRASIL, 1973; 1974; 1975; 1976; 1977; 1978), Central Brazil tablelands and on the coastal uplands (Fig. 2b). They occur on almost all types of relief although they are more common on rolling to hilly topography which may limit the use of farm machinery.

Very strong leaching of minerals leads to low base saturation, strong acidity and possible aluminum toxicity (Table 2). The low base exchange capacity may also limit ion adsorption when fertilizer is applied. If precaution is not taken, erosion may represent a serious hazard because the horizonation which limits infiltration, promotes sliding, sheet and gully erosion.

The natural vegetation is mainly forest (coastal upland, and Amazon basin) although Cerrado may also occur in some areas of lower moisture regime.

Agricultural use of this soil in the southern states includes coffee, citrus, sugar cane, corn, rice, pasture and many other types of annual and perennial crops and in the Northeastern states sugar cane. In the Amazon, areas with these soils remain unexplored (FAO/UNESCO, 1971)

3 Quartz Sands

Soil showing weak horizon differentiation derived from quartz sandstones or their detritus with a large proportion of quartz (Lemos and Melo Marques, 1979). These mineralogical and textural properties imply physical and chemical constraints to agricultural production such as very low water retention capacity, extreme permeability, very low natural fertility, low CEC, acidity and high aluminum saturation (Table 2).

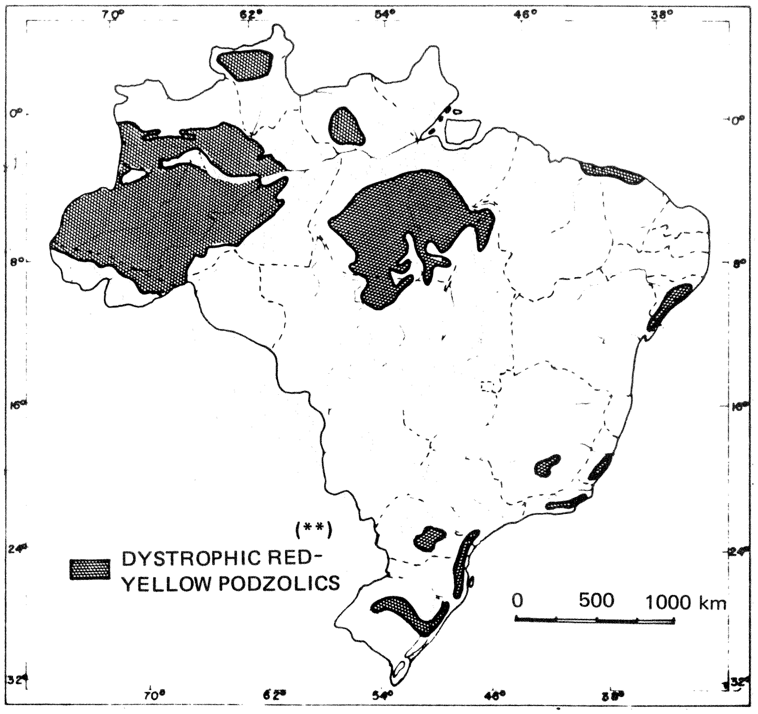

Fig. 2(b) Approximate distribution of the main Brazilian Problem Soils (Dystrophic Red-Yellow Podzolics)*.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location.
There is no relationship between the areas of soils shown in the map and their effective dimension.

They occur on flat to gently rolling relief and the natural vegetation cover is predominantly Cerrado. Quartz Sands occupy extensive areas in the Cerrado Region (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1962; 1971; EMBRAPA, Centro de Pesquisas Pedológicas, 1975a; 1975d; 1976; 1978b; Goiás, Secretaria da Agricultura, Projeto Zoneamento Agricola, 1978) (Fig. 2c)

In Brazil, areas with those soils, have been used mainly as natural pastures (FAO/UNESCO, 1971).

4 Hydromorphic Soils

In this class are considered soils which present temporary or permanent excess of water as main limitation for agricultural use. They include Humic Gley, Low Humic Gley, Ground-Water Laterite, Grey Hydromorphic, Thiomorphic Gley and Hydromorphic Podzol and correspond to the Aquic taxa of various orders of the U.S. Comprehensive System (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1962). The Ground-Water Laterite, Humic Gley and Low Humic Gley are the most important hydromorphic soils in Brazil, because of the area they occupy.

They are developed mainly from sediment deposits (Jacomine, 1979b). Besides presenting excess of water as the main limitation, other problems such as low natural fertility and high alumi-

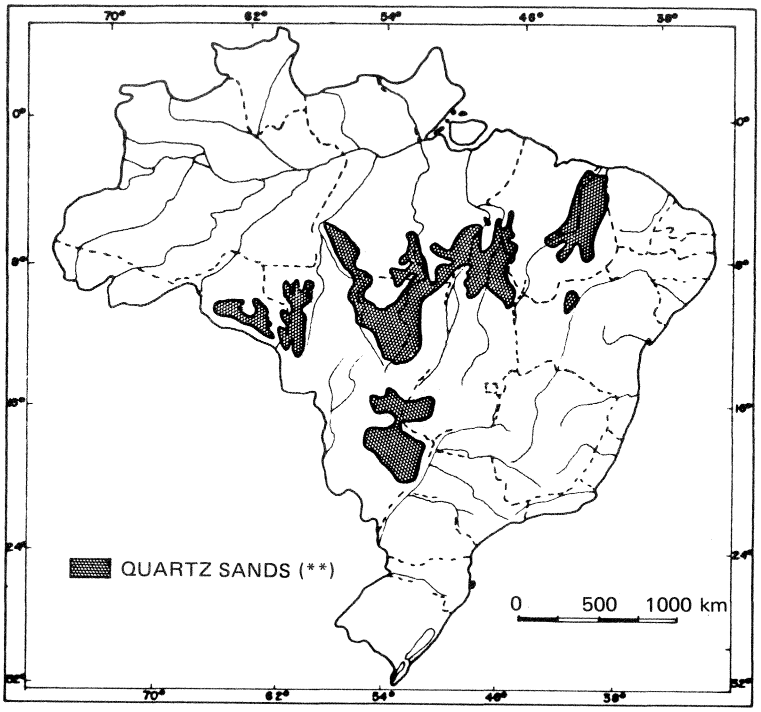

Fig. 2(c) Approximate distribution of the main Brazilian Problem Soils (Quartz Sands)*.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

num content and acidity may exist in some of these soils.

The Ground-Water Laterites are mainly Plinthaquults and Plinthaquox, of very low CEC and nutrient status (Table 2). Their main characteristic is to present a great amount of plinthite in the B horizon, which may harden irreversibly when the soil is drained (Sanchez, 1973; 1976). They occur more extensively in the Amazonic region (floodplain of many rivers of the Amazonic river basin) (Brasil Departamento Nacional de Produçâo Mineral, Projeto RADAMBRASIL, 1973; 1974; 1975; 1976; 1977; 1978) and in the Cerrado area, mainly on the floodplain of the Araguaia river (Bananal Island) (Goiás, Secretaria da Agricultura, Projeto Zeneamento Agrícola, 1978), and Pantanal (floodplains of the Paraguai, and Paraná rivers) (EMBRAPA, Centro de Pesquisas Pedológicas, 1978a) (Fig. 2d). Despite the many problems this soil presents for agricultural production, more than 30,000 ha have been drained and cultivated to rice in the Cerrado region.

The Humic Gley and Low Humic Gley are Aquepts which present strong gleying as a result of reduction conditions due to water saturation. The distinction between these two soil types is made according to the A horizon (Jacomine, 1979b). The value of these Inceptisols is primarily governed by the quality of the parent rocks. So, the Humic Gley and Low Humic Gley derived from basic rocks have high base status (Goedert, 1967; Goiás, Secretaria da Agricultura, Projeto Zoneamento Agrícola, 1978) and CEC, while the ones from acid rocks are very poor (EMBRAPA, Centro de Pesquisas Pedológicas, 1978b). Their natural vegetation consists mainly of wet grasslands. In many places land with these soils and vegetation is used as grasslands. In the (southernmost) part large extensions of Humic and Low Humic Gley have been used for paddy rice production.

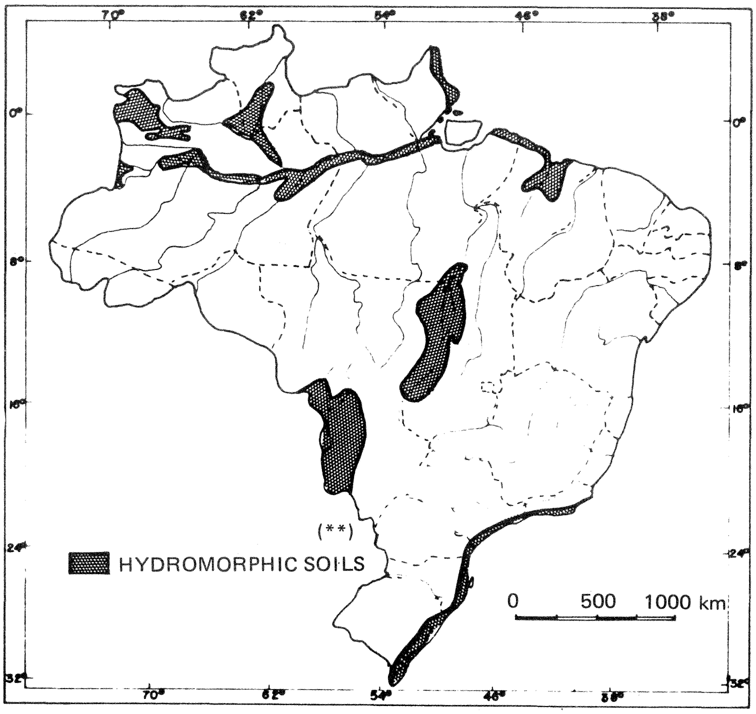

Fig. 2(d) Approximate distribution of the main Brazilian Problem Soils (Hydromorphic Soils) *.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

5 Lithosols

These are shallow soils with an horizon sequence of AR or ACR (Jacomine, 1979b). They correspond to some Inceptisols, Entisols and shallow skeletal varieties of Ultisols, Oxisols, Alfisols and Mollisols (Camargo and Falesi, 1975).

Lithosols commonly occur on steep sloping land under a wide range of environmental conditions and have been found in almost all soil surveys conducted in Brazil (Brasil, Departamento Nacional de Produçâo Mineral, Projeto RADAMBRASIL, 1973; 1974; 1975; 1976; 1977; 1978; Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1958; 1960; 1962; 1971; Brasil, Ministério da Agricultura, Departamento Nacional de Pesquisas Agropecuária, Divisâo de Pesquisas Pedológica, 1971; 1973a; 1973b; 1972; EMBRAPA, Centro de Pesquisas Pedológicas, 1975a; 1975b; 1975c; 1975d; 1976; 1977; 1978a; 1978b). They appear as dominant mapping units in the Brazilian boundaries with Guiana, Surinam and Venezuela; in the south of the Amazon region; in the northeastern portion of the Cerrado region (EMBRAPA, Centro de Pesquisas Pedológicas, 1975a); and in the mountainous eastern boundaries of the Brazilian plateau (FAO/UNESCO, 1971) (Fig. 2e). Because of the position they occupy on the relief and because of their shallowness and stoniness, Lithosols are very seldom used for agriculture. In areas of open savanna they have been used as natural pasture. Some of the eutrophic Lithosols originally covered with forest have been changed to grassland and to crop production.

6 Cambisols

The main characteristic of these soils is to present a cambic horizon (Estados Unidos, 1975) where some easily weathered minerals remain. They are usually shallow to moderately deep although some may be thicker than 1.5m (EMBRAPA, Centro de Pesquisas Pedológicas, 1978b).

Cambisols may develop from a great variety of parent rocks such as phyllites, silt stones, shales, micaschists, quartzites, sericites, sericite schists, granite and gneiss (Brasil, Ministério da Agricultura, Centro Nacional de Ensino e Pesquisas Agronomicas, Serviço Nacional de Pesquisas Agronômicas, Comissão de Solos, 1971; EMBRAPA, Centro de Pesquisas Pedológicas, 1978b;

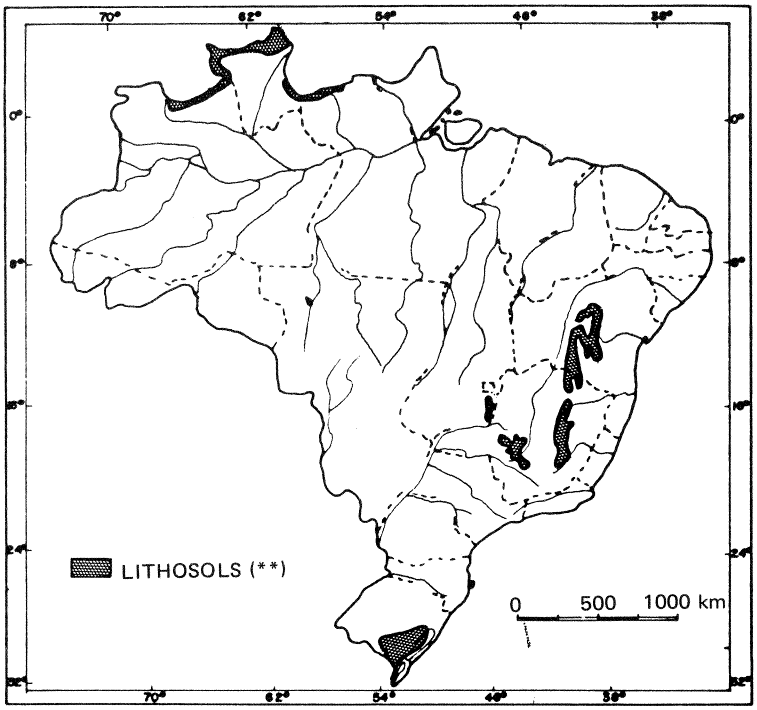

Fig. 2(e) Approximate distribution of the main Brazilian Problem Soils (Lithosols) *.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

Goiás, Secretaria da Agricultura, Projeto Zoneamento Agrícola, 1978). The natural fertility of these soils is closely related to their parent materials. So, Cambisols derived from basic rocks are generally very productive. This is the case of some eutrophic Cambisols of coastal Bahia which have been used for a long time for cocoa production. Cambisols derived from acid rocks are usually very poor and acid besides being located mainly on steep slopes. They are found in the coastal and Cerrado regions and have not been used for crop production. Natural pastures have been their most intensive use (Fig. 2f).

Because of their physical properties and the relief where they occur erosion is a serious problem for these soils. Sheet, rill and gully erosion is very common.

7 Planosols

This class includes soils with a light textured surface layer over a heavier horizon (Jacomine, 1979b) corresponding to the Albaquults, Paleustalf, Tropaqualf and Albaqualf of the Soil Taxonomy System (Estados Unidos, 1975). They usually occur on lowlands where the topography allows for an excess of water, sometimes only for short periods as is the case of rolling relief. On flat areas and depressions Planosols develop into real Hydromorphic soils.

The main obstacle for agricultural production is the excess of water due to the difference in texture between the A and B horizons. However other problems such as low CEC, low base status and sometimes high concentration of sodium (Solodic Planosol) may become additional problems

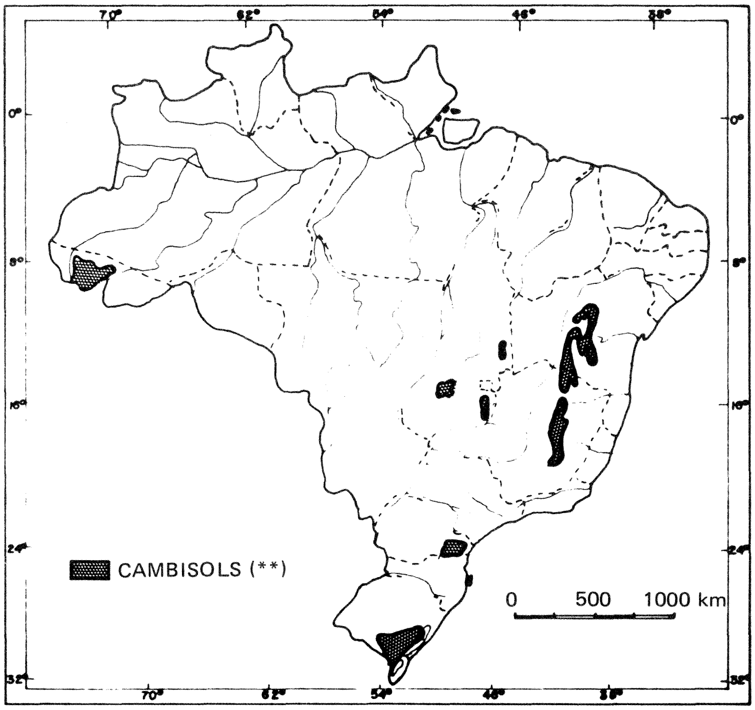

Fig. 2(f) Approximate distribution of the main Brazilian Problem Soils (Cambisols) *.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

for their use.

In Brazil Planosols occur more extensively in the Northeastern region (Brasil, Ministério da Agricultura, Departamento Nacional de Pesquisas Agropecuára, Divisão de Pesquisas Pedológica, 1971; 1973a; 1973b; 1972; EMBRAPA, Centro de Pesquisas Pedológicas, 1975b; 1975c), in the Pantanal area (EMBRAPA, Centro de Pesquisas Pedológicas, 1978a) and in the southermost areas (Fig. 2g). Planosols of the northeast are located mainly in the Semi-Arid Region and are mostly of the solodic type. Adverse climatic conditions and the high salt content of these soils have prevented their agricultural use. Planosols of the Pantanal are seasonally flooded, and are used mainly as natural grassland. In the southern region Planosols are predominantly eutrophic. These are soils with a medium to high CEC and base saturation above 50%, clay minerals are mainly montmorillonite, illite and kaolinite (Goedert and Formos, 1970). Large areas of this soil have been used for rice production in this region.

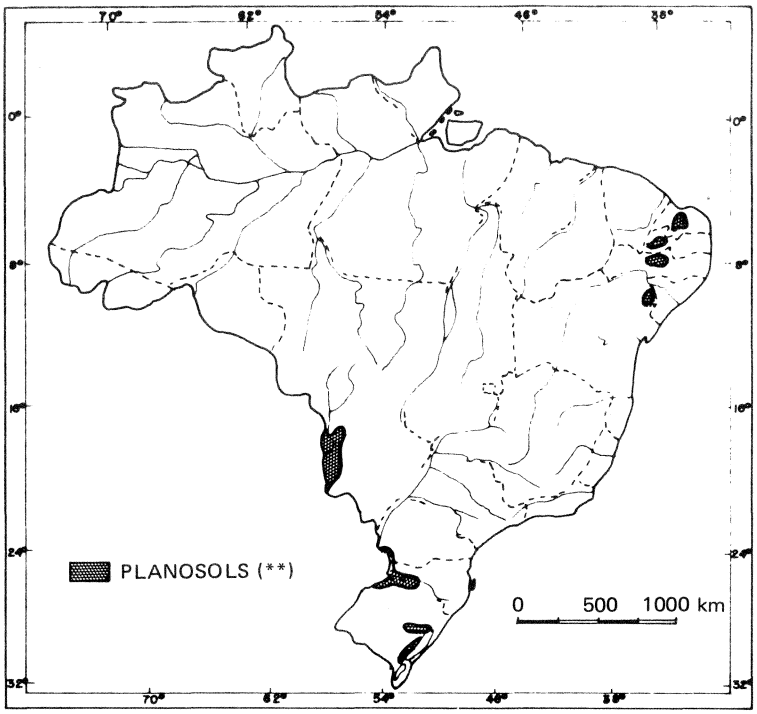

Fig. 2(g) Approximate distribution of the main Brazilian Problem Soils (Planosols) *.

* These figures are summaries of soil surveys and maps referred in the text.
** The soil distribution presented on figures is only a rough approximation of their location. There is no relationship between the areas of soils shown in the map and their effective dimension.

Conclusions

Being almost entirely in a tropical environment where precipitation and temperature are usually high, Brazil is covered predominantly by strongly weathered soils which present some type of constraint to agricultural use. Among the problem soils, Latosols, Dystrophic Red-Yellow Podzolics, Quartz Sands, Litholics, Cambisols, Humic and Low Humic Gley, Ground-Water Laterites and Planosols, correspond to about 80% of the Brazilian Soils.

Low cation exchange capacity, high Al saturation and low nutrient status (P being more frequently the limiting one) are the general problems presented by these soils, although low water retention capacity, high risk of erosion, shallowness and stoniness, restricted drainage and salinity are other important limitations presented by some of the soils considered in this paper.

Problem soils are found almost everywhere in Brazil and do not predominate only in areas of the South, South-Southwest, East-Northeast Coast, South-West of Amazonia and other relatively small portions of Brazil. Agriculture developed preferably in those soils. In the most recent years however the increasing demand for food, fiber and fuel has driven the expansion of agriculture toward areas with problem soils. This expansion has been done mainly on the Latosols of the Central Brazil Tablelands covered by savannas. Here a great effort of research has been applied to overcome natural limitations of these soils, and today a broad variety of crops are grown in this area. Similar emphasis has been put on the Latosols of the Amazonic region, where mainly cattle raising has expanded lately, but other agricultural activities have proven to be possible. Agriculture has expanded very rapidly also, in the areas with hydromorphic soils. Limited risks of yield reduction due to dry spells and the possibility of growing more than one crop per year with irrigation have stimulated the use of these areas.

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Discussion

Kyuma, K. (Japan): 1) Are there Eutrophic Latosols and Eutrophic Red Yellow Podzolic soils in your system of soil classification? 2) What is your estimate of the land area which could be turned into rice growing land in the future?

Answer: 1) Yes, there are both Eutrophic Latosols and Eutrophic Red Yellow Podzolic soils in the Brazilian system of soil classification. 2) I do not have precise data that allow a good estimation of the land area which could be turned into paddy fields. However, from the FAO Map Soil of the World, it appears that in Brazil there are approximately 60 million ha of Gleysols which are usually suitable for this crop. Also some of the Fluvisols with about 13 million ha and some of the Planosols with about 16 million ha could be cultivated with irrigated rice.

Imai, H. (Japan): 1) You have mentioned that aluminum saturation was very high in the Latosols and Red Yellow Podzolic soils. How did you determine the aluminum saturation? 2) Was the aluminum content of the soils you presented determined as exchangeable aluminum?

Answer: 1) The aluminum saturation is determined by the following equation:

$$Al^{+++}\,\% = 100\,\frac{Al^{+++}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+} + Al^{+++}}$$

2) Yes. The aluminum content presented in the tables refers to exchangeable Al.