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PHYSICAL AND CHEMICAL PROPERTIES OF CAMBODIAN SOILS

by

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INTRODUCTION

Basic information on the nature of soils, their potentialities, and their limitations is necessary to evaluate Cambodian agriculture properly, and to develop a program for increasing food and other crops. Suitable information has, however, been limited, especially as there is not to be found in any report much data relating to soils of different origins over the whole country. There is, needless to say, some information on confined areas of Cambodia.

In 1957, the Hyogo University of Agriculture, Japan, has delegated an agricultural expedition consisted of Prof. Takashi SATO and Ass. Prof. Takahiro TAKAYAMA to Cambodia with a view to obtaining fresh knowledge for tropical agriculture and to bring together some basic materials available for Cambodian agriculture.

A large number of soil samples used for the present study were supplied by courtesy of the research members by permission of the Minister for Agriculture. The localities in which soil sampling was carried out comprise every province of Cambodia, that is, Stung Treng, Kratie, Kp. Cham, Kp. Thom, Kp. Chhang, Siem Reap, Battambang, Pursat, Prey Veng, Svay Rieng, Kandal, Kp. Speu, Takeo and Kampot provinces.

The soil samples were collected during the former half of 1957 before the long-rains period.

The present study of Cambodian soils under both cultivated and virgin conditions was undertaken with the object of obtaining information which would assist in providing an available indication for higher production and for exploitation in the future.

LANDSCAPE

Cambodia is situated at the west-southern part of the Indo-China peninsula, extending from 11° to 15° of north Latitude and from 111° to 117° of east Longitude, and comprises an area of 175,000 square kilometers.

One half of the northern border is limited by Laos, another northern-half and north-western boundaries are restricted by Thailand, the eastern and southern limits are bounded by South Vietnam, and the south-western end forms a short irregular coastline to the Bay of Thai.

The main part of Cambodia is composed of a broad alluvial basin surrounded by mountainchains and highlands at all its boundaries other than the south end.

The central part of the country consists mainly of a wide spread plain along the catchment areas of the Mekong and Tonle Sap rivers, and extends far towards the south. The Mekong River joining with the Tonle Sap branch in the southern part of the country, and flowing gently south-eastward, draining into the sea across South Vietnam.

The eastern apex of the basin has a common boundary, together with the Annan mountainchain. The north-eastern edge is surrounded by the table lands

of Lower Laos about 150 meters above sea level which forms the eastern margin of the Korat plateau in Thailand. The border to Thailand is composed of the Dangrek mountainchain on the north-western part, and of the Kardamom and Elephant mountainchains on the western and south-western regions of Cambodia.

It has been accepted that the persent basin surrounded by these mountains has been formed through the following course. That is to say, a low-lying land resulted from downward land movements of high lands, and was submerged into sea water over a wide space to build up a broad bay. The newly formed bay was subjected to continuous flooding of the Mekong River up to the time of settlement near the outlets. Consequently, the bay resulted in a wide lake owing to "damming up" of the outlets. With continuous deposition of the Mekong muds a gradual uplifting of lake beds was brought about. Finally, the wide spread deltaic basins which comprise the main plains of Cambodia as seen at present time have been completed. The present Lake Tonle Sap is regarded as a remnant left behind by the above circumstance at an early stage.

In rainy seasons, as the water head of the lake becomes lower in level than that of floody rivers, the lake changes therefore, into the outlet for over flow, playing the role of a water controller to regulate the flood. On the contrary, in dry seasons, water held in the lake pours again itself into the river, and water diverted from the river is used to irrigate rice fields.

GEOLOGY

1) Eastern mountain regions are in contact with parts of the old Annan territory in South Vietnam, on which volcanic rocks of late eruption are widespread, and basaltic lava flows are found to a wide extent within a limited area.

2) North-eastern high lands are composed of plateaux about 150 meters in altitude extending from Lower Laos, whose beds are mainly composed of sandstone marking a thick and distinct horizontal stratification; and these sandstone areas are partly mixed with limestone.

3) North-western mountain regions are close to the Dangrek mountainchain. Red sandstone formed druing the Triassic period of Mesozoic era are broadly superimposed over such rocks of old origin as quartzites and limestones of Carboniferous and Permian periods.

4) Western mountain regions have a similar geological base to that of the former, i.e., 3). However, rocks covering the base are mainly made up of sandy shales and limestone,and sandstone of Triassic period.

5) Large basin lands surrounded by the above described mountains and high lands comprise large areas of flood plains and rolling lands, and extend downward gently, sloping and undulating from the north towards the outlet of the Mekong River.

Low-lying areas of the basin occur in a marsh adjucent to South Vietnam, which are covered at times by water. Along the catchment areas of the Mekong

River from the marsh to the north, flood plains at every recent origin are, to a great extent, to be found. These are at present, or up to recent years, flooded annually, and are sufficiently utilized for paddy fields.

Old alluvial lands of which the origin is of early deposition are partly situated on the northern watersheds of the Mekong River, and are somewhat higher in altitude, in general, than the recently flooded plains, and they are now beyond the reach of floods.

Much of lower part of the old alluvium is under cultivation of paddy and upland crops, while in the higher parts, and far distant regions from the towns, natural open forests are dominant. On the hilly lands eastward from the central basin, basaltic soils are widespread, on which plenty of rubber plantations have been well worked by the foreigners.

CLIMATE

The only climatological data available for the flood plains and neighbouring areas are recorded for a few regions.

Since the situation of Cambodia is located on the part of low altitude of the Indo-China peninsula, the atmospheric temperatures are relatively high over the whole year, showing the maximum in April, and the minimum in December.

The annual mean temperatures for 34 years at Ph. Penh are 27.4°C, where the approximate monthly mean ranges from about 29.6°C in April to about 24.3°C in December. All over the country, variance in the annual temperatures amongst the different regions is not so much, so that even the south Kampot region where the highest annual temperature of the country is recorded, is not so hot as to far exceed Ph. Penh.

The annual rainfall in Cambodia, as a whole, would seem to be over 2,000 millimeters. It is however noted to differ remarkably from place to place.

Low rainfall is seen on parts of low-lying inlands, while high rainfall comes on the surrounding hilly and mountainous lands. The rainfall is not well distributed in every month of a year, and the distribution is divided into two periods, i.e., dry and rainy seasons. Seven months from May to November belong to the rainy period; during which season 90 per cent of the annual rainfall has been supplied.

Generally the heavy and continuous rains are associated with rain-bearing winds from the south-west. In this season the cultivation of rice crops is made possible. On the other hand, from December to April the dry season results from the north-easterly winds, especially through the period of January to February seldom is there any rainfall.

The average annual rainfall at Ph. Penh under typical climatic conditions of low-lying plains, account for about 1,400 mm which would seem to be the lowest amount recorded in the country. The humidity at Ph. Penh expressed by Lang's rain factor —R.F.— shows about 50. As compared with 74 at Saigon and 77 at Hanoi, it is found that the humidity at Ph. Penh is less pronounced than in these other regions.

On the northern and north-eastern high lands, the west-southerly monsoon is interrupted by the Dangrek mountainchains and the Melplei plateaux, so that the rainfall being higher than that of the central plains, reaches up to about 2,000 mm. Owing to their high humidity, it makes possible the formation of dense forests and jungles extending from Stung Treng to Voene Sai; although there, it is somewhat lower in temperature than Ph. Penh situated on the central plains. The R.F. values of this area are assumed to be approximately 75.

The basaltic red soil areas — terres rouges areas — where, stretches for above 100 kilometers from Snoul and Mimot to Kp. Cham show a high annual rainfall which ranges from 2,500 to 3,000 mm, such a high rainfall is resulted from the obstruction of the monsoon by the Moi high land. The mean temperature of this area is nearly similar to that of Ph. Penh, although it may be seen slightly different in degree. R.F. values are therefore regarded as at about 100. This area lies under conditions available to make superior rubber plantations.

Areas having the highest rainfall, that is that which exceeds 5,000 mm in a year, are found on the south Kampot district beside the Bay of Thai. The substantial falls in the rainy season are associated with the south-westerly monsoon, which is hindered by the Elephant and Kardamom mountainchains. As the mean temperature in this region is somewhat higher than that of Ph. Penh, R.F. values are likely to reach up to approximately 180. Such a tropical marine climate makes conditions more favorable for the production of pepper and the formation of dense forests.

EXPERIMENTAL PROCEDURE

The samples were prepared for analysis by air-drying in the laboratory, and grinding to pass a 2-mm round-hole sieve.

Comparisons between the soil samples in each related group were made in terms of soil color, pH value, exchange acidity, hydrolytic acidity, total nitrotgen, organic carbon, total cation-exchange capacity, degree of calcium saturation, exchangeable calcium, and available phosphorus, calcium, and potassium.

All the determinations except color comparisons were carried out in duplicate on individual samples.

Procedures of the estimation of each are outlined below.

1. Soil Color

In an attempt to describe more precisely the individual colors of soil samples the Standard Soil Color Chart published under the supervision of the Ministry of Agriculture, Japan, was used to air dried fine soils passed through a 2-mm sieve. By this procedure a consistent color difference was found.

2. pH value

The pH value was determined with a glass-electrode pH meter on both the 1 : 2.5 soil-water suspension and soil-potassium chloride mixture with a 1 : 3.5 soil: *N*-KCl ratio.

3. Exchange acidity

100 g of air dried fine soil was mixed with 250 ml of *N* potassium chloride

solution, and the suspension was shaken intermittently for one day. Then 125 ml portion of the supernatant liquid was transferred to other flask and titrated with a standard N sodium hydroxide solution. The readings of ml required for neutralization were referred to as "exchange acidity y_1".

4. Hydrolytic acidity

This procedure was conducted in the same way as exchange acidity, except that N calcium acetate solution as the extract solution was employed instead of N potassium chloride.

5. Total nitrogen

Total nitrogen content was determined by the modified Gunning method which employed salitylic acid and sodium thiosulfate besides sulfuric acid to complete the digestion.

6. Organic carbon

Organic carbon was measured by means of the Tyurin procedure which involved wet oxidation by chromic acid and determination by titration.

7. Humus

Humus content was obtained by multiplying the organic carbon content by the conventional factor 1.72.

8. Cation-exchange capacity (C•E•C)

Total cation-exchange capacity was determined by somewhat modified procedure of the Schollenberger method (Soil Sci., *30*, 161, 1930).

The soil was leached successively with N ammonium acetate solution buffered at a neutral pH value, and the excess of ammonium salts washed out with 95 per cent ethanol. The soil saturated with ammonium was then leached with 10 per cent sodium chloride solution of pH 2.5 and the released ammonium ion was determined by the usual procedure from an aliquot portion of the leachate. From the value of ammonium ion obtained here, milliequivalent of the total cation-exchange capacity was calculated.

9. Exchangeable calcium

Air dried fine soils were extracted by N ammonium acetate solution according to the Schollenberger method, and then were determined volumetrically by means of EDTA (Dotite 2Na) method.

To estimate the amount of calcium which was exchanged for ammonium, pH values of the extract were raised up to above 12 by the addition of N sodium hydroxide solution, then the extract was titrated with 0.01 M Dotite 2Na solution in the persence of Dotite MX as an indicator.

10. Available nutrients

In Japan, it has been admitted that the element which is soluble in 0.2N hydrochloric acid is defined as available nutrients in soils. The estimation was carried out as follows:

At first, as a preliminary test, 10 g of a soil sample was mixed with 100 ml of 0.2N hydrochloric acid and heated at 40°C for 5 hours. After filtration, the filtrate was titrated with a standard sodium hydroxide solution. By this pre-test, the amount of hydrochloric acid which was consumed as a result of absorption by

the soil is found.

Then, as a regular experiment, 50 g of a soil was mixed with 500 ml of hydrochloric acid solution of which the concentration was adjusted to become equivalent to $0.2N$ in the suspension, under considering the absorption by the soil. The subsequent experiment was advanced by similar procedure to the prior-test.

Thus, obtained filtrate was used to estimate available calcium, phosphorus, and potassium, as described below.

Calcium in the extract was determined by the same way as that for exchangeable calcium described above.

Phosphorus in the extract was estimated colorimetrically with the molybdophosphoric blue color method. The reductant used in this determination was either chlorostannous acid, or 1, 2, 4, -aminonaphthol sulfonic acid, and the data were obtained from the color developed at the wave length of 680 mμ using "Elma" spectrophotometer Model IV.

Potassium in the extract was determined at 768 mμ using "Hitachi H-2" flame photometer.

11. Mechanical analysis

In the present experiment the mechanical analysis was performed by the A. S.K. method which has been officially adopted in Japan, in which parts of the body used for the work are the modified Kopecky's apparatus of two-tube type.

The relation between the names of separates and their diameters has been decided as follows:

		Name	Diameter (mm)
		Gravel and Debris	above 2
Fine Soil	Sand	Coarse Sand	2 —0.25
		Fine Sand	0.25—0.05
		Silt	0.05—0.01
		Clay	below 0.01

For the physical and chemical experiments the fine soil was employed here.

Soil classes have been recognized as shown in the next table on the basis of the proportion of the clay fraction present in the fine soil.

Soil Classes	Clay (%)
Sand	below 12.5
Sandy Loam	12.5—25
Loam	25 —37.5
Clayey Loam	37.5—50
Clay	above 50

RESULTS AND DISCUSSION

I. *DESCRIPTION OF SAMPLING SITES*

The soil sampling was carried out over much of the inland basins and surrounding plateaux.

TABLE 1 *The Description of Sampling Sites* (see the later map)

Lab. No.	*Depth cm*	*Locality*	*Land Classification*	*Color*	*Soil Classes*	*Remarks*
			Alluvial Soils			
76	0~20	Near Sandan, 24 km north of Kratie	Banana plantation	Dark grey brown	C. L	River-side of the Mekong, annually submerged by floods
77	0~20	South of Kbal Chour, 16 km north of Kratie	Rice field	Light orange grey	C. L	After harvest, soil layer deep, river-side of the Mekong
78	40	〃	〃	Yellowish grey brown	C. L	Yellowish brown spots, underlayer of No. 77
79	0~20	15 km north of Kratie	Peanuts field	Reddish orange grey	C	After harvest, river-side of the Mekong
80	0~20	13 km north of Kratie	Rice field	〃	C	After harvest, hard topsoil, river-side of the Mekong
81	25	〃	〃	Grey brown	C	Underlayer of No. 80
82	0~20	5 km north of Kratie	Tobacco field	Light grey brown	C	River-side of the Mekong, annually submerged by floods
83	50	〃	〃	Reddish orange grey	C	Underlayer of No. 82
84	0~20	Kratie	Vegetable field	Grey brown	C. L	Granular structure, more or less manured
85	0~20	23 km south of Kp. Thom	Rice field	Yellowish grey brown	S	Floating rice area
86	0~20	Near Ang Konh, 14 km north of Kp. Thom	〃	Light brown grey	S	Many open teak forests at environs
87	0~20	Near Spean Traeh, 30 km north of Kp. Thom	Open forest	Greyish red brown	S. L	Start of mixed forests with teak and pine trees
88	0~20	6 km north from No. 87	〃	Dark brown grey	S	Pine forests
89	0~20	Near Ph. Sanko, 22 km north-west of Kp. Thom	Rice field	Reddish orange grey	S. L	No floating rice fields
90	0~20	39 km South-east of Siem Reap	〃	Light orange grey	C	Annually submerged by the Lake Tonle Sap
91	0~20	8 km north-west of Siem Reap	〃	Reddish orange grey	S. L	Baray Occidental Irrigation Project
92	0~20	Near Siem Reap	Banana plantation	Dark grey brown	L	Highly productive
93	0~20	3 km north-west of Sisophon	Uncultivated	Brownish black	—	Short gramineous grass, less trees, hill lands
94	0~20	44 km east of Sisophon	Rice field	Grey brown	C. L	Pond water white turbid
95	20~40	51 km east of Sisophon	〃	Reddish orange grey	C	Subsoil

96	50	51 km east of Sisophon	Rice field	Reddish orange grey	C	Underlayer of No. 95
97	0~20	〃	〃	Orange grey	C. L	Topsoil of No. 95 and 96
98	0~20	Kh. Prek Ropou, 4 km south of Sisophon	〃	〃	C	
99	30~40	〃	〃	Grey brown	C	Underlayer of No. 98
100	60	〃	〃	〃	—	Underlayer of No. 99
101	0~20	18 km north of Battambang	〃	Dark grey brown	C	Pilot Station du Riz
102	20~40	〃	〃	Grey brown	C	Underlayer of No. 101
103	0~20	Northern outskirts of Battambang	Mandarine garden	Yellowish grey brown	C. L	Manured with plenty of chaff ashes
104	0~10	3 km south of Battambang	Rice field	Light yellow orange	C	Test plot in Station Génétique du Riz
105	10~20	〃	〃	〃	C. L	Underlayer of No. 104
106	0~20	2 km south of Ph. Au Tpong, 28 km north of Pursat	〃	Ligh orange grey	C	
107	0~20	2 km north of Pursat	〃	Grey brown	S. L	
108	0~20	1 km south of Krakor, 34 km south of Pursat	Rice field	Light brown grey	C. L	
109	0~20	58 km north of Ph Penh	〃	Reddish orange grey	S	
110	0~20	Near Batheay, north of Ph. Penh	〃	Orange grey	C	Uppermost layer somewhat sticky
111	0~20	Near Samkoeup, 13 km south of Batheay	〃	Grey brown	L	Marshes
112	0~20	17 km north of Ph. Penh	〃	Light orange grey	C	Outside of levee (road) of the Tonle Sap River
113	0~20	3 km north of Ph. Koki, 14 km South of Ph. Penh	Grass land	Grey brown	C. L	Alan-alan (Imperate cylindrica BEA), submerged in rainy season
114	0~15	Near No. 113	Peas field	〃	C	With high furrows
115	0~15	〃	Sugar cane plantation	〃	C	Marshes
116	0~20	Saway Rolom, 18 km south-east of Ph. Penh	Vegetable field	〃	C. L	Marshes
117	>20	〃	〃	〃	S. L	Underlayer of No. 116

(cont'd)

Table 1 (Cont'd)

Lab. No.	*Depth cm*	*Locality*	*Land Classification*	*Color*	*Soil Classes*	*Remarks*
118	0~30	Near No. 116	Uncultivated	Grey brown	C	10 m from riverside
119	150	6 km north-west of Banam	〃	Yellowish grey brown	C	Agr. Centre de Samrong Thom, section in pond under construction
120	300	〃	〃	Light yellow orange.	C	Below No. 119
121	10~20	5 km south-west of Banam	Corn field	Grey brown	L	Submerged in rainy season
122	10~20	6 km south-west of Banam	Miscanthus land	〃	C	Submerged in rainy season
123	0~20	25 km south-east of Banam	Rice field	〃	C. L	Marshes
124	0~20	Near Kp. Trabek, 35 km south-east of Banam	〃	Yellowish grey brown	C	Marshes, roadside to Saigon
125	0~20	Western outskirts of Svay Rieng	〃	Orange grey	L	Marshes, roadside to Saigon
126	0~20	Near air port at Ph. Penh	〃	Reddish orange grey	S. L	
127	0~20	32 km south-west of Ph. Penh	〃	Yellowish grew brown	S. L	
128	30	〃	〃	Orange grey	L	Underlayer of No. 127
129	0~20	38 km south of Ph. Penh	〃	Reddish orange grey	C	Marshes
130	0~20	6 km south of Tran Khnar, 48 km south-west of Ph. Penh	〃	〃	S. L	Marshes
131	0~20	4 km west of Takeo	〃	Orange grey	C. L	Marshes
132	0~20	16 km east of Kampot	〃	Light brown grey	C	Many salt farms at environs
133	0~20	10 km east of Kampot	Pepper field	Dark greyish red brown	L	Near seashore, manured
134	0~20	8 km west of Kampot	Uncultivated	Light brown grey	S	Near seashore
135	0~20	30 km west of Kampot	Rubber plantation	Greyish red brown	S. L	Near seashore
			Basaltic soils			
51	0~20	10 km north of Snoul	Open forest	Reddish orange grey	S	Teak etc.
52	0~20	5 km north of Snoul	Rice field	Grey brown	L	200 m from rubber plantations
53	0~20	Near No. 52	Uncultivated	Dark reddish brown	C	200 m north from No. 55—rubber plantations
54	100	〃	〃	Brown grey	L	Underlayer of No. 53
55	0~20	Near Snoul	Rubber Plantation	Dark reddish brown	C. L	Resistant to dig

56	60	Near Snoul	Rubber plantation	Reddish brown	C	Underlayer of No. 55
57	0~20	〃	Uncultivated	Dark reddish brown	C	50 m from rubber plantations
58	100	〃	〃	Dark red brown	C . L	Underlayer of No. 57
59	200	〃	〃	〃	C	Underlayer of No. 58
60	0~20	4 km south of Snoul	〃	Dark reddish brown	C	Adjucent to new rubber plantations
61	0~20	4 km south from No. 60	Open forest	Greyish yellow brown	L	Teak etc.
62	0~20	10 km south from No. 61	Rubber plantation	Dark red brown	C	
63	0~20	1 km west of Mimot, 15 km south from No. 62	Rice field	Yellowish grey brown	C	After harvest
64	0~20	6 km south from No. 63	Rubber plantation	Dark reddish brown	C	
65	0~20	Near No. 64	〃	〃	—	
66	0~20	19 km south from No. 65	〃	Grey brown	L	
67	0~20	14 km east of Kp. Cham	〃	Dark reddish brown	C	
68	0~20	Bos Por. 37 km north-west of Kp. Cham	Coffee plantation	Yellowish grey brown	C . L	Station Experimental Agricole
69	0~20	Adjucent to No. 68	Rubber plantation	Dark red brown	C	
70	70	〃	〃	Dark reddish brown	C	Underlayer of No. 69
71	0~20	69 km south-east of Kp. Thom	Kapok plantation	Dark brown grey	C . L	Just near the end of red soil zones, poor growth
72	0~20	5 km south-west from No. 71	Banana plantation	Dark reddish brown	C	No gravel throughout deep layers
73	0~20	3 km north-west from No. 72	Pre-arranged rubber plantation	Reddish brown	C	Jungles have been cleared
74	0~20	10 km north-west from No. 73	Rice field	Brown grey	L	Surrounded by open teak forests
75	0~10	Adjucent to No. 74	Open forest	Brownish black	L	Teak etc.

Sandstone soils

1	0~20	4 km south of Stung Treng	Jungle	Light brown grey	S . L	Soil layer deep
2	0~20	6 km south from No. 1	〃	Brown grey	S . L	Soil layer deep
3	0~20	11 km south from No. 2	〃	Grey brown	S . L	From roadside cuttings near jungles
4	0~20	Near No. 3	〃	Greyish red brown	S	

(Cont'd)

Table 1 (Cont'd)

Lab. No.	*Depth cm*	*Locality*	*Land Classification*	*Color*	*Soil Classes*	*Remarks*
5	0～20	6 km south from No. 4	Jungle	Grey brown	L	Near south margin of jungle zone
6	0～20	2 km east along road branched at 20 km south of St. Treng	〃	Reddish brown	C	Soil layer deep
7	0～20	3 km east from No. 6	〃	Brown grey	S	Soil layer deep
8	60	〃	〃	Reddish orange grey	S . L	Underlayer of No. 7
9	0～20	5 km east from No. 7	〃	Light brown grey	S . L	Soil layer deep
10	0～20	10 km east from No. 9	〃	Light orange grey	L	Evergreen dominant
11	40	Adjucent to No. 10	〃	Light grey orange	—	5 m from No. 10, roadside cutting, subsoil
12	100	〃	〃	〃	C	Underlayer of No. 11
13	0～20	3 km east from No. 10	〃	Light brown grey	S	
14	20～40	〃	〃	Yellowish grey brown	S . L	Underlayer of No. 13
15	40～100	〃	〃	〃	S . L	Underlayer of No. 14
16	0～20	5 km east from No. 13	〃	Dark red orange	L	Soft topsoil
17	0～16	3 km east from No. 16	Open forest	Grey brown	S . L	Teak etc.
18	0～10	8 km east from No. 17	〃	Greyish red brown	—	Teak etc.
19	20～25	〃	〃	Brown	—	Underlayer of No. 18
20	0～15	Chrop, 34 km east of St. Treng	Rice field	Light orange grey	C	Low-lying area surrounded by hills
21	15～30	〃	〃	Yellowish grey brown	L	Underlayer of No. 20
22	0～10	Srá Pok, 38 km east of St. Treng	Open forest	Brown grey	S . L	Teak etc., 50 m from river-side
23	30	〃	〃	Light orange grey	L	Underlayer of No. 22
24	0～20	28 km south of St. Treng	〃	Greyish red orange	C	1 km from No. 5 at south margin of jungles
25	0～20	27 km south from No. 24	〃	Light orange grey	S	
26	0～20	32 km south from No. 25	Rice field	Reddish orange grey	S	Surrounded by forests
27	20～30	〃	〃	Brown grey	L	Underlayer of No. 26
28	0～20	7 km south from No. 26	Open forest	Reddish orange grey	S	Teak etc. many puddles
29	0～20	10 km east of Kratie	Jungle	Reddish brown	C	
30	20～100	〃	〃	〃	—	Underlayer of No. 29
31	0～15	1 km east of Svay Ties, 37 km east from No. 29	Rice field	Light orange grey	S . L	Surrounded by open forests near jungles

32	0～20	P. Préeh, north of road to Camp La Rollang	Rice field	Brown grey	C	Surrounded by jungles
33	0～20	P. Peam, north of road to Camp La Rollang	Open forest	Dark grey brown	S. L	Teak etc.
34	0～20	13 km east from No. 31	Jungle	Brown grey	L	Soil layer deep
35	0～15	26 km from Kp. Speu to Kp. Som	〃	Reddish orange grey	S. L	Plains, foot of Kirirom
36	0～15	Kirirom area	Open forest	Greyish red brown	S. L	Teak etc., Flat on highlands
37	0～15	〃	〃	Yellowish grey brown	L	Dense undergrowth, gentle slope, teak etc.
38	0～10	〃	〃	Reddish brown	C	Slope, start of pine tree forests
39	50	〃	〃	Light orange	C. L	Underlayer of No. 38
40	0～10	〃	〃	Brown	C. L	Pine tree, flat on highlands
41	50	〃	〃	Reddish brown	—	Underlayer of No. 40
42	0～15	〃	〃	〃	L	Pine tree, flat on highlands
43	0～10	〃	〃	Light brown	S. L	Pine tree, gentle slope
44	10～20	〃	〃	Greyish yellow brown	—	Underlayer of No. 43
45	0～10	〃	〃	〃	L	Pine tree, gentle splope, near jungles
46	10～30	〃	〃	Greyish yellow	L	Underlayer of No. 45
47	0～15	〃	Mixed forest	Grey brown	C. L	Border of pine forests and jungles, gentle slope
48	0～10	〃	Jungle	Dark grey brown	L	Gentle slope
49	20～25	〃	〃	Grey brown	L	Underlayer of No. 49
50	0～15	〃	〃	Brown grey	S. L	Near stream on highlands, typical tropical jungles

TABLE 2 *The Analytical Data*

Lab. No.	*Depth cm*	*Mechanical Composition %*				*Soil classes*	pH		*Acidity*	
		Gravel	*Coarse and Fine sands*	*Silt*	*Clay*		H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
										Alluvial
76	0~20	0.5	21.0	37.5	41.5	C . L	5.9	5.4	0.21	8.65
77	0~20	1.4	35.5	24.0	40.5	C . L	6.0	5.5	0.42	5.06
78	40	0.9	34.0	23.0	43.0	C . L	5.6	5.3	1.06	8.86
79	0~20	2.8	13.0	20.5	66.5	C	5.6	5.0	0.84	17.94
80	0~20	0.5	11.5	29.0	59.5	C	5.7	5.1	0.32	14.56
81	25	0.3	12.5	33.0	54.5	C	5.8	5.1	0.63	10.76
82	0~20	25.0	8.0	31.0	61.0	C	6.2	6.0	0.63	—
83	50	0.8	3.0	13.0	84.0	C	5.1	4.2	2.11	19.00
84	0~20	1.0	24.0	35.0	41.0	C . L	6.1	5.8	0.21	4.64
85	0~20	61.6	77.5	14.0	8.5	S	5.8	5.0	1.90	7.60
86	0~20	0.1	72.5	19.0	8.5	S	6.0	5.4	1.69	8.44
87	0~20	1.3	69.0	6.5	24.5	S . L	5.3	4.3	5.06	17.30
88	0~20	0.6	79.0	12.5	8.5	S	5.5	4.5	2.95	18.51
89	0~20	0.1	67.0	16.5	16.5	S . L	5.7	5.0	0.84	4.01
90	0~20	1.1	18.0	22.0	60.0	C	5.4	4.7	3.59	8.44
91	0~20	0.2	51.5	29.0	19.5	S . L	5.7	5.5	0.84	4.43
92	0~20	2.6	43.5	26.5	30.0	L	6.7	6.6	0.21	1.69
93	0~20	1.0	—	—	—	—	7.5	7.2	0.42	3.38
94	0~20	5.7	32.5	19.0	48.5	C . L	5.1	4.5	7.81	16.46
95	20~40	2.5	28.5	12.5	59.0	C	4.8	4.3	22.37	28.49
96	50	4.3	10.5	11.0	78.5	C	4.7	4.2	34.18	46.42
97	0~20	9.6	19.0	36.5	44.5	C . L	5.2	4.3	11.61	17.94
98	0~20	0.1	6.0	14.0	80.0	C	5.3	5.0	4.64	11.08
99	30~40	23.3	11.0	13.0	76.0	C	5.0	4.2	28.70	38.40
100	60	52.8	—	—	—	—	5.3	4.3	16.04	—
101	0~20	13.5	12.5	17.5	70.0	C	5.3	4.5	9.07	19.20
102	20~40	53.8	23.5	14.0	62.5	C	5.2	4.6	10.13	17.72
103	0~20	0.3	3.0	57.0	40.0	C . L	6.4	6.3	0.21	2.95
104	0~10	11.0	23.0	21.5	55.5	C	5.3	4.5	2.74	30.60
105	10~20	0.4	30.5	27.0	42.5	C . L	5.8	5.3	0.84	6.85
106	0~20	1.2	11.5	26.5	62.0	C	4.7	4.1	13.29	19.41
107	0~20	0.3	58.0	19.0	23.0	S . L	5.4	4.8	4.85	8.65
108	0~20	0.3	39.0	19.0	42.0	C . L	5.1	4.8	2.53	7.39
109	0~20	3.7	90.5	8.0	1.5	S	6.1	6.0	0.63	—
110	0~20	0.7	2.5	17.5	80.0	C	5.6	4.9	1.48	4.85
111	0~20	2.8	46.0	24.0	30.0	L	5.7	5.6	0.41	4.22
112	0~20	35.5	7.5	10.0	82.5	C	4.7	4.0	8.23	44.10
113	0~20	0.3	21.0	36.5	42.5	C . L	5.9	5.1	0.63	6.96
114	0~15	3.3	4.0	24.5	71.5	C	5.9	5.2	0.42	6.75
115	0~15	1.3	8.5	34.5	57.0	C	6.3	5.7	0.21	5.70
116	0~20	31.3	14.5	41.0	44.5	C . L	6.6	6.5	1.06	6.54
117	>20	17.2	72.5	12.5	15.0	S . L	5.9	5.9	0.21	2.73
118	0~30	tr.	10.0	37.5	52.5	C	6.8	6.3	0.42	12.03
119	150	10.8	9.5	33.5	57.0	C	7.3	6.3	0.21	14.77
120	300	31.9	1.5	3.5	95.0	C	7.3	6.7	0.21	119.64

of Cambodian Soils

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
soils									
0.15	1.32	9.2	2.27	24.39	7.33	30.05	0.014	0.031	0.010
0.09	0.75	8.2	1.29	15.04	2.81	18.68	0.008	0.001	0.014
0.05	0.41	8.2	0.71	27.83	3.21	11.53	0.028	tr.	0.003
0.26	2.81	10.7	4.83	33.79	5.68	16.81	0.082	0.025	0.020
0.15	1.20	7.9	2.06	17.60	4.25	24.15	0.018	0.011	0.007
0.18	1.72	9.5	2.97	29.87	8.12	27.18	0.017	0.007	0.014
0.15	1.16	7.5	1.99	35.55	10.54	29.65	0.002	0.030	0.013
0.14	1.21	8.3	2.07	8.74	5.82	66.59	0.006	0.039	0.011
0.15	1.16	8.1	2.00	33.55	10.38	30.94	0.012	0.045	0.019
0.05	0.32	6.4	0.55	15.88	1.40	8.82	0.004	0.001	tr.
0.08	0.67	8.4	1.15	20.55	2.82	13.72	0.059	0.001	tr.
0.11	1.43	13.5	2.45	22.51	3.37	14.97	0.079	0.004	0.004
0.08	0.94	11.8	1.62	21.77	1.00	4.59	0.027	0.002	0.003
0.04	0.27	6.8	0.47	36.73	0.88	2.40	0.004	0.001	0.002
0.09	0.62	6.8	1.06	23.41	1.60	6.83	0.012	0.001	0.043
0.06	0.57	10.1	0.98	15.29	0.88	5.76	0.005	0.001	tr.
0.15	0.97	6.7	1.66	27.67	12.06	43.59	0.029	0.185	0.079
0.26	1.68	6.5	2.90	84.88	81.69	96.24	0.921	0.001	0.016
0.12	1.09	9.7	1.87	23.50	0.53	2.26	0.011	<0.001	0.005
0.05	0.29	7.0	0.51	32.71	2.73	8.35	0.001	tr.	0.003
0.03	0.29	9.2	0.49	27.69	2.40	8.67	0.004	tr.	0.002
0.07	0.45	6.4	0.78	13.45	4.73	35.17	0.045	tr.	0.009
0.16	1.22	7.7	2.09	30.48	11.51	37.76	0.061	0.005	0.006
0.08	0.68	9.3	1.17	29.27	4.59	15.68	0.010	tr.	0.002
0.05	0.27	5.4	0.47	—	—	—	0.019	tr.	tr.
0.23	1.43	6.2	2.47	45.38	8.09	17.83	0.023	0.006	0.009
0.08	0.58	6.9	1.00	38.52	6.61	17.16	0.040	tr.	0.008
0.08	0.44	6.1	0.76	22.78	14.32	62.86	0.024	0.064	0.010
0.09	0.61	6.4	1.04	34.29	13.16	38.38	0.014	0.009	0.008
0.08	0.53	6.4	0.92	36.39	12.44	34.19	0.028	0.001	0.007
0.11	0.73	6.6	1.26	26.19	2.05	7.83	0.006	0.003	0.011
0.07	0.49	7.0	0.84	15.61	1.41	9.03	0.001	<0.001	0.003
0.08	0.52	6.4	0.89	16.53	1.67	10.10	0.033	0.001	0.003
0.06	0.44	7.3	0.76	14.96	0.88	5.88	0.005	0.001	tr.
0.05	0.56	11.1	0.96	2.75	1.01	36.73	0.099	0.001	0.004
0.06	0.47	7.8	0.81	17.22	3.36	19.51	0.009	0.001	0.003
0.19	0 97	4.9	1.67	39.02	15.57	39.90	0.037	0.007	0.010
0.11	0.75	6.7	1.29	6.62	5.61	84.74	0.016	0.036	0.009
0.07	0.81	11.1	1.39	14.35	9.73	67.80	0.041	0.028	0.010
0.10	1.17	11.4	2.01	30.85	12.20	39.55	0.028	0.022	0.007
0.09	0.58	7.2	1.00	25.58	13.34	52.15	0.045	0.059	0.012
0.08	0.67	8.3	1.16	25.21	5.55	22.02	0.012	0.010	0.026
0.17	0.95	5.5	1.64	28.00	10.75	38.39	0.039	0.033	0.011
0.06	0.24	4.6	0.41	35.21	7.47	21.22	0.031	0.001	0.002
0.06	0.36	6.8	0.61	30.45	8.58	28.18	0.74	<0.001	0.005

(Cont'd)

Table 2 (Cont'd)

Lab.No.	Depth cm	Mechanical Composition %				Soil Classes	pH		Acidity	
		Gravel	Coarse and Fine Sands	Silt	Clay		H_2O	KCl	Exchange y_1	Hydrolytic y_1
121	10~20	2.2	14.0	59.5	26.5	L	5.8	5.2	1.27	6.33
122	10~20	1.7	6.0	20.5	73.5	C	5.5	4.6	2.11	15.83
123	0~20	2.2	21.0	32.5	46.5	C . L	5.6	5.1	1.48	4.64
124	0~20	2.2	4.5	16.0	79.5	C	5.2	4.5	3.38	16.46
125	0~20	0.1	27.0	41.0	32.0	L	5.4	4.8	4.01	10.34
126	0~20	0.4	52.5	24.0	23.5	S . L	5 9	5.7	0.42	4.64
127	0~20	4.9	60.5	14.5	25.0	S . L	5.1	4.7	1.69	9.92
128	30	18.9	56.5	10.0	33.5	L	5.1	4.5	7.49	10.76
129	0~20	0.7	27.5	12.5	60.0	C	5.5	5.1	1.69	9.23
130	0~20	3.0	41.5	34.0	24.5	S . L	6.3	5.7	0.21	3.38
131	0~20	12.1	41.5	19.0	39.5	C . L	5.3	4.5	10.16	15.61
132	0~20	0.3	27.5	11.0	61.5	C	5.4	4.7	1.90	5.49
133	0~20	0.4	27.0	43.5	29.5	L	4.7	4.2	8.86	4.22
134	0~20	0.3	76.5	17.0	6.5	S	5.8	5.2	1.48	6.75
135	0~20	2.1	73.5	13.5	13.0	S . L	5.3	4.6	6.96	14.35
Mean		4.2	33.6	24.2	42.1	C . L	5.7	5.1	2.65	10.61
										Basaltic
51	0~20	1.0	68.5	25.0	6.5	S	6.0	5.8	0.42	26.38
52	0~20	0.2	46.0	17.5	36.5	L	5.2	4.2	4.85	17.09
53	0~20	5.4	30.0	17.5	52.5	C	4.7	4.4	5.70	18.36
54	100	1.6	60.5	9.0	30.5	L	5.4	4.9	4.43	11.39
55	0~20	3.9	39.0	14.5	46.5	C . L	5.4	4.7	1.69	23.63
56	60	6.8	24.5	7.0	68.5	C	5.7	5.6	0.42	21.52
57	0~20	2.0	3.5	13.5	83.0	C	4.4	4.3	6.75	28.27
58	100	0.4	22.0	36.5	41.5	C . L	5.2	5.0	0.63	8.23
59	200	0.7	9.0	16.5	74.5	C	5.4	5.6	0.21	6.54
60	0~20	15.7	7.5	14.5	78.0	C	4.7	4.3	6.33	18.36
61	0~20	39.8	51.0	14.5	34.5	L	6.0	5.0	0.63	9.07
62	0~20	0.5	9.0	10.0	81.0	C	4.3	4.3	9.92	39.56
63	0~20	17.2	16.5	15.0	68.5	C	4.7	4.4	6.33	27.54
64	0~20	0.7	3.5	6.5	90.0	C	5.1	4.8	4.22	21.94
65	0~20	—	—	—	—	—	5.2	4.8	3.80	—
66	0~20	2.2	47.5	16.5	36.0	L	5.2	4.5	7.17	17.51
67	0~20	0.5	2.5	21.5	76.0	C	5.5	5.2	0.63	19.41
68	0~20	5.6	22.0	29.0	49.0	C . L	6.3	6.2	0.42	6.33
69	0~20	5.7	14.0	21.5	64.5	C	5.6	5.2	0.21	17.72
70	70	0.5	7.0	13.0	80.0	C	5.3	4.6	1.90	25.95
71	0~20	41.1	37.0	22.5	40.5	C . L	6.3	6.2	0.21	5.06
72	0~20	1.9	5.0	2.0	93.0	C	5.6	5.6	0.42	9.71
73	0~20	24.6	5.0	10.0	85.0	C	6.1	6.1	0.21	11.82
74	0~20	75.5	26.0	39.0	35.0	L	5.9	5.2	0.63	14.35
75	0~10	37.0	33.0	31.0	36.0	L	5.8	5.2	0.21	13.72
Mean		17.3	24.6	18.0	57.5	C	5.4	5.0	3.04	18.20
										Sandstone
1	0~20	0.3	75.0	10.5	14.5	S . L	5.7	5.2	1.90	7.81
2	0~20	0.7	68.5	16.0	15.5	S . L	6.1	5.9	0.21	6.96
3	0~20	0.1	75.5	2.0	22.5	S . L	5.6	4.6	2.74	8.23
4	0~20	0.2	81.5	6.5	12.0	S	6.0	5.7	0.63	7.81

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
0.17	1.17	6.8	2.01	34.99	15.26	43.61	0.022	0.025	0.013
0.16	1.33	8.3	2.29	40.11	8.66	21.59	0.006	0.021	0.013
0.07	0.49	7.0	0.84	24.28	3.33	13.71	0.018	0.001	0.003
0.15	1.10	7.1	1.89	31.29	8.67	27.71	0.025	0.009	0.008
0.07	0.66	9.3	1.13	23.44	1.07	4.56	0.016	0.002	0.002
0.08	0.78	9.8	1.34	20.74	2.99	14.42	0.007	0.001	0.003
0.08	0.51	6.3	0.87	17.90	1.73	9.66	0.054	0.001	0.002
0.05	0.23	4.6	0.39	20.83	1.60	7.68	0.010	tr.	tr.
0.08	0.56	7.0	0.97	17.62	16.77	95.18	0.006	0.001	0.003
0.12	0.63	5.2	1.08	20.92	11.63	55.59	0.018	0.007	0.008
0.05	0.37	7.4	0.64	20.92	1.06	5.07	0.013	tr.	0.002
0.07	0.60	8.6	1.03	21.70	2.47	11.38	0.018	0.001	tr.
0.18	2.14	11.8	3.68	40.30	1.80	4.47	0.042	0.018	0.008
0.05	0.41	8.2	0.71	12.78	0.70	5.48	0.140	0.001	tr.
0.12	1.17	9.7	2.01	27.77	2.47	8.89	0.031	0.003	0.004
0.11	0.92	8.2	1.57	25.12	6.58	25.01	0.040	0.012	0.008
soils									
0.04	0.37	9.3	0.64	19.53	2.64	13.52	0.015	0.001	0.003
0.17	1.49	8.6	2.56	23.31	16.55	71.00	0.006	0.001	0.005
0.16	1.30	8.1	2.24	30.77	3.03	9.85	0.012	tr.	0.003
0.08	0.61	7.8	1.05	34.69	13.14	37.88	0.021	0.002	tr.
0.24	1.70	7.0	2.93	28.42	5.65	19.88	0.069	0.001	0.003
0.08	0.62	7.4	1.06	20.53	1.28	6.23	0.016	0.001	0.003
0.33	2.30	6.9	3.95	41.18	3.46	8.40	0.015	0.001	0.007
0.06	0.48	7.8	0.82	19.82	2.57	12.97	0.019	tr.	0.005
0.06	0.41	6.3	0.70	18.33	7.46	40.70	0.013	tr.	0.003
0.17	1.47	8.9	2.54	45.45	0.52	1.14	0.013	tr.	0.006
0.09	0.90	11.0	1.54	31.51	2.85	9.04	0.074	tr.	0.011
0.22	2.77	12.6	4.76	25.81	10.66	41.30	0.024	0.002	0.003
0.16	1.56	9.9	2.68	18.82	2.48	13.18	0.014	0.005	0.004
0.14	1.43	9.9	2.45	30.75	7.97	25.92	0.017	tr.	0.008
0.17	1.26	7.6	2.16	32.04	1.26	3.93	0.005	0.001	0.008
0.12	0.74	6.4	1.28	27.59	2.53	9.17	0.004	0.001	0.005
0.15	1.26	8.7	2.17	42.49	3.47	8.17	0.029	<0.001	0.011
0.27	1.76	6.4	3.03	32.34	9.86	30.49	0.077	0.041	0.044
0.18	1.20	6.8	2.07	36.63	6.06	16.54	0.081	0.025	0.032
0.09	0.51	5.4	0.88	21.90	2.39	10.91	0.009	0.019	0.013
0.25	1.87	7.4	3.22	31.51	15.31	48.59	0.015	0.001	0.018
0.18	1.06	5.9	1.82	35.35	6.32	17.88	0.019	0.011	0.004
0.23	1.65	7.2	2.83	37.96	14.51	38.22	0.076	0.122	0.062
0.20	1.84	9.3	3.17	16.02	13.13	81.96	0.006	0.003	0.005
0.21	2.36	11.1	4.06	43.29	15.99	36.94	0.074	0.002	0.020
0.18	1.52	8.3	2.61	31.54	7.24	23.00	0.032	0.011	0.013
soils									
0.07	0.51	7.3	0.88	15.77	0.88	5.58	0.019	0.002	0.003
0.10	0.85	8.5	1.47	36.59	4.42	12.08	0.054	0.005	0.008
0.06	0.46	7.7	0.79	20.34	0.53	2.61	0.021	0.001	0.003
0.07	0.56	8.0	0.97	15.92	1.41	8.86	0.009	0.001	0.006

(Cont'd)

Table 2 (Cont'd)

Lab.No.	Depth cm	Mechanical Composition %				Soil Classes	pH		Acidity	
		Gravel	Coarse and Fine Sands	Silt	Clay		H_2O	KCl	Exchange y_1	Hydrolytic y_1
5	0~20	1.3	69.5	5.0	25.5	L	5.4	5.2	0.63	6.96
6	0~20	0.5	18.0	4.5	77.5	C	5.5	4.8	2.53	9.50
7	0~20	0.5	82.0	7.5	10.5	S	6.0	5.8	0.42	8.65
8	60	0.4	75.0	6.0	19.0	S.L	5.2	4.8	3.59	6.75
9	0~20	1.8	78.5	8.0	13.5	S.L	5.4	4.6	2.11	12.45
10	0~20	35.1	54.5	8.5	37.0	L	5.4	4.8	2.53	10.34
11	40	41.5	—	—	—	—	5.0	4.4	11.18	19.00
12	100	4.0	32.5	7.5	60.0	C	5.1	4.6	13.08	17.09
13	0~20	0.3	77.5	14.0	8.5	S	6.1	5.8	0.84	8.65
14	20~40	0.1	75.5	7.5	17.0	S.L	5.3	4.9	3.48	6.12
15	40~100	0.5	68.5	11.0	20.5	S.L	5.6	4.8	7.17	10.97
16	0~20	1.2	61.5	13.0	25.5	L	5.9	5.7	0.21	—
17	0~16	1.2	62.5	17.5	20.0	S.L	5.6	5.0	1.90	9.50
18	0~10	33.0	—	—	—	—	5.3	5.1	0.42	16.25
19	20~25	15.0	—	—	—	—	5.4	4.7	—	—
20	0~15	0.4	10.5	4.5	85.0	C	5.4	4.7	2.32	7.60
21	15~30	2.0	61.5	8.0	30.5	L	5.8	5.5	0.84	4.85
22	0~10	14.0	65.5	16.5	18.0	S.L	6.1	5.9	0.11	9.71
23	30	46.5	67.0	7.0	26.0	L	6.0	5.4	0.63	5.06
24	0~20	3.2	9.0	13.5	77.5	C	5.9	5.3	0.84	7.39
25	0~20	0.8	81.5	11.5	7.0	S	6.2	6.0	0.80	6.54
26	0~20	tr.	75.5	16.5	8.0	S	6.0	5.8	0.42	4.22
27	20~30	tr.	46.5	27.0	26.5	L	6.2	5.9	0.21	3.80
28	0~20	0.8	76.5	18.0	5.5	S	6.1	5.8	0.21	2.95
29	0~20	5.1	19.0	6.0	74.0	C	4.8	4.6	5.70	21.94
30	20~100	8.1	—	—	—	—	4.2	4.2	—	—
31	0~15	0.5	54.5	29.0	16.5	S.L	6.0	5.3	0.84	5.70
32	0~20	1.2	26.0	24.0	50.0	C	5.7	5.0	0.32	13.29
33	0~20	69.3	59.0	19.0	22.0	S.L	5.8	5.4	1.06	7.39
34	0~20	0.3	50.0	16.0	34.0	L	5.1	4.9	0.32	9.92
35	0~15	0.4	70.5	17.0	12.5	S.L	5.8	5.3	0.42	7.17
36	0~15	1.1	69.0	13.0	18.0	S.L	5.5	5.0	2.11	13.93
37	0~15	1.0	67.0	6.5	26.5	L	6.0	5.9	0.42	3.59
38	0~10	46.8	24.0	14.5	61.5	C	4.9	4.3	36.50	44.10
39	50	3.9	41.0	18.5	40.5	C.L	4.7	4.4	22.37	32.07
40	0~10	16.2	50.0	12.5	37.5	C.L	5.6	5.0	2.60	13.93
41	50	—	—	—	—	—	5.0	5.0	—	—
42	0~15	9.6	56.5	11.0	32.5	L	5.5	5.0	4.43	19.00
43	0~10	4.3	66.5	11.5	22.0	S.L	5.0	4.7	8.86	23.42
44	10~20	2.2	—	—	—	—	5.0	4.8	8.40	17.09
45	0~10	2.4	59.0	11.0	30.0	L	4.9	4.6	8.65	24.48
46	10~30	5.4	53.5	16.5	30.0	L	4.9	4.8	7.81	12.24
47	0~15	3.4	46.5	14.0	39.5	C.L	4.6	4.1	12.66	27.22
48	0~10	5.7	50.0	16.5	33.5	L	4.5	4.0	16.25	43.56
49	20~25	1.4	52.5	12.0	35.5	L	5.0	4.7	10.55	19.62
50	0~15	0.8	68.0	17.5	14.5	S.L	4.9	3.9	11.82	25.11
Mean		7.6	57.6	12.7	28.8	L	5.4	5.1	4.01	10.19
Total mean		7.9	40.3	19.0	41.0	C.L	5.6	5.1	3.34	13.14

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
0.10	0.87	8.6	1.49	24.23	10.11	41.73	0.026	<0.001	0.019
0.06	0.66	10.2	1.13	4.71	0.79	16.77	0.018	0.001	0.007
0.09	0.97	10.7	1.67	23.33	3.01	12.90	0.010	0.001	0.004
0.05	0.36	7.2	0.61	18.31	1.84	10.05	0.036	<0.001	tr.
0.09	0.77	9.6	1.32	15.84	1.95	12.31	0.020	0.001	0.014
0.11	1.31	11.8	2.25	16.27	1.76	10.82	0.031	0.002	0.010
0.07	0.29	4.0	0.49	24.20	2.65	10.95	0.005	<0.001	0.007
0.04	0.23	5.8	0.39	13.78	4.27	30.99	0.014	tr.	0.005
0.11	0.59	5.3	1.01	17.86	5.74	32.14	0.088	0.001	0.008
0.06	0.44	7.3	0.76	13.26	0.88	6.64	0.054	tr.	0.004
0.02	0.19	9.5	0.33	21.16	1.06	5.01	0.004	tr.	0.002
0.29	2.47	8.5	4.25	29.00	15.65	53.97	0.012	0.002	0.026
0.06	0.42	7.0	0.73	20.28	4.42	21.79	0.009	tr.	0.003
0.19	2.18	11.6	3.74	5.85	3.85	65.81	0.071	tr.	0.014
0.13	1.53	12.2	2.63	—	—	—	0.021	tr.	0.003
0.08	0.57	7.0	0.98	22.88	1.94	8.48	0.027	0.001	0.004
0.04	0.21	5.0	0.36	39.79	2.48	6.23	0.028	tr.	tr.
0.09	0.72	7.9	1.23	14.51	4.06	27.98	0.039	0.001	0.007
0.04	0.32	7.8	0.55	31.57	3.01	9.53	0.031	tr.	0.005
0.12	0.87	7.9	1.50	39.14	12.94	33.06	0.011	tr.	0.021
0.06	0.29	4.8	0.50	20.72	4.05	19.55	0.026	0.001	0.011
0.06	0.57	9.5	0.98	20.46	4.58	22.39	0.035	0.002	tr.
0.06	0.61	10.2	1.05	25.82	8.95	34.66	0.057	<0.001	0.003
0.04	0.29	7.3	0.50	20.73	1.57	7.57	0.029	<0.001	0.008
0.16	1.36	8.7	2.33	12.65	0.55	4.35	0.011	tr.	0.006
0.08	0.69	8.1	1.19	—	—	—	0.005	tr.	tr.
0.07	0.64	9.1	1.10	29.24	8.47	28.97	0.030	0.005	0.006
0.18	0.82	4.4	1.41	37.83	8.61	22.76	0.062	0.005	0.005
0.09	0.79	8.6	1.36	15.88	4.84	30.48	0.027	tr.	0.006
0.16	1.38	8.4	2.37	22.98	17.11	74.46	0.039	0.002	0.009
0.10	0.55	5.5	0.95	18.17	2.82	15.52	0.006	0.001	0.002
0.16	1.25	7.8	2.14	31.14	15.60	50.10	0.044	0.003	0.011
0.07	0.59	8.4	1.02	43.47	2.82	6.49	0.073	<0.001	0.009
0.08	0.91	10.9	1.57	26.69	1.46	5.47	0.015	tr.	0.026
0.08	0.83	10.3	1.43	12.70	0.86	6.77	0.022	tr.	0.021
0.14	1.28	9.0	2.20	20.00	3.20	16.00	0.004	tr.	0.007
0.05	0.47	8.2	0.80	—	—	—	0.008	tr.	0.002
0.09	1.06	11.8	1.83	22.78	1.80	7.90	0.026	tr.	0.005
0.16	2.11	12.9	3.64	26.47	3.94	14.88	0.074	<0.001	0.008
0.10	1.08	10.6	1.86	14.20	1.12	7.89	0.020	tr.	0.005
0.18	2.05	11.3	3.52	31.14	3.68	11.82	0.039	<0.001	0.008
0.08	0.67	8.3	1.15	28.61	0.53	1.85	0.038	tr.	0.003
0.14	1.81	12.6	3.11	27.38	1.62	5.92	0.014	<0.001	0.005
0.40	5.36	13.4	9.22	34.85	3.30	9.47	0.050	0.005	0.011
0.10	1.33	13.2	2.28	12.15	1.19	9.79	0.023	tr.	0.004
0 15	1.60	10.6	2.75	2.33	1.58	67.81	0.021	0.001	0.006
0.12	1.15	9.0	1.98	22.59	4.69	22.79	0.031	0.001	0.009
0.13	1.08	8.5	1.85	25.57	6.43	25.15	0.038	0.008	0.009

TABLE 3 *The Comparison of Properties*

Soils		*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
					H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Alluvial soils	47 mean	4.2	42.1	C . L	5.7	5.1	2.65	10.61
Basaltic soils	20 mean	17.3	57.5	C	5.4	5.0	3.04	18.20
Sandstone soils	35 mean	7.6	28.8	L	5.4	5.1	4.01	10.19
Total mean		7.9	41.0	C . L	5.6	5.1	3.34	13.14

Locality, geology, land classification, color, soil classes, and depth of sampling are briefly recorded in Table 1 in which the description was arranged in the order of the following, i.e., alluvial, basaltic and sandstone soils.

II. *ANALYTICAL RESULTS OVER THE WHOLE SOIL*

All the analytical data for soil samples collected throughout the whole province in Cambodia are presented in Table 2.

From observations of the topsoils in this table the following conclusions are drawn in general, though there are more or less variations from soil to soil.

The chemical and physical properties of the soils are generally outlined below.

Soil classes of Cambodian soils belong to a clayey loam with some gravel. The soils have a lower degree of acidity. Total nitrogen and humus contents are low. Carbon-nitrogen ratios show a moderate value. Cation-exchange capacity is sufficient or good. The content of exchangeable calcium is normal. The percentage of calcium saturation is slightly low. The content of available calcium is low, available phosphorus and potassium values are much lower.

In short, it was seen as a rule that although Cambodian soils have such favorable features as suitable soil classes, weak acidity, moderate C/N ratio and high exchange capacity, they are extremely poor in available plant nutrients.

III. *SOIL GROUPS OF DIFFERENT GEOLOGICAL ORIGINS*

A brief geological illustration is shown on the Map at page 47.

Classifying the soils in Cambodia, from the geological point of view, they can possibly be divided into three broad groups as follows:

A) Alluvial soil (Lab. No. 76—135)
B) Basaltic soil (Lab. No. 51—75)
C) Sandstone soil (Lab. No. 1—50)

Alluvial soils occupy the broad inland basins, which are mainly utilized as paddy rice fields. Outcrops of basaltic rocks from gentle hilly lands in confined area, as seen in the map; on which the overlying soils are carefully cultivated as rubber plantations under modern management. Sandstone soils comprise large areas in the regions of plateaux, and mountains, surrounding the inland basins, where they are covered with either dense or open forests.

Comparing the soils from these three groups, their properties are as given in

between Different Origins of Cambodian Soils

N %	C %	C/N	*Humus* %	*C.E.C.* me.	*Exch.* CaO me.	*Degree* Ca *Sat.* %	*Available Nutrient* % CaO	P_2O_5	K_2O
0.11	0.92	8.2	1.57	25.12	6.58	25.01	0.040	0.012	0.008
0.18	1.52	8.3	2.61	31.54	7.24	23.00	0.032	0.011	0.013
0.12	1.15	9.0	1.98	22.59	4.69	22.79	0.031	0.001	0.009
0.13	1.08	8.5	1.85	25.57	6.43	25.15	0.038	0.008	0.009

Table 3. On the basis of the results shown in Table 3, the property of soils in each geological group can be summarized as shown in the following.

A) Alluvial Soils (Lab. No. 76—135)

Soil class name is "clayey loam" with almost no gravel. Soil reaction is weakly acid to neutral which shows the lowest acidity amongst the three groups. The content of nitrogen and humus is much less than that of soils elswhere. Cation-exchange capacity is sufficient, but the level belongs to medium class of all groups. Exchangeable calcium is usual in content and belongs to medium level of all. Saturation degree of calcium is somewhat low, but is the highest in every group. Available calcium content is normal, but is the maximum of all. The content of available phosphorus shows the highest value among the three groups, though it is deficient in amount. Potassium in the available form is extremely poor.

B) Basaltic Soils (Lab. No. 51—75)

The name of soil class is a clay, rich in gravel. The acidity ranges from weakly to strongly acid. Nitrogen content is medium, but is the highest of all the groups. Humus amount is not enough, but this also is the maximum of all. Both cation-exchange capacity and exchangeable calcium are adequate. The degree of calcium saturation is somewhat low. The content of available calcium is poor. Phosphorus in the available status is in defect, but is the highest class as well as that of alluvial soils. The amount of available potassium also reaches the maximum of all groups, although the value is considerably low.

C) Sandstone Soils (Lab. No. 1—50)

Soil class name is "loam" with some gravel. The acidity ranges from fairly to weakly acid, which is somewhat lower than that of basaltic soils. Nitrogen and humus contents are low, but they have intermediate values between the two groups of soil. Exchange capacity is adequate, but is the minimum of the three groups. The content of exchangeable calcium is normal, but is the lowest of all the groups. The percentage of calcium saturation is relatively low. Available calcium content is as low as that of basaltic soils. Available phosphorus is surprisingly lacking, of which, the level is only one tenth of that of the other groups. The amount of available potassium is very poor, as is also alluvial soils.

TABLE 4 *The Comparison of Properties*

Soils	Gravel %	Clay %	Soil Classes	pH		Acidity	
				H_2O	KCl	Exchange y_1	Hydrolytic y_1
A) Eastern region from the Mekong River 6 mean	5.2	51.7	C	5.9	5.5	0.44	10.25
B) Eastern region from the Lake Tonle Sap 7 mean	0.9	22.0	S.L	5.6	4.9	2.41	9.82
C) Western region from the Lake Tonle Sap 15 mean	6.1	50.7	C	5.5	5.0	5.20	14.85
D) Southern region from Ph. Penh 19 mean	3.6	63.6	C	5.6	5.0	2.61	9.07
Mean for 47 Sandstone soils	4.2	51.2	C	5.7	5.1	2.65	10.61

D) Summary

Comparison between these three soil groups which were made in terms of soil classes, acidity, exchange capacity and nutrient content, gives us an indication of how the soils are, in order of fertility. Namely, these groups can be evaluated as under:

In physical properties, both basaltic and alluvial soils are of fine texture, and their soil classes belong to a clay, whereas sandstone soils are classified as a loam. Gravel content is highest in basaltic soils, lowest in alluvial soils, and intermediate in sandstone soils.

In chemical properties, the degree of acidity is in the following order, basaltic soils > sandstone soils > alluvial soils. Nutrient content shows the order of basaltic soils >alluvial soils > sandstone soils. Exchange capacity increases in the order of basaltic soils=alluvial soils>and sandstone soils.

In short, from the above comparison the following conclusions are possibly drawn as a whole with reference to the properties of the soils. That is to say, basaltic soils are regarded as the best of all, in spite of their somewhat strong acidity. Alluvial soils are of second order, though they have the least acidity of all. It would appear that sandstone soils are in the lowest class of all, since there is a low clay content, defects of nutrition, and low exchange capacity in their feature, even though soil acidity is in intermediate range amongst the three groups.

IV. *ALLUVIAL SOILS (Lab. No. 76—135)*

Alluvium is found in large areas of the inland basins of Cambodia, much of which distributes widely along catchment areas of the Mekong River and around the Lake Tonle Sap, and extends far open towards the southern boundary. In regions that are protected by overlying alluvial soils, most of the agricultural resources in this country have been cultured by natives over a long period. As above mentioned, alluvial soils have the lowest degree of acidity in the whole group of soils, but their nutritional levels and food holding capacity, belong to the intermediate class of Cambodian soils.

The soils of this group can possibly be distinguished by, and divided into the following two kinds owing to regional and environmental conditions.

between Different Regions of Alluviums

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient* %		
							CaO	P_2O_5	K_2O
0.16	1.40	8.6	2.41	26.65	6.83	25.04	0.023	0.024	0.014
0.07	0.69	9.1	1.18	22.31	1.71	8.16	0.027	0.001	0.007
0.11	0.80	7.1	1.34	28.37	11.10	29.11	0.089	trace	0.007
0.10	0.85	8.1	1.46	24.13	6.74	31.37	0.031	0.014	0.006
0.11	0.92	8.2	1.57	25.12	6.58	25.01	0.040	0.012	0.008



Fig. 2 Alluvial soil (Lab. No. 82). Tobacco field. River-side of the Mekong. Annually submerged by floods. 5 km north of Kratie



Fig. 1 Alluvial soil (Lab. No. 77). Rice field. River-side of the Mekong. 16 km north of Kratie



Fig. 4 Alluvial soil (Lab. No. 90). Rice field. Annually submerged by the Lake Tonle Sap. 39 km south-east of Siem Reap



Fig. 3 Alluvial soil (Lab. No. 88). Pine forest. 36 km north of Kp. Thom

1) Alluvial Soils in Different Regions

Comparisons were made as to soil properties of the following four regions where alluvial lands were regionally classified, i.e., A) Eastern region from the Mekong River (St. Treng—Kratie), B) Eastern region from the Lake Tonle Sap (Kp. Cham—Siem Reap), C) Western region from the Lake Tonle Sap (Sisophon —Ph. Penh), D) Southern region from Ph. Penh (Ph.Penh—Svay Riem, Takeo).

Analytical results on alluvial soils of the four regions are summarized in Table 4.

The characteristics of the soils in these regions were compared with one another as the following.

A) Eastern region from the Mekong River (Lab. No. 76—84)

The name of this soil class, as a whole, is a clay with some gravel. Soil reaction shows weakly acidic to neutral which is the lowest in acidity of all the alluviums. Total nitrogen and humus levels are the maximum of the regions. Exchange capacity belongs to a high class amongst the regions. The content of exchangeable calcium and the percentage of calcium saturation are intermediary of the alluviums. Available calcium content is in the lowest level of which, the amount is only less than half of the mean values for alluviums. Levels of available phosphorus are the highest, which is twice as much as the mean values for alluviums and three times higher than that of the whole country. Potassium content in the available state is poor, but it belongs to the highest class of all alluviums, and also to a high rank amongst all the Cambodian soils.



Fig. 6 Alluvial soil (Lab. No. 92). Banana plantation. Near Siem Reap

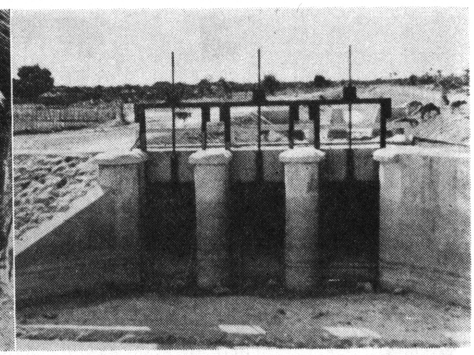


Fig. 5 Alluvial soil (Lab. No. 91). Rice field. Baray Occidental Irrigation Projects. 8 km north-west of Siem Reap

B) Eastern reigon from the Lake Tonle Sap (Lab. No. 85—92)

Textures are coarser than that of the other regions, and the soil is classified as clayey loam without gravel. Total nitrogen and humus have values which are surprisingly lower than those of the other regions. Exchange capacity, exchangeable calcium, and saturation degree also, are the least of all the regions. The amount of calcium, phosphorus and potassium in the available status is very low.

C) Western region from the Lake Tonle Sap (Lab. No. 93—112)

The name of this soil class is:-a clay with some gravel. The soil shows weak acidity. Nitrogen levels are higher than the average of alluviums. Humus is very deficient in amount. The value of exchange capacity, and exchangeable calcium, show the highest of all the regions. Saturation degree of calcium keeps at relatively high levels. The content of calcium in the available form, is as much as two times the usual content in alluviums. While the amount of available phosphorus is extremely deficient, being ranked the lowest of all. The content of potassium in the available status is of intermediate value.

D) Southern region from Ph. Penh (Lab. No. 113—135)

Soil textures are much heavier than those of the other regions in alluviums, and soil class belongs to a clay with almost no gravel. Soil acidity indicates weakly acidic to neutral reaction. Total nitrogen content is about the usual level for alluviums. Humus content is poor. Exchange capacity and exchangeable calcium have a medium degree of all the regions. Saturation degree of calcium has the highest value in alluvium. Available calcium pertains to higher levels of all the regions, despite the poorness. Phosphorus in the available form is poor, but is medium of the alluviums. The content of potassium available for plant growth is so extremely low, that the levels are the least of the four regions.

E) Summary



Fig. 8 Alluvial soil (Lab. No. 103). Mandarine garden. Northern outskirts of Battambang



Fig. 7 Alluvial soil (Lab. No. 101). Rice field. Pilot Station du Riz. 18 km north of Battambang

TABLE 5 *The Comparison of Properties*

Soils	*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
				H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Marshes 6 mean	3.4	47.0	C . L	5.6	5.9	3.39	9.94
Recent alluviums 29 mean	4.8	43.9	C . L	5.7	5.2	2.80	10.29
Old alluviums 9 mean	3.5	39.1	C . L	5.5	4.9	3.60	14.80
Mean for 47 alluviums	4.2	51.2	C	5.7	5.1	2.65	10.61

Comparing the characteristics of the different alluvial regions from the above description, they can possibly be ranked as follows, on the basis of their fertility.

The best region of alluviums is decided to be the east of the Mekong River, i.e., *A*) where the highest content of nutrients and the lowest acidity are shown, even though exchange capacity is somewhat lower.

Soils of the second order are situated at the west of the Lake Tonle Sap, i.e., *C*), which have the highest exchange capacity and the second highest content of nutrition, but indicate relatively strong acidity. Soils belonging to the third class are therefore regarded as those situated on the southern region from Ph. Penh.

The eastern region from the Lake Tonle Sap, i.e., *B*) on which the soils have the lowest nutrient content, and the exchange capacity is placed in the lowest class of all alluvial soils.

2) Alluvial Soils under Different Conditions

In low-lying areas along the southern part of catchment basins of the Mekong River, there are wide spread marshes and swamps which are covered at times by water.

The more upper course of the river is composed of alluvium of recent origin which is either flooded annually during the present time or up to recent years, much of which has been tilled and utilized sufficiently.

Alluvium of old origin in somewhat high altitude is located in far distances from the present upper course of the river and is now beyond the reach of floods.

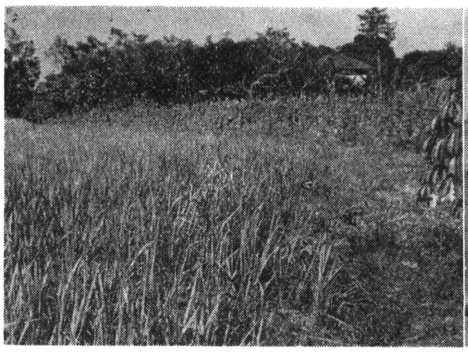


Fig. 10 Alluvial soil (Lab. No. 113). Alan-alan grass land. 3 km north of Ph. Koki, Kandal Province



Fig. 9 Alluvial soil (Lab. No. 112). Rice field. River-side of the Tonle Sap. 17 km north of Ph. Penh

between Different Kinds of Alluvium

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
0.09	0.63	7.2	1.09	23.08	7.09	33.65	0.016	0.003	0.005
0.12	0.94	8.0	1.62	26.31	8.36	31.77	0.057	0.013	0.009
0.09	0.83	8.8	1.43	22.52	4.74	20.15	0.040	0.003	0.004
0.11	0.92	8.2	1.57	25.12	6.58	25.01	0.040	0.012	0.008

Most of this lands still is covered with open forests of broardleaved trees, hence less cultivation of rice crops.

Comparing these three kinds of alluvium, i.e., marshes, recent, and old alluviums, there is a general tendency as shown in Table 5.

On the basis of these values given in Table 5, characteristics of each kind of the soils were pointed out below.

A) Marsh Soils (Lab. No. 123—125, 129—131)

This soil class name is : —a clayey loam without gravel, which has the highest clay content among the three kinds of alluvium. Soil reaction is weakly acid. Nitrogen and humus contents are very low. Exchange capacity and exchangeable calcium are both sufficient. Saturation degree of calcium is appreciably high and shows the top level amongst the three. Available calcium has a surprisingly low content which is the lowest of alluviums. Phosphorus in the available state is only contained in as poor a quantity as one fourth of the average of alluvial soils. Available potassium also is very poor and the content is only about one half of the average.

It has been reported from the Institute of Science, Cochin-China, that this acidity of the soil is mainly caused by the presence of much sulfuric acid. However, T. NAGATA, *et al.* has found that the degree of acidity was in almost no proportion to the amount of water soluble SO_4 ranging from 0.382 to 0.004 per cent, and they led to the conclusion that such a high SO_4 content cannot be only

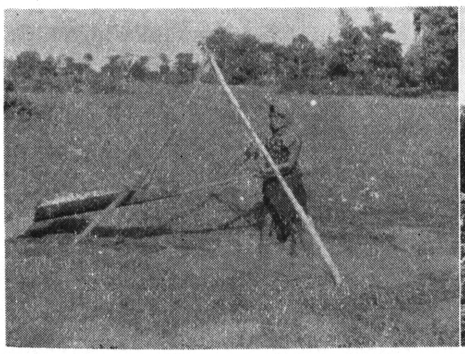


Fig. 12 Alluvial soil (Lab. No. 131). Rice field. 4 km west of Takeo

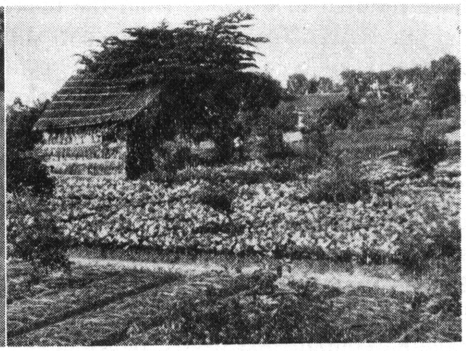


Fig. 11 Alluvial soil (Lab. No. 116). Vegetable field. 18 km south-east of Ph. Penh

one cause of the acidity. J. KOBAYASHI, making water analyses of numerous rivers, has reported the following results as to the water quality of the Mekong River, at the course running along the northern boundary of Thailand.

(Mean values for three sites, ppm.)

pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SiO_2	Fe	PO_4	NO_3-N	NH_4-N
6.9	30.0	5.5	7.5	1.6	110.9	14.7	6.6	14.4	0	tr.	0.03	0.04

As seen here, SO_4 is in outstandingly high concentration and, in addition, calcium, and magnesium also, are contained in quantity while the content of sodium, potassium and chlorine shows low levels. Much of SO_4 in the river water might therefore be expected to result in SO_4 accumulation in the marsh soils.

B) Recent Alluvial Soils (Lab. No. 76—84,85,89—97,106,108,111,112—122, 126—128,132—135)

A term of "clayey loam without gravel" represents the general soil classes for this soil. Soil acidity is weak to neutral. Total nitrogen and humus contents stand at the top of the whole alluvium, despite their depletion. Exchange capacity and exchangeable calcium are both adequate and they indicate therefore the highest level in alluvium. The percentage of calcium saturation is intermediate. Available calcium is rich in some degree, holding the top level of alluvial soils. The content of phosphorus and potassium in the available state is maximal amongst the three kinds, in spite of its poorness.

C) Old Alluvial Soils (Lab. No. 86—88,98—105,107,109,110)

Alluvium early deposited, is called Terres grieses, in which the soils are now beyond the reach of floods and have been subjected to relatively long weathering. Under-layers contain some iron rust spots or iron concretions which seem to have resulted in leaching from the upper-layers.

T. NAGATA, *et al.* have reported that the topsoil has remarkablly high SiO_2/Al_2O_3 ratios because of low Al_2O_3 content, whereas the subsoil comprises much of SiO_2, Al_2O_3, and Fe_2O_3, and ratios of SiO_2/Al_2O_3 are therefore appreciably lower than those of the topsoil. Accordingly, the topsoil is regarded as a siallitic soil, subjected to the leaching action.

The name of this soil class is a "clayey loam without gravel", in which the clay content is the least of alluviums. Soil reaction ranges from weakly to strongly acid, of which the acidity is the highest of all the alluvial soils. Nitrogen content is less than that of marsh soils. The accumulation of humus belongs to the intermediate class of alluviums. Exchange capacity, exchangeable calcium content and degree of calcium saturation are all in the lower degree among the three kinds of alluvium. Available calcium is moderate in amount. Available phosphorus content is very poor, as well as that of marsh soils. Potassium in the available form is the poorest of these kinds.

D) Summary

From the facts above mentioned, comparing these three kinds of alluvial soil with one another, they can evaluate themselves as follows:

The best is the recent alluvial soil, because of lowest acidity, highest nutriment content, and exchange capacity. The second is the marsh soil which has weak acidity, medium nutrient content, and exchange capacity. The last is determined to be that of the old alluvial soil; by reason of its highest acidity, least food content, and lowest exchange capacity.

V. *BASALTIC SOILS (Lab. No. 51—75)*

Areas covered by overlying basaltic soils are running in the long band shape, from near Kratie and Mimot to the south of Kp. Thom through Kp. Cham. These areas on which most of the rubber plantations have been concentrated are noted as the main place of superior rubber production in Cambodia.

The soils are estimated as the best soil of the whole country on account of the fact that their nutrient content, depth of soil layer, and exchange capacity are significantly higher than both alluvial and sandstone soils, although they have some weak points, for example, they are stronger in acidity than the other.

Basaltic red soils have surprisingly deep horizons ranging from about 15 to 18 meters on the average, from 30 to above 35 meters at maximum, and from 1.5 to 2 meters at minimum. As the deep layers are very rich in a clay fraction, their moisture holding power is sufficiently high to avoid the drought. In the case of extreme dryness on the surface, the soil maintains the moisture, as much as to be moulded even at the depth of 20 to 25 centimeters.

According to the result reported by T. NAGATA, *et al.*, SiO_2/Al_2O_3 ratios of underlying basaltic rocks north-west of Kp. Cham were 4.56, whilst those of clay fractions in overlying basaltic red soils accounted for only about 1.31, owing to decreasing of SiO_2 and increasing of Al_2O_3. The value of 1.31 is appreciably lower than that of 1.33 which has been shown as a standard for laterite by E.J. MARTIN, *et al.* (1927). From these reasons, Y. HENRRY and T. NAGATA give the conclusion that the basaltic red soils are subjected to the



Fig. 14 Basaltic soil (Lab. No. 55). Rubber plantation. Near Snoul



Fig. 13 Alluvial soil (Lab. No. 133). Pepper field. 10 km east of Kampot

TABLE 6 *The Comparision of Properties*

Soils	*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
				H_2O	KCl	*Exchange* y_1	*Hydroly-tic* y_1
Eastern region from the Mekong River 13 mean	7.4	57.4	C	5.1	4.7	4.50	22.26
Western region from the Mekong River 7 mean	27.3	57.6	C	5.9	5.7	0.32	11.24
Mean for 20 basaltic soils	17.3	57.5	C	5.4	5.0	3.04	18.20

weathering under the condition of medium-graded lateritization.

1) *Basaltic Soils of Different Regions*

Areas protected by overlying basaltic soils are likely to vary in their features from place to place, for example, from the east, to the west of the Mekong River. These soils were therefore compared as to their property between the following two areas.

Basaltic soils east of the Mekong River: This region where the present study has been carried out is confined to a range of Kratie—Snoul—Mimot—Kp. Cham.

Basaltic soils west of the Mekong River: They comprise a range from Kp. Cham to near Kp. Thom.

The analytical data for these two regions are compared with each other in Table 6, from which their characteristics can be pointed out below.

A) Basaltic Soils East of the Mekong River (Lab. No. 51—67)

Textural name of this soil is a clay with some gravel. Acidity ranges from weakly to strongly acidic, which is therefore much more high than that of "*B*". Nitrogen levels are less pronounced than those of "*B*". Humus is more deficient than that of "*B*". Exchange capacity is lower. Exchange capacity and percent of calcium saturation are both only one half of "*B*". Available calcium also is

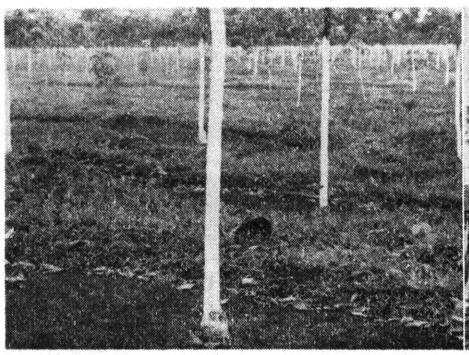


Fig. 16 Basaltic soil (near Lab. No. 60). New rubber plantation. South of Snoul



Fig. *15* Basaltic soil (near Lab. No. 55). Pre-arranged rubber plantation, open forest is clearing. Near Snoul

between Different Regions of Basaltic Soils

N %	C %	C/N	*Humus* %	*C.E.C.* me.	*Exch.* CaO me.	*Degree* Ca *Sat.* %	*Available Nutrient* %		
							CaO	P_2O_5	K_2O
0.17	1.43	8.6	2.45	30.59	4.85	15.86	0.023	0.001	0.006
0.22	1.68	7.7	2.89	33.30	11.60	34.83	0.050	0.029	0.027
0.18	1.52	8.3	2.61	31.54	7.24	23.00	0.032	0.011	0.013

a half. Available phosphorus content is one third of "*B*". Potassium in the available form is only as low as one fourth of that of "*B*".

B) Basaltic Soils West of the Mekong River (Lab. No. 68—75)

Soil class name, together with "*A*", is a clay, while gravel content is much higher than that of "*A*". Soil reaction is weakly acid to neutral, which is of the least acidic amongst the soils in Cambodia. Nitrogen is appreciably high, which belongs to the highest class of all. Humus is however not so much, but pertains to one of the higher classes. Exchange capacity, exchangeable calcium content, and degree of calcium saturation are the highest in this soil than of all the soils. The content of available calcium is relatively the highest level of the country. Phosphorus and potassium in the available status have the highest content, of which the former is four times as much as mean values for the whole soil and the latter reaches up to the three-fold respectively.

C) Summary

The findings from the above comparisons for basaltic soils are that there are wide variations in both chemical and physical soil properties, between these two basaltic regions.

The basaltic soils west of the Mekong River of which the content and holding capacity of the plant food are significantly higher, and soil acidity is much more weak than that of the eastern region.

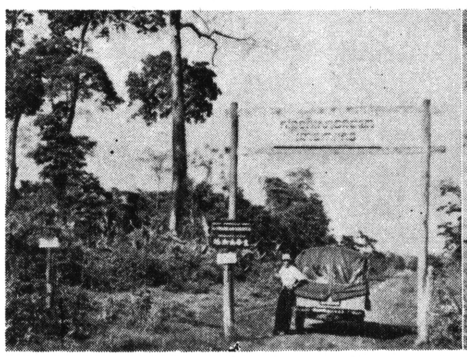


Fig. 18 Basaltic soil (Lab. No. 68). Coffee plantation. Agr. Expt. Station. 37 km north-west of Kp. Cham



Fig. 17 Basaltic soil (Lab. No. 67). Rubber plantation. Agr. Expt. Station. 14 km east of Kp. Cham

TABLE 7 *The Properties of Basaltic Soils*

Soils	*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
				H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Rubber plantation soils 7 mean	2.3	65.7	C	5.2	4.7	3.94	23.30
Mean for 20 basaltic soils	17.3	57.5	C	5.4	5.0	3.04	18.20

The soils of basaltic origin on the westside of the river must, of necessity, be regarded as the best of all the Cambodian soils in many respects.

D) Basaltic Soils of Rubber Plantations (Lab. No. 55,56,62,64—67,69,79)

Most of the rubber plantations are under cultivation on basaltic soils without distinction of region.

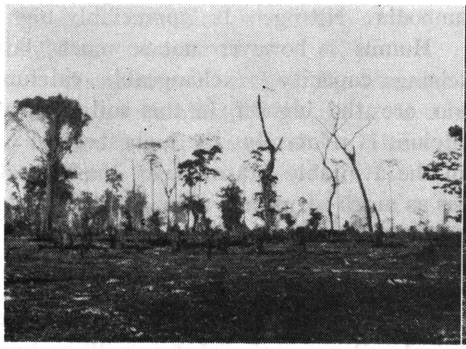


Fig. 20 Basaltic soil (Lab. No. 73). Pre-arranged rubber plantation. Jungle is clearing. Half-way between Kp. Cham and Kp. Thom



Fig. 19 Basaltic soil (Lab. No. 71). Kapok plantation. 69 km south-east of Kp. Thom



Fig. 22 Sandstone soil (near Lab. No. 10). Rice field in jungle. South of Stung Treng



Fig. 21 Sandstone soil (Lab. No. 1 and 2). Jungle. Southern outskirts of Stung Treng

under Rubber Plantation

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
0.17	1.48	8.4	1.98	31.96	5.37	17.84	0.033	0.004	0.010
0.18	1.52	8.3	2.61	31.54	7.24	23.00	0.032	0.011	0.013

The analysis of basaltic soils where rubber plants are cultured are presented in Table 7.

From the results shown in the table, comparing the analytical data of these soils with the mean values for basaltic soils, the following characteristics are found.

The name of the soil class is a clay without gravel. Clay content accounts for up to about 67 per cent, on the average, which is the highest of both basaltic and other soils.

Soil reaction is strong to weakly acid. Nitrogen and humus contents are appreciably less than those the average of basaltic soils. Exchange capacity, exchangeable calcium and percentage of calcium saturation show close agreement with the mean values for all basaltic soils. Available calcium and potassium are in the intermediate levels, while phosphorus in the available status has the content so low as to reach only about one third of the average.

From the point of view of the fertility, the following conclusions with reference to rubber plantation soils are drawn:

These soils are, at present, not fertile so much as to be evaluated as the best soil of all, against expectation. Their nutrient content is less pronounced than the average of all basaltic soils. Especially, the outstanding weak points of higher acidity, and depleted available phosphorus. In addition, humus content tends to be exhausted. It seems probable, that these unfavorable features are, of necessity, taking place owing to continuous cultivation.

On the other hand, the fact that this region has produced high yields of superior rubber materials, because of more vigorous growth than other southern countries, appears to be governed mainly by the superiority of physical properties, such as soil texture, profile, and water holding capacity, besides climatic conditions.

It can be, however, said that since the inherent fertility of the soil has shown such very high levels; that continuous good management is necessary to maintain and improve the soil features.

VI. *SANDSTONE SOILS (Lab. No. 1—50)*

Sandstone is superimposed over the high lands and plateaux surrounding the central alluvial basins, much of which is mainly covered with either jungle, or open forests and is therefore rarely used for the purpose of agricultural utilization.

Most of the overlying soils are of Triassic red sandstone origin, whilst areas in, or close to the Kirirom high land where they abut on the central plains, are composed of outcrops of Jurassic sandstones.

Sandstone soils, as a whole, belong to a loam and they comprise a clay content so low, as only about one half of the other geological soils. The soils are moderately acid, but since their nutrient content and exchange capacity are both in the lowest level as mentioned above, they must be regarded as being of the least agricultural value, in the country.

1) Sandstone Soils of Different Origins

Sandstone soils were divided into two according to the difference of geological period of mother rocks.

Triassic red sandstone soils.....areas other than Kirirom.

Jurassic sandstone soils.....area of Kirirom.

The composition of these two kinds of soil is given in Table 8.

The properties of the two kinds of soil are outlined below respectively.

A) Triassic Red Sandstone Soils (Lab. No. 1—34)

Triassic sandstones are of older origin, as long as one geological period in Mesozoic Era than those of the Jurassic period. Owing to high content of ferric iron in Triassic sandstones, they are reddish colored. Therefore, soils derived from these sandstones also are reddish in color.

The name of this soil class is:- a loam with some gravel similar to those of "*B*", i.e., the Kirirom area. Soil reaction is weakly acidic to neutral, which is somewhat lower acidity than that of "*B*". Nitrogen content is less than "*B*" and humus shows much lower content. Exchangeable calcium and degree of calcium saturation are both greater than "*B*". Each of available calcium, phospho-

TABLE 8 *The Comparison of Properties between*

Soils	*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
				H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Triassic sandstone soils, 24 mean	7.3	29.6	L	5.5	5.3	1.25	9.12
Jurassic sandstone soils, 11 mean	8.3	29.8	L	5.2	4.7	9.52	12.34
Mean for 35 sandstone soils	7.6	28.8	L	5.4	5.1	4.01	10.19

TABLE 9 *The Comparison of Properties between*

Soils	*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
				H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Jungle soils 13 mean	3.6	29.0	L	5.5	5.1	1.89	10.24
Open forest soils 9 mean	18.1	24.0	S . L	5.9	5.5	0.71	10.58
Mean for 24 Triassic sandstone soils	7.3	29.6	L	5.5	5.3	1.25	9.12

rus, and potassium, shows no significant difference in amount as compared with that of "*B*".

B) Jurassic Sandstone Soils (Kirirom area) (Lab. No. 35—50)

Mother rocks on this area are not red sandstones. Soil classes of Jurassic sandstone soils, together with "*A*", belong to a loam with some gravel. Soil acidity is stronger than "*A*". Nitrogen has much higher content than that of "*A*". Humus content is twice as much as "*A*". Exchange capacity is higher than "*A*". Exchangeable calcium and percentage of calcium saturation are exceedingly lower than those of "*A*". Available calcium, phosphorus, and potassium are equal in amount to those of "*A*".

C) Summary

From above results, comparing the soil properties of Jurassic sandstone soils on the Kirirom area with those of Triassic red sandstone soils on areas other than Kirirom, it can be said that the former has higher content of nitrogen and humus, and greater exchange capacity, and has a similar amount of available calcium, phosphorus, and potassium, to those of the latter, whereas the latter shows lower acidity, hence higher a saturation degree of calcium.

Favorable features of the Kirirom soils are much accumulation of humus owing to adaptable climatic conditions, and abundant pine forests. Thus high humus contents have resulted in much nitrogen and enhanced exchange capacity, whilst they have also caused such unfavorable properties as high acidity and a low saturation degree, because of noteworthy humus accumulation. The amount of available calcium, phosphorus, and potassium, shows, however, no remarkable differences in the two kinds of soil.

Different Genetic Periods of Sandstone Soils

N %	C %	C/N	*Humus* %	*C.E.C.* me.	*Exch.* CaO me.	*Degree* Ca *Sat.* %	*Available Nutrient* %		
							CaO	P_2O_5	K_2O
0.10	0.87	8.4	1.50	20.96	5.14	24.59	0.030	0.001	0.009
0.15	1.70	10.4	2.94	25.86	3.80	19.20	0.033	0.001	0.009
0.12	1.15	9.0	1.98	22.59	4.69	22.79	0.031	0.001	0.009

Two Forest Types of Triassic Sandstone Soils

N %	C %	C/N	*Humus* %	*C.E.C.* me.	*Exch.* CaO me.	*Degree* Ca *Sat.* %	*Available Nutrient* %		
							CaO	P_2O_5	K_2O
0.12	1.05	8.5	1.80	20.41	5.70	25.57	0.027	0.001	0.009
0.09	0.76	8.8	1.30	20.91	4.58	25.42	0.034	trace	0.009
0.10	0.87	8.4	1.50	20.96	5.14	24.59	0.030	0.001	0.009

2) *Jungle- and Open Forest Soils of Triassic Sandstone Origin*

Much of Triassic red sandstone areas is overlaid with either jungles or open forests. A comparison of the properties was made in Table 9 between the two kinds of soil with different forest types.

The results shown in Table 9 are explained as follows:

A) Jungle Soils (Lab. No. 1—16,29,30,34)

The name of this soil class is a loam without gravel, and texture is somewhat finer than that of "*B*", i.e., open forest soils. Soil acidity is higher than "*B*", which shows weakly acidic to neutral reaction. Nitrogen is much higher than "*B*" in spite of the poorness. Humus content is higher, but it is poor. Exchange capacity is similar to "*B*" and is in sufficient amount. Exchangeable calcium is more than "*B*". The percent of calcium saturation is in same degree as "*B*". Available calcium is much more poor. Phosphorus in the available form is higher than "*B*", but it is surprisingly poor also. Available potassium is very poor similar to "*B*".

B) Open Forest Soils (Lab. No. 17—19,22—25,28,33)

This soil class is sandy loam that is rich in gravel; texture is therefore much more coarse than that of jungle soil "*A*". The soil is weaker in acidity, as a whole, than "*A*", though it indicates weakly acidic to neutral reaction as well as "*A*". Nitrogen content is only two thirds of "*A*". Humus is in a less amount. Exchange capacity is equal to "*A*", which is adequate. Exchangeable calcium content is lower than "*A*", but it is normal. The percentage of calcium saturation is the same level as "*A*", which is slightly low. Available calcium content is higher, but poor. Phosphorus in the available status is lower, which means it is extremely deficient. Available potassium shows similar content to that of "*A*", but it also is very poor.



Fig. 24 Sandstone soil (Lab. No. 11 and 12). Profile under jungles. 20 km east along the road branched at 20 km south of Stung Treng



Fig. 23 Sandstone soil (Lab. No. 5 and 24). Border of jungle and open forest. Left side is open forest, another side is jungle. 27 km south of Stung Treng

It can be possibly said from above results that jungle soils are, in general, more fertile than open forest soils, hence the former higher content of nitrogen, humus, exchangeable calcium, and available phosphorus, despite the somewhat higher acidity.

3) *Kirirom Soils under Different Forest Types*

Sandstone soils of the Kirirom area were divisable into the following five; and compared with one another according to the forest types in which they are situated:

A) Dense forests on plain
B) Open teak forests on highland
C) Open pine forests on highland
D) Mixed forests with pine and jungle on highland
E) Jungles on highland

The soils on which these types of forest are present were compared as to their chemical properties in Table 10.

A) Dense forest on plain (Lab. No. 35)

The dense forests are found on a plain situated at the foot of the Kirirom highland.

Soil classes are "sand without gravel" and these have the coarsest texture of all. Soil acidity is significantly lower than all the other Kirirom soils. Nitrogen and humus are very poor, and both have therefore the minimum of every forest soil. Exchange capacity and exchangeable calcium are both at the minimum, but the former is sufficient, whilst the latter is poor. The degree of calcium saturation is in the intermediate range of all. Available calcium, phosphorus, and potassium contents are the last in order in the Kirirom area, and they are therefore extremely deficient.



Fig. 26 Sandstone soil (near Lab. No. 28). Open forest with puddle. North of Kratie



Fig. 25 Sandstone soil (near Lab. No. 28). Open forest. North of Kratie

TABLE 10 *The Comparison of Properties between Different Forest*

Soils		*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
					H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Dense forests on plains	1 only	0.4	12.5	S	5.8	5.3	0.42	7.17
Open teak forests	2 mean	1.1	22.3	S . L	5.8	5.5	1.27	8.76
Open pine forests	5 mean	15.9	36.7	L	5.2	4.9	11.32	30.57
Mixed forests	1 only	3.4	39.5	C . L	4.6	4.1	12.66	27.22
Jungles	2 mean	3.3	24.0	S . L	4.7	4.0	14.04	34.34
Mean for 11 Kirirom soils		8.3	29.8	L	5.2	4.7	9.52	12.34

B) Open teak forests (Lab. No. 36,37)

Soil class is "sandy loam without gravel". Soil acidity is slightly higher than that of "*A*", although it ranges from weakly acid to neutral. Nitrogen and humus content is higher than "*A*". Exchangeable calcium and exchange capacity indicate the maximum in the Kirirom area. The degree of calcium saturation belongs to the second class in this area. Available calcium content is the highest in the Kirirom area. Phosphorus in the available status is in the second highest class, in amount, but is very poor. Available potassium shows the highest in content, together with "*E*", despite its significant poorness.

C) Open pine forests (Lab. No. 38—46)

Soil class name is "loam without gravel". Soil reaction is stronger than that of "*B*", of which the acidity ranges from fairly to strongly acid. The content of total nitrogen and humus is higher than that of "*B*". Exchange capacity and exchangeable calcium are both less than "*B*". The degree of calcium saturation and the content of available calcium are so poor as to be about one half of those of "*B*". Phosphorus in the available form is surprisingly poor, and is the minimum of all, over the Cambodian soils. The amount of available potassium indicates the maximum in this area, but even so it is low.



Fig. 28 Sandstone soil (Lab. No. 45). Pine forest. Kirirom area



Fig. 27 Sandstone soil (Lab. No. 35). Dense forest on plains near Kirirom. 26 km from Kp. Speu to kp. Som

Types of Kirirom (Jurassic) Sandstone Soils

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %*		
							CaO	P_2O_5	K_2O
0.10	0.55	5.5	0.95	18.17	2.82	15.52	0.006	0.001	0.002
0.12	0.92	8.1	1.58	37.31	9.21	28.30	0.059	0.002	0.010
0.13	1.48	11.2	2.55	25.41	2.81	11.22	0.031	trace	0.011
0.14	1.81	12.6	3.11	27.38	1.62	5.92	0.014	trace	0.005
0.28	3.48	12.0	5.98	18.59	2.44	38.64	0.035	0.003	0.008
0.15	1.69	10.4	2.94	25.86	3.80	19.20	0.033	0.001	0.009

D) Mixed forests with pine and jungle (Lab. No. 47)

Soil class name is "clayey loam without gravel", of which the texture is the finest in the Kirirom area. Soil acidity is strongly acid. Total nitrogen and humus contents, and exchange capacity all belong to the second highest class. Available calcium, phosphorus, and potassium are so poor as to be below one half of the mean values for this area.

E) Jungles (Lab. No. 48—50)

Soil class name is:- "a sandy loam without gravel". The soils have strong acidity which is the strongest of all the soils of Cambodia, that is to say, their mean values for pH (H_2O) and pH (KCl) are 4.7 and 4.0 respectively. Such a greatly enhanced acidity of these soils is regarded as a result of the high accumulation of humus substances.

Total nitrogen and humus have the highest content of all the Cambodian soils. The high content of nitrogen is related to vigorous accumulation of soil organic matters under the cool climatic condition. Exchange capacity of this soil belongs, against expectation, to the lowest class, together with "*A*". Exchangeable calcium has intermediate values in the Kirirom area, but it is very low. The percentage of calcium saturation accounts for it being the highest in the Kirirom area. Available phosphorus content shows it to be of the top order in the area, although still it is very poor. Calcium and potassium in the available form are both situated in the second top class amongst the soils in every forest type, yet they are not enough.

A comparison of the soils amongst these different forest types in the Kirirom area leads to the following conclusions.

Soil acidity and nitrogen content are both raised in proportion to the higher accumulation of humus. Their levels increase in the following order, with respect to the forest type: Jungles>Mixed forests>Open pine forests > Open teak forests >Dense forests on plain. The nitrogen content of these soils is in the relative order Jungles>Open teak forests>Open pine forests>Mixed forests>Dense forests on plain.

The dense forest zone on the broad plain running from Kp. Speu to Kirirom, from which the soil sample "*A*" refered to as "dense forests on plain" was

obtained, is expected to be of great promise for the exploitation in future by the agricultural expedition of our university. But it would seem, against expectation, difficult to look on as fertile soils. The reason for this is that the content and holding capacity of plant nutrients are much lower than what would have been expected from the spot observation, with the exception of the weakness of acidity. The authors regret to say that the decided conclusion can not be drawn as to the soil of "dense forests on plain" by reason of insufficient number of samples obtained.

VII. *SOIL PROFILES*

1) General View throughout the Regions

Cambodian soils were compared with one another as to how the variation of properties between their top and subsoils, with special reference to the status of soil constituents, has been taking place, as showing in Table 11.

From the data shown in Table 11, topsoils can be generally compared with subsoils as follows:

Soil classes, gravel content, and pH values, are found to be in no significant variation between soil layers. Exchange acidity of topsoils is however lower, whereas hydrolytic acidity is rather higher than that of subsoils. The content of total nitrogen and humus, exchange capacity, exchangeable calcium, and available calcium, phosphorus, and potassium all indicate higher values than those of subsoils.

In short, it can be summarized that there are no noticeable differences of soil classes and acidity between top and subsoils, whilst the levels of nutrients are much higher in topsoils and reach an amonut as much as twice that of subsoils. These trends are likely to suggest that Cambodian soils, generally speaking, have not as yet been subjected to the pronounced downward leaching process of nutritional constituents under ordinary conditions.

2) Soil Profiles of Different Geological Origins

A comparison was made in Table 12 as to top and subsoils of the following three groups which were classified according to the geological units; basaltic, sandstone and alluvial soils.

On the basis of the data shown in Table 12, the characteristics of the profiles are described below.

TABLE 11 *The Comparison of Properties between*

Soils		*Gravel* %	*Clay* %	*Soil Classes*	pH		*Acidity*	
					H_2O	KCl	*Exchange* y_1	*Hydrolytic* y_1
Topsoils	26 mean	9.3	49.4	C.L	5.3	4.9	4.44	18.13
Subsoils	31 mean	9.4	49.3	C.L	5.3	4.9	6.47	15.54

A) Profiles of basaltic soils (Lab. No. 53—59,69,70)

Surface soils of basaltic region which has very deep soil layers comprise somewhat higher content of clay and gravel than those of subsoils. Exchange and hydrolytic acidities are much stronger than those of subsoils. The content of total nitrogen and humus is much higher. Also topsoils show higher exchange capacity and exchangeable calcium, and comprise higher content of calcium, phosphorus and potassium in the available form, compared with subsiols.

The amount of total nitrogen, humus and available calcium in surface soils is three times larger, and available phosphorus and potassium are twice as much that of subsoils. The outstanding feature of the profiles in the basaltic region is the fact that there are the most remarkable difference in soil acidity between top and subsoils compared with other regions. One of the reasons for this seems to be dependant upon the high accumulation of humus substances on surface layers.

B) Profiles of Sandstone Soils (Lab. No. 7,8,10—15,18—23,26,27,29,30,38—46,48,49)

The content of clay and gravel in surface soils is somewhat higher than that of subsoils as well as in the case of basaltic soils. Soil acidity shown in the terms pH value and exchange acidity is weaker than that of subsoils. Total nitrogen and humus are contained much more, than in those of subsoils. Exchange capacity shows no difference between the two layers; And then, exchangeable calcium, and available calcium, phosphorus, and potassium, are kept in higher content than those of subsoils.

In short, topsoils of this region have, in general, less acidity than subsoils, this is contrary to the case of basaltic regions. These sandstone topsoils have much higher nutritional content, that is to say, all the nitrogen, humus and available calcium and potassium, two times as much as that of subsoils, are contained in them. Comparing the sandstone soils of two different origins as to their profiles the result is shown in Table 13.

No difference of nutrient mobilization in profiles was found between the soils derived from sandstones of the two genetic origins. It was however found, that in the case of Jurassic sandstones only, the exchange capacity, exchangeable calcium, and available calcium, were higher in topsoils as generally seen in Cambodian soils, whereas in Triassic sandstone soils no variation of these constituents, between top and subsoils was shown.

C) Profiles of Alluvial Soils (Lab. No. 77,78,80—83,94—96, 98—102,104, 105,116,117—122,127,128)

Top and Subsoils over the Whole Country

N %	C %	C/N	*Humus* %	*C.E.C.* me.	*Exch.* CaO me.	*Degree* Ca *Sat.* %	*Available Nutrient* %		
							CaO	P_2O_5	K_2O
0.17	1.37	8.0	2.36	27.49	7.56	27.50	0.034	0.007	0.009
0.07	0.59	8.4	1.01	24.02	4.86	20.23	0.019	0.003	0.005

TABLE 12 *The Comparison of Profiles*

Soils		Gravel %	Clay %	Soil classes	pH		Acidity	
					H_2O	KCl	Exchange y_1	Hydrolytic y_1
Basaltic topsoils	4 mean	4.3	61.6	C	5.0	4.7	3.59	22.00
〃 subsoils	5 mean	2.0	59.0	C	5.4	5.1	1.52	14.73
Sandstone topsoils	13 mean	12.6	32.8	L	5.4	5.0	6.59	18.22
〃 subsoils	15 mean	9.4	30.6	L	5.2	4.9	7.44	12.88
Alluvial topsoils	9 mean	10.2	53.8	C	5.6	5.1	3.15	14.18
〃 subsoils	11 mean	16.7	58.4	C	5.3	4.8	11.25	19.00

TABEL 13 *The Comparison of Profiles between*

Soils		Gravel %	Clay %	Soil classes	pH		Acidity	
					H_2O	KCl	Exchange y_1	Hydrolytic y_1
Triassic topsoils	8 mean	11.1	30.2	L	5.6	5.3	1.60	10.92
〃 subsoils	10 mean	11.8	28.5	L	5.4	4.9	5.02	9.21
Jurassic topsoils	5 mean	15.1	36.9	L	5.0	4.5	14.57	28.90
〃 subsoils	5 mean	3.2	35.3	L	4.9	4.7	12.28	20.26

In alluvial soils the content of clay and gravel is more or less higher in subsoils, than topsoils, this is contrary to the case of basaltic and sandstone soils. Less acidity is shown by topsoils. Total nitrogen and humus contents in topsoils, are much higher than those of subsoils. Exchange capacity shows no difference between the two layers. The content of exchangeable calcium, and available calcium, phosphorus, and potassium, in topsoils is much higher than that of subsoils.

In short, the inherent fertility of alluvial soils is much higher in surface layers, than the under layers because of lower acidity, and higher food content. The amount of nitrogen, humus, exchangeable, and available calcium, held in topsoils is half as much again as that of subsoils, and phosphorus in the available status amouts up to the three-fold that of subsoils.

VIII. *AMELIORATION OF CAMBODIAN SOILS*

1) Ameliorative Management for the Whole Soil

Cambodian soils vary in their natural fertility from high to low, most of which are not regarded at present as soils having a high agricultural value. There are therefore even some soils where the fertility is so low as to limit in some degree their production.

The present yields on these soils are likely to be dominantly dependant upon the climatic condition,such as high temperatures rather than that of the soil fertility.

However, with careful management, especially the careful cropping and the judicious application of suitable fertilizers, both fertility, and productivity, can be improved to satisfactory levels, together with the combined effect of the hot climate.

between Different Origins of Soils

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Available Nutrient %* CaO	P_2O_5	K_2O
0.23	1.62	7.0	2.79	34.22	12.19	35.62	0.044	0.007	0.011
0.07	0.53	7.6	0.91	23.05	5.37	23.30	0.016	0.004	0.005
0.14	1.54	11.0	2.65	21.00	3.16	15.05	0.032	0.001	0.009
0.07	0.62	8.9	1.07	21.30	2.40	11.27	0.024	trace	0.004
0.13	0.95	7.3	1.63	27.26	7.33	26.89	0.026	0.014	0.008
0.08	0.63	7.9	1.08	27.71	5.31	19.16	0.016	0.005	0.007

Two Different Origins of Sandstone Soils

N %	C %	C/N	*Humus* %	*C.E.C.* *me.*	*Exch.* CaO *me.*	*Degree* Ca *Sat.* %	*Avaiable Nutrient %* CaO	P_2O_5	K_2O
0.11	1.04	9.5	1.79	22.98	3.19	13.88	0.029	0.001	0.007
0.06	0.49	8.2	0.84	23.49	3.14	13.37	0.026	trace	0.003
0.19	2.34	12.3	4.02	27.83	3.12	11.21	0.036	0.001	0.012
0.08	0.88	11.0	1.51	16.91	0.92	5.44	0.022	trace	0.007

TABLE 14 *Ameliorative indications to Cambodian soils*

Geology and Region	*Acidity*	N	*Humus*	*Available* Ca	P	K
	Need of liming	*Need of manuring*	*Need of org. sub.*	*Need of manuring*	*Need of manuring*	*Need of manuring*
Over the whole country		+	+ +	+	+++	+++
Alluvial soils		+ +	+++	+	+++	+++
East of the Mekong (St. Treng-Kratie)			+ +	+ +	+	+ +
East of the Tonle Sap (Kp. Cham-Siem Reap)		+ + +	+ + +	+ +	+ + +	+ + +
West of the Tonle Sap (Sisophon -Ph. Penh)		+ +	+ + +		+ + +	+ + +
South from Ph. Penh (Ph. Penh-Svay Rien-Takeo)		+ +	+ + +	+ +	+ +	+ + +
Basaltic soils	+		+	+ +	+++	+ +
East of the Mekong (Kratie-Snoul-Kp. Cham)	+ + +			+ +	+ + +	+ + +
West of the Mekong (Kp. Cham-Kp. Thom)					+	+
Rubber plantations	+ + +		+ +	+ +	+ + +	+ + +
Sandstone soils	+	+ +	+ +	+ +	+++	+++
Triassic red sandstones		+ +	+ + +	+ +	+ + +	+ + +
Jurassic sandstones (Kirirom area)	+ + +			+ +	+ + +	+ + +

+++ Essential, ++ High need, + Need.

The most outstanding weak point of Cambodian soils, considered as a whole, is an extreme deficiency of available phosphorus and potassium; and the second point is that most of the soils are poor in nitrogen, humus and exchangeable calcium.

To increase production, therefore, the heavy application of phosphatic and potash fertilizers is essential; at the same time, the addition of lime, and nitrogen, are necessary irrespective of manurial form.

2) *Management for the Soils of Different Geological Origins*

The necessity of ameliorative management, and the fertilizing requirement of the soil groups of different geological origins are conclusively summarized in Table 14.

SUMMARY AND CONCLUSIONS

The present study was carried out with soils which were kindly supplied by the agricultural expedition of our university who were delegated to Combodia in 1957. The soils used were broadly collected from all provences of the country, in which the samples included 103 surface soils, and 32 subsoils.

Physical and chemical properties, such as color, texture, soil classes, pH values, exchange and hydrolytic acidities, nitrogen, organic carbon, humus, carbon-nitrogen ratio, exchange capacity, exchangeable calcium, degree of calcium saturation, and available calcium, phosphorus, and potassium, were examined from all the soil samples.

The description of each sampling site is shown in Table 1. Analytical data for each of soils over the whole area are given in Table 2.

Cambodian soils were classified to three groups on the basis of different geological origins, that is, basaltic, alluvial and sandstone origins. These three groups of soil were compared with one another in Table 3.

Then, alluvial soils in which the following four divisions were divided by the difference of regions, are listed in Table 4, that is, eastern region from the Mekong River, eastern region from the Lake Tonle Sap, western region from the Lake Tonle Sap, and southern region from Ph. Penh. Owing to the differences of either genetic relationship, or environmental conditition, the alluvium was divided into three, i.e., marsh, recent alluvium, and old alluvium, of which the characteristics were compared in Table 5.

Basaltic soils also were divided into the two regions of the east, and the west of the Mekong River, and their distinguishable features was presented in Table 6. And further, soils of basaltic origin, being under rubber plantation, were considered in Table 7, as to their special characteristics in comparison with those of other basaltic soils.

According to the different genetic periods, the two kinds of sandstone soil in the country were recognized-Triassic red sandstone and Jurassic sandstone soils. Their chemical and physical properties are indicated in Table 8. Jungle- and open forest soils of Triassic red sandstone origin showed in Table 9 how their properties are alike and yet how they differ. At the same time, sandstone soils of Jurassic origin on the Kirirom area were compared with one another in Table 10 according to the difference of overgrowing forest types.

As to how the variation of constituents between top and subsoils has occurred, soil profiles over the whole region were observed in Table 11. And then a comparison of profiles was made in Table 12 among the three groups of soil with different genetic origins.

A similar comparison to the above was made in Table 13 between the two kinds of sandstone soil of Triassic and Jurassic origins.

It is not possible from these results to say conclusively that the Cambodian soils, as a whole, are of adequate inherent fertility: even though they are under the condition of a suitable physical nature, low acidity, and sufficient food holding capacity, their nutrient levels should be generally by no meams highly evaluated, because of the extreme deficiency of available phosphorus, and potassium, and the poorness of the nitrogen content.

Comparing the soils of the different genetic origins, there are wide variations between their properties. In physical properties, the soil class name of basaltic soils is "clay", alluvial soils "clayey loam" and sandstone soils "loam".

In chemical properties, acidity is in the increasing order of basaltic > sandstone>alluvial soils. Nutrient content shows the order—of basaltic > alluvial> sandstone soils. Nutrient holding capacity increases in the order of basaltic = alluvial > sandstone soils.

As a result of this, basaltic soils are regarded as the best soil of all, despite their more or less strong acidity. Alluvial soils are of intermediate fertility, while sandstone soils belong to the last class of all.

Basaltic soils were divided into two regions according to their localities. The soils of the region west of the Mekong River are much more fertile than the soils east of the river.

The best region among alluviums is that which lies to the east of the Mekong River, and the region of the second order is that which lies to the west of the Lake Tonle Sap, and next is the southern region from Ph. Penh, and the last in order in alluviums is given to the eastern region from the Lake Tonle Sap.

Sandstone soils were distinguished into two regions of the Triassic and Jurassic periods. The Jurassic sandstone soils which are situated on the Kirirom area have a higher content of nitrogen and humus, and a greater exchange capacity than those of the Triassic origin. While the Triassic red sanstone soils show lower acidity and a higher saturation degree of calcium than those of the Jurassic period. However, regarding the available calcium, phosphorus, and potassium, each shows no remarkable difference of amount between the two kinds of soil.

Some indications for amelioration of the different kinds of Cambodian soil were listed in Table 14.

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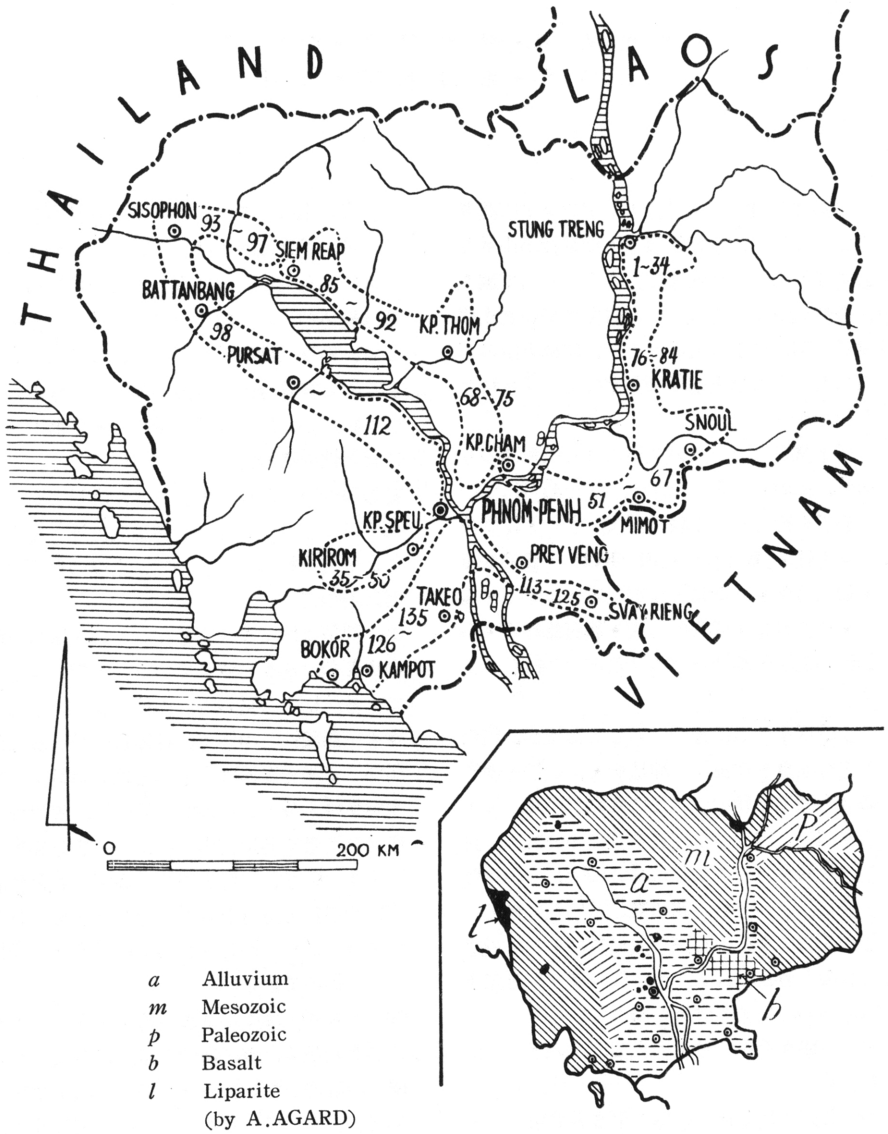
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MAPS SHOWING SAMPLING SITES
AND
GEOLOGY IN CAMBODIA



a Alluvium
m Mesozoic
p Paleozoic
b Basalt
l Liparite
(by A. AGARD)

摘　　要

カンボディア国土壌の物理的及び化学的性質

佐伯秀章・岡本昌雄・東　順三
井上博文・滝内雅宏・樽味　宏

昭和32年(1957)1月、カンボディア国農業調査団として、教授佐藤孝・助教授高山敏弘の両氏を本学より派遣し、全土に亘って調査と資料の蒐集を行った。本研究に用いた土壌試料は両氏によって採取され、農林大臣の認可のもとに本学土壌学研究室にもたらされたものである。

採集試料はカ国内の全州に亘る広範囲のもので、そのうち表土103点、心土32点について分析を行った。実験項目は，土色・粒度分布・土性・pH（水）・pH（KCl）・置換酸度・加水酸度・全窒素・有機炭素・炭素率・腐植・置換容量・置換性石灰・石灰飽和度・有効性の石灰・燐酸及びカリなどの測定である。

土壌採集地点は地図に示してあるが、国内の主な地質を網羅し、冲積層・玄武岩・砂岩の3大地質系統のすべてに亘っている（第1表参照）。国内の全地質系統について、一貫して比較を行った文献はないので、その意味に於て、また分析土壌の数の多い点に於て、この報告は今後のカ国農業の資料として役立つものと考えられる。更に深い研究をカ国土壌について進める計画を持つている。

この研究で得た結果の大要は次のようである。

(1)　カ国土壌全体の通覧：第2表参照。
粘土含量は平均約40%で、土性は礫を含む埴壌土である。酸度は弱酸性、窒素と腐植は少い。炭素率は8.5でまず適度。置換容量は高く十分。置換性石灰は普通。石灰飽和度はやや低い。有効性石灰は少く、有効性燐酸とカリは極めて少い。結局カ国の土壌は、長所として、物理的性質の良いこと、酸性の弱いこと、および養分の吸収力が高いことなどが挙げられるが、然し養分含量は一般に低く、特に有効性の燐酸とカリに極端に乏しく、また窒素が少いことなどのために、決して高く評価することはできない。勿論次に述べるように、地質系統の差によつて、土壌の良否は非常に違つている。

(2)　冲積土壌：第3表参照。この土壌はカ国中央部の盆地を形成している、米作の中心地である。粘土含量42%。土性は礫を含まぬ埴壌土。弱酸性—中性で、各地質中最も酸性は弱い。窒素と腐植は少く、各地質中最少。置換容量は十分で、各地質中の中位。置換性石灰は普通量で各地質中の中位。石灰飽和度はやや小さいが、各地質中では最高。有効性石灰は普通量であるが各地質中では最高。有効性燐酸は乏しいが各地質中では最高。有効性カリは極めて乏しい。

(3)　玄武岩土壌：第3表参照。コンポンチャムの北西から、東に向つて帯状に分布しゴム園の中心地をなし、森林が多い。粘土含量は58%。土性は礫に富む埴土。明—弱酸性で、砂岩土壌とともに、冲積土壌よりも酸性は強い。窒素は普通量で各地質中の最高。腐植は

やや乏しいが最高。置換容量は十分で最高。置換性石灰は豊富で最高。飽和度はやや小。有効性石灰・燐酸・カリ何れも乏しいが、それでも燐酸とカリは各地質中で最高である。

(4) 砂岩土壌：第3表参照。中央盆地の周辺部をなし、主に疎林・密林をなしている。粘土含量は29%。土性は礫を含む壌土で各地質のうちでは最も粗な土壌をなす。明—弱酸性で玄武岩土壌と大体同じ。窒素と腐植も乏しいが各地質中の中位。置換容量は十分で最高。置換性石灰は普通量であるが各地質中の最少。飽和度はやや小。有効性石灰は乏しく、玄武岩土壌と同程度。有効性燐酸は極めて欠乏し、前2者の地質のものの1/10以下、有効性カリも非常に乏しく、冲積土壌と同程度である。

(5) 冲積層・玄武岩・砂岩の土壌の比較

酸性は　玄武岩土壌>砂岩土壌>冲積土壌
養分量は　玄武岩土壌>冲積土壌>砂岩土壌
置換容量は　玄武岩土壌>冲積土壌>砂岩土壌

の順である。結局、玄武岩土壌は酸性はやや強いが、最良の土壌で、冲積土壌は酸性は最も弱いが第2位、砂岩土壌は酸性は中位であるが、養分に最も乏しく、置換容量も最小であるため、最下位の土壌と見なされる。

(6) 地域別の冲積土壌：第4表参照。4地域に分けて比較すると、冲積土壌中の最良の土壌は、プノンペンより上流のメコン河東側の河沿いの冲積地である。面積は余り広くない。これは置換容量はやや低いが、酸性は最も弱く、また養分は冲積地のうちで最も多い。第2位は米作の中心地をなす湖西の冲積地で、酸性は比較的強いが、置換容量は最大で、養分含量は冲積地中の2位である。第3位はプノンペン以南、国境までの冲積地である。最下位は湖東の冲積地で、養分含量も最も乏しく、置換容量も最小である。

(7) 環境別の冲積土壌：第5表参照。

冲積地を低湿地・新期冲積地（毎年河水または雨水の浸水する地域）・古期積冲地（氾濫をもはや受けないやや小高い地域）に分けて比較すると、最良の冲積土は新期冲積地の土壌で、酸性は最も弱く、養分と置換容量は前者に次ぐ。最下位は古期冲積地で、酸性が冲積地のうちで最も強く、養分と置換容量は最も低い。この土壌は相当に溶脱を受けている。

(8) 地域別の玄武岩土壌：第6表参照。

これをメコン河東側地域と西側地域に分けて比較すると，その性質に甚だしい差が認められる。すなわち、西側地域のものが優良で、東側地域に比べて酸度は遙かに低く、各養分も置換容量も極めて高い。メコン河の西側地域の玄武岩土壌はカ国の最良の土壌をなしている。

(9) ゴム園土壌：第7表参照。大部分のゴム園は玄武岩土壌に集中し、しかもその多くは河東地域であるが、河西地域すなわちコンポンチャムの北西にもある。これらのゴム園の土壌は強—弱酸性で玄武岩の平均よりも強く、窒素と腐植は平均よりも低い。置換容量・置換性石灰・飽和度などは平均と大体同じ。有効性石灰やカリも平均と同じであるが、有効性燐酸は極めて乏しく、平均の1/4にすぎない。これによるとゴム園土壌は世評ほどには肥沃でなく、養分含量は玄武岩土壌の平均値よりやや低く、ことに酸性が強いことと、有効性燐酸の欠乏が目立つ。また耕作に伴う腐植の消耗や地力減退の傾向がみられる。今後の管理に注意が必要である。

(10) 生成年代別の砂岩土壌：第8表参照。

カ国の砂岩には中生代三畳紀の赤色砂岩と、ジュラ紀の砂岩とがあつて、前者は冲積盆地の周辺に広く分布し、後者はキリロム高地附近に局限されている。いずれも疎林やジャングル地帯をなし、農業的にはまだ殆んど利用されていない。

三畳系の赤色砂岩壌土と、ジュラ系の砂岩土壌とを比較すると、三畳系のものは、土性は礫を含む壌土で、ジュラ系のものと同じである。酸度は弱酸性—中性でジュラ系よりやや酸性は弱い。窒素はジュラ系より少く、腐植はジュラ系より非常に少い。置換容量はジュラ系と同程度であるが、カ国中では最小である。置換性石灰や飽和度はジュラ系より高い。有効性石灰・燐酸・カリはいずれもジュラ系と同程度であるが、欠乏している。

他方、キリロム地方のジユラ系砂岩土壌の特徴は、気候条件と、松林の多いことのために腐植の集積が多いことであつて、そのために窒素や置換容量は三畳系よりも高いが、反面、酸性が強く、飽和度が低く、置換性石灰に乏しい欠点がある。有効性養分の含量は両者に差は見られない。

(11) 林型別の三畳系砂岩土壌：第９表参照。三畳系赤色砂岩土壌を、疎林とジヤングルの２つの林型に分けて比較すると次のようになる。

ジヤングル土壌は、土性は礫を含まぬ壌土で、疎林土壌の礫に富む砂壌土に比べて多少密である。酸度は弱酸性―中性で疎林土壌よりもやや酸性が強い。窒素・腐植は疎林土壌よりも遙かに多い。置換容量・石灰飽和度は疎林土壌と同程度。有効性石灰は疎林土壌よりも少いが、有効性燐酸は疎林土壌よりも多い。しかし絶対量は極めて欠乏している。有効性カリは疎林土壌と同程度であるか、やはり絶対量は極めて乏しい。

結局、ジヤングル土壌は疎林土壌よりも、酸性はやや強く、有効性石灰にも乏しいが、窒素・腐植・有効性燐酸の含量が高く、全般的にみるとジヤングル土壌の方がすぐれている。

(12) 林型別のジユラ系（キリロム地方）砂岩土壌：第10表参照。キリロム地方を、麓の平地の密林と、高地にあるチークの疎林、松の疎林、松とジヤングルの混淆林、およびジヤングルの５つに分けて、それらの土壌を比較すると、酸度・窒素・腐植は、ジヤングル＞混淆林＞松疎林＞チーク疎林＞平地密林の順序で、他の養分の含量はジヤングル＞チーク疎林＞松疎林＞混淆林＞平地密林となる。

コンポンスプーとコンポンソムの間にある平地の密林地帯は、調査団によつて今後の開発に有望であろうと期待されたが、土壌の性質は良好ではなく、キリロム高地の土壌に遙かに劣るようである。しかしこの平地密林地帯の採集土壌の点数が足りないから、決定的な結論は下し得ない。

(13) 土層断面の通覧：第11表参照。カ国の各土壌を表土と心土に分けてその性質を比較すると、全般的にみて、表層土は下層土に比べて次のようである。

土性や礫の含量には、表土、心土に差はなく、また pH にも差はない。置換酸性は表土の方が弱いが、加水酸性は逆に表土の方が強い。窒素・腐植は表土に多いが、炭素率はやや表土が低い。置換容量・置換性石灰・有効性石灰・燐酸・カリはいずれも表土が高い。結局、土性と酸度は表土と心土の間に殆んど差はないが、養分はみな表土に多く、心土の約２倍に達している。

(14) 地質別の土層断面：第12表参照。玄武岩・砂岩・冲積層の３つの地質系統別の土壌の表土と心土を比較すると次のようである。

玄武岩土壌の表土は心土に比べて、粘土分と礫はやや多く、酸性は強い。窒素・腐植は多く、心土の３倍に達し、置換容量・置換性石灰も多く、有効性石灰・燐酸・カリは心土の２倍程度に多い。玄武岩土壌の心土の酸性は、各地質系統の心土のうちで最も弱いにもかかわらず、玄武岩の表土は最も酸性が強いということは注目すべき事実である。

砂岩土壌の表土は心土に比べて、玄武岩と同様、粘土分と礫はやや多い。酸性は概して表土の方が弱く、窒素・腐植は心土の２倍に達し、置換性石灰・有効性石灰・燐酸・カリも表土が遙かに多い。また砂岩を三畳系の赤色砂岩とキリロム地方のジユラ系砂岩とに分けて、表土と心土を比較すると第13表に示すように、表土と心土の間の性質の相異は、どの砂岩土壌も殆んど同じ傾向にある。

冲積土壌の表土を心土と比較すると、他の地質系統の土壌と反対に、表土の方が粘土分と礫が少い。酸性は砂岩土壌と同様に表土の方が弱い。養分も表土が高く、窒素・腐植・置換性および有効性石灰は心土の 1.5 倍に達し、有効性燐酸は心土の３倍で、有効性カリはやや多い。

(15) 管理対策：第14表参照。全土壌を通じて一般的にいえば、燐酸とカリの施用は絶対に必要であり、有機物の増成と窒素・石灰の導入も考慮すべきである。

更に各地質系統別の土壌や、地域別の土壌につき、施肥の必要度を表示した。