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Properties of Some Soils of the Upper Amazon Basin of Peru

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Properties of Some Soils of the Upper Amazon Basin of Peru[1]

P. A. SANCHEZ AND S. W. BUOL[2]

ABSTRACT

Several representative soil profiles of the Peruvian Amazon jungle were collected in the vicinity of Yurimaguas and Iquitos and characterized in the laboratory in order to classify them according to the US soil taxonomic system. The most extensive well-drained soils are Typic Paleudults; the poorly-drained ones are Typic Tropaqualfs or Tropaquepts. The Paleudults were predominantly of kaolinitic mineralogy with small quantities of 2:1 minerals present. The poorly-drained soils were predominantly montmorillonitic or of mixed mineralogy. Where coarse-textured parent materials occur in localized areas, Tropaquods and Haplorthods are found. High base status Haplaquolls are found along the margins of the Amazon and Napo Rivers. The base status of the Paleudults is not as low as in the main soils of the South American savannas. The base status of the more poorly-drained soils is higher. Evidence from surrounding countries suggests that these soils are very extensive in the Upper Amazon Basin of South America, outside the influence of the Brazilian and Guyana shields. These areas have been previously mapped as Oxisols or their equivalents.

Additional Index Words: tropical soils, Ultisols, Alfisols, Spodosols, Mollisols, Peru.

QUANTITATIVE characterizations of soils from the interior of South America are scarce. Very little is known about the soils of the Upper Amazon Basin which covers about 45% of Peru's land surface and a large proportion of Colombia, Ecuador, and Brazil as well. Throughout the years, it has frequently been assumed from genesis theory that the main soils of these humid tropical lowlands are Oxisols (5). Recently published, large-scale soil maps of South America (6) and the Tropics (2) indicate that most of the Amazon Basin consists of Oxisols or their taxonomic equivalents.

The Amazon Basin of Peru or "Low Jungle," situated east of the last Andean cordillera, is increasingly gaining in economic and political importance due to recent oil discoveries and the construction of a road network linking it to the rest of Peru and neighboring countries. This region consists of a broad plain interlaced with large, meandering rivers. It has been formed by Pleistocene, or Plio-Pleistocene, unconsolidated clayey and sandy sediments with Recent deposits near the rivers (15). The overall slope to the ea is extremely gentle. Yurimaguas is 182 m above sea leve Iquitos, 390 kms to the east, is 108 m above sea level. (Fi 1) Temperatures are high (> 22C) and nearly constant i dicating an isohyperthermic soil temperature regime. Th annual rainfall ranges from 2 to 4 m in most of the regio The monthly evapotranspiration/rainfall ratio ≈ 1 i at least 9 months and the so-called dry season is not pr nounced, suggesting the predominance of a udic soil moi ture regime (11, 13). Except for small subsistence croppin areas under shifting cultivation, a broadleaved evergree humid forest covers the region.

The most detailed soils study of the region is a recon naisance survey of one-half million hectares surroundin Yurimaguas (9). About 57% of the area is mapped as th Yurimaguas, Shanusi, and Pucallpa series classified a Red-Yellow Podzolic soils and Ground Water Laterites Swamps cover 28% of the area, and Alluvial soils close t the rivers comprise about 8% of the area.

The purpose of this paper is to describe the propertie and classification of selected soils from two areas of th Upper Amazon region of Peru.

MATERIALS AND METHODS

Eleven soil profiles (Y-1 to Y-11) were described and char acterized in a 40-km stretch west of Yurimaguas on the road t Tarapoto (Fig. 1). Profiles Y-1 to Y-6 were collected in pair representing the well- and poorly-drained members of thre toposequences. Profiles Y-7 and Y-9 were collected on nearly level surfaces associated with the Shanusi River, and profiles Y-10 and Y-11 are from well-drained, upland areas as possible sites for a soil management research project. For purposes of comparison, five additional profiles were studied in the Iquitos area (I-1 to I-5). Profiles I-1 and I-2 were collected on well- and poorly-drained sites close to the Amazon and Napo Rivers about 40 km east of Iquitos. Profiles I-3 and I-4 were collected from the flood plain terraces of these rivers. Profiles Y-8 and I-5 were collected from coarse parent ma[illegible] areas near Yurimaguas and Iquitos, respectively.

The samples were air dried and analyzed at the Soils Department of La Molina Experiment Station in Lima for physical and chemical properties. Particle size distribution was determined by the hydrometer method, without additional pretreatments other than dispersion with sodium metaphosphate (4). Organic matter was determined by the Walkley-Black method and available P by the Olsen method (1, 10). Exchangeable bases were extracted with 1*N* ammonium acetate; Ca and Mg were determined by atomic adsorption and K and Na by flame photometry. Exchangeable Al was extracted with 1*N* KCl and determined by titration. Exchange capacity and base saturation of the soils were computed as the sum of neutral salt-extractable Al and bases. Cation exchange capacity of the clay was calculated with no organic matter correction. The pH values were determined in 1:2.5 water. The layer silicate clay mineralogy was determined by X-ray diffraction of peroxide, dithionite-citrate cleaned K, and Mg-saturated clay samples using nickel-

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Table 1—Characteristics of representative well-drained soils

Profile no.	Horizon	Depth	Sand	Silt	Clay	pH	Organic matter	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	CEC of clay	Base saturation	Silicate clay minerals*
		cm	%				%	meq/100 g							%	
Y-4	A1	0-30	57	20	23	3.4	2.8	3.0	5.2	0.1	0.16	0.08	8.5	37.1	65	K3, Mtr
	B21	46-90	53	16	31	3.5	1.1	4.5	1.0	0.1	0.04	0.06	5.7	18.4	21	K3, Mtr
	B22	90-113	53	10	37	3.6	0.9	4.7	0.6	0.1	0.04	0.08	5.5	14.9	15	K3, Mtr
	HB23	123-210+	17	20	63	3.8	0.5	15.1	0.6	0.1	0.24	0.08	16.2	25.7	6	K3, Mtr
Y-6	A1	0-7	67	18	15	4.0	2.5	0.8	1.6	0.1	0.12	0.06	2.7	18.2	69	K3, Mltr
	B1	7-48	57	20	23	3.5	0.9	3.2	1.6	0.1	0.08	0.06	4.1	17.8	21	K3, Mltr
	B21	48-67	57	18	25	3.5	0.9	4.4	0.8	0.1	0.08	0.04	5.4	21.7	19	K3, Mltr
	B22	65-157+	57	14	29	3.5	0.7	5.3	0.6	0.1	0.08	0.06	6.2	21.3	14	K3, Mltr
Y-10	A1	0-5	60	28	12	3.6	4.0	1.9	1.0	0.4	0.26	0.08	3.6	29.3	48	K3, M1, Mtl
	A21	5-40	44	36	20	4.2	1.1	4.2	0.2	0.1	0.16	0.04	4.7	23.0	11	K3, Mtr, Mtl
	A22	40-60	48	28	24	4.1	0.8	4.5	0.4	0.1	1.20	0.04	6.2	25.6	28	K3, M1, Mltr
	B1	60-90	40	36	24	4.2	0.6	6.0	0.2	0.1	0.18	0.02	6.5	26.8	8	K3, M1, Mltr
	B2	90-140+	44	26	30	4.0	0.4	6.1	0.2	0.1	1.92	0.02	8.4	27.5	27	
I-2	A1	0-16	34	36	30	4.0	4.2	5.9	1.0	0.2	0.20	0.10	7.4	24.7	20	K3, V2
	B1	16-35	30	30	40	4.5	1.8	6.7	0.4	0.1	0.08	0.10	7.4	18.4	9	K3, V2
	B21	35-70	20	26	54	4.3	0.9	9.5	0.2	0.1	0.08	0.04	9.9	18.4	4	K3, V2, Intl
	B22	70-100	20	26	54	4.5	0.6	11.6	0.2	0.1	0.06	0.04	12.0	22.2	3	K3, V2, Intl
	B23	100-150	20	34	46	4.5	0.6	10.9	0.2	0.1	0.08	0.01	11.3	24.6	4	K3, V2, Mtl
	C1	150-240	52	20	28	4.7	0.4	5.4	0.2	0.1	0.08	0.04	5.8	20.6	7	K3, V2, Mtl
	C2g	240-250+	24	36	40	4.6	0.3	9.0	0.7	0.1	0.08	0.04	9.5	23.7	4	K3, V2, Mtl2

* K = kaolinite, M = montmorillonite, Mt = mica, V = vermiculite, Int = 2:1 - 2:2 intergrade, tr = trace; 1 = present, 2 = 10-50%, 3 = more than 50%.

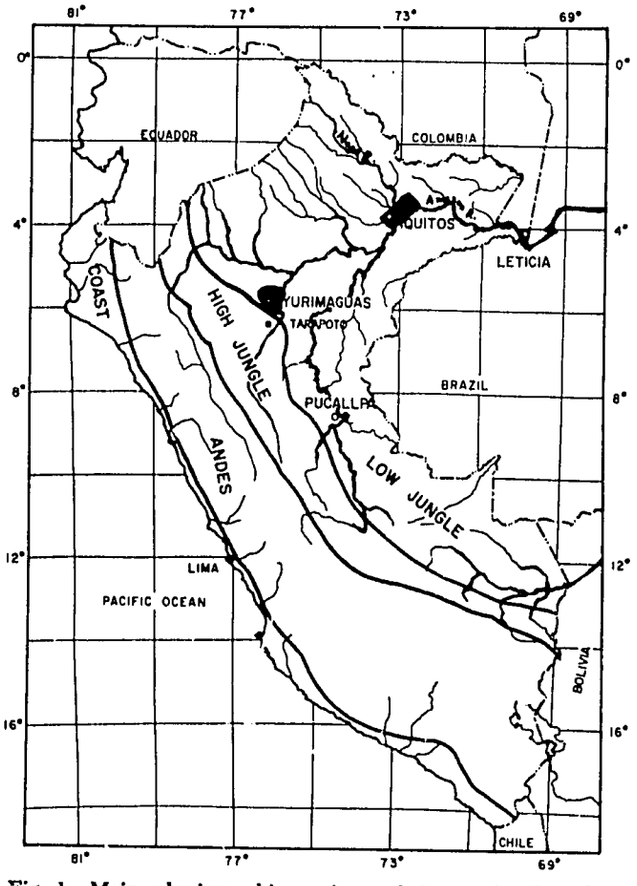

Fig. 1—Main physiographic regions of Peru, showing the sampling areas around Yurimaguas and Iquitos shaded.

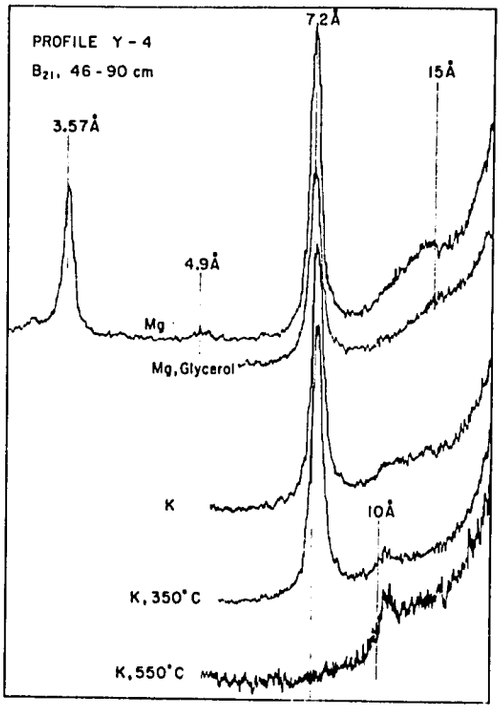

Fig. 2—X-ray diffractogram of the subsoil of a well-drained Typic Paleudult.

filtered CuK radiation at a scanning rate of 2° per minute on an XRD X-ray unit. The profiles were classified according to the 1970 draft of the US Soil Taxonomy System (11).

RESULTS AND DISCUSSION

Characterization

The well-drained profiles on rolling landscapes away from the rivers are deep and morphologically uniform with control-section textures ranging from fine-loamy to clayey. All consist of an ochric epipedon (moist values greater than 3.5 or too thin for mollic or umbric despite sufficient organic matter contents) over an argillic horizon of yellowish red (5YR 4/8) to red (2.5YR 4/6) colors, with subangular blocky structure and visible clay skins. No oxic horizons were identified. The analytical data of four representative profiles appear in Table 1. They all show extremely low pH values, with little change in depth, and low base saturation except for the A horizon where most of the forest-soil nutrient cycle presumably takes place. The bicarbonate-extractable phosphorus values were approximately 1 ppm in all horizons. The layer silicate clay fraction is dominated by kaolinite, but with detectable quan-

Table 2—Characteristics of representative poorly-drained soils

Profile no.	Horizon	Depth	Sand	Silt	Clay	pH	Organic matter	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	CEC of clay	Base saturation	Silicate clay minerals*
		cm	%				%	meq/100 g							%	
Y-2	A1	0-9	67	18	15	4.4	1.9	0.0	3.6	0.2	0.16	0.16	3.2	27.8	99	K3, M1
	A2	9-20	61	20	19	4.4	1.4	0.1	5.2	0.2	0.16	0.18	5.8	30.7	98	K3, M1
	B21	20-43	55	10	35	3.9	1.0	5.9	6.4	0.3	0.16	0.20	13.0	37.2	54	K3, M1
	B22g	43-83	63	8	29	3.5	0.5	6.1	3.0	0.1	0.18	0.16	9.6	33.0	36	K3, M1
	Cg	83-160+	25	28	47	4.5	0.5	27.2	18.2	0.4	0.64	0.46	46.9	99.9	42	M3, K1
Y-3	A1	0-15	27	28	45	7.0	1.0	0.0	37.6	0.3	0.60	0.62	39.2	87.0	100	M3, K1
	B21g	15-33	23	32	51	4.1	0.8	16.5	19.4	0.3	0.56	0.34	37.1	72.7	56	M3, Ktr
	B22g	33-64	25	32	43	4.1	0.5	18.2	22.8	0.4	0.50	0.32	42.2	98.2	57	M3, Ktr
	Cg	64-145+	31	44	25	7.9	0.3	0.0	32.4	0.2	0.42	0.60	33.7	134.7	100	M2, K2
Y-7	A1	0-5	23	32	45	5.5	4.6	0.5	14.0	5.5	0.72	0.36	21.1	45.9	97	M2, K2, Mtl
	B21g	5-25	18	26	55	4.9	1.3	9.2	10.8	6.5	0.66	0.38	27.5	49.2	67	M2, K2, Mtl
	B22g	25-80	18	28	53	5.0	1.1	12.5	9.0	6.0	0.42	0.42	28.3	52.5	56	M2, K2
	B23g	80-100+	24	12	63	5.2	0.7	14.5	10.4	7.3	0.44	0.68	33.4	52.1	56	M3, K1, Mtlr
I-1	A1	0-5	28	36	36	5.6	7.9	0.0	12.8	3.4	0.36	0.16	16.7	46.4	100	
	A2g	5-10	19	21	60	4.7	2.1	5.5	8.6	3.5	1.56	0.16	19.3	32.2	72	
	B21g	10-50	19	21	60	4.6	1.1	14.6	20.0	1.3	0.44	0.08	18.4	30.7	21	
	B22g	50-90	18	2	80	4.7	0.5	29.3	1.8	3.4	0.72	0.09	35.3	44.1	17	
	Cg	90-125+	14	46	40	4.4	0.3	11.0	2.2	2.8	0.56	0.12	16.7	41.7	34	

* See Table 1.

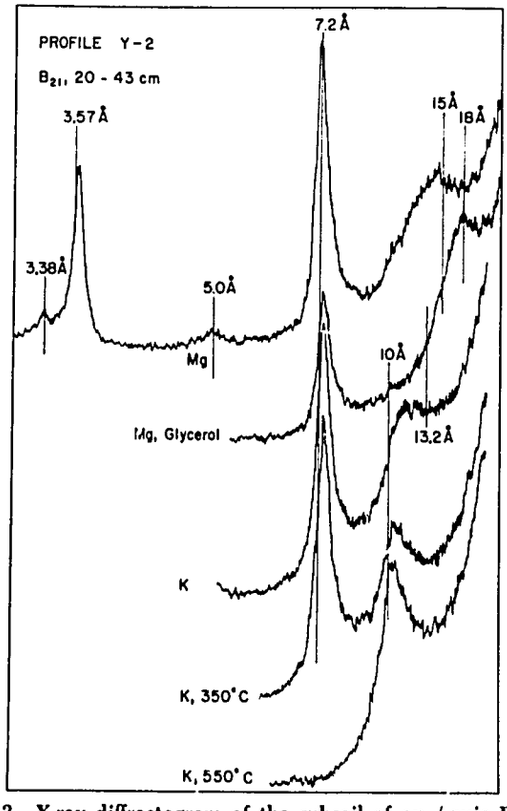

Fig. 3—X-ray diffractogram of the subsoil of an Aquic Paleudult.

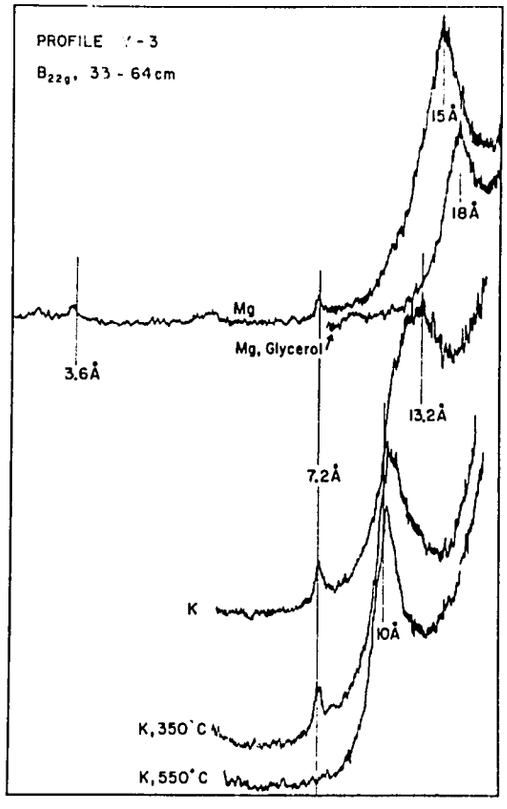

Fig. 4—X-ray diffractogram of the subsoil of a Typic Tropaquept.

tities of montmorillonite, vermiculite, micas, and 2:1–2:2 intergrade minerals. A representative X-ray diffractogram is shown in Fig. 2. These profiles are all classified in the Typic Paleudult subgroup (Table 5) which corresponds to the Acric Nitosols in the FAO legend (6) and the Yurimaguas and Shanusi series in the Peruvian Soil Survey (9).

The less well-drained associates located in the same toposequence as the previously discussed profiles are shown in Table 2. These soils have ochric epipedons (moist values 4 to 6), over cambic or argillic horizons of reddish brown colors mottled with white to grey (10YR 6/1 to 8/1), red (10R 4/6), and yellowish red (5YR 5/6–4/8). Although their base saturation is generally greater than 35%, these argillic horizons contain high amounts of exchangeable Al. The layer silicate clay mineralogy is either a mixture of kaolinite and montmorillonite (Fig. 3) or is predominantly montmorillonitic (Fig. 4).

The former classification of these soils was Ground Water Laterite and the Bg horizons with red mottles were often incorrectly described as plinthite. Red mottles are common but these are not found to harden upon exposure in a cut bank or in the laboratory upon repeated wetting and drying.

Although acid, the pH and base saturation of these profiles are considerably higher than that of their well-drained

Table 3—Characteristics of two Spodosols derived from coarse parent materials

Profile no.	Horizon	Depth	Sand	Silt	Clay	pH	Organic matter	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	Base saturation
		cm	%				%	meq/100 g						%
Y-8	A1	0-19	90	6	4	4.6	2.1	0.25	2.2	0.2	0.20	0.04	2.89	91
	A21	19-115	86	12	2	4.6	0.3	0.10	0.4	0.1	0.16	0.04	0.80	88
	A22	115-150	85	12	2	4.6	0.3	0.15	0.2	0.1	0.14	0.04	0.63	76
	A23	150-180	92	8	0	4.1	0.3	0.20	0.2	0.1	0.12	0.02	0.64	67
	Bhirm	180-210	74	10	16	4.5	3.7	1.50	0.2	0.1	0.12	0.02	1.94	23
I-5	A1	0-15	88	10	2	4.2	4.9	0.15	2.6	0.2	0.12	0.04	3.11	95
	A2	15-50	84	14	2	5.1	0.5	0.10	0.6	0.1	0.08	0.02	0.92	89
	Bh	50-66	84	14	2	5.1	1.3	0.10	1.2	0.1	0.06	0.04	1.50	93
	A'2	66-75	84	14	2	5.1	1.0	0.05	0.6	0.1	0.08	0.04	0.87	94
	B2	75-100	86	12	2	5.1	1.3	0.10	0.4	0.1	0.06	0.04	0.70	86
	B3	110-150	86	12	2	5.2	1.1	0.00	0.2	0.1	0.04	0.04	0.38	100
	C1	150-190+	84	14	2	5.2	0.6	0.00	0.4	0.1	0.04	0.04	0.22	100

Table 4—Characteristics of two soils on the first terrace of the Napo and Amazon rivers

Profile no.	Horizon	Depth	Sand	Silt	Clay	pH	Organic matter	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	CEC of clay
		cm	%				%	meq/100 g						
I-3	A	0-50	14	66	20	5.9	1.7	0	8.2	2.4	0.20	0.12	10.9	54.5
	IIC	50-100+	18	58	24	6.1	1.1	0	7.6	2.9	0.10	0.16	10.9	45.4
I-4	A	0-10	13	63	24	6.0	2.6	0	11.0	3.1	0.22	0.16	14.5	60.5
	IIC	10-50	19	61	20	6.1	1.3	0	10.4	3.6	1.52	0.20	15.8	79.0
	IIIC	50-120+	36	54	10	6.3	0.6	0	6.8	2.3	0.20	0.18	9.5	95.0

Table 5—Classification of the soil profiles studied

Profile no.	Classification
Y- 1	Typic Paleudult, clayey, kaolinitic isohyperthermic.
Y- 2	Aquic Paleudult, fine, kaolinitic, isohyperthermic.
Y- 3	Typic Tropaquept, fine, montmorillonitic, acid, isohyperthermic.
Y- 4	Typic Paleudult, fine-loamy, siliceous, isohyperthermic.
Y- 5	Aquic Paleudult, clayey, mixed, isohyperthermic.
Y- 6	Typic Paleudult, fine-loamy, siliceous, isohyperthermic.
Y- 7	Typic Tropaqualf, fine, mixed, isohyperthermic.
Y- 8	Aeric Grossarenic Tropaquod, sandy, siliceous, isohyperthermic.
Y- 9	Typic Tropudult, fine-loamy, mixed, isohyperthermic.
Y-10	Typic Paleudult, fine-loamy, siliceous, isohyperthermic.
Y-11	Typic Paleudult, fine-loamy, siliceous, isohyperthermic.
I- 1	Aeric Tropaquult, clayey, mixed, isohyperthermic.
I- 2	Typic Paleudult, clayey, kaolinitic, isohyperthermic.
I- 3	Fluventic Haplaquoll, fine-loamy, mixed, isohyperthermic.
I- 4	Fluventic Haplaquoll, fine-loamy, mixed, isohyperthermic.
I- 5	Typic Haplorthod, sandy, siliceous, isohyperthermic.

counterparts. Their available phosphorus status is similar, however. At the subgroup level these soils are Aquic Paleudalfs, Aquic Paleudults, Typic Tropaqualfs, Aeric Tropaquults, or Typic Tropaquepts, depending principally on the depth of the gleyed horizon and degree of base saturation (Table 5). They classify as Dystric and Eutric Gleysols in the FAO mapping legend and as the Pucallpa and Aguajal series in the Peruvian Soil Survey.

The characteristics of two profiles collected in less extensive but locally important areas with coarse parent materials are shown in Table 3. These sandy soils are characterized by the presence of a spodic horizon and are Aeric Grossarenic Tropaquods and Typic Haplorthods, respectively. The presence of such "tropical podzols" has been previously described (14). In some areas, the A horizon is several meters deep before the spodic horizon is found. These deeper soils, observed but not sampled, are probably Tropopsamments.

On the first terraces of the major rivers, young, high-base-status Fluventic Haplaquolls such as the one shown in Table 4 are found. Such areas represent about 8% of the total area in the Yurimaguas map, and much of the present agriculture is concentrated on the more infrequently flooded phases of such soils.

It is relevant to emphasize at this point that base saturation was estimated from the sum of cations extracted by neutral salts. The Soil Taxonomy criteria for differentiating between Ultisols and Alfisols specifies base saturation based on the BaTEA extraction of "exchangeable acidity" at pH 8.2 and NH_4OAc at pH 7 for identifying Mollisols (11). Although the sum of cations method is more relevant to actual exchange reactions, its use may raise questions about the placement of these soils in the Ultisol, Alfisol, and Mollisol orders. In order to answer this question, base saturation percentages were calculated by BaTEA and sum of cation methods in 88 soils from the Midwest and Southeastern US having more than 18% clay and less than 0.67% organic carbon. A very close correlation was obtained between the two methods indicating that 35% base saturation by BaTEA (the division between Ultisols and Alfisols) is equivalent to 50% base saturation by neutral salts. A similar study with soils having more than 0.67% organic carbon from mollic and umbric epipedons, a base saturation of 50% by NH_4OAc at pH 7, corresponded to 90% base saturation calculated by neutral salt extractions. These relationships were taken into consideration in the classification shown in Table 5.

Landscape Relationships

Within the area studied, three landscape patterns were observed. The highest areas are composed of flat-top hills deeply dissected by drainages. Most of these drainages have very narrow flood plains. The nearly level hill tops have Paleudults such as profile Y-6. The side slopes (10–25% slope) are also dominated by Paleudults such as profile Y-4. Low chroma mottling is present in the subsoil for an unusually great distance up slope from the drainage bottoms. This can be attributed to lateral water seepage in the profiles and/or slow permeability engendered by substantial amounts of montmorillonite in the clay fraction.

The most extensive areas have rolling topography of

more gentle relief. The rounded hill tops are occupied by well-drained Paleudults (Y-10) that grade into less well drained Ultisols and Alfisols nearer the drainages (Y-2). Characteristics of reducing conditions (low chroma mottling) are usually observed within 1 m of the surface several hundred meters up 5 to 10% slopes from the drainage. Apparently this can also be attributed to the udic climatic conditions and the impermeable nature of clayey subsoils containing appreciable amounts of montmorillonite. The residents frequently obtain water by maintaining a cut bank about a meter deep into the gley horizon on the side slope.

The rather extensive areas of flood plain soils occur in old meander scar areas and along the present river channels. These areas are subject to various frequencies of flooding depending upon their relative elevation. There is a minimum of stratification observable which could be attributed to subsequent depositions of similar material and to the profuse vegetative cover which would interrupt flood water movement and also contribute to pedoturbation processes.

These results indicate that the main soils of the Upper Amazon Basin of Peru are not Oxisols as traditionally thought but Udults and less well-drained Aquults, Aqualfs, and Aquepts. Also, there are areas of Spodosols and Mollisols associated with sandy parent material and flood plains, respectively. Morphologically the main soils are very similar to many soils of the Upper Coastal Plain and Piedmont regions of the Southeastern United States. Evidence of this relationship was published by Marbut and Manifold in 1926 (7) but this information has been largely ignored. Studies of the Amazon Jungle of Ecuador (8), Colombia (S. T. Benavides, 1972. Mineralogical and chemical characteristics of some soils of the Amazonia of Colombia. Ph.D. Thesis. North Carolina State Univ.), and Brazil (3, 7, 12) indicate the presence of argillic horizons or clay mineral suites similar to those reported in this work. There is not sufficient information available to accurately limit the eastward extent of these soils towards the lower Amazon basin. However, it appears from the above citations that the Oxisols may be confined to those areas of the Amazon Basin directly influenced by the Guyana and Brazilian shields.

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