Soils of French Guiana

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Natural conditions

The french "departement" of Guiana is located between the 2 nd and 6 th North parallel, and between the 54 th and 56 th West longitude. This part of South America is under the influence of a tropical rain climate ; (Koeppen) ; the rainfall varies from the coastal zone (80 - 120 inches) to the interior of the country (137 inches and more). The annual mean temperature is about 26º C (79º F). Two small dry seasons (March and September - October - November) with a rainfall less than 100 mm, more or less marked, are characteristic of this climate. Regular winds (trade winds) blow at the coastal region but there are no hurricanes or storms.

So all conditions are present for a maximum intensity of bed rock weathering.

Differents vegetational landscapes are in correlation with geological formations :

- the lowlands (3700 sq km) are formed out of marine clay deposits from the holocene up till now. A mangrove vegetation grows on the parts flooded by marine waters ; behind the mangrove "Avicennia" and "Rhizophora", there are swamps which are flooded almost all the year round by brackish or fresh water (wet savannas).

- the emerged savannas (1500 sq km).
They form a narrow strip, parallel to the coast, behind the swamps ; they are covered with grass vegetation, forest ridges or wet gallery forest running through the landscape These savannas are growing on fine sorted sands (median about 110 microns) representing old shores ; this deposit originates from the upper Pleistocene. Clays of the Medium and Lower Pleistocene can be found, mixed with the sands.

- behind these regions we find the Precambrian shield, part of the large Guiana shield (84.800 sq km), composed of cristalline metamorphous rocks and some lavas. The mantle of weathered rocks is very deep (several scores of meters). The landscape shows numerous hills separated by small valleys and sometimes by swamps. A sheet of detrital sands forms the border between this part and the emerged savannas.

This landscape is covered by Tropical Rain Forest.

The different soils

According to the french classification (AUBERT 1967) 5 soil-classes can be distinguished :

Classe des sols minéraux bruts	(USDA entisols)
Classe des sols peu évolués	(USDA inceptisols)
Classe des Podzols et sols podzoliques	(USDA spodosol)
Classe des sols ferrallitiques	(USDA typic or plinthic Udorthox, ochric or plinthic tropudult (Latosols)).
Classe des sols hydromorphes	

I Sols minéraux bruts

These soils are represented in French Guiana by the "sols minéraux bruts d'apport marin" which consist of recent clay deposits, under mangrove (Avicennia or Rhizophora). These marine clays (clay 60 %, fine silt 30 %) show 40 % kaolinite, 20 % montmorillonite, 20 % illite and 20 % quartz. In these soils, the upper 30 centimeters are marked by oxydation, aeration, biological disturbation and accumulation of small amounts of organic matter. Chemically these clays are salty clays (pH 7) ; Magnesium and Sodium are predominating. The stability of structure in the upper horizon is low. A very important character is, that these deposits do not countain calcium carbonate.

Among these "sols minéraux bruts" soils also exist which are formed on eroded areas of ironstone or on granitic hills in the interior of the "département".

II Sols peu évolués

These are the soils of the best part of the lowlands ; swamp vegetation takes the place of the mangrove ; such soils are formed by marine clay soils showing a beginning of evolution by a fairly thorough aeration of the profile accompanied by loss of salt and structuration.

Among several groups of soils two groups can be distinguished : poorly developped hydromorphic soils and poorly developped salty ones.

Poorly developped hydromorphic soils cover a large surface East of Cayenne and offer interesting development possibilities when they do not contain any pyrites ; they show a clay texture (60 % clay) and dessaturation is rather marked, attaining about 50 % of the absorbing complex. The capacity of this complex is about 30 milliequivalents. Permeability is variable, depending on internal structure after drying and on oxyded iron tubes originating from fossil roots. A series containing pyrites exists within this group ; such soils show acidity by oxydation.

Poorly developped salty soils are as well represented : in most cases, salt is leaving the upper horizon, and deeper down, the total amount of salts rises. The pH values vary from 5,6 - 6,4 in the upper horizons to pH 7-8 in lower layers of the profile.

There is also a series with pyrites where, in spite of salt, pH can decrease to 4 because of oxydation.

On sandy ridges (old shores) among marine clays, we also find poorly developped soils on sandy material (90-95 % sand) ; the layer containing organic matter is fairly thick and the amerindian populations went there to establish their plantations ; such soils are submitted to the varying level of ground water which is related to the water level in adjacent marine clay. Podzolic profiles can appear if the water reaches the organic horizon.

III Podzolics soils and podzols

These soils are located on well drained sandy material of old sandy ridges or on detritic sands (95 % sand) bordering the precambrian shield. A hard pan of humic and ferric material can be distinguished under a bleached horizon. A ground water level often exists in the soil ; specially in savannas on fine sorted sands, where the varying level of water maintains the migration of elements.

IV Les sols ferrallitiques (latosols)

The greater part of French Guiana is covered by those soils, either on precambrian rocks or on material resulting from erosion of the guianese shield. These soils show profiles A (B) C or A B C, (AUBERT and SEGALEN, 1967), often deep, displaying an accentuated decomposition of organic matter, strongly bound to minerals. Weathering of minerals is very strong, and an important individualisation of iron, manganese and aluminium sesquioxydes can be observed. The clay mineral is most often composed of kaolinite, sometimes illite, not counting aluminium and iron sesquioxydes.

According to the french classification, which considers dessaturation of the complex first of all, the most represented soils among ferrallitic ones are the very strongly dessaturated ferrallitic soils, where exchangeable bases are lower than I Meq., Saturation less than 20 % of the complex, sometimes only 10 %, and exchange capacity of the order of 5-10 milliequivalent according to the amount of clay. Organic matter increases this exchange capacity in the upper horizon : this is the only way to modify the chemical poverty of these soils. The carbon ratio in the surface layer varies from 1 to 8 %, C / N ratio being between 12 and 15. The low differences in chemical status which are noted between differents soils are not so important as to be considered as a fertility test. In such cases, one tries to define physical properties, particularly texture and structural stability ; for this purpose the composition of the soil with respect to particle size distribution and amount of coarse elements (given by concretions or dismantling of iron stone) are to be considered.

Leaching is generally not well marked in the precambrian shield : the amount of clay increases progressively following depth, and texture changes at the level of weathered rock ; this change is well marked by a larger amount of silt. Important leaching can only be seen in fine sorted sands of quaternary deposits with a moving ground water level.

Texture depends on the type of parent-rock (BRUGIERE - MARIUS, 1967)

Clay texture (0 - 20 microns : 60 - 80 %) : on Paramaca lavas Gabbros, Paramaca schists Orapu schists, Amphibolites.

Sand-clay texture (0 - 20 microns : 40 - 60 %) : alluvions from Bonidoro and Orapu schists, alluvions from granite.

Clay-sand texture (0 - 20 microns : 20 - 40 %) : on granites and quartzites of the precambrian shield and on fine sorted sands of the coastal plain.

Sand texture (0 - 20 microns : 0 - 10 %) : detritic sands.

The amount of coarse elements can be due either to iron stone formation (this phenomenon being located on table lands and terraciform deposits), or to dismantling of old ironstone, or to the presence of layers of old concretions or rocky varnished ironstones. These elements can be found as follows :

- Ironstone or remains of iron stone (thin soils) : on table-land summits of Orapu and Paramaca schists, on Paramaca lavas, amphibolites and down the slopes on schists and Amphibolites.
- Abundant coarse elements : slopes and at the base of slopes on schists and amphibolites.
- Fairly abundant coarse elements : on steep schist-slopes.
- Few coarse elements: on top of slopes on gabbros, on alluvions from schists and from amphibolites.
- Soils without coarse elements : alluvions and colluvions or soils on granite and gneiss.

V Hydromorphic soils

These soils are well represented : peat is frequent and shows large surfaces on flooded marine clay or in inland depressions. Gley soils are present on the bottom of depressions in wet gallery forest and in quaternary depressions of the coastal plain.

The soils on alluvial terraces fairly often show a pseudo-gley surmounting a gley.

Problems of fertility and development

Marine clays ("sols minéraux bruts" and "sols peu évolués") have a high chemical fertility but the amelioration of physical properties correlated to clay texture needs important care. Land improvement is possible by empoldering accompanied by severe control of water level and drainage / irrigation - equilibrium. This equilibrium can be modified during the dry season : in the coastal plain, 2 or 3 months with less rain than one inch are frequent : the possibilities of irrigation with fresh water during this period require serious survey. Mecanisation would be necessary, though supplementary expenses of road-construction would have to be considered.

The ferrallitic soils of the precambrian shield could yield important surfaces for land improvement ; the physical properties are fairly to well developped but these soils are chemically very poor. Forest-clearing modifies the equilibrium between soil and vegetation ; when so modifying natural conditions, care should be taken to preserve the layer of organic matter located in the first 10 or 20 centimeters. After clearing, covering of the soil is necessary. The structural stability is good in the upper layer but decreases rapidly in lower horizons. Soil management has to prevent the top of the soil to be cleared off by erosion (anti-erosive systems). Soils on steep slopes (schists, dolerites) cannot be used ; soils on granites or on gabbros with gentle slopes and without coarse elements present some advantages (good physical properties ~~in particular~~). Mecanisation is easier on such slopes, manuring is necessary.

Land use

The population of French Guiana is actually gathered along the coastal plain where their houses are generally situated on sandy ridges or along the estuaries. The agricultural production, barely sufficient for home consumption is the result of shifting cultivation, practised on a wide range of soils. Round the houses, there are small orchards. Extensive breeding is restricted to the savannas.

Pedological studies actually give an idea of developmental possibilities and define the vocation of the soil ; citrus plantations are thought of today, and soils on granite are prospected. In the coastal plain, there is a grouping of cattle-breeders. On leached ferrallitic soils (fine sorted sands) and hydromorphic soils with pseudo-gley, fodder-grass may be grown.

We can distinguish :

Land of medium quality : for its improvement one does not need anti-erosive systems, but medium or high manuring are necessary (grass land). In this category we find leached ferrallitic soils on fine sorted sands (savannas) or soils with a pseudo-gley and gley in the lower horizons.

Land of poor or medium quality : land improvement should be taken care of when clearing off the forest (protection of organic layer, covering of the soil, improvement of anti-erosive systems) and manuring in medium or high quantity is necessary.

In this category we find soils on granites, soils on lavas and soils on schists, but the last ones posing problems due to steep slopes and the abundance of coarse elements

Land with good chemical properties but needing very intensive management : On this land we find marine clay soils, the best among these being those on fresh clays.

Land without any development possibilities :
gley soils, salty soils, soils containing pyrites, podzolic soils.

According to our knowledge of natural environment, tropical cultures could be promoted from a technical point of view. But the main problem owing to the small populatio density (35.000 h.) is the lack of agricultural labour.

The local market is limited and labour is high-priced. So the cost price is rather high and dispositions aiming at maximum mechanisation are the only means to arrive at a system of competitive production, but these methods would put up the question of the international market. During the present period of difficult openings in this market the economical aspect of agricultural development would be among the most important problems.

Summary

"According to the work of Soil Survey in French Guiana, the differents soils of French Guiana are briefly described in correlation with the geological sub-soil and landscape ; Physical and chemical properties are presented according to the possibilities of agriculture. A large part is devoted to Ferrallitic soils (french classification).

The management of the differents soils is considered and an outline of the different dispositions is given".

Reference reading

G. AUBERT Classification des sols
Cah. ORSTOM Sér. Péd. 1965 nº 3 269 - 288
modification G. AUBERT - P. SEGALEN 8.11.1966.

COLMET-DAAGE (F.) SUBRA (P.) 1958 Mission agro-économique dans les Guyanes. Etude des possibilités de la mise en valeur des terres basses guyanaises. Crédit Social Antilles Guyane Cayenne 206 p multigr.

LEVEQUE (A.) 1962 Mémoire explicatif de la carte des sols des terres basses de Guyane Française O.R.S.T.O.M. PARIS 85 p. 2 cart.

LEVEQUE (A.) 1967 Les sols ferrallitiques de Guyane Française O.R.S.T.O.M. PARIS 168 p. graph.

BRUGIERE (J-M.) 1965 Etudes pédologiques et mise en valeur agricole de la Guyane Française in Compte-rendu du congrès des Recherches agricoles dans les Guyanes 27 Nov - 3 Déc. 1963 Landbouwproefstation in Surinam Paramaribo pp 107 - 111

SOURDAT (M.) 1965 Notice de la carte provisoire au 1/50.000 des sols du littoral Guyanais entre KOUROU et SINNAMARY Guyane Française Centre ORSTOM de Cayenne 90 p. multigr. cart. photos.

MARIUS (Cl.) 1966 Carte pédologique au 1/50 000 et notice explicative Feuille de Cayenne Centre ORSTOM de Cayenne 57 p. multigr. 1 cart.

TURENNE (J-F.) 1966 Conservation du sol et culture par abattis Centre ORSTOM de Cayenne 11 p. multigr.

BRUGIERE (J-M.) et MARIUS (Cl.) 1967 Relation sol substrat géologique Centre ORSTOM de Cayenne 10 p. multigr. 1 diagr.

MARIUS (Cl.) TURENNE (J-F.) 1967 Problemes de classification et de caractérisation des sols formés sur alluvions marines récentes dans les Guyanes Centre ORSTOM de Cayenne 62 p. multigr.

VAN AMSON (F.W.) 1967 Soils of Surinam
Caribbean Food Crops Society 5th Annual Meeting
July 24 - 31, 1967 Paramaribo - Suriname 4 p. multigr.

Soil	Depth cm	hori-zon	Coarse elem. > 2mm	Clay < 2µ	Silt 2-20 µ	Fine sand 20-200 µ	Coarse sand 0,2-2 mm	C ‰	N ‰	C/N	pH H2O	Ca (milliéquivalents)	Mg	K	Na	S	T	Fe libre	Fe total
Sol minéral brut d'apport marin (TURENNE)	0-30	(A)C	.6	53.5	34.	1.5	1.5	17.4	1.47	11	7.3	5.4	11.80	2.12	21.2		38.4		3.6
	50-90	C	.3	56.	34.	0.5	0.3	15.2	1.36	11	7.	5.18	11.95	2.74	22.		36.4		3.2
Sol peu évolué d'apport sableux (cordon) (TURENNE)	0-5	A1	1.3	3.	0.5	38.	55.7	12.2	1.08	12	5.7	0.69	0.13	0.09	0 03		3.		1.4
	30-40	C	.1	4.5	2.	46.5	45.1				5.6	0.19	0.02	0.04	0.02		2.1		3.5
	40-130	C	.01	2.	0.5	45.5	52.1				5.5	0.19	0.02	0.02	0.01		1.4		3.8
Sol peu évolué d'apport marin hydromorphe (LEVEQUE)	0-15	A_{oo}		59.	31.	0.1	0.1	14.1	1.8	7.8	4.9	1.02	12.94	0.08	1.41	15.35	33.13		
	15-35	A_1		56.	33.	0.3	0.05	6.3	1.3	4.8	5.	1.61	16.4	0.15	0.8	18.99	26.92		
	55-75	C		52.	38.	0.4	0.15	5.2	1.	5.2	5.4	2.35	18.28	0.12	2.53	23.28	25.44		
	95-115	C		46.	40.	0.5	0.30	13.3	1.7	11.	5.	1.94	15.37	0.46	0.43	18.20	30.58		
Sol peu évolué d'apport marin salé (MISSET)	10-45	A1	0.01	62.	25.	0.5	0.5	40.	2.48	16.2	5.1	11.	20.15	2.93	36.23	70.	28.		
	45-90	C	0.01	56.	21.	2.5	1.	7.2	0.7	9.9	6.8	10.3	21.18	3.23	40.24	74.	25.		
Sol peu évolué d'apport à pyrites (MISSET)	0-20	A1	4.2	49.	35.	2.	1.	24.7	2.6	10.	4.2	4.52	6.43	0.6	1.6	13.	40.		3.2
	70-90	C	3.3	43.	44.	3.2	3.2	12.6	1.83	8.	2.7	3.72	7.55	0.1	0.28	11.	33.		3.3
Podzols sur sables grossiers (TURENNE)	0-7	Aoo	2.7	2.	0.5	6.	88.	2.2	0.15	14.		0.26	0.25	0.12	0.09	0.7	4.2		
	20-30	A1	4.2	1.	1.	9.	89.	0.2	0.05	5.5		0.06	0.01	0.02	0.03	0.12	1.7		
	45-55	A2	6.8	2.	0.1	16.	82.	0.4	0.04	9.9		0.06	0.01	0.02	0.03	0.12	2.2		
	90-110	Bh	4.6	3.	0.01	5.	87.	2.76	0.8	34.		0.06	0.02	0.04	0.06	0.18	11.6		

Soil	Depth cm	horizon	Coarse elem. > 2mm	Clay <2 µ	Silt 2-20 µ	Fine sand 20-200 µ	Coarse sand 0,2-2mm	C o/oo	N o/oo	C/N	pH H_2O	Ca milliéquivalents	Mg	K	Na	S	T	Fe libre	Fe total
Ferrallitique fortement dessaturé appauvri sur granite	1-7	A1	2.6	27.	6.5	10.5	42.	76.	4.3	17.	4.5	0.11	0.25	0.15	0.07	0.58	9.9	2.2	1.9
	20-40	AB	2.7	32.	11.	11.	39.	43.	2.8	15.	5.2	0.06	0.06	0.02	0.01	0.15	5.3	3.9	2.8
	120-140	(B)	4.5	39.	11.5	6.5	37.5				5.2	0.09	0.06	0.02	0.01	0.18	3.5	4.8	3.5
Weathered rock granito gneiss	780-840	(C)	1.	6.5	37.	8.5	48.				5.	0.04	0.01	0.02	0.02	0.14	5.6	7.5	5.7
Ferrallitique fortement dessaturé sur schistes Paranaca (MARIUS)	0-20	A-1	36.7	42.	15.	12.5	16.	58.	3.6	16.1	4.9	0.19	0.10	0.24	0.28	0.81	12.7	10.	26.6
	30-50	(B)	38.8	51.	14.	8.	17.5	38.5	2.4	16.	4.9	0.06	0.01	0.12	0.11	0.30	8.6	10.3	28.9
	100-120	(B)	28.2	48.5	13.5	10.5	22.5				5.1	0.09	0.01	0.06	0.06	0.22	3	13.4	28.4
ferrallitique fortement dessaturé sur schistes Bonidoro (MARIUS)	0-15	A1	12.2	35	18	16.	16.	61.4	3.95	15.5		0.94	0.15	0.19	0.11	1.39	16.6	12.2	19.8
	30-50	(B)	38.	61	9.5	13.	9.5	19.5	1.50	13.		0.06	0.01	0.06	0.05	0.18	8.9	11.5	21.3
	100-120	(B)	13.8	63	12.	11.	9.					0.06	0.01	0.04	0.02	0.13	4.3	12.5	23.
	200		0.8	16.5	34.	23.	24.					0.06	0.01	0.04	0.02	0.13	4.8	16.8	25.1
Ferrallitique fortement dessaturé lessivé (Fine sorted sands) (TURENNE)	0-5	Al.	2.6	10.	2.	63.5	10.5	18.5	1.15	16.1		0.96	0.50	0.19	0.13	1.73	8.2	0.9	1.2
	15-25	AB	1.7	12.5	4.	70.	10.5	11.3	.77	14.		0.54	0.22	0.13	0.07	.96	5.2	1.6	1.8
	50-70	B	1.1	20.5	5.5	61.	10.5					0.54	0.40	0.06	0.07	1.07	4.2	2.2	3.7
	175-185	BC	22	15.5	6.5	62.	14.					0.49	0.08	0.4	0.03	0.64	2.4	3.	3.9

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