SOILS OF AMAZON AREAS WITH NATURAL PASTURES

by W.G. Sombroek

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CONTENTS

1. INTRODUCTION

Some full descriptions are given of the most important soils found in the regions of the Amazon valley with natural pastures, where surveys of mineral deficiencies are carried out. The descriptions are according to the standards established in the SOIL SURVEY MANUAL, 1951. The pH was determined in the field with the Soiltex (1) pH kits. The Munsell Soil Color Charts (2) were used for soil colors.

The classification is according to the drainage conditions of the soils and, as far as possible, conform to published schemes (THORP and SMITH, 1949; DAY, 1961).

The nature of the field work made it difficult to prepare profile pits. Most of the observations are based on diggings using a Dutch auger. Therefore, the data about soil structure is restricted.

The generalisations attached to each soil description, such as about vegetation and distribution, concern in general only the regions with cattle grazing, where the mineral deficiencies surveys were carried out.

For each described profile representative samples were collected that were analysed at the "Instituto de Quimica Agrícola" in Rio de Janeiro, under the supervision of Dr. Leandro Vettori. Micro-nutrient analysis of topsoils was executed at the "Bedrijfslaboratorium voor grond- en gewas-onderzoek" in Oosterbeek, Holland.

2. LABORATORY METHODS

The laboratory methods applied are the following:

The air dry earth was first separated into fractions of > 20 mm, 20 - 2 mm and < 2 mm respectively. The following physical and chemical characteristics of the air dry fine earth (fraction < 2 mm) were determined:

Physical analysis:

1. Apparent bulk density: Weighing of 100 ml earth, compacted in a metallic cylinder of that capacity.
2. Real bulk density: A known weight of fine earth dried at 105 ^{o}C, is put in a receiver of 50 ml, which is then filled up with absolute ethyl alcohol.

(1) Soiltex pH Kit - The Edwards Laboratory, Cleveland, Ohio, U.S.A.
(2) Munsell Soil Color Charts - Munsell Color Company, Inc., Baltimore 2, Maryland, U.S.A.

3. Natural porosity: Obtained by comparing apparent bulk density with real bulk density. Natural porosity = 100 x (1-a.b.d./r.b.d).

4. Mechanical analysis: Sedimentation in a Koettgen cylinder, using NaOH as dispersion agent. In the samples with more than 1% C the organic material was first destroyed by H_2O_2.

   Note: Separation was made in four fractions according the International Classification (2.0 - 0.2 mm, 0.2 - 0.02 mm, 0.02 - 0.002 mm, < 0.002 mm). The textural class names generally used in the field (sandy loam, clay loam, silty clay, etc.), are based upon the classification of the U.S. Department of Agriculture (separation in fractions 2.0 - 0.05;0.05 - 0.002 mm, < 0.002 mm). To arrive at these textural class names, the percentages of the 0.05 - 0.002 mm fraction were estimated by interpolation on the sommation curve of the data obtained according the International Classification.

5. Textural ratio B/A: The mean of the clay percentages of the subhorizons of the B (exclusive B_3), divided by the mean of the clay percentages of the subhorizons of the A.

6. Natural clay: Determination in % age of fine earth by shaking with distilled water.

7. Index of structure: Obtained by comparing natural clay content with clay content after dispersion with NaOH. Index of structure = 100 x (1 - natural clay/total clay).

8. Moisture equivalent: Determination by centrifuge, according the process of Briggs and Mac-Lane.

Chemical analysis:

9. Organic carbon, C: Oxidation of the organic material with potassium bichromate 0.4 N (method of Tiurin).

10. Total nitrogen, N: Digestion with sulphuric acid, catalized with copper and potassiumsulphate. After transformation of all N into ammonia salt, this was decomposed by NaOH and the distilled ammonia collected in a solution of boric acid 4% and titrated with H_2SO_4, 0.02 N.

11. Relation C/N: Dividing organic carbon by total nitrogen.

12. Acidity, pH_{H2O} and $pH_{KCl,N}$: Determined with potentiometer in a soil paste with relation soil-water approximately 1:1, using glass electrode.

13. Available phosphorus, P_2O_5: Extraction according to the Truog method, using tin chloride as reducer. Photometric determination using the "Unicam" colorimeter.

14. Attack by H_2SO_4 d = 1.47: Under reflux cooler, 2 g of fine earth are boiled for an hour with 50 ml H_2SO_4 d = 1.47. After boiling, the material is cooled, diluted and filtered into a receiver of 250 ml capacity.

a) SiO_2 The residue of the sulphuric acid attack is boiled for half an hour with 200 ml of Na_2CO_3, 5%. The mixture is filtered and in a measured part of the filtrate the dissolved silica is precipitated by excess of concentrated H_2SO_4 and heating in a sandbath until smoking. This silica is determined gravimetrically.

b) Al_2O_3, total aluminium: In 50 ml of the filtrate of the sulphuric acid attack the other heavy metals are separated with an excess of NaOH, 30%. A measured part of the new filtrate is gradually neutralized with HCl and the aluminium determined volumetrically with EDTA.

c) Fe_2O_3, total iron: Determination on 50 ml of the filtrate of the sulphuric acid attack by the bichromate method, using diphenilamine as indicator and tin chloride as reducer.

d) TiO_2: Determination in the filtrate of the sulphuric acid attack, by the colorimetric method of H_2O_2, after elimination of the organic material by heating with some drops of concentrated $KMnO_4$.

e) P_2O_5, total phosphorus: Colorimetric determination on the filtrate of the sulphuric acid attack, using ascorbic acid as reducer, in the presence of ammonium molybdate, sulphuric acid, and bismuth salt.

15. Relation Ki (SiO_2/Al_2O_3) and Kr ($SiO_2/Al_2O_3 + Fe_2O_3$): Calculation on molecular basis from the data obtained under 14. The I.Q.A. found that this determination of Ki and Kr on the fine earth fraction generally gives the same results as the internationally used determination on the clay fraction (VETTORI 1959). Kr can give minor differences if concretions are present.

16. Exchangeable bases:

a) The sum of exchangeable bases, S. Determination by percolation of 12.5 g fine earth with 250 ml normal ammonium acetate at pH7. See however 20. S represents also the sum of separately determined Ca^{++}, Mg^{++}, K^{+} and Na^{+}.

b) Exchangeable calcium, Ca^{++} and magnesium, Mg^{++}. A measured part of the solution prepared for direct determination of S (see a) is used for determination of $Ca^{++} + Mg^{++}$ by EDTA, applying Eriochrome as indicator. In another measured part of this solution, Ca^{++} is likewise determined by application of the indicator Murexide.

c) Exchangeable potassium, K^{+} and sodium, Na^{+}. Direct determination in the percolate of ammonium acetate with a flame photometer. See however 20.

17. Exchangeable hydrogen, H^{+}: Extraction with normal calcium acetate pf pH7. See however 21.

18. Base exchange capacity, T: The sum of S and H^{+}.

19. Base saturation, V: Obtained by comparing S with T: V = 100 S/T.

20. Soluble salts: If the Na^{+} determined under 16c) was rather high, the presence of free salts in the soil solution was suspected. In this case, the quantity of free anions (referred to as "soluble salts" or "Cl^{-}") was determined by measuring the conductivity of the saturation extract.

Note: In the presence of soluble salts, the sum of bases determined by percolation with normal ammonium acetate (see 16a) represents the exchangeable bases and the soluble bases. It is assumed that the latter are mainly Na^{+}. Therefore in this

case the Na^+ in the saturation extract was determined separately. This amount of Na^+ is subtracted from the amount determined under 16c), to obtain the real amount of exchangeable Na^+ on the adsorption complex. The S-value determined under 16a) was diminished with the amount of Na in the saturation extract, to obtain the approximately real sum of exchangeable bases in the adsorption complex.

21. Exchangeable aluminium, $(Al)^+$: Determination by shaking 10 g fine earth with 200 ml normal KCl, followed by decantation, and titration with NaOH, 0.1N in the presence of bromethymol blue.
    Note: Since the H^+ is determined at pH7 (see 17), it includes the exchangeable $(Al)^+$.

Micro-nutrients:

22. Available copper, Cu: Solution in 0.4 N HNO_3. Data are given in mg/kg dry soil.

23. Available cobalt, Co: Solution in 2.5% acetic acid. Data are given in mg/kg dry soil.

24. Available manganese, Mn: Reducible and exchangeable Mn. Data are given in mg/kg dry soil.

3. PROFILE DESCRIPTIONS AND ANALYTICAL DATA

3A. LOW HUMIC GLEY AND HUMIC GLEY SOILS

Introduction

The Low Humic Gley and Humic Gley soils are poorly drained soils of recent sediments. They have an A_1 horizon of varying thickness, overlying a mineral, gleyed subsoil. In a matrix of grey, there occur common mottles, fine to medium sized, distinct; the colour of the mottles is predominantly yellowish brown or strong brown (10YR 5/6 - 5/8 or 7.5YR 5/6 - 5/8, respectively). The soils are mostly heavy textures and often contain a considerable amount of silt.

The distinction between the Low Humic Gley soils and the Humic Gley soils lies in the thickness and the organic matter content of the A_1. The limit of organic matter content above which it is predominant for the characteristics of the soil layer is generally higher in heavy textured soils than in light textured ones. Arbitrarily classified as humic were those soils that have a toplayer of 20 or more cm with a % age of C surpassing 1.5 + 0,015 x % clay.

The Low Humic Gley soil, Carbonate subsoil phase differs from the norma- Low Humic Gley soil by being a strongly alkaline in the subsoil, in the presence of carbonate concretions. Above the alkaline layer there always occurs a very compact, mostly dark, horizon.

The Humic Gley soil, Upland phase differs from the normal Humic Gley soil (that of the flood-plains) by being extremely acid and having a predominance of kaolinite in the clay fraction.

The solonetzic Humic Gley soil, intergrade to Ground Water Laterite soil resembles the Humic Gley soil, but has also some of the characteristics of the soils of group B and C. The soil has a pronounced prismatic structure, and a predominance of Mg and Na at the adsorption complex. In the subsoil soft plinthite occurs: many, coarse, prominent mottles of reddish hue are present in a matrix of light grey; the reddish mottles are partly half hardened to iron concretions.

LOW HUMIC GLEY SOIL

Soil profile no. A.1 (field description no. 174 A)

Location: Farm no. 12, area 2 - Lat. 0° 27' N, Long. 49° 32' W. Igara pé do Lago, southern part of Territory of Amapa.

Relief and drainage: Flat lowland; floodplain of meandering small river; poorly drained: in the rainy season flooded by about 1m river water, with a load of sediments.

Parent material: Recent fluviatile sediments.

Vegetative cover: Grasses, some scattered large trees, in the rainy season, covered with floating "canarana" grasses (Echinochlon polystachya, Paspalum repens, Mymenachae amplexicaulis).

A_1 0-10 cm - Dark grey (10YR 4/1), very friable silty clay loam. Slightly sticky and slightly plastic. Dry, slightly hard. pH (SOILTEX) 4. Transition clear.

G_1 10-60 cm - Gray (10YR 7/1), friable to firm loam, with many, fine, distinct mottles of strong brown (7.5YR 5/8). Slightly sticky and slightly plastic. pH 5. Transition gradual.

G_2 60-150 cm - Yellowish-brown (10YR 5/6), friable loam, with common to many, coarse, distinct mottles of light grey (N 7/0) and yellowish red (5YR 5/8). Also, many fine black (N 2/0) points (probably Mn). Slightly sticky and slightly plastic. pH 6. Transition gradual.

G_3 150-250+cm - Light gray (N 7/0), friable loam, with few, fine, faint mottles of brown (7.5YR 4/4). Slightly sticky and slightly plastic. pH 6.

Range in characteristics: The textures are mostly heavier than those described, being clay or silty clay. In that case, the profile may be rather compact and have a plastic and sticky consistence.

Relief: Flat lowlands: floodplains.

Soil profile no. A.1 Classification: Low Humic Gley Soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.891	A_1	0- 10	0	0	100.0	0.62	2.02	69	94.0
31.892	G_1	10- 60	0	0	100.0	1.40	2.69	48	32.1
31.893	G_2	60-150	0	0	100.0	1.40	2.68	48	31.3
31.894	G_3	150-250	0	0	100.0	1.42	2.65	46	27.0

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.891 ✱	18.9	10.9	40.9	29.3	50	12.5	57
31.892	1.5	51.4	22.7	24.4	38	14.4	41
31.893	0.5	46.3	29.1	24.1	46	16.6	31
31.894	0.1	61.3	19.1	19.5	36	14.2	27

✱ Mechanical analysis without destruction of the organic material

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.891	40.56	13.94	2.19	0.37		4.95	4.49
31.892	16.98	11.37	6.24	0.49		2.54	1.88
31.893	18.68	11.29	5.81	0.49		2.81	2.12
31.894	15.44	9.34	3.07	0.48		2.81	2.32

Soil profile no. A.1 Classification: Low Humic Gley Soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.891				4.6	3.9	5.28	2.2
31.892	0.30	0.09	3.3	5.4	4.0	0.52	1.4
31.893	0.28	0.08	3.5	6.5	5.1	0	1.4
31.894	0.40	0.08	5.0	6.1	4.7	0	1.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.891	0.48	0.50	0.30	0.15	1.43	33.45	34.88	4.1	
31.892	5.27	6.98	0.14	0.32	12.71	3.33	16.04	79.2	
31.893	7.45	7.24	0.11	0.49	15.29	1.66	16.95	90.2	
31.894	5.08	4.95	0.11	0.33	10.47	1.64	12.11	86.5	

Drainage: Run off and internal drainage are slow. The soils are flooded, either halfyearly or daily, by water that carries some mineral material.

Vegetation: On the daily flooded terrains there is commonly found a floodplain forest, in which the palmtree "acaí" (Euterpe oleracea) is rather characteristic. The halfyearly flooded terrains have mainly a cover of grasses (partly floating), and other, tall, herbacecus plants (e.g. "manjurana", Ipomea fistulosa).

Distribution: Observed in the territory of Amapá: on parts of the low, coastal region and on the narrow floodplains within the upland region bordering the larger streams.
On Marajo island: on low coastal parts.
On the Lower Amazon floodplain: mainly on the parts directly bordering the main stream and its side channels.

Considerations about the analysis data: The high percentages of silt accentuate the recentness of the sediment. The data for the Ki indicate the predominance of 2:1 lattice silicate clay minerals. The base exchange capacity is very high, namely about 50-60 m.e./100 g clay (after correction for the organic matter content*). The soil has a high degree of base saturation, except for the thin surface horizon.

LOW HUMIC GLEY SOIL, CARBONATE SUBSOIL PHASE

Soil Profile no. A.2 (field description no. 190)

Location: Farm no. 16 B, area 1a. Lat. 2° 12' S, Long. 54° 08' W.
About 20 km S of Monte Alegre, Lower Amazon region.

Relief and drainage: Slightly elevated, ridgelike part ("restinga") of the Amazon floodplain, bordering an Amazon side channel ("paraná"). Poorly drained: flooded by about 2 m Amazon water in high water season.

Parent material: Recent fluviatile sediments.

* estimation of the activity of the organic matter by graphical comparison of the base exchange capacity and the percentage C of samples with about equal clay content and equal Ki and Kr.

Vegetative cover: grasses and other, tall, herbaceous plants; scattered shrubs and low trees.

A_1 0-15 cm - Very dark grey (10YR 3/1), firm clay, with many, fine, distinct, mottles of yellowish red (5YR 4/8), mainly along the roots. Coarse angular blocky structure of moderate strength, breaking into fine subangular blocks of the same strength. Dry, hard. pH (SOILTEX) 4.5. Transition clear.

G_1 15-50 cm - Grey (N 5/0), friable clay, with many, medium-sized, distinct mottles of yellowish red (5YR 4/8). A fine subangular blocky structure of moderate strength. pH 5. Transition clear.

G_2 (A'_{1b}) 50-110 cm - Black (N 2/0), firm clay with a moderate to strong coarse angular blocky structure. Slight clay skins. Plastic and slightly sticky. Compact. pH 5.5. Transition clear.

G_3 110-180 cm - (with Dutch auger:) Light grey (N 6/0), silty clay with many, medium-sized, distinct mottles of yellowish brown (10YR 5/8). Sticky and very plastic. Rather compact. pH 8. Transition clear.

G_4ca 180-230 cm - Light grey (N 6/0), silty clay with similar mottling as the G_3. Sticky and very plastic. pH 9. The horizon gives a strong HCl effervescence. Several, mostly round, small (0.2 - 1 cm) stones occur, reacting strongly with the fluid: carbonate concretions. Transition clear.

G_5 (A''_{1b}) 230-260+ cm - Very dark grey (N 3/0) clay, Sticky and very plastic. pH 9. Some light grey streaks and spots, which give a HCl effervescence.

Notes: The profile is located at the riverbank; at one meter distance of the water of the "paraná" (which has pH 5); the surface of the water is about 1.5 m below the top of the profile. Three hours after the augering, the ground-water had not reached the bottom of the augerhole. This indicates a very slow permeability.
By eroding action of the "paraná" water a steep bank has formed, exposing the subsoil. At the time of low water this comes within the reach of cattle; they lick and eat from the horizons which have high pH. Such sites are generally called "barreiros" (i.e.: "places of mud eating").

Soil profile no. A.2 Classification: Low Humic Gley Soil, Carbonate subsoil phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.928	A_1	0- 15	0	0	100.0	1.31	2.52	48	34.9
31.929	G_1	15- 50	0	0	100.0	1.43	2.62	45	29.9
31.930	G_2	50-110	0	0	100.0	1.37	2.57	47	36.3
31.931	G_3	110-180	0	0	100.0	1.49	2.70	45	37.6
31.932	G_{4ca}	180-230	0	0	100.0	1.41	2.65	47	29.6

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.928	0	40.5	15.0	44.5	28	23.0	48
31.929	0.1	40.7	18.4	40.8	33	25.3	38
31.930	0.1	13.8	27.0	59.1	35	48.1	19
31.931	0.1	6.2	45.6	47.1	52	35.4	25
31.932	0.6	19.2	32.9	47.3	45	41.0	13

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.928	25.10	13.19	3.44	0.40		3.24	2.77
31.929	22.36	13.44	5.01	0.44		2.83	2.29
31.930	29.45	16.97	4.67	0.56		2.95	2.51
31.931	24.29	16.07	5.51	0.45		2.57	2.11
31.932	24.70	14.89	5.29	0.40		2.82	2.30

Soil profile no. A,2 Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.928	1.54	0.19	8.1	4.6	3.6	1.88	1.8
31.929	0.55	0.08	6.9	4.8	3.7	0.80	1.0
31.930	0.64	0.10	6.4	4.9	3.7	0.44	1.0
31.931	0.28	0.06	4.7	7.3	6.2	0	1.4
31.932	0.25	0.08	3.1	7.9	6.5	0	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.928	8.06	4.37	1.03	0.03	13.49	5.44	18.93	71.2	0.26
31.929	7.24	6.46	0.49	0.65	14.84	2.09	16.63	87.6	0.40
31.930	8.50	6.76	0.29	4.52	20.07	3.40	23.47	85.5	0.80
31.931	17.25	7.98	0.18	6.97	32.38	0	32.38	100.0	0.67
31.932	12.43	8.72	0.19	5.78	27.12	0	27.12	100.0	0.59

Soil profile no. 17.1a

Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.926	G_2	40- 80	0	0	100.0	1.42	2.63	46	33.8
31.927	G_{3ca}	80-150	0	0	100.0	1.48	2,71	45	32.9

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.926	0.2	28.3	24.6	46.9	36	33.4	29
31.927	0.1	14.0	48.8	37.1	57	32.5	12

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.926	24.16	15.22	4.61	0.44		2.70	2.26
31.927	20.85	14.23	4.51	0.40		2.49	2.07

Soil profile no. A,2 Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.928	1.54	0.19	8.1	4.6	3.6	1.88	1.8
31.929	0.55	0.08	6.9	4.8	3.7	0.80	1.0
31.930	0.64	0.10	6.4	4.9	3.7	0.44	1.0
31.931	0.28	0.06	4.7	7.3	6.2	0	1.4
31.932	0.25	0.08	3.1	7.9	6.5	0	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.928	8.06	4.37	1.03	0.03	13.49	5.44	18.93	71.2	0.26
31.929	7.24	6.46	0.49	0.65	14.84	2.09	16.63	87.6	0.40
31.930	8.50	6.76	0.29	4.52	20.07	3.40	23.47	85.5	0.80
31.931	17.25	7.98	0.18	6.97	32.38	0	32.38	100.0	0.67
31.932	12.43	8.72	0.19	5.78	27.12	0	27.12	100.0	0.59

Soil profile no. 17.1a Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.926	G_2	40- 80	0	0	100.0	1.42	2.63	46	33.8
31.927	G_{3ca}	80-150	0	0	100.0	1.48	2,71	45	32.9

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.926	0.2	28.3	24.6	46.9	36	33.4	29
31.927	0.1	14.0	48.8	37.1	57	32.5	12

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.926	24.16	15.22	4.61	0.44		2.70	2.26
31.927	20.85	14.23	4.51	0.40		2.49	2.07

Soil profile no. 17.1a

Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.926	0.63	0.09	7.0	5.0	3.8		1.0
31.927	0.14	0.04	3.5	7.6	6.5		1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.926	7.88	7.63	0.49	2.65	18.65	3.36	22.01	84.7	0.40
31.927	9.02	7.72	0.15	4.21	21.10	0	21.10	100.0	0.20

Soil profile no. 14.3 Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.922	G_{1ca}	10-40	0	0	100.0	1.51	2.67	43	52.1

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.922	0.8	45.0	26.0	28.2	43	28.2	0

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.922	19.10	11.39	6.01	0.58		2.85	2.13

Soil profile no. 14.3 Classification: Low Humic Gley soil, Carbonate subsoil phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.922	0.15	0.04	3.8	9.0	7.3		1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.922	2.97	6.91	0.10	9.16	19.14	0	19.14	100.0	0.39

Range in characteristics: The structure of the compact layer, as well as of the underlying alkaline layers, is often prismatic. The layers occur at varying depth; the compact layer may even be the surface horizon. The color value of the compact layer may be higher than described above. The HCl effervescence of the alkaline layer may be slight.

Relief: The soils were observed always on the slightly elevated, often parallel running, ridges ("restingas"), that are a common occurrence in the flood plain, and are apparently present-day or old levees of the Amazon mainstream or its "paranás". Most studies were made at "restingas" of which the subsoil was exposed by action of the riverwater and which, consequently, constituted a "barreiro". The few inland "restingas" studied showed, however, similar alkaline subsoils.

Drainage: Internal drainage is very slow. The ridges are covered by 0.5 to 2 m Amazon water during the time of high water.

Vegetation: Few grasses, but many other, tall, herbaceous plants (e.g. "artemisia", Ambrosia artimisiaefolia); scattered shrubs and low trees.

Distribution: The carbonate subsoil phase of the Low Humic Gley soil was observed frequently in the Amazon floodplain near Prainha and Monte Alegre, at both the north and the south side of the main river.

Considerations about the analysis data: (For comparison the data of subsoil horizons of two similar profiles - 17,1a and 14,3 of the table with topsoil analyses in the back of the printed report - are given as well)
The compact layer has the heaviest texture, while the alkaline horizons are rich in silt. The data for Ki indicate the predominance of 2:1 lattice silicate clay minerals. The base exchange capacity is high, namely 35 - 40 m.e./100 g clay (after correction for the organic matter content). For the calcareous horizons this value is even about 60 m.e.* Throughout the profile, the degree of base saturation is high or total. The predominant exchangeable cation is calcium, but in the subsoil layers alo considerable quantities of magnesium and sodium are present. Assuming that in these layers the calcium is mainly concentrated in the concretions*, it becomes plausible that the poor structure - as illustrated by the low index of structure - is due to the effective predominance of Mg and Na (see also 3B. Saline and Alkali soils).

* It is likely that the values for base exchange capacity and for Ca^{++} are too high, since with the analysis method applied the Calcium of the concretions is probably included in the Ca^{++} data.

The small amounts of soluble salts in these levee profiles may be due to some Ca SO_4, originating from oxidation of some Fe S_2.
The dark color of the compact horizon is not correlated with presently high organic matter content.

Origin of the soils: The compactness and the often humic appearance of the G_2 suggest that this horizon was originally an A_1 of a now buried profile (compare with similar horizons in profile A.3). Alkaline horizons were only observed under such a layer which indicates that they had been deposited some time ago. It is possible that this was done by rivers coming down from the area of Paleozoic outcrops, among which are many carbonate rich rocks, at the north side of the Amazon floodplain.
On the other hand, the alkaline layers were also found many km's south of the present main stream. It is also noteworthy that the present Amazon water contains rather high percentages of HCO_3^- and Ca^{++} ions, namely about 17 mg/1 HCO_3^- and about 9 mg/1 Ca^{++}, while the pH is about 7 (SIOLI, 1951).

HUMIC GLEY SOIL

Soil profile no. A.3 (field description no. 188)

Location: Farm no. 14, area 2 - Lat. 1° 59' S, Long. 53° 30' W. About 20 km S. of Prainha, Lower Amazon region.

Relief and drainage: Flat lowland, basin land of floodplain of rivers Amazon and Purus. Poorly drained: in high water season about 1.5 m flooded.

Parent material: Recent fluviatile sediments.

Vegetative cover: Grasses, and many tall, herbaceous plants.

A_1 0-25 cm - Grey (10YR 5/1), friable, silty clay loam, with some strong brown (7.5YR 5/8) along the grass roots. Structure medium-sized subangular blocky, of moderate strength. Surface hard when dry, slightly cracked. Sticky and plastic. pH (SOILTEX) 5. Transition clear.

G_1 25-70 cm - Light grey (N 6/0), silty clay loam, with many, medium-sized distinct mottles of reddish-yellow (7.5YR 6/8). Sticky and plastic. pH 5.5. Transition abrupt.

G_2 (A'_{1b}) 70-120 cm - Very dark grey (10YR 3/1), firm clay, with common, fine, faint mottles of dark yellowish-brown (10YR 4/4). Compact. Sticky and very plastic. pH 4.5. Transition gradual.

G_3 120-170 cm - Grey (N4 - 5/0), firm clay, with many, medium-sized, distinct mottles of reddish-yellow (7.5YR 6/6). Sticky and very plastic. pH 5. Transition abrupt.

G_4 (A''_{1b}) 170-190 cm - Very dark grey (10YR 3/1), firm clay. Sticky and very plastic. Transition gradual.

G_5 190-210 cm - Grey (N 5/1) clay with common, fine, distinct mottles of yellowish-red (5YR 5/8). Sticky and very plastic. Transition clear.

G_6 (A'''_{1b}) 210-220+ cm - Black (10YR 2/1) clay with organic relics. Sticky and very plastic. pH 5.5.

Soil profile no. A.4 (field description no. 186)

Location: Farm no. 15B, area 1a. Lat. 1° 50' S, Long. 53° 45'W. About 30 km W. of Prainha. Lower Amazon region.

Relief and drainage: Flat lowland; basin land of floodplain of the Amazon river. Poorly drained: in high water season about 1.0 - 1.5 m flooded.

Parent material: Recent fluviatile sediments.

Vegetative cover: Grasses, with many tall herbs, especially "manjurana" (Ipomea fistulosa). During the high water season floating grasses of the "canarana" type are present (Echinochloa polystachya a.o.).

A_o 5-0 cm - Dense net of undecomposed or partly decomposed plant residues, especially of "canarana", and roots.

A_{11} 0-5 cm - Black (10YR 2/1) heavy clay. Moderate fine granular structure. Very sticky and very plastic. pH (SOILTEX) 4. Transition gradual.

A_{12} 5-20 cm - Dark grey (10YR 4/6) heavy clay. Very sticky and very plastic. Transition abrupt.

G_1 20-140 cm - Light grey (n 6/0) silty clay, with many, medium-sized, distinct mottles of yellowish brown (10YR 5/6). Sticky and plastic. pH 6. Transition gradual.

G_2 140-220 cm - Grey (10YR 5/1) fine sandy loam. Sticky and slightly plastic. pH 6.5.

Range in characteristics: The humic top layer varies in thickness from 20 to 40 cm. It is always considerably more conspicuous than that of the soils on the "restingas" (see A.2).
The textures may be clay or heavy clay throughout the profile, but sandy horizons may occur in the subsoil as well.
The occurrence of compact, dark-colored subsurface layers is not frequent.

Relief: The soils are common on the lower parts (basin lands) of the Amazon floodplain, i.e. the low strips between the mentioned "restingas" (see A.2), or the general terrain where "restingas" are absent.

Drainage: Internal drainage is slow. The terrains become covered with 1 to 3 m river water during the high water season.

Vegetation: Grasses, and tall, herbaceous plants, especially "manjurana". During high water time, many floating grasses ("canarana").

Distribution: Observed throughout the floodplain in the Lower Amazon region.

Considerations about the analysis data: (See also topsoil analysis of 17.1b and 16.B.1b of Appendix*). The high percentages of silt stress the recentness of the sediments. The data for Ki indicate the predominance of 2:1 lattice silicate clay-minerals. The soil has a high base exchange capacity, namely roughly 40 m.e./100 g clay (after correction for the organic matter content). The base saturation is high. Ca^{++} is mostly the predominant cation, but in the A.3 profile Mg^{++} is present in relatively high percentages too.
The C/N value of the topsoils is relatively low, namely about 8. The dark colour of the G_2 of profile A.3 is not correlated with presently high organic matter content.

* See back of main, printed report.

Soil profile no. A.3 Classification: Humic Gley soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.923	A_1	0- 25	0	0	100.0	1.17	2.53	54	43.1
31.924	G_1	25- 70	0	0	100.0	1.36	2.69	49	34.6
31.925	G_2	70-120	0	0	100.0	1.25	2.60	52	41.4

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.923	0.1	29.4	30.8	39.7	46	17.5	56
31.924	0.1	31.4	30.3	38.2	46	22.0	42
31.925	0	13.4	30.2	56.4	37	35.6	37

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.923	23.53	13.22	3.95	0.44		3.03	2.54
31.924	23.78	14.93	4.97	0.55		2.71	2.23
31.925	32.71	17.53	4.60	0.55		3.17	2.72

Soil profile no. A.3 Classification: Humic Gley soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.923	2.69	0.32	8.4	4.8	3.8	0.72	2.0
31.924	0.47	0.09	5.2	5.2	3.9	0.52	1.0
31.925	0.71	0.12	5.9	4.9	3.6	1.32	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.923	8.18	6.97	0.99	0.29	16.43	5.62	22.05	74.5	
31.924	7.43	7.23	0.31	0.45	15.42	2.08	17.50	88.1	
31.925	9.37	8.61	0.29	1.30	19.57	3.77	23.34	83.8	0.26

Soil profile no. A.4 Classification: Humic Gley soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.917	A_1	0- 20	0	0	100.0	1.05	2.28	54	54.5
31.918	G_1	20-140	0	0	100.0	1.38	2.69	49	37.1
31.919	G_2	140-220	0	0	100.0	1.46	2.70	46	24.2

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.917	3.4	10.0	28.6	58.0	35	32.5	44
31.918	0.1	18.5	40.5	40.9	53	31.9	22
31.919	0.3	73.6	16.7	9.4	30	6.1	35

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.917	33.27	16.55	3.13	0.48		3.42	3,05
31.918	25.98	16.64	6.25	0.58		2.65	2.14
31.919	12.30	7.13	3.76	0.43		2.93	2.19

Soil profile no. A.4 Classification: Humic Gley soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.917	5.64	0.67	8.4	5.0	4.1	0.36	2.9
31.918	0.33	0.08	4.1	6.1	4.8	0.0	1.8
31.919	0.41	0.06	6.8	4.4	3.6	0.72	18.4

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.917	23.23	6.29	1.03	0.51	31.06	12.98	44.04	70.5	
31.918	17.81	5.25	0.22	0.36	23.64	0.63	24.27	97.4	
31.919	12.00	7.65	0.20	0.24	20.09	1.43	21.52	93.3	

Origin: The compact, dark-coloured subsurface horizons of profile A.3 represent apparently periods of locally slacking down of the sedimentation, during which a vegetation could leave some organic material. Similar layers have been found in the floodplain soils of other river systems, e.g. in the Netherlands. There they are denominated as "lak" (lacquer) layers (EDELMAN 1950).

HUMIC GLEY SOIL, UPLAND PHASE

Soil profile no. A.5 (field description no. 119)

Location: Farm no. 12, area 1c - Lat. 0° 27' N, Long. 51° 38' W., Igarapé do Lago, southern part of Territory of Amapá.

Relief and drainage: Bottomland in undulating upland. Poorly drained.

Parent material: Colluvial deposits from heavy textured sediments of surrounding upland.

Vegetative cover: Tall grasses.

A_1 0-40 cm - Black (5YR 2/1), friable clay with a strong very fine subangular blocky structure. Plastic and slightly sticky. Apparently high in organic matter. Many roots. pH (SOILTEX) 5.

A_{1g} 40-60 cm - Olive brown (2.5Y 4/2) clay, with common, medium-sized, distinct mottles of dark grey (N 4/0) and dark brown (7.5YR 4/4). Sticky and plastic. pH 4.5.

G_1 60-100 cm - Yellowish brown (10YR 5/4) clay, with many, medium-sized, distinct to prominent mottles of yellowish red (5YR 4/6) and black (N 3/0). Sticky and plastic to very plastic. pH 4.5.

G_2 100-120 cm - Pale brown (10YR 6/3) clay, with common, medium-sized, faint to distinct mottles of yellowish red (5YR 6/6). pH 4.5.

Range in characteristics: In some locations - where associated with light textured uplands - the textures are lighter, i.e. sandy loam or sandy clay loam.

Soil profile no. A.5 Classification: Humic Gley soil, Upland phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.547	A_1	0- 40	0	0	100.0	1.10	2.48	56	40.2
31.548	O_1	60-100	0	0	100.0	1.23	2.63	53	34.6

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.547	2.6	14.6	6.4	76.4	9	23.9	69
31.548	4.6	23.3	2.5	69.6	3	5.8	92

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.547	30.17	26.80	4.08	0.87		1.91	1.74
31.548	27.60	25.27	4.03	1.00		1.86	1.69

Soil profile no. A.5 Classification: Humic Gley soil, Upland phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.547	3.19	0.19	16.8	4.8	3.9		1.4
31.548	1.42	0.08	17.8	5.0	4.0		1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.547	0.42		0.17	0.04	0.63	13.32	13.95	4.5	
31.548	0.29		0.08	0.02	0.39	5.76	6.15	6.3	

Relief: Flat or very gentle sloping bottomlands of undulating upland terrains.

Drainage: Poorly drained. Both runoff and internal drainage are slow.

Vegetation: Grasses; often many palms ("buriti", Mauritia flexuosa). The latter appear to be rather characteristic for the soils in these locations.

Distribution: Observed in relatively small bottomlands, associated with the upland savannah areas north of the Lower Amazon region and in eastern and southern Amapá Territory.

Considerations about analysis data: The percentages of silt are very low. The data for Ki indicate that the predominant silicate clay minerals are those with 1:1 lattice structure*. The C/N value are relatively high, namely about 17. The base exchange capacity is lower than that of the other described Low Humic Gley or Humic Gley soils, and practically totally due to the organic matter. After correction for the latter, the base exchange capacity amounts to only 2 - 3 m.e./100 g clay. The degree of base saturation is very low.

SOLONETZIC HUMIC GLEY SOIL, INTERGRADE TO GROUND WATER LATERITE SOIL

Soil profile no. A.6 (field description no. 178)

Location: Lat. 0° 59' S. Long. 49° 60' W. About 8 km NW of Arariuna; river bank near fazenda Curralinho. East-central part of Marajó Island.

Relief and drainage: Flat lowland. During the rainy season covered by about 1 m, relatively clear, fresh water. In the dry season a ground-water level at about 4 m depth.

Parent material: Subrecent marine-deltaic (?) sediments.

Vegetative cover: Grasses, and some tall herbaceous plants; scattered shrubs.

* Textures and Ki and Kr are similar to those of the Yellow Latosol, very heavy textured, of the surrounding upland. - See profile D.1.

A_1 0-15 cm - Very dark grey brown (10YR 3/2) clay, with some strong brown (7.5YR 5/8), mainly along the roots. Structure moderate medium-sized prismatic, breaking into moderate coarse subangular blocky. Moist, firm. Sticky and plastic when wet, very hard and cracked when dry. Many roots, with tendency to follow structural cracks. pH (SOILTEX) 4. Transition abrupt and smooth.

G_1-(A2) 15-20 cm - Grey brown (10YR 5/2) clay loam, with common, fine, distinct mottles of yellowish red (5YR 5/8). Moderate medium-sized subangular blocky structure. Moist friable. Plastic and slightly sticky when wet. Slightly hard when dry. pH 4. Transition abrupt and smooth.

G_2-(B1) 20-55 cm - Dark grey (10YR 4/1) clay, with many, fine, distinct mottles of red (2.5YR 4/6). Structure weak fine prismatic, breaking into strong fine subangular blocky. Moist, firm. Sticky and very plastic when wet. Slightly hard when dry. pH 4. Transition clear and smooth.

G_3-(B21) 55-100 cm - Light grey (10YR 6/1) clay, with many, fine, distinct mottling of red (2.5YR 5/6) and reddish yellow (7.5YR 6/8). Strong very coarse prismatic structure. Prominent clay skins on horizontal surfaces, faint to distinct clay skins on vertical pedfaces. Moist, very firm. Very sticky and very plastic when wet. Hard when dry. pH 4. Transition diffuse and smooth.

G_4-(B22) 100-180+ cm - Light grey (N 6/0) clay, with many, large, prominent mottles of dark red (10R 5/6) and reddish yellow (7.5YR 6/8). Structure weak to moderate coarse prismatic, breaking into strong coarse subangular blocky. Prominent clay skins on both horizontal and vertical pedfaces. Moist, firm. Very sticky and very plastic when wet. pH 4.

Soil Profile no. A.7 (field description no. 155)

Location: Farm no. 4, area 1. - Lat. 0^{o} 59' S. Long. 48^{o} 57' W. About 3 km N of Arariuna. East-central part of Marajó Island.

Relief and drainage: Flat lowland. During the rainy season covered by about 1 m rainwater. In dry season ground-water level at about 3 m depth.

Parent material: Subrecent marine-deltaic (?) sediments.

Vegetative cover: Grasses; some tall herbaceous plants.

(with Dutch auger:)

A_1 0-30 cm - Black (10YR 2/1) heavy clay, with few to common, fine, faint mottles of dark brown (7.5YR 4/4). Moist, firm. Sticky and very plastic when wet. Surface is dry, hard and cracked. pH (SOILTEX) 4. Transition gradual.

G_1 30-60 cm - Grey (10YR 5/1) heavy clay, with many, coarse, prominent mottles of black (10YR 2/1) and common to many, fine, distinct mottles of red (10YR 4/6). Moist, firm. Sticky and very plastic when wet. pH 4. Just above the transition to the G_2, which is abrupt, black is the predominant colour.

G_2 60-75 cm - Light grey (10YR 7/1) fine sandy clay loam. Moist, friable. Slightly sticky and slightly plastic when wet. Transition clear.

G_3 75-130 cm - Light grey (10YR 6/1) clay, with few, fine, distinct to prominent mottles of red (10R 4/6). Compact. Moist, very firm. Sticky and plastic when wet. pH 5. Transition gradual.

G_4 130-170 cm - Light grey (N 7/0) clay, with common to many, coarse, prominent mottles of red (10R 4/8) and some brownish yellow (10YR 6/8). Compact. Moist, very firm. Sticky and plastic when wet. pH 4.5. Transition gradual.

G_5 170-270 cm - White (N 8/10) fine sandy clay loam, with many, coarse, prominent mottles of brownish yellow (10YR 6/8), pale red (7.5R 6/4) and red (3.5YR 5/8). Moist, friable. pH 5. Transition gradual.

G_6 270-325+ cm - White (N 8/0) clay, with many, coarse, prominent mottles of reddish yellow (7.5YR 6/8) and dark red (7.5R 3/6). Most of the dark red parts are half hardened. pH 4.5.

Range in characteristics: Horizons with medium textures, as present in both described profiles, are not frequent; textures are generally heavy throughout the profiles. Relatively thick, very dark coloured A_1 horizons, as in profile A.7, are most common.

Soil Profile no. A.6

Classification: solonetzic Humic Gley soil, intergrade to Ground Water Laterite soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.906	A_1	0- 15	0	0	100.0	1.21	2.53	52	38.5
31.907	G_1	15-20	0	0	100.0	1.33	2.56	48	31.6
31.908	G_2	20-55	0	0	100.0	1.31	2.61	50	33.9
31.909	G_3	55-100	0	0	100.0	1.34	2.67	50	32.0
31.910	G_4	100-180	0	0	100.0	1.46	2.65	45	30.4

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.906	0.1	27.9	19.8	52.2	28	23.0	56
31.907	0.7	49.3	19.8	30.2	33	12.8	58
31.908	0.3	28.8	21.5	49.4	30	22.7	54
31.909	0.9	24.8	18.5	55.8	27	7.1	87
31.910	0.9	28.8	20.2	50.1	30	8.8	98

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.906	25.99	14.25	4.52	0.52		3.10	2.58
31.907	16.70	9.01	3.50	0.48		3.15	2.53
31.908	21.53	14.15	6.04	0.55		2.59	2.03
31.909	25.76	18.32	6.34	0.69		2.59	1.96
31.910	22.76	16.60	4.21	0.65		2.33	2.01

Soil profile no. A.6

Classification: solonetzic Humic Gley soil, intergrade to Ground Water Laterite soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.906	1.81	0.26	7.0	4.4	3.3	7.12	1.0
31.907	0.93	0.13	7.2	4.5	3.4	4.76	1.0
31.908	0.92	0.12	7.7	4.4	3.5	8.32	0.7
31.909	0.28	0.07	4.0	4.3	3.5	10.30	0.3
31.910	0.19	0.07	2.7	4.2	3.5	7.52	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.906	1.52	3.31	0.24	0.19	5.26	10.54	15.80	33.3	
31.907	1.24	1.36	0.20	0.10	2.90	7.65	10.55	27.5	
31.908	0.54	0.92	0.27	0.13	1.86	10.43	12.29	15.1	
31.909	0.19	0.96	0.23	0.42	1.80	10.62	12.42	14.5	
31,910	0.18	1.34	0.20	0.69	2.41	8.24	10.65	22.6	

Soil profile no. A.7 Classification: solonetzic Humic Gley soil, intergrade to Ground Water Laterite soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.848	A_1	0- 30	0	0	100.0	1.29	2.50	48	37.4
31.849	G_1	30- 60	0	0	100.0	1.44	2.61	45	35.2
31.850	G_3	75-130	0	0	100.0	1.53	2.64	42	27.4
31.851	G_5	170-270	0	0	100.0	1.57	2.64	41	20.2

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.848	0.1	19.1	14.5	66.3	22	32.7	51
31.849	0.4	21.2	12.6	65.8	19	31.3	52
31.850	0.1	30.6	15.2	54.1	25	2.9	95
31.851	0.1	68.8	7.6	23.5	16	11.2	52

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.848	28.97	20.98	3.20	0.64		2.35	2.13
31.849	28.36	20.36	4.35	0.60		2.37	2.08
31.850	21.51	17.31	1.67	0.62		2.11	1.99
31.851	10.39	7.81	1.43	0.40		2.26	2.03

Soil profile no. A.7 Classification: solonetzic Humic Gley soil, intergrade to Ground Water Laterite soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.848	1.90	0.23	8.3	4.8	3.8	10.96	1.0
31.849	0.81	0.13	6.2	4.8	3.9	10.76	1.0
31.850	0.22	0.04	5.5	5.1	4.5	4.36	1.0
31.851	0.06	0.01	6.0	5.2	4,9	1.50	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.848	0.68	2.37	0.41	0.29	3.75	16.88	20.63	18.2	
31.849	0.68	4.56	0.29	0.50	6.03	13.20	19.23	31.4	
31.850	0.71	4.43	0.15	1.00	6.29	4.79	11.08	56.8	
31.851	0.51	2.00	0.14	0.72	3.37	1.63	5.00	67.4	

Relief: Flat, lowlying terrains.

Drainage: Both internal drainage and run-off are slow. During the rainy season the soils are submerged with rainwater or flooded by clear water from nearby streams to a depth of 1-1.5 m. During the dry season they dry out to a great depth: ground-water level below 3 m.

Vegetation: Open grass savannahs, with many tall herbaceous plants ("salsa", Ipomea pescabrae; "algodao bravo", Ipomea Sistulosa). Near the rivers are also scattered shrubs.

Distribution: The soils were observed in the east- and south-east central part of Marajó Island, in a broad band along the area with Solonetz, Coastal phase.

Considerations about the analysis data: (see also analysis of topsoils of 9.2 and 5.2 of the table in the back of the printed Report)
The clay/silt ratio is between 4 and 2, which is higher than that of the proper Humic Gley soils and most of the Saline and Alkali soils (see B), but lower than most of the Ground Water Laterite soils.
The Ki values are mostly between 2.5 and 2.1; the silicate clay minerals will therefore be partly of 2:1 lattice, partly of 1:1 lattice structure.
The abrupt transitions between some of the horizons, and the variations in mechanical composition and in Ki and Kr values, make it very probable that the textural differences within the profiles are due mainly to different ways of sedimentation of the parent material, not to profile development.
The C/N values of the topsoils are relatively low (7-8).
The base exchange capacity is lower than that of the proper Humic Gley and Low Humic Gley soils and the Saline and Alkali soils, but higher than that of the Ground Water Laterite soils, namely about 20 m.e./100 g clay (after correction for the organic matter content). The degree of base saturation is medium to low. There is a predominance of Mg^{++} over Ca^{++} and of Na^{+} over K^{+}, the latter in the subsoil, at the exchange complex, but this is not as outspoken as in the Solonetz, Coastal phase (see profiles B.1, B.2 and B.3). Exchangeable $(Al)^{+}$ is high; it amounts to 40-80% of the base exchange capacity.

3B. SALINE AND ALKALI SOILS

INTRODUCTION

The soils are characterised by containing either excessive concentrations of exchangeable Na^+ and Mg^{++}, or soluble salts, or both.

They are called saline, if the conductivity of the saturation extract exceeds 4 mmhos/cm at 25°C, corresponding to about 0.15% salts in the dry soil, (SOIL SURVEY MANUAL, 1951, page 360). Assuming that the soluble salts are predominantly NaCl (see also analysis of salt water spring, page 53), this value corresponds to approximately 2.5 m.e./100 g soluble salts as determined by IQA. The following salinity classes were distinguished, in agreement to those given in the Soil Survey Manual: 2.5-5.9 m.e. soluble salts/100 g: slightly saline; 6-10.9 m.e./100 g: moderately saline; more than 11 m.e./100 g: strongly saline.

The Solonetz is a soil that has a cloddy B horizon, with a prominent prismatic or columnar structure, while the exchangeable cations of this horizon are, for a large part, Na^+ and/or Mg^{++} ($Mg^{++} + Na^+ > Ca^{++} + H^+$; see SOIL SURVEY STAFF, 1960 page 45). That Mg^{++} can have a similar detrimental effect on the structure as Na^+ is recognised only recently, but confirmed by laboratory trials e.g. those of SCHUYLENBORGH and VEENENBOS (1951). Solonetzes are mostly found in dry climates. They exist however also along sea coasts, independent from the climatic conditions. Here they have developed on sediments with high percentages of Mg and Na, due to deposition in marine-deltaic conditions. They are known as "coastal Solonetzes" and described e.g. by EDELMAN (1950) for Holland, where they have the names "pik" or "knip" clays.

The Marajó soils denominated as Solonetz have mostly only a moderate prismatic structure. Partly they have a thick humic top with a crumbly structure and slickensides in the subsoil horizons. These soils are, in fact, intergrading to Grumosols. Others, with only a thin humic top and a moderate to weak prismatic structure, are intergrading to Low Humic Gley soils. The Marajó Solonetzes have partly a saline subsoil.

On Marajó there are also some saline soils that have no structure or a weak, fine, granular one. The water movement through the profile is rapid, contrary to the situation with the Solonetzes. These soils are classified

as Saline Soil.

In some subsoil horizons the pH dropped from 6-8 to 3 or less after drying. Here the presence of mudclay was assumed. This is a Ca-poor, FeS_2-rich clay, originating under anaerobic circumstances on sites with presence of brackish water and much organic material. On exposure to air the sulphide oxidises to H_2SO_4; the clay then becomes very sticky and dense, and extremely acid. It is then called catclay (EDELMAN, 1950).

SOLONETZ, COASTAL PHASE*

Soil profile no. B.1 (field description no. 175 B)

Location: Farm no. 3, area 2 - Lat. 0° 32' S, Long. 48° 47' W. North-east-central part of Marajó Island.

Relief and drainage: Flat lowland. Poorly drained: in the rainy season submerged with about 100 cm rainwater.

Parent material: Subrecent marine-deltaic sediments.

Vegetative cover: Grasses and other, tall herbaceous plants.

A_1 0-20 cm - Dark grey (10YR 4/1) clay with many, fine, distinct mottles of strong brown (7.5YR 5/8), mainly along the grassroots. Trampled by cattle. Dry, very hard, strongly cracked. Structure very coarse prismatic of moderate strength (related with cracks); breaking into coarse angular blocks, generally of weak, but in lower part, locally, of moderate strength. Very sticky and very plastic when wet. Upper 10 cm has many insect channels; lower part is massive within the structure elements. pH (SOILTEX) 4.5. Transition clear and irregular.

B_{21g} 20-40 cm - Very dark grey brown (10YR 3/2) clay, with common, very fine, faint mottles of strong brown (7.5YR 5/8). Structure moderate coarse prismatic, locally columnar. Faint, locally distinct, clay skins on all vertical pedfaces. Distinct slickensides on the sub-horizontal wands. Dry, very hard. Very sticky and very plastic when wet. Scattered small (2-5 cm diam.), round, half-hard, black concretions, effervescing with H_2O_2: concretions of manganese. pH 6. Transition clear and wavy.

* Formerly described as "Humic Gley soil, alkaline subsoil phase" (DAY, 1961).

B_{22g} 40-140 cm - Dark grey (5Y 4/1) clay, with many, fine, faint mottles of light yellowish brown (2.5Y 6/4). Structure in upper part medium prismatic, of weak to moderate strenght. Common, faint clay skins on vertical pedfaces. Distinct slickensides on the sub-horizontal surfaces. Moist, lower part still wet. Very sticky and very plastic. Concretions of managanese as above. pH 9. No effervescence with HCl. Transition gradual.

(with Dutch auger:)

B_{3g} 140-210 cm - Light grey (5YR 6/1) clay, with many, coarse, prominent mottles of yellowish red (5YR 5/8). In the yellowish red, half-hard lateritic tubes. Wet. Very sticky and very plastic. pH 9. No effervescence with HCl. Transition clear.

G 210-225+ cm - Grey (N 4/0) clay. Wet. Very sticky and very plastic. pH 9. No effervescence with HCl.

Soil profile B.2 (field description no. 160 A)

Location: Farm no. 6, area 1. Lat. 0^{o} 47' S, Long. 48^{o} 41' W. Eastern part of Marajó island.

Relief and drainage: Lowland, at transition zone between dried out creek and about 1 m higher, flat terrain. Poorly drained: upper terrain submerged with about 0.5 m water in the rainy season.

Parent material: Sub-recent marine-deltaic sediments.

Vegetative cover: High grasses.

A_{11} 0-12 cm - Very dark grey (10YR 3/1) clay, with common, fine, distinct mottles of yellowish-brown (10YR 5/6), mainly along the grass roots. Structure medium angular blocky, of moderate strength. Dry, very hard, surface slightly cracked. Very sticky and very plastic when wet. Many roots. pH (SOILTEX) 4. Transition clear.

A_{12} 12-18 cm - Dark grey (10YR 4/1) clay, with many, very fine, distinct mottles of reddish brown (5YR 4/4). Structure moderate to strong fine angular blocky. Dry, hard. Very sticky and very plastic when wet. Many roots. pH 4. Transition abrupt and irregular.

B_{2g} 18-38 cm - Very dark grey (5Y 3/1) clay, with common, coarse, faint to distinct mottles of light olive brown (2.5Y 5/4). Also, locally, fine mottles of red (2.5YR 4/6). Structure moderate coarse columnar to prismatic. Distinct clay skins on all vertical pedfaces. Faint slickensides on the subhorizontal wands. Compact. Dry, very hard. Very sticky and very plastic when wet. Some small concretions of manganese. pH 5.5. Transition gradual.

B_{3g} 38-110 cm - Light yellowish brown (2.5Y 6/4) clay, with many, medium-sized, distinct mottles of very dark grey (5Y 3/1), mainly on the pedfaces. Structure in upper part is coarse prismatic, of moderate strength. Distinct clay skins on all vertical pedfaces. Strong slickensides on the subhorizontal wands. Upper part dry, hard; lower part, humid. Very sticky and very plastic when wet. pH 7.5. No effervescence with HCl. Transition gradual.

(with Dutch auger:)

G_1 110-170 cm - Light grey (N 7/0), silty clay, with many, coarse, prominent mottles of yellow (10YR 6/8). In the upper part, red (2.5YR 4/6) centers in the yellow mottles, occasionally hardened. pH 6.

G_2 170-270+ cm - Grey (N 5/0) clay. Wet, muddy. Very sticky and very plastic. pH 7.

Note: the creek bottom soil has an apparently more humic top, and a weakly developed structure in the B horizon. The soils of the upper terrain itself have most probably a more pronounced structure than described.

Soil profile no. B.3 (field description no. 154)

Location: Farm no. 1, area 1. Lat. 0° 43' S. Long. 49° 03' W. About 50 km N of Arariuna. Central part of eastern Marajó island.

Relief and drainage: Flat lowland, intersected with very shallow creeks. Poorly drained: submerged by about 1 m rainwater during rainy season.

Parent material: Subrecent marine-deltaic (?) sediments.

Vegetative cover: Grasses, and some tall, scattered herbs. Rarely, low trees.

(with Dutch auger:)

A_1 0-20 cm - Dark grey (10YR 4/1) clay, with many, fine to medium-sized, distinct mottles of strong brown (7.5YR 5/8). Dry, very hard, with large cracks and much cattle trampling. pH (SOILTEX) 5. Transition clear.

B_{2g} 20-70 cm - Brownish yellow (10YR 6/6) clay, with many, fine, distinct mottles of grey (N 5/0). In upper part also some faint, reddish brown (2.5YR 3/4) spots, in lower part some black (N 2/0) spots. Very compact. Moist, very firm. pH 7.5. Transition gradual.

G_1 70-110 cm - Light grey (N 7/0) silty clay, with many, fine, distinct mottles of reddish yellow (7.5YR 6/8). Moist, firm. pH 8. Transition clear.

G_2 110-120 cm - White (N 8/0) sandy loam. With thin bands of silty clay loam, that are variegated grey (N 6/8) and strong brown (7.5YR 5/6) coloured. Moist, very friable. pH 9. Transition gradual.

G_3 170-250 cm - Bluish grey (N 5/0) clay, with a few black (N 2/0) spots and stipes. With thin bands of silty clay loam, that are variegated grey (N 6/0) and yellowish brown (10YR 5/4) coloured. Wet, sticky and plastic. pH 9.

Range in characteristics: As shown in the three descriptions, the thickness of the A_1 is variable, as well as the strength of the structure in the B_2, and the texture of the horizons of the deeper subsoil.

Relief: Flat low land, intersected with very shallow, often overgrown, creeks.

Drainage: Poorly drained. Runoff and internal drainage are very slow. During the rainy season, the terrains are covered with 0.5-2 m standing rainwater.

Vegetation: Grasses and, mainly in the creeks, many tall herbaceous plants, e.g. "algodao bravo", Ipomea fistulosa; "arumá", Ischnosiphon Sp. Trees and shrubs are absent, except scattered along the larger rivers.

Soil profile no. B.1 Classification: Solonetz, Coastal phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.862	A_1	0- 20	0	0	100.0	1.42	2.66	47	38.1
31.896	B_{21g}	20- 40	0	0	100.0	1.39	2.61	47	47.3
31.897	B_{22g}	40-140	0	0	100.0	1.46	2.71	46	48.3
31.898	B_{3g}	140-210	0	0	100.0	1.41	2.70	48	57.0

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.862	0.4	9.1	24.7	65.8	31	39.9	39
31.896	0.3	23.3	12.2	64.2	20	58.2	9
31.897	0.3	24.3	20.4	55.0	32	53.9	2
31.898	0.5	18.4	19.8	61.3	30	60.7	1

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.862	22.88	18.49	8.14	0.55		2.10	1.64
31.896	27.83	17.13	6.73	0.66		2.76	2.21
31.897	22.35	14.61	7.10	0.58		2.60	1.99
31.898	25.28	16.99	8.07	0.69		2.53	1.94

Soil profile no. B.1 Classification: Solonetz, Coastal phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.862	1.16	0.13	8.9	5.0	3.8		2.0
31.896	1.18	0.12	9.8	5.3	4.2	0.16	1.0
31.897	0.25	0.04	6.3	8.0	6.8	0	3.8
31.898	0.21	0.04	5.3	7.9	6.9	0	3.8

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.862	2.86	11.24	0.73	1.56	16.39	5.73	22.12	74.1	1.06
31.896	2.93	8.41	0.51	8.02	19.87	4.71	24.58	80.8	3.75
31.897	3.12	9.44	0.54	8.40	21.50	0	21.50	100.0	6.24
31.898	3.34	10.71	0.80	7.90	22.75	0	22.75	100.0	7.86

Note: Sampling of A_1 at beginning of dry season: of B_{21}, B_{22} and B_3 at end of dry season.

Soil profile no. B.2 Classification: Solonetz, Coastal phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.880	A_{11}	0- 12	0	0	100.0	1.11	2.40	54	44.6
31.881	A_{12}	12- 18	0	0	100.0	1.34	2.64	49	40.8
31.882	B_{2g}	18- 38	0	0	100.0	1.45	2.67	46	45.0
31.883	B_{3g}	38-110	0	0	100.0	1.46	2.69	46	44.9
31.884	G_1	110-170	0	0	100.0	1.48	2.70	45	41.7
31.885	G_2	170-270	0	0	100.0	1.44	2.63	45	35.2

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.880	0.1	19.8	20.7	59.4	32	25.9	56
31.881	0.7	7.7	24.9	66.7	30	36.5	45
31.882	1.3	12.9	20.0	65.8	28	59.5	10
31.883	0.2	4.0	38.6	57.2	40	53.6	6
31.884	1.2	14.4	34.8	49.6	42	5.7	89
31.885	0.3	40.1	15.6	44.0	33	0	100

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.880	28.01	17.29	4.98	0.53		2.75	2.33
31.881	28.80	18.31	8.05	0.61		2.67	2.09
31.882	23.83	17.38	7.62	0.54		2.33	1.82
31.883	26.64	15.35	6.71	0.50		2.95	2.31
31.884	23.26	13.89	6.77	0.50		2.85	2.17
31.885	20.36	11.41	5.10	0.47		3.03	2.36

Soil profile no. B.2 Classification: Solonetz, Coastal phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.880	3.86	0.45	8.6	4.8	3.7	6.40	0.7
31.881	1.17	0.12	9.8	5.1	3.8	3.12	0.7
31.882	0.54	0.09	6.0	6.4	5.3	0	1.0
31.883	0.35	0.06	5.8	7.0	6.0	0	0.7
31.884	0.16	0.05	3.2	5.3	4.5	0	0.7
31.885	0.62	0.08	20.3	2.6	2.3	24.00	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.880	1.42	4.89	0.43	0.58	7.32	17.00	24.32	30.1	0.80
31.881	1.46	10.64	0.30	1.52	13.92	5.31	19.23	72.4	0.92
31.882	2.73	17.67	0.39	4.69	25.48	0	25.48	100.0	2.29
31.883	2.65	16.50	0.60	5.09	24.84	0	24.84	100.0	4.94
31.884	2.14	12.01	0.59	4.23	18.97	0	18.97	100.0	6.36
31.885	2.92	1.09	0.64	0.27	4.92	24.49	29.41	16.7	7.72

Soil profile no. B.3 Classification: Solonetz, Coastal phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.832	A_1	0- 20	0	0	100.0	1.32	2.58	49	37.5
31.883	B_{2g}	20- 70	0	0	100.0	1.45	2.65	45	41.5
31.834	G_1	70-110	0	0	100.0	1.52	2.66	43	40.3
31.835	G_2	110-170	0	0	100.0	1.48	2.67	45	24.2
31.836	G_3	170-250	0	0	100.0	1.48	2.70	45	30.1

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.832	0.4	15.5	22.9	61.2	34	31.0	49
31.833	1.3	20.2	20.6	57.9	31	57.1	1
31.834	0.3	18.4	31.6	49.8	42	47.3	5
31.835	0.1	67.4	14.0	18.5	27	18.5	0
31.836	0.1	46.9	20.4	32.6	36	31.4	4

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.832	26.17	16.71	7.79	0.62		2.67	2.05
31.833	27.60	16.59	7.36	0.58		2.82	2.21
31.834	23.61	13.81	6.37	0.58		2.91	2.25
31.835	11.10	7.08	3.17	0.46		2.67	2.07
31.836	17.95	10.70	5.08	0.50		2.86	2.19

Soil profile no. B.3 Classification: Solonetz, Coastal phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.832	1.47	0.18	8.2	5.1	3.7	2.96	1.0
31.833	0.48	0.07	6.9	7.1	5.9	0	3.8
31.834	0.20	0.04	5.0	8.3	6.9	0	5.4
31.835	0.10	0.02	5.0	8.2	7.0	0	4.9
31.836	0.53	0.05	10.6	7.3	6.5	0	5.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.832	1.75	5.69	0.38	0.93	8.75	7.59	16.34	53.6	0.20
31.833	1.66	5.61	0.28	3.20	10.75	0	10.75	100	1.19
31.834	2.45	10.69	0.29	3.83	17.26	0	17.26	100	2.94
31.835	2.74	12.42	0.22	2.93	18.31	0	18.31	100	2.18
31.936	2.55	7.19	0.89	3.13	13.76	0	13.76	100	3.57

Distribution: The soils are common in the central part of eastern Marajó island. They are most probably also common in the northern part of the lowlands of coastal Amapá.

Considerations about the analysis data: (see also topsoil analyses of farm no. 11, table in the back of the printed Report)
The textures of the horizons are variable, not only in the deeper subsoil. This indicates that, notwithstanding the signs of vertical transportation of clay sized particles (clay skins in the B horizon), this process has not been as pronounced as to eradicate the textural differences due to deposition. But notable is the fact that the percentages of silt are comparatively low in the upper 50 cm of the profiles. The C/N values of the topsoils are between 8 and 10.

Almost all subsurface horizons have high percentages of natural clay, indicating a high degree of dispersion of the clay fraction. The Ki values are between 2.5 and 3.0; there will be a predominance of silicate clay minerals with 2:1 lattice structure.

The base exchange capacity is about 20-35 m.e./100 g clay (after correction for the organic matter content). The degree of base saturation is rather high to total. The Mg^{++} and Na^{+} ions are strongly predominant, especially in the subsurface horizons. Except for the topsoil, the soils are slightly or moderately saline.

The lowest horizon of profile B.2 has a mudclay character. Its organic matter content is rather high, the C/N value high (20), the natural clay content (after drying!) very low.

SALINE SOIL

Soil profile no. B.4 (field description no. 163)

Location: Farm no. 5, area 1. Lat. 0^{o} 41' S, Long. 48^{o} 30' W. About 10 km NW of Soure. East coast of Marajó island.

Relief and drainage: Lowland, flat with micro-relief. Poorly drained: in the rainy season, covered with 0.5-1 m (rain?) water, in the dry season, logged till about surface with brackish water, in connection with nearby brackish water creek.

Parent material: Recent marine sediments.

Vegetative cover: Juncus species, some grasses.

A_0 10-0 cm - Fresh grass roots, with hardly mineral material.

A_1 0-40 cm - Black (N 2/0), loose clay loam. Weak, fine, granular structure. Sticky and plastic. pH (SOILTEX) 5.5. Many fresh and half-decomposed small roots. Transition gradual.

(with Dutch auger:)

G_1 40-90 cm - Grey (10YR 5/1), loose clay loam. Sticky and plastic. pH 7. Transition gradual.

G_2 90-120 cm - Grey (N 6/0) clay loam, with common to many, medium-sized, distinct mottles of brownish yellow (10YR 6/8). Plastic and very sticky. pH 6.

G_3 120-200+ cm - Light grey (N 7/0) clay. Plastic and slightly sticky. The soil mass falls easily apart in small parts (1-2 cm diam.). Many small, brown, half decomposed organic relics. pH 4.5.

Note: The soil auger is easily pushed through the whole profile.

Range in characteristics: The texture may be a clay throughout the profile. The black toplayer may be thinner. At the lowest spots there occurs less mottling in the profile. The hue of the soil colours may be 2.5Y or 5Y. Near the tidal creeks the soil may have more structure.

Relief: Flat lowland; under influence of brackish water of tidal creeks or of rivers with tidal movement.

Drainage: Surface drainage is very poor, due to the position of the terrain. Internal drainage is probably good.

Vegetation: Herbaceous plants (Juncus, Salicornia, grasses) or mangrove (Rizophora mangle L, Avicennia spp), the latter especially at sites with strong influence of tides.

Soil profile no. B.4 Classification: Saline soil

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.857	A_1	0- 40	0	0	100.0	1.20	2.46	51	39.1
31.858	G_1	40- 90	0	0	100.0	1.33	2.59	49	33.1
31.859	G_2	90-120	0	0	100.0	1.40	2.62	47	35.5
31.860	G_3	120-200	0	0	100.0	1.33	2.50	47	42.7

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.857	0.1	50.6	17.0	32.3	30	11.3	65
31.858	0.1	51.0	18.2	30.7	34	13.3	57
31.859	0.4	34.7	21.1	43.8	33	21.3	51
31.860	0.1	24.8	21.7	53.4	33	2.6	95

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.857	19.12	8.41	3.56	0.48		3.86	3.04
31.858	17.43	8.80	2.39	0.51		3.37	2.87
31.859	21.72	12.60	3.74	0.61		2.93	2.46
31.860	22.58	13.82	3.42	0.56		2.78	2.40

Soil profile no. B.4 Classification: Saline soil

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.857	2.97	0.24	12.4	4.0	3.6	1.16	0.7
31.858	1.08	0.09	12.0	4.1	3.6	0.60	0.7
31.859	1.05	0.09	11.7	3.9	3.4	1.00	0.7
31.860	2.96	0.14	21.1	3.2	2.9	?	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.857	2.46	7.39	1.19	0.30	11.54	9.03	20.37	55.7	9.33
31.858	1.47	5.63	1.12	1.23	9.45	3.32	12.77	74.0	7.15
31.859	1.83	7.79	1.96	1.34	12.92	4.38	17.30	74.7	8.01
31.860	2.26	8.89	1.10	1.61	13.86	14.78	28.64	48.4	14.79

Distribution: Coastal low terrains under influence of tides with brackish or salt water, e.g. eastcoast of Marajó island.

Considerations about the analysis data: The silt/clay ratio is higher than that of the Solonetz, Coastal phase profiles (see B.1, B.2 and B.3). The percentage of natural clay is rather low in the upper three horizons, in contrast to that of the Solonetz, Coastal phase profiles. The Ki values vary between 2.8 and 3.8; the silicate clay minerals will be of the 2:1 lattice structure.

The base exchange capacity is 30-35 m.e./100 g clay (after correction for the organic matter content). The degree of base saturation is medium to rather high. The predominant exchangeable cations are Mg^{++} and Na^{+} (the actual Mg/Na ratio at the adsorption complex is probably lower than indicated; the given data are based upon the assumption that all of the soluble cations are Na^{+} (see description of analysis methods). The soil is moderately saline. The C/N values are about 12.

Exceptional is the lowest horizon. It has a mudclay character, with analysis data similar to those of the lowest horizon of profile B.2. In fact, the low values of the laboratory pH of the other horizons do assume that also these have such a mudclay character, to some extent. Part of the determined "soluble salts" may be therefore due to SO_4^{--}, formed after drying.

BRACKISH GROUND WATER IN THE CENTRAL PART OF MARAJÓ ISLAND

The salinity of the subsoils of the described Solonetz, Coastal phase is related to brackish ground water, which is a common occurrence over a large part of central Marajó (about 5000 sq-km) during the dry season. The spots, where the presence of brackish ground water was reported and/or established, are indicated on the accompanying map. On several farms, the ground water is too salty to serve as potable water for man and sometimes even for animals. A boring at farm Severino (farm no. 1), situated about 10 km from the fresh water lake Arari, revealed brackish ground water up to a depth of 65 m.

In one instance, a small, salt water spring was seen, namely at farm Menino Jesus. It was located about 10 km southwest of the fresh water lake Arari, within, perhaps, one meter of the same height and about 100 m distance from

the fresh water river Arari. The water from this spring was quite salty to the taste and it is surrounded by a white crust during severely dry periods (see photo). During the rainy season the whole of the area is covered with about 1.5 m standing rainwater. Analysis of the springwater by IQA gave the following data:
(For comparison, also the composition of sea water is given.)

Analysis of water of salty spring

Farm Menino Jesus, central part of Marajó island
(analysis by IQA, Rio de Janeiro)

	g/l	me/l	seawater ★ g/l
Sodium, as Na^+	2.91	126.5	10.56
Magnesium, as Mg^{++}	0.25	20.5	1.27
Calcium, as Ca^{++}	0.05	2.3	0.40
Potassium, as K^+	0.07	1.8	0.38
Chlorine, as Cl^-	5.04	142.0	18.98
Bicarbonate, as HCO_3^-	0.55	9.0	0.14
Carbonate, as CO_3^{--}	absent		
Sulphate, as SO_4^{---}	trace		2.65
Others			0.10
Total	8.89 g/l		34.48 g/l
pH: 7.4	(total of anions: 151.1 me/l total of cations: 150.0 me/l)		

The presence of brackish ground water in the central part of Marajó island appears rather curious. It is true that most of the rivers in the area are affected to some extent by tides, especially in the dry season, but there are no points of penetration of brackish or salty water into the central area by way of rivers.

The region is receiving an average annual rain fall of approximately 2000 mm. This amount is mainly falling in the period February-June. In this season there is an unsufficient discharge of the water through the generally narrow,

★ RANKAMA and SAHAMA (1949)

curvy rivers past the relatively higher coastal regions. Therefore almost the whole central region is, in this season, covered with about 1 m of standing fresh water. That nevertheless the subsoil water contains free salts is only explainable by assuming that the soils are extremely slowly permeable for surface water.

The analysis data of the salty spring water show that the concentration of salts is about one-fourth of that of seawater. The proportions of the salts are partly different from those in seawater.

3C. GROUND WATER LATERITE SOILS

INTRODUCTION

The Ground Water Laterite soils are imperfectly drained, very strongly or extremely acid, moderately to strongly weathered soils. They have a definite A2 horizon. The B horizon has, characteristically, an abundant prominent mottling of red (and yellow) in a white or light grey matrix ("soft plinthite"). In the red parts, hardening centers are often present.

The described heavy textured phase and light textured phase are only moderately weathered soils, in which there exists no marked textural difference between the A and the B horizons. The first has developed on clayey, the latter on sandy sediments. The heavy textured phase has clayey A and B horizons, and often a conspicuous A1 horizon. The light textured phase has sandy A and B horizons.

The medium textured phase is a strongly weathered soil. It has an A2 of rather light texture (mostly sandy loam), with a gradual transition to a dense B horizon that consists of rather heavy texture (mostly sandy clay).

The Low phase is a very strongly weathered soil. Its profile has a thick, bleached, generally very sandy A2, which grades sharply into a B horizon, that is dense, heavy textured and slowly permeable.

The Truncated phase is an old, strongly weathered soil, with the geologic erosion progressed to the point that all of the light textured horizon A and part of the heavy textured B of the original Ground Water Laterite have been stripped away. The originally soft, red concretions of hydrated iron in the old B horizon are dried and hardened over some depth. They remain as a concentration of hardened laterite fragments ("hard plinthite") in the now mainly heavy textured surface layer. The subsoil of the new profile keeps the soft plinthitic appearance of the lower part of the original B.

Note: The Truncated phase is an almost well-drained soil. Morphologically, the profile has the characteristics of either a Latosol or a Red Yellow Podzolic soil. Just to which of these two units a specific profile belongs is difficult to establish in the field, because of the stoniness.

Since, moreover, the concretions present a marked difference in agricultural value with the normal Latosols and Red Yellow Podzolic soils, the soils are classified separately, with the genetic name "Ground Water Laterite, Truncated phase", in accordance with DAY (1961).

GROUND WATER LATERITE SOIL, HEAVY TEXTURED PHASE

Soil Profile no. C.1 (field description no. 157)

Location: Farm no. 8, area 2. Lat. 1° 09' S, Long. 49° 11' W. About 40 km N of Muaná. Southeast-central part of Marajó island.

Relief and drainage: Low, flat terrain. During the rainy season, covered by about 0.5 m rain water; during the dry season a ground water level at 3-4 m.

Parent material: Subrecent fluviatile (?) sediments.

Vegetative cover: Grasses; scattered palmtrees ("buriti") and shrubs.

A_1 0-30 cm - Black (N 2/0), very friable, humic clay loam. Strong fine granular structure. pH (SOILTEX) 4. Transition gradual.

(with Dutch auger:)

A_2 30-60 cm - Light grey (10YR 7/1), firm clay with a few, fine, distinct mottles of reddish yellow (7.5YR 6/8). pH 4. Transition gradual.

B_2 60-270 cm - White (N 8/0), very firm clay, with many large prominent mottles of dark red (7.5R 3/6) and some yellow (10YR 7/8). Throughout the horizon in the dark red many, small, dusky red, half-hardened concretions. Compact. pH 4. Transition clear.

C_g 270-325+ cm - White (N 8/0), very friable to loose fine sandy loam, with many, large, prominent mottles of yellow (10YR 8/8) and light red (2.5YR 6/8). pH 4.

Note: A similar profile in the neighbourhood (Fazenda Espírito Santo) showed in the B_{21} the following structure: weak to moderate coarse prismatic, breaking into strong coarse subangular blocky. Presence of clayskins. Its topsoil, estimated as "clay loam", gave, upon analysis, 31% clay.

Soil profile no. C.2 (field description no. 182)

Location: Farm no. 10, area 1. Lat. 1^{o} 16' S, Long. 49^{o} 26' W. About 35 km NW of Muaná. Southeast-central part of Marajó island.

Relief and drainage: Low, flat terrain. During the rainy season, covered with 1 or 2 m rainwater; during the dry season a ground water level at 3-4 m.

Parent material: Subrecent fluviatile (?) sediments.

Vegetative cover: Grasses. Scattered shrubs. The vegetation is attacked by fire in most dry seasons.

(with Dutch auger:)

A_1 0-40 cm - Grey (10YR 5/1), friable to firm clay loam, with common, fine, distinct mottles of yellowish red (5YR 4/8), mainly along the roots. Plastic and slightly sticky when wet. Many roots. pH (SOILTEX) 4 or less. Transition clear.

A_2 40-60 cm - Light brownish grey (10YR 6/2), firm clay loam, with many, fine, faint to distinct mottles of reddish yellow (7.5YR 6/8). Sticky and plastic when wet. pH 4 or less. Few roots. Transition clear.

B_2 60-125+ cm - White (N 8/0), firm clay, with many, coarse, prominent mottles of dark red (7.5R 3/6) and reddish yellow (7.5YR 6/8). Very compact. Sticky and plastic when wet. Very few roots.

Range in characteristics: Profile C.1 is more characteristic for the phase than profile C.2. The A_2 is often without any mottling.

Relief: Flat, low lying terrains. With several, tree fringed, streamlets, under influence of fresh water tidal movements.

Soil profile no. C.1

Classification: Ground Water Laterite soil, heavy textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.852	A_1	0- 30	0	0	100.0	1.29	2.48	48	29.4
31.853	A_2	30- 60	0	0	100.0	1.50	2.63	43	26.2
31.854	B_2	60-270	0	3.5	96.5	1.51	2.72	44	30.3
31.855	C_g	270-325	0	0	100.0	1.62	2.64	39	16.2

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.852	0.3	69.0	13.1	17.6	23 ?	5.1	71
31.853	0.1	48.8	9.9	41.2	16	0.4	99
31.854	3.5	26.3	17.9	52.3	18	0.8	98
31.855	0.4	78.2	10.7	10.7	20 ?	0.4	96

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.852	8.17	6.04	0.72	0.43		2.30	2.14
31.853	17.25	14.28	1.54	0.62		2.05	1.92
31.854	22.61	18.07	7.60	0.66		2.13	1.68
31.855	4.72	3.80	1.01	0.36		2.11	1.81

Soil profile no. C.1

Classification: Ground Water Laterite soil, heavy textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.852	3.13	0.21	14.9	4.7	3.8	3.36	1.3
31.853	0.42	0.05	8.4	4.8	3.8	4.92	1.0
31.854	0.21	0.03	7.0	4.8	3.7	7.80	1.0
31.855	0.04	0.01	4.0	4.7	3.7	0.50	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.852	0.43		0.10	0.08	0.61	11.73	12.34	4.9	
31.853	0.55		0.09	0.06	0.70	5.15	5.85	12.0	
31.854	0.77		0.14	0.06	0.97	7.92	8.89	10.9	
31.855	0.64		0.08	0.07	0.79	0.61	1.40	56.4	

Soil profile no. C.2

Classification: Ground Water Laterite soil, heavy textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.912	A_1	0- 40	0	0	100.0	1.36	2.54	46	30.0
31.913	A_2	40- 60	0	0	100.0	1.49	2.62	43	28.6
31.914	B_2	60-125	0	0	100.0	1.45	2.66	45	32.2

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.912	0	45.8	23.5	20.7	40	12.8	58
31.913	0.1	36.3	27.0	36.6	42	18.1	51
31.914	0.7	28.2	18.8	52.3	31	3.9	93

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.912	14.24	9.97	1.75	0.47		2.43	2,19
31.913	16.44	12.12	2.26	0.58		2.31	2.06
31.914	22.52	18.35	4.33	0.55		2.09	1.81

Soil profile no. C.2

Classification: Ground Water Laterite soil, heavy textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.912	1.57	0.11	14.3	4.2	4.1	5.12	1.3
31.913	0.67	0.10	6.7	4.4	4.1	5.82	1.3
31.914	0.19	0.07	2.7	4.6	4.1	7.84	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.912	0.31		0.22	0.11	0.64	8.85	9.49	6.7	
31.913	0.25		0.19	0.08	0.52	7.43	7.95	6.5	
31.914	0.54		0.17	0.08	0.79	8.27	9.06	8.7	

Drainage: Both internal drainage and runn-off are slow. During the rainy season the terrains are submerged with a thin layer of rain water (up to 50 cm); during the dry season they dry out to a great depth.

Vegetation: Open grass savannah; often scattered "buriti" (Mauritia flexuosa) palms and some shrubs.

Distribution: The soils were only observed in the southeast-central part of Marajó island, in the region of the middle courses of the rivers Anabiju and Afuá.

Considerations about the analysis data: The percentages of silt are mostly medium. (The high values in the upper part of profile C.2 are probably due to siltiness of the original sediment.) There is an increase in texture from the A to the B horizon, but this is not pronounced (textural ratio B/A is about 1,5; the low value for the clay percentage in the A_1 of C.1 is probably due to incomplete dispersion of the humic structure elements during the laboratory analysis).

The Ki values are about 2.4 in the topsoil, about 2.1 in the subsoil. In the latter, silicate clay minerals of 1:1 lattice structure (kaolinite) will be predominant. The base exchange capacity is rather low, namely 10-15 m.e./100 g clay (after correction for the organic matter content). The degree of base saturation is low or very low. The amount of exchangeable $(Al)^+$ is high; it amounts to 50-90% if the base exchange capacity. The C/N value of the topsoil is relatively high, namely about 15.

GROUND WATER LATERITE SOIL, LIGHT TEXTURED PHASE*

Soil profile no. C.3 (field description no. 151)

Location: Farm no. 8, area no. 1. Lat. 1° 09' S. Long 49° 11' W. About 40 km N of Muaná. Southeast-central part of Marajó island.

Relief and drainage: Ridgelike terrain, slightly elevated (1-2 m) above, in the season shallowly submerged, lowland. Imperfectly drained: ground water level at 2 m in the dry season, at 1.5 m in the rainy season.

* Formerly "Sandy Ground Water Laterite" (DAY, 1961)

Parent material: Late Pleistocene, or early Holocene, fluvio-marine (?) sediments.

Vegetative cover: Grasses; occasionally low trees and palms ("tucuma", Astrocaryum vulgare). Vegetation gets burned in most dry seasons. Formerly probably forest-covered.

A_{11} 0-20 cm - Grey (10YR 6/1) fine sand. Single grains. Moist, loose. Not sticky and not plastic when wet. Soft when dry. Many roots. Transition gradual.

A_{12} 20-70 cm - Dark grey brown (10YR 4/2) fine sand. Structureless, to weak fine crumbly. Moist, very friable. Not sticky and not plastic when wet. Many pores. Many roots. Transition gradual.

(with Dutch auger:)

A_2 70-140 cm - Pale yellow (2.5Y 7/4) loamy fine sand. Moist, loose. Not sticky and not plastic when wet. Common roots. Transition gradual.

B_1 140-170 cm - Brownish yellow (10YR 6/8) loamy fine sand, with common, medium-sized, distinct mottles of red (10R 5/8). A few, small, hard, iron concretions. Moist, loose. Not sticky and not plastic when wet. Transition gradual.

B_{21} 170-200 cm - Red (2.5YR 4/8) loamy fine sand, with many, coarse, distinct mottles of brownish yellow (10YR 6/8). Moist, loose. Not sticky and not plastic when wet. Transition gradual.

B_{22} 200-230 cm - White (N 8/0) loamy fine sand, with many, medium-sized, distinct mottles of light red (2.5YR 6/8) and yellow (10YR 7/8). Wet, not sticky and not plastic. Transition gradual.

C 230-325+ cm - White (N 8/0) fine sand. Wet, not sticky and not plastic.

Note: The pasture at the site of the profile has received some fertilizers.

Soil profile no. C.4 (field description no. 162)

Location: Farm no. 7, area no. 1. Lat. 0° 48' S. Long. 48° 40' W. About 25 km W of Soure. Eastern part of Marajó island.

Relief and drainage: Slightly dipping part of extensive, flat, low, upland, about 2-3 m above high water level. Imperfectly drained: ground water level at 2.5 m in the dry season, at 1 m in the rainy season.

Parent material: Late Pleistocene, or early Holocene, fluvio-marine (?) sediments.

Vegetative cover: Grasses; scattered low trees and shrubs. Vegetation gets burned in almost all dry seasons. Formerly probably forest covered.

A_1 0-30 cm - Black (10YR 2/1) sandy loam, with white points of bleached quartz grains. Single grains. Moist, loose. Not sticky and not plastic when wet. Soft when dry. Many pores. Many roots. Transition gradual.

A_2 30-90 cm - White (10YR 8/2) light sandy clay loam. Very little coherent porous massive. Moist, very friable. Not sticky and slightly plastic when wet. Slightly hard when dry. Many pores. Common roots. Transition gradual.

B_1 90-120 cm - Yellow (10YR 6/8) light sandy clay loam, with many, medium-sized to coarse, distinct to prominent mottles of red (2.5YR 4/8) and white (10YR 8/1). Within the red some small iron concretions. Structure weak to moderate medium-sized prismatic, falling apart into weak medium-sezed subangular to angular blocks. Common, faint clayskins.

B_2 120-260 cm - White (N 8/0) sandy clay loam, with many medium-sized to coarse, prominent mottles of red (10R 4/6) and some brownish yellow (10YR 6/8), in a reticulate-prismatic pattern. Centres of the red half hardened. Structure moderate medium-sized angular blocky, composing weak medium-sized prisms. Common, faint to distinct, clayskins. Moist, friable. Slightly sticky and and slightly plastic when wet. Hard when dry. Very few pores. No roots. Transition gradual.

(with Dutch auger:)

B_3 260-200+ cm - White (N 8/0) light sandy clay loam, with many, coarse, prominent mottles of pale yellow (2.5Y 8/4) and light red (2.5YR 6/6). Scattered, large, loose iron concretions, especially in the lower part.

Note: The profile is located near a spot with traces of former, longlasting, indian occupation ("terra preta").

Range in characteristics: Profile C.3 is more characteristic for the phase than profile C.4. The latter, with the pronouncedness of its A_2 and the medium textures, is, in fact, intergrading to both the medium textured phase and the Low phase.

The A horizon is often less thick than that of profile C.3 and its colour more often grey than brown or yellow. The basic colour of the B horizon is often white, with many coarse, prominent mottles of red. The pattern of mottling is mostly tubular. The structure of the B horizon is mostly less pronounced than that of C.4, often massive.

The subdivision of the A_1 horizon in a lighter coloured upper part and a darker lower part (see C.3), is a common feature of the phase, when found under grass-cover. Apparently some illuviation of organic matter to the lower part of the A_1 has taken place. Sometimes even a thin, dark, indurated layer (Ortstein) is found in the lower part of the A horizon. The fact that this illuviation was never observed in profiles still under forest cover, does assume that the process is rather recent, namely having started only after destruction of the primeval vegetation by human occupation. Notable is, that the places where the light textured phase occurs, were generally favoured as settling sites of the late Marajó indians.

Relief: Extensive, approximately flat, low upland, 2-3 m above yearly high water level. Narrow ridges ("tesos"), 1-3 m above surrounding submergeable lowland.

Drainage: Imperfectly drained.

Parent material: Late Pleistocene, or early Holocene, fluvio-marine (?) sandy sediments. The ridges may have a similar origin as the "ritsen" in the coastal landscape of the Guianas (see VAN DER EYK, 1957).

Soil profile no. C.3

Classification: Ground Water Laterite soil, light textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.927	A_1	0- 70	0	0	100.0	1.59	2.63	40	5.0
31.828	A_2	70-140	0	0	100.0	1.53	2.63	42	7.9
31.829	B_1	140-170	0	0	100.0	1.55	2.79	45	10.8
31.830	B_2	170-230	0	0	100.0	1.54	2.64	42	8.5
31.831	C	230-325	0	0	100.0	1.51	2.63	43	5.9

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.827	8.2	88.0	1.8	2.0	5 ?	0.2	90
31.828	7.0	84.6	2.6	5.8	7 ?	3.6	38
31.829	6.5	82.4	3.4	7.7	7 ?	0.2	97
31.830	5.7	85.5	2.8	6.0	7 ?	0.4	93
31.831	9.2	84.6	2.0	4.2	5 ?	2.6	38

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.827	0.52	1.02	0.70	0.17		0.87	0.60
31.828	1.81	3.03	0.60	0.20		1.02	0.90
31.829	3.48	3.39	1.61	0.25		1.75	1.34
31.830	2.81	2.51	1.61	0.25		1.90	1.35
31.831	2.55	2.15	0.40	0.17		2.02	1.80

Soil profile no. C.3

Classification: Ground Water Laterite soil, light textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.827	0.43	0.05	8.6	5.7	4.5	0.24	1.0
31.828	0.19	0.02	9.5	5.6	4.6	0.24	0.7
31.829	0.10	0.02	5.0	5.2	4.3	0.24	0.7
31.830	0.05	0.02	2.5	5.3	4.2	0.40	0.7
31.831	0.06	0.02	3.0	5.1	4.0	0.52	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.827	0.34		0.06	0.02	0.42	0.6	1.02	42.0	
31.828	0.30		0.08	0.02	0.40	0.6	1.00	40.0	
31.829	0.34		0.07	0.07	0.48	0.4	0.88	54.5	
31.830	0.34		0.06	0.02	0.42	0.5	0.92	45.5	
31.831	0.30		0.05	0.04	0.39	0.6	0.99	39.5	

Soil profile no. C.4

Classification: Ground Water Laterite soil, light textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.886	A_1	0- 30	0	0	100.0	1.34	2.47	46	25.0
31.887	A_2	30- 90	0	0	100.0	1.57	2.62	40	16.5
31.888	B_2	120-260	0	5.3	94.7	1.50	2.64	40	20.6
31.889	B_3	260-300	0	8.8	91.2	1.52	2.62	42	17.1

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.886	32.3	41.1	10.1	16.5	19	5.0	70
31.887	37.0	33.4	7.7	21.9	12	11.8	46
31.888	36.9	26.2	7.1	29.8	11	0	100
31.889	39.1	34.7	4.0	22.8	7	0	100

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.886	7.68	6.87	0.83	0.41		1.90	1.76
31.887	9.87	8.13	1.22	0.48		2.06	1.88
31.888	14.67	11.75	2.84	0.51		2.12	1.84
31.889	10.76	8.85	1.61	0.47		2.07	1.85

Soil profile no. C.4

Classification: Ground Water Laterite soil, light textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.886	3.33	0.20	16.7	4.5	4.4	3.04	1.0
31.887	0.22	0.03	7.3	4.9	4.7	1.56	1.0
31.888	0.09	0.02	4.5	5.0	4.9	2.48	1.3
31.889	0.71 ?	0.06	11.8	4.9	5.0	1.08	1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.886	0.33		0.10	0.09	0.52	15.95	16.47	3.2	
31.887	0.28		0.06	0.04	0.38	3.05	3.43	11.1	
31.888	0.30		0.07	0.03	0.40	3.26	3.66	10.9	
31.889	0.40		0.07	0.08	0.55	1.61	2.16	25.5	

Vegetation: The soils are found both under low forest (partly as small islands within large areas of low, grass covered, plains), and under open savannahs with scattered shrubs and low trees. The savannahs are probably the result of long lasting anthropogenic influence (see photo). A rather characteristic palm, both of the forest and the savannah, is the "tucuma" (Astrocaryum vulgare).

Distribution: Only observed on Marajó island. The common soil of the region of low upland in the south-eastern coastal part of the island. On narrow ridges, scattered throughout the low, central part of the island.

Considerations about the analysis data: (see also topsoil analyses of 4.2 and 6.2, in table at end of printed Report)
The silt content is relatively rather low. There has apparently been some illuviation of clay sized particles to the B horizon, especially in profile C.4 (textural ratio B/A = 1.2-1.5). The Ki values are about 2.0 in most horizons (the Ki of the A horizon of C.3 has little indicative value, in view of the very low percentage of clay). The predominant silicate clay minerals will be those of 1:1 lattice structure.

The base exchange capacity is rather low to low, namely roughly 10 m.e./100 g clay (after correction for the organic matter content). The base saturation is mostly low and the exchangeable $(Al)^+$ relatively high, namely amounting to about 50% of the base exchange capacity (profile C.3 is exceptional, because of the fertilizing). The C/N value is high in profile C.4, namely 17, rather low (9) in profile C.3 - but it should be kept in mind that in the latter the top sample comprises 70 cm!

GROUND WATER LATERITE SOIL, MEDIUM TEXTURED PHASE

Soil profile no. C.5 (field description no. 136)

Location: Farm no. 18, area no. 1. Lat. 2^{o} 07' S. Long 56^{o} 27' W. Terra Santa, Lower Amazon region.

Relief and drainage: Large, totally flat terrain, a few meters above the yearly high water level. Imperfectly drained.

Parent material: Late Pleistocene, or early Holocene, fluviatile sediments.

Vegetative cover: Open grass savannah (yearly burned), with occasional patches of low trees.

A_1 0-10 cm - Dark grey brown (10YR 4/2), very friable fine sandy loam, with a few, fine, faint mottles of strong brown (7.5YR 5/8), mostly along the roots. pH (SOILTEX) 4. Transition clear.

A_2 10-40 cm - Brownish yellow (10YR 6/8), friable fine sandy clay loam, with a few, fine, distinct mottles of grey (10YR 5/1). pH 4. Transition clear.

B_{21} 40-150 cm - Reddish yellow (5YR 6/8), firm sandy clay, with many, lar prominent mottles of red (2.5YR 5/8). A few, small, fine textured, soft, dusky red iron concretions occur within the red mottles. pH 4. Transition diffuse.

B_{22} 150-225+ cm - Light red (2.5YR 6/8), firm sandy clay, with many, la prominent, mottles of light grey (N 7/0) and yellow (10YR 6/8). Several small, fine textured, soft, dusky red iron concretions occur within the light red parts.

Soil profile no. C.6 (field description no. 124)

Location: Farm no. 15, area 1. Lat. 1^{o} 48' S. Long. 53^{o} 40' W. About 20 km NNW of Prainha. Lower Amazon region.

Relief and drainage: Flat remnant of terrace, about 50 m above nearby streamlet. Imperfectly drained.

Parent material: Early Pleistocene (?) sediments.

Vegetative cover: Grasses; scattered shrubs. Surface paved with stratified plates of laterite, coarse textured, fine textured, or combined.

A_1 0-10 cm - Yellowish brown (10YR 5/4) light fine sandy loam.

A_2 10-30 cm - Brownish yellow (10YR 6/6) fine sandy loam.

B_1 30-60 cm - Reddish yellow (5YR 6/8) fine sandy clay loam, with few to common, medium sized, prominent mottles of weak red (7.5R 4/4); also some white spots. A few (15%), small (213 cm), coarse textured iron concretions.

B_2 60-110+ cm - Light reddish brown (5YR 6/4) clay, with many, coarse, prominent mottles of dusky red (7.5YR 3/4), strong brown (7.5YR 5/8), and light grey (N 7/0).

Relief: Mostly flat terraces of Late Pleistocene, or old Holocene, deposits, one or two meters above yearly high water level. Sometimes also on higher, older terraces, especially where the substratum is little permeable.

Drainage: The flat relief hampers the surface drainage during the rainy season. Internal drainage is imperfect because of the dense, slowly permeable nature of the B horizon.

Vegetation: The soil is commonly associated with open grass savannahs. In the dry season, the vegetation dries out almost completely and is frequently burned; the remaining trees are mostly fire-resistent, e.g. "cajueiro do campo" (Curatella americana). The soil was, however, also observed at sites with a rather poor to moderately good cover of tropical rain forest.

Distribution: Extensive low upland areas between Oriximiná and Faro (Lower Amazon region). Scattered throughout the Amazon floodplain, namely on small, somewhat elevated patches, that are never or only rarely flooded, and then with almost siltless water of the Amazon tributaries.

Considerations about the analysis data: (see also topsoil analyses of 19.1 and 14.1, in table at end of printed Report)
The percentage of silt is low. There is a distinct increase in texture from the A to the B (textural ratio B/A = 1.9-2.9). The Ki values are between about 1.9 and 2.1; the silicate clay minerals will be, very predominantly, of the 1:1 lattice structure (kaolinite).

The base exchange capacity is low to very low. In profile C.5 is amounts to about 10 m.e./100 g clay (after correction for the organic matter content). The degree of base saturation is low to very low. The amount of exchangeable Al is high, especially in the subsoil (about 75% of the T value). The C/N value of the topsoil varies between 10 and 14.

Soil profile no. C.5

Classification: Ground Water Laterite soil, medium textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.814	A_1	0- 10	0	0	100.0	1.38	2.59	47	19.2
31.815	A_2	10- 40	0	0	100.0	1.41	2.64	47	20.2
31.816	B_{21}	40-150	0	0	100.0	1.40	2.68	48	28.7
31.817	B_{22}	150-225	0	0	100.0	1.46	2.69	46	29.5

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.814	2.5	72.5	7.1	17.9	13 ?	5.1	72
31.815	2.5	67.7	8.2	21.6	14 ?	6.3	71
31.816	2.1	50.9	9.9	37.1	15 ?	0.2	99
31.817	2.4	49.6	11.5	36.5	16 ?	0	100

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.814	7.81	6.34	2.45	0.41	0.01	2.09	1.68
31.815	9.22	8.42	2.84	0.47	0.01	1.86	1.53
31.816	18.27	14.62	5.76	0.58	0.01	2.12	1.70
31.817	20.12	15.45	3.49	0.58	0.01	2.21	1.93

Soil profile no. C.5

Classification: Ground Water Laterite soil, medium textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.814	1.12	0.09	12.4	4.6	3.8	2.04	1.0
31.815	0.53	0.05	10.6	4.8	4.0	2.00	0.7
31.816	0.34	0.05	6.8	5.3	4.0	4.00	0.7
31.817	0.15	0.02	7.5	5.4	3.9	5.61	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.814	0.37		0.08	0.04	0.49	5.30	5.79	8.5	
31.815	0.24		0.05	0.03	0.32	3.26	3.58	8.9	
31.816	0.23		0.06	0.04	0.33	4.74	5.07	6.5	
31.817	0.23		0.08	0.04	0.35	7.01	7.36	4.8	

Soil profile no. C.6

Classification: Ground Water Laterite soil, medium textured phase

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.552	A_1	0- 10	0	0.6	99.4	1.61	2.60	38	11.5
31.553	A_2	10- 20	0	0.4	99.6	1.61	2.62	39	17
31.554	B_1	30- 60	0	12.7	87.3	1.63	2.64	38	13
31.555	B_2	60-110	0	0.5	99.5	1.53	2.66	42	16

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.552	6.5	77.4	6.0	10.1	13 ?	7.0	31
31.553	6.0	69.2	8.1	16.7	17 ?	10.9	35
31.554	5.1	59.1	6.9	28.9	13 ?	13.6	53
31.555	2.9	38.1	10.2	48.8	16 ?	0.6	99

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.552	5.19	4.18	0.69	0.33		2.11	1.91
31.553	8.11	6.69	1.09	0.40		2.06	1.87
31.554	13.10	10.98	1.98	0.52		2.03	1.82
31.555	22.57	18.89	3.79	0.67		2.03	1.80

Soil profile no. C.6

Classification: Ground Water Laterite soil, medium textured phase

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^+$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.552	0.51	0.05	10.2	5.4	4.3		1.0
31.553	0.47	0.05	9.4	4.8	3.9		1.0
31.554	0.32	0.04	8.0	4.8	3.8		1.0
31.555	0.21	0.03	7.0	5.0	3.7		1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^+	Na^+	S	H^+	T		
31.552	0.40		0.22	0.05	0.67	1.61	2.28	29.4	
31.553	0.24		0.07	0.03	0.34	2.02	2.36	14.4	
31.554	0.24		0.09	0.03	0.36	2.02	2.38	15.1	
31.555	0.24		0.05	0.03	0.32	3.66	3.98	8.0	

3D. YELLOW LATOSOLS

INTRODUCTION

The Yellow Latosols are deeply and strongly weathered, very strongly or extremely acid, well drained soils, with a latosolic B horizon. Their colour is mostly of yellowish hue. Kaolinite is probably very predominant in the clay fraction. For practical mapping, the Yellow Latosols are subdivided according the texture of the B horizon.

The characteristics and the variations of the soils are extensively dealt with in the report on the recently concluded reconnaissance survey of an area along the upper part of the new Belém-Brasília highway (SOMBROEK, 1962). In the latter report the soils are classified as "kaolinitic Yellow Latosol".

YELLOW LATOSOL, LIGHT/MEDIUM TEXTURED*

Profile no. D.1 (field description no. 125)

Location: Farm no. 15A, area 2. Lat. 1° 40' S., Long. 53° 40' W. About 20 km NNW of Prainha, Lower Amazon region.

Relief and drainage: Gentle sloping middle terrace in undulating upland. Well drained.

Vegetative cover: Grasses and low brush (forest-cleared).

A_1 0-15 cm - Very dark grey (5YR 3/1), very friable loamy sand. pH (SOILTEX) 4. Transition gradual.

AB 15-30 cm - Strong brown (7.5YR 5/6), very friable sandy loam. pH 4. Transition diffuse.

B_2 30-120+ cm - Reddish yellow (5YR 6/8), very friable sandy loam. pH 4.

Range in characteristics: The colour in the B horizon may range from yellow (2.5Y 7/6) to yellowish red (5YR 6/8).

* Formerly "Sandy Yellow Latosol" (DAY, 1961)

Soil profile no. D.1

Classification: Yellow Latosol, light/medium textured

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.556	A_1	0- 15	0	0	100.0	1.54	2.58	40	10.3
31.557	B_2	50-120	0	0.5	99.5	1.59	2.64	40	9.8

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.556	40.9	45.8	5.8	7.5	11	4.2	44
31.557	50.4	31.3	1.8	16.5	4	7.7	53

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.556	5.17	4.32	0.49	0.30	0.01	2.03	1.89
31.557	7.53	6.36	0.78	0.40	0.01	2.01	1.86

Soil profile no. D.1

Classification: Yellow Latosol, light/medium textured

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.556	1.78	0.09	19.8	4.7	3.7		1.3
31.557	0.57	0.03	19.0	4.8	3.9		1.0

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.556	0.40		0.07	0.02	0.49	4.84	5.33	9.2	
31.557	0.24		0.05	0.02	0.31	1.41	1.72	18.0	

Relief: Level to moderately sloping tops of medium to high (till 100 m above sea level), alluvial terraces.

Drainage: Well drained.

Vegetation: Normally, tropical rain forest of moderate timber volume. However, in the Lower Amazon region, in the Amapá territory and on Marajó island (all regions with a distinct dry season), the soils often support an open brushy or low forest-savannah type of vegetation.

Distribution: (within the cattle grazing areas) Common on the medium and relatively high terraces on the north-side of the Lower Amazon floodplain.
On the remnants of Pleistocene terraces within this floodplain.
On some of the highest, coastal parts of Marajó island (e.g. around Soure).
On some parts of the uplands in eastern Amapá.

YELLOW LATOSOL, VERY HEAVY TEXTURED*

Soil profile no. D.2 (field description no. 120)

Location: Farm no. 12, area 1b, Lat. 0^{o} 27' W. Long. 51^{o} 38' W. Igarapé do Lago, south-eastern part of Amapá Territory.

Relief and drainage: Gentle sloping middle terrace in undulating upland. Internal drainage not quite good, due to rather low infiltration rate.

Parent material: During Pleistocene redeposited material from Pliocene lacustrine sediments (?).

Vegetative cover: Grasses; scattered fire-resistent trees ("cajueiro do campo", Curatella americana).

A_1 0-15 cm - Yellowish brown (10YR 5/4), friable heavy clay. Moderate very fine subangular blocky structure. The proper surface is sealed by splashing raindrops. Plastic and slightly sticky. pH (SOILTEX) 4.5. Transition gradual.

* Formerly "Yellow Latosol" (DAY, 1961)

A_3 15-25 cm - Yellowish brown (10R 5/4), friable heavy clay, with common, medium-sized, faint to distinct mottles of reddish yellow (7.5YR 6/8). pH 5. Transition gradual.

B_1 25-40 cm - Yellowish brown (10R 5/4), friable heavy clay. Plastic and slightly sticky. pH 4.5. Transition gradual.

B_2 40-120 cm - Yellowish red (5YR 6/8), friable heavy clay. Compact. Plastic and slightly sticky. pH 4.5.

Range in characteristics: Most of the very heavy textured Yellow Latosols are not, or less, compact and have a more gradual change in colour from A to B. Occurrence of any mottling is exceptional. The colour in the B ranges from yellow (2.5Y 7/6) to yellowish red (5YR 6/8); strong brown (7.5YR 5/8) is the most common.

Relief: Characteristically, on high (about 150 m above sea level) flat terraces, far from the main rivers (the Amazon "planalto"). In some areas, e.g. eastern Amapá, the soil occurs on a lower level.

Drainage: Well drained.

Vegetation: Normally tropical rain forest. In eastern Amapá, however, supporting an open savannah vegetation.

Distribution: (within the cattle grazing areas) Observed on the uplands of eastern Amapá.

Considerations about the analysis data of D.1 and D.2: The percentage of silt is low. Profile D.1 has a rather distinct increase in texture from the A to the B horizon. The Ki values are 1.9-2.0, and the Kr values are only slightly lower, namely 1.7-1.9, due to very small amounts of iron oxides. These data do assume that the silicate clay minerals are, very predominantly, of the 1:1 lattice structure (kaolinite), and that the sesquioxides (e.g. gibbsite, goethite) comprise only very small percentages of the clay fraction. This is confirmed by some DTA and X-ray analyses on similar soils from other localities.

The base exchange capacity is very low. If no organic matter were present, it would amount to hardly anything. The degree of base saturation is low or rather low. The amount of exchangeable $(Al)^+$ is rather low.

Soil profile no. D.2

Classification: Yellow Latosol, very heavy textured

Lab. no.	HORIZON		AIR DRY SAMPLE (%)			BULK DENSITY		Natural porosity	Moisture equivalent
	Symbol	Depth (cm)	> 20 mm	20-2 mm	< 2 mm	Apparent	Real		
31.769	A_1	0- 15	0	0	100.0	1.09	2.59	58	29.4
31.770	B_2	40-120	0	0	100.0	1.15	2.66	57	35.3

Lab. no.	MECHANICAL ANALYSIS (%) (size in mm)				Estimated silt-U.S.	Natural clay	Index of structure
	Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002	0.05-0.002		
31.769	4.8	16.6	6.3	72.3	11	29.4	59
31.770	2.2	13.6	11.4	72.8	15	0	100

Lab. no.	ATTACK BY H_2SO_4 d = 1.47 (%)					$\frac{SiO_2}{Al_2O_3} = Ki$	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = Kr$
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5		
31.769	29.80	27.13	5.09	0.98	0.01	1.87	1.67
31.770	53.89	32.28	5.48	1.04	0.01	1.89	1.71

Soil profile no. D.2

Classification: Yellow Latosol, very heavy textured

Lab. no.	C (%)	N (%)	C/N	pH		$(Al)^{+}$ exchangeable (m.e./100 g)	P_2O_5 available (mg/100 g)
				H_2O	KCl n.		
31.769	1.57	0.14	11.2	5.1	4.3	0.52	0.7
31.770	0.33	0.04	8.3	5.6	4.6	0.32	0.7

Lab. no.	EXCHANGEABLE CATIONS (m.e./100 g)							Base-saturation V (%)	Soluble salts (m.e./100 g)
	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	S	H^{+}	T		
31.769	0.92		0.25	0.05	1.22	4.48	5.70	21.4	
31.770	0.36		0.09	0.03	0.48	2.03	2.51	19.1	

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