Soil of the Sambor, Cambodia

Tatsuhiko SUZUKI and Kanji KAWAI

カンボジア国サンボールの土壌

鈴木達彦・河井完示

農業技術研究所報告 B 第22号 別刷
昭和46年1月

...d from THE BULLETIN OF THE NATIONAL
...TE OF AGRICULTURAL SCIENCES (Japan)
...eries B, No. 22 (January, 1971)

Soil of the Sambor, Cambodia

Tatsuhiko SUZUKI and Kanji KAWAI

Contents

I. Introduction

1) Location

The Sambor Area is in the middle east of Cambodia, being along the Mekong River, situated between the Laos frontier and Phnom Penh, capital of Cambodia. The Sambor is one part of Kratie Province, about 150 km northeast of Phnom Penh and extends from north latitude 12°12′ to 12°37′ and east longitude 105°50′ to 106°15′. The total extent of the Sambor area is approximately 69,000 ha, distributing on both banks of the Mekong River around Kratie. Kratie, the main city of the Province as well as a key town of the Sambor area, is an important place from political, economical and strategical points of view. It is located as a relay city to Stung Treng, the northern border town to Laos.

The development of the Mekong and its valley region for future economical and industrial progress has been desired for a long period. The reconnaissance investigation for water resources in the Lower Mekong River Basin was started in 1951. Soil survey was carried out during the dry season in 1965 to 1966, as one of agricultural development plannings in the Sambor area, cooperating with hydrological, hydroelectrical, navigational and general agricultural investigations. This is one of the multipurpose development projects of the Mekong valley region, that is, flood control,

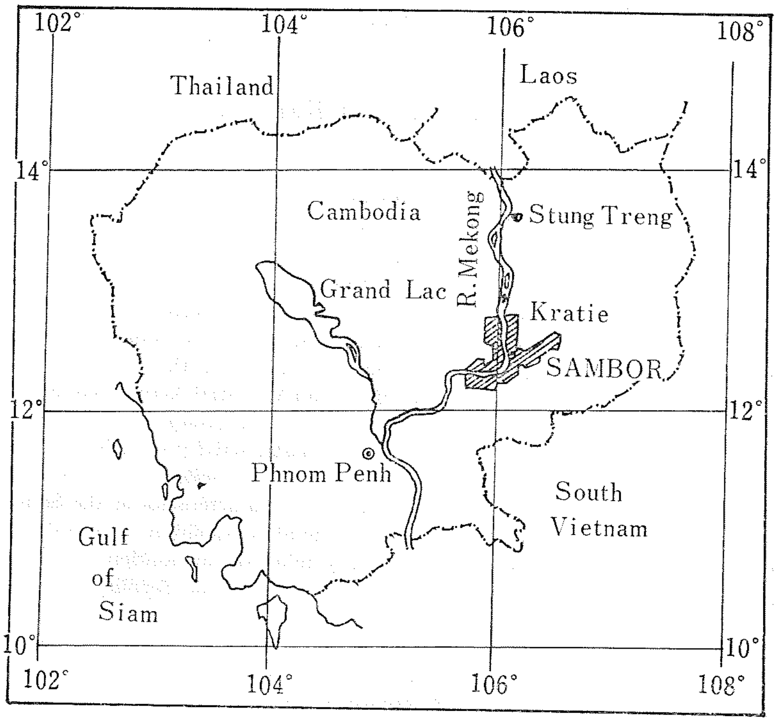


Fig. 1. Location of Sambor area, Cambodia

hydropower generation and its utilization, effective utilization of irrigation water for agricultural development, and improvement of navigation systems are expected to be undertaken.

2) **Climate**

The climate of Cambodia, a typical monsoon type, is characterized by showers, much rainfall in the summer, and dry high temperature in the winter, The daily temperature fluctuation is higher than amplitude of average monthly temperature. The season can be divided into two seasons, the rainy season from May to October and the dry season from November to April. During the summer, the warm and humid south-west monsoon comes from the south, continuing from mid-April to October. On the contrary, continental high pressure covers all downstream areas of the Mekong as well as the whole country, which have no rainfall during the period from November to April. It is called the dry season.

During the monsoon period, shower type precipitation is most common, and regional precipitation and hourly rainfall vary remarkably. The Mekong downstream areas are also in the Pacific typhoon circle, but most typhoons are weakened by the Indochina Peninsula, and reach the Mekong downstream areas with less strength. The typhoon in the latter period of the rainy season brings much precipitation and causes great floods. Irrigation water in all provinces as well as in the Mekong valley regions is supplied by both rainfall and river water. As the result, the starting time of the rainy season, plus the total amount of rainfall gives great influence to the agricultural potential.

Table 1. Climatic condition in Phnom Penh[8] (1931—1960)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Remarks
Average temperature	℃	26.1	27.5	28.9	29.4	28.8	28.1	27.6	27.7	27.3	27.2	26.7	25.4	27.6	
		25.3	27.3	28.9	29.7	28.1	27.5	26.8	27.0	26.5	26.4	25.7	24.7	27.0	Kratie[16]
Maximum temperature	℃	30.7	32.1	33.7	34.6	33.5	32.5	31.7	31.7	30.9	30.4	30.1	29.9	31.8	
Minimum temperature	℃	21.3	22.0	23.2	24.3	24.3	24.3	24.1	24.7	24.6	24.4	23.3	21.7	23.5	
Rainfall	mm	9	8	28	73	146	129	129	147	231	250	134	36	1320	
		21	8	17	113	236	236	304	305	273	148	106	13	1780	Kratie (1937–44)
Average evaporation (day)	mm	3.6	4.2	4.9	4.3	3.2	3.5	3.0	2.6	2.0	2.0	2.2	2.9	3.2	
Average humidity (month)	%	71	69	60	73	80	80	81	82	84	82	78	74	77	

Note : Phnom Penh : North latitude 11°33′, east longitude 104°51′, elevation 12 m.
Kratie : North latitude 12°30′, east longitude 106°01′, elevation 24 m.

The monthly average temperature in Phnom Penh is lowest 25.4 °C in December, and highest 29.4°C in April. These are not much different from those in Kratie, the highest monthly temperature in Kratie is higher than in Phnom Penh, and the lowest monthly temperature in Kratie is lower than in Phnom Penh. The annual average temperature in Phnom Penh is 27.6°C and 27.0°C in Kratie.

The annual rainfall in Kratie is 1,780 mm and 1,320 mm in Phnom Penh. The highest rainfall month in Kratie is during July or August, but in Phnom Penh it is highest during October. The lowest rainfall month in those places is February. The annual precipitation in Kratie is higher than in Phnom Penh, and the annual average temperature in Kratie is slightly lower, but monthly variation is higher than in Phnom Penh. But in general, the monthly fluctuation in these places is relatively small or somewhat negligible. Such tendency can be seen at other regions in Cambodia, for instance, at Stung Treng the monthly temperature extends from 29.0°C of high average temperature in April to 23.9°C of the low average temperature in December. At Kompong Cham, it ranges from 29.1°C in April to 25.1°C in December. Daily fluctuation of temperature is rather large, somewhat over 10°C during the dry season. Relative humidity is high throughout the year, being 60 to 90 per cent, the highest being in September, the lowest in March. During the rainy season the humidity approaches 100 per cent on the Mekong Delta. Evaporation is greatest during April, and lowest during August. Though evapotranspiration of the Area was not observed, the water requirement for paddy fields obtained at the Cambodia-Japan Experimental Farm in Battambang showed that the mean evapotranspiration of paddy field was 6.7 mm/day from December, 1965 to April, 1966.

The water level of the Mekohg River fluctuates during the year. It is recorded that 18 m above sea level during the rainy season at the highest and 3 m during the dry season at the lowest were observed. The rising of water level of the Mekong River causes flood in a wide range from the Mekong valley region to its tributaries area. Of 69,000 ha of the Area, about 38,000 ha is inundated severely, but the inundation condition is affected by the location, inundation period and water depth which depends upon the topography. The average inundation period of the Mekong valley region starts from July or early August ends in October. The inundation period lasts 60 days in the shortest, 105 days in the longest, and the average is about 90 consecutive days. The inundation depth was recorded ranging from 1.5 to 4.3 m, generally 3.0 to 3.5 m around the Area. Making use of the natural condition, colmatage technique which dresses sediments from flooding water to the inundation area, has been practiced habitually for long time.

As the average chemical composition of water of the Mekong River is shown in Table 2, the content of Ca, Mg is higher than average Japanese river water. The

Table 2. Quality of water of the Mekong River[12] (annual average : mg/L)

	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SiO_2	Residue on evap.	Float. matter	Turbi-dity	pH	Hardness
Nongkai	31.1	5.7	7.7	1.6	115.6	14.7	6.2	15.0	139.2	174.1	134.5	6.9	101.0
Mukdaharn	26.8	4.9	7.5	1.4	100.3	12.2	6.6	13.8	124.3	99.9	57.1	6.9	87.3
Japanese average[13]	8.8	1.9	6.7	1.2	31.0	10.6	5.8	19.0	74.8	29.2	—	—	—

Note : Nongkai : Nongkai province, Thailand.
Mukdaharn : Mukdaharn village, Mukdaharn District, Nakorn Province, Thailand.

total amount of inorganic elements of the dry season is about 2 times as much as that of the rainy season; especially the concentration of Ca, Mg, Na and SO_4 during the dry season is remarkably high. Kobayashi[12] explained that the annual total amount of inorganic matters lost by water from the Mekong amounts to 20,500,000 tons, and the annual total amount lost by the Tone River which is the largest in Japan, is 1,250,000 tons, and that the unit amout of inorganic elements given to its river valley region is 71 t/Km^2 for the Mekong region, and 80 t/Km^2 for the Tone region respectively. He also stressed that the losing degree of inorganic elements for the Mekong is not more than that for the Tone. The water unit supply for the Mekong is greater than that for the Tone, and the inundation does not occur for the Tone region. The Mekong provides muddy water containing a considerable amout of inorganic elements.

3) **Geology**

The present central plain of Cambodia was under sea water not until the beginning of the Quaternary period, the central plain was formed by alluvial deposits during the Quaternary period, then the present mountain ranges and plateau regions facing to the Gulf of Thailand and Pacifiic Ocean was formed. According to the geological map compiled and printed by l'Institut Géographique National, Paris in 1936, the parent rock of the mountain ranges extending to northeastern part of Cambodia, which is connecting with South-Vietnam is composed mainly of Indosinias and Indosinias moyennes, Mesozoic sedimetary rock, and partly of igneous rocks such as basalt, granite and porphyrite. In the same way, in the southwestern region Indosinias superieurs, partly igneous rocks such as dacite, granite and Paleozoic such as Devonien schist predominate.

In between the moutaineous and hilly area, central plain lowland which includes Grand Lac, its surrounding area and alluvial plain were formed. It is derived from alluvium and old alluvium that mainly occurs not deep from the surface on the transitional area to the hill lands. The parent materials of the Sambor area are mainly composed of alluvium, old alluvium and basaltic distributed on the hilly land of the east part of the Area. On the surrounding areas of the hilly regions, alluvium overlies Tertiary bedrocks such as sandstone, silt stone, and shale.

4) **Topography**

The land forms of this area were classified by M. Shiki into the following categories; hill lands and their piedmont, and delta surface area. The former is slope of hill lands, valley flat plain and piedmont gentle slope. The latter consists of ridge of natural levee, back slope of natural levee, deposited landforms by small streams in back marsh, back marshy lowlands, and tarn and shallow streams in back marshy lowands.

The slope of the hilly land is mostly located in the hilly regions, valley flat plain in hill lands is developed in the dissected slightly concaved area, and the piedmont gentle slope is developed in between the hilly lands and the alluvial lowlands.

The natural levee faces are divided into the ridge which is a higher part as ridge-form, and back slope which is gently inclined from ridge line of natural levee to its back marsh. The deposited land forms by small streams in the back marsh is a secondary natural levee or delta deposit formed by small streams.

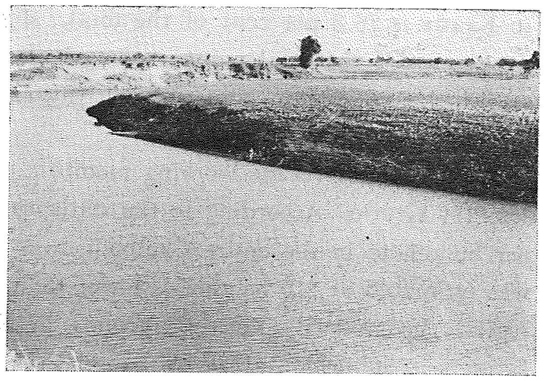


Fig. 2. The Prek Te River and its natural levee, at a place close to a confluence to the Mekong.

5) **Agriculture**

The total land area of Cambodia amouts to 181,111 Km^2 according to Bulletin de la Statistique et des Etudes Agricoles (1958). The total possible arable land in Cambodia[9] amounts to 26.2 per cent that is equal to 4,739,000 ha, of which about 2,938,000 ha is cultivated for agriculture at present. Most areas of cultivated lands are utilized for paddy. As for Kratie Province[16], the total area is 11,151 Km^2 that is corresponding to about 6 per cent of the country, and the percentage for forest land is remarkably high, it amounts to 94 per cent. At present, the acreage of 28,800 ha corresponding to 3 per cent is cultivated for agriculture.

The local administrative system of Cambodia consists of Province (State), Srok

Table 3. Land utilization (1958)

	Forest	Cultivated land					Uncultivated	Total
		Total	Paddy field	Common crops	Orchard and rubber	Others		
Cambodia	13, 372, 486	2, 938, 131	2, 492, 736	230, 187	40, 512	174, 696	1, 800, 942	18, 111, 559
(%)	73. 8	16. 2					10. 0	100
Kratie	1, 046, 381	28, 806	21, 216			7, 590	40, 000	1, 115, 187
(%)	93. 8	2. 6					3. 6	100

Cited from *Paddy in Cambodia* by S. HATTA[9], *Rice Cultivation in Southeast Asian Countries, Special ed.*, *Proc. Crop Soi. Scc. Japan (1968)* (Originally from *Revision of Agricultural Basic Statiitics in Cambodia* by T. TAKAHASHI, *Asian Economy*, **6**. *1965*)
Cited from *Sambor Project Report, IV. Irrigation and Agriculture, Overseas Technical Cooperation Agency*[16], *1969* (Originally from *la Superficies de Riziers* compiled by the Agriculture Office of the Kratie Province, 1962)

(County), Khum (Town) and Phum (Village). Province governor is appointed by the Government, and Srok chief is appointed by Governor. Chief of Khum and Phum is elected by the inhabitants, and supervises mainly taxation, census, registration, and community security.

The population of Kratie Province was 126, 231 according to the 1962 census. The population density was 11. 4 presons/Km^2 being equivalent to about one thrid of that of the entire country. The total number of agricultural household of Cambodia is 835, 900, corresponding to 85 per cent of the total household. The agricultural household in Kratie is 76. 5 per cent of the total, slightly lower percentage than the national average. Of the total number of agricultural household in Kratie, only 58 per cent of farmers are engaging in rice cultivation, which is somewhet lower in comparison with that of the entire country.

The national average working members per household are 2. 4 persons and 2. 7 persons for Kratie. According to the statistical data in 1962[16], the average cultivated land per household in the entire Cambodia was 2. 93 ha, the farm size for Kratie Province was estimated at 2. 0 ha that is lower than the national average. Being an urban region the majority of the farmers in Kratie are relatively small in scale, the farmers in suburban areas as Saop, Prek Prasap, and Prek Chamlak regions are engaging in larger scale farming. About 40 per cent of farmers own more than 3 ha of arable land.

Most Provinces have an agricultural experimental station, and also seed multiplication farms that are propagating superior varieties for farmers. A Province has a sectional agricultural office, sécteur agricole, under the superviser of the Ministry of Agriculture. There are eleven officers in Kratie Regional Office, of Agriculture. Also the Cambodian Government is taking great emphasis on training and general education. It is noted that 19. 2 per cent of the national budget in 1966 was appropriated for education.

Principal agricultural products are rice, maize, mung bean, tobacoo, and peanuts. Among these, the production of rice and maize is greatest. The following table shows the average production for main crops of Kratie Province.

The paddy rice in Cambodia is mainly rainy seasonal rice, covering 90 per cent of the total rice production. The bulk of the rice is provided for main foodstuff, with some for export, industry, and livestock foods. Export amounted to about 600 to 700 thousand tons in 1963 to 64. According to agricultural statistical data[9], acreage of

Table 4. Total yield of rice, planted area, unit yield and quantity of exported rice

Year	Area 1,000ha	Unit yield tons/ha	Production 1,000 tons	Export of rice 1,000 tons	Population 1,000
1950	1,657	0.930	1,576	187	4,117
1960	2,150	1.056	2,335	609	5,434
1961	2,182	1.060	2,383	444	5,585
1962	2,206	0.890	2,039	279	5,740
1963	2,250	1.128	2,622	697	5,895
1964	2,296	1.165	2,760	775	6,054

Cited from *Paddy in Cambodia* by S Hatta[9], *Rice Cultivation in Southeast Asian Countries, Proc. Crop. Sci. Soc. Japan, Special ed.*, *1968.* (Originally from *Revision cf Agricultural Basic Statistics in Cambodia by* T. Takahashi, *Asian Economy,* **6**, *1965.*)

paddy field, total yield as well as unit yield are increasing year after year as shown in Table 4. In 1964, it is recorded that total rice production of 2.76 million tons, 2.3 million ha of paddy field planted, and 1.165 tons/ha of unit yield. The latest unofficial data in 1968 says that paddy production may attain 3.5 million tons. Also the production of maize increased 10 per cent, and rubber increased 4 per cent from

Table 5. Average yield of rice (1961—1963)

Country	Average yield (tons/ha)		
	1961	1962	1963
Cambodia	1.06	0.89	1.13
Thailand	1.44	1.50	1.59
Burma	1.57	1.65	1.56
Fed. Malaya	2.42	2.56	2.29
Philippines	1.24	1.25	1.22
India	1.52	1.37	1.54
Pakistan	1.66	1.51	1.72
Taiwan	3.21	3.31	3.50
Japan	5.04	5.28	5.24
U.S.A	3.82	4.18	4.44
Brazil	1.66	1.54	1.77
Spain	6.36	6.23	6.23
Italy	5.68	5.50	5.12

Cited from *Lowland Rice Soils in Thailand* by Kawaguchi & Kyuma[10] (1969), (originally from *Agricultural Statistics of Thailand, p. 49, 1964*)
Average yield in Cambodia is cited from Table 4.

the previous year.

As generally known, it is obvious that the difference in yield among rice-growing countries is great. Those of Southeast Asian Countries including India and Burma are lower than those of Japan and Southern Europe. When compared to the average yield of Southeast Asian Countries[19], those of Thailand Burma, India and Pakistan range from 1.4 to 1.7 tons/ha, and those of Malaya and Taiwan are 2.3 to 3.5 tons/ha. It can be said that average yield of Cambodia is lowest in the world from the agricultural statistical point of view. There is a high potentiality for rice increase in Cambodia.

In Kratie Province, Sécteur Agricole de Kratié showed that it is not enough to be self-sustaining in the province. It has to be purchased from other provinces. The consumption for foodstuff is 31,000 tons, and 2,000 tons for seed. The total consumption of 35,000 tons exceeds the total production of 25,000 tons in Kratie.

Table 6. Unit yielld of rice and maize in Sambor (t/ha)

	Rainy season				Dry season			
	1963	1964	1965	Average	1963	1964	1965	Average
Rice	1.10	1.07	1.07	1.07	1.14	1.00	1.00	1.04
Maize	0.92	1.10	2.00	1.34	1.10	1.00	1.35	1.15

Cited from *Sambor Project Report, IV. Irrigation and Agriculture*[16] *(1969)*

Table 7. Yield of main crops in Kratie (ton)

Name of Srok	Rainy season			Dry season					
	Paddy	Maize	Sesame	Paddy	Corn	Mung bean	Peanut	Sesame	Tobacco
Srok Kratie	6,076	2,373	28	150	247	960	89	19	231
Srok Chhlong	3,507	4,243	33	640	2,404	19	7	15	369
Srok Sambor	4,423	—	2	—	2	28	3	1	1
Srok Prek Prasap	4,800	2,600	150	437	1,073	300	47	149	471
Srok Snoul	3,538	2	—	—	—	—	—	—	—
Total	22,347	9,218	213	1,227	3,726	1,307	146	183	1,072

Cited from *Sambor Project Report, IV. Irrigation and Agriculture*[16] *(1969)*.

Maize is one of the important export items of Cambodia with rice and rubber. In Kratie, special attention has been given for the training of maize farming technique. Cultivating areas for tobacco are expanding also. Leaves of superior quality are increasing in production.

Main livestock such as cattle and buffalo are employed for plowing, harrowing, and transporting. Swine and poultries are for meat and eggs. The number of main livestock in Cambodia are increasing year after year as shown in Table 8. In 1964 the number of cattle amounted to 1.53 million. Buffalo and swine are 580 and 930 thousand respectively. The number of buffalo in Kratie increased by 23 per cent within 5 years, and of swine by 11.3 per cent.

Table 8. Number of main livestock in Cambodia

Year	Cattle	Buffalo	Swine
1960	1,247,067	445,623	616,147
1961	1,278,084	447,421	671,334
1962	1,321,964	470,588	688,908
1963	1,403,243	511,917	848,919
1964	1,532,607	577,227	932,827

Cited from *Paddy in Cambodia* by S. HATTA[9], *Rice Cultivation in Southeast Asian Countries, Proc. Crop Sci. Soc. Japan, Special ed.*, *(1968)* (originally from *Annuaire Statistique du Cambodge 1963/64.*)

In general, animal power implements with plow, harrow, and cart are used for agricultural cultivation. Manually operated implements such as hoes, sickles, and mortars are used also. Chemical fertilizer as well as agricultural chemicals for paddy fields on the basis of the entire country, have not been used much. Agricultural statistics showed that only 30 per cent of farmers use fertilizer for paddy as shown in

Table 9. Number of household using fertilizer for paddy field

	Number of household investigated	Number of household	
		Using fertilizer	No using fertilizer
Cambodia	3,683	1,077 (29.2%)	2,606 (70.8%)
Kratie	24		24 (100%)

Cited form *Sambor Project Report, IV Irrigation and Agriculture*[16] *(1969)*

Table 9. In Kratie farmers have not used fertilizer for paddy field, but poultry excrements and manure are utilized for tobacco seedling on the right bank of the Prek Te. A few farmers at Kaoh Trung are applying bean-cake and urea or ammonium sulphate for upland crops on irrigated lands.

The Government of Cambodia planned the second five-year production increase of rice in 1967. In the course of the program it is scheduled to produce 10,860 tons of ammonium and 21,720 tons of superphosphate, and to extend the acreage of fertilizing paddy field to the 10 per cent of total cultivated land.

II Classification of Soils

The parent material of the Sambor Area is mainly composed of alluvium, old alluvium, Tertiary sediments such as sandstone and shale, and igneous rock as basalt. Most of the soils of the Area are of fine texture, attributable to base-enriched deposits from the Mekong River and its tributaries. The soils on natural levees and on some parts directly influenced by inundation of the Mekong, are usually of medium to coarse textured. The lower the land to back marsh, the finer the soil texture. As the result, drainage conditions of the lowland areas are poor to very poor. Swamp or marshy lands are found in some parts even during the dry season.

According to the soil map, surveyed and drafted by CHARLES D. CROCKER in 1963, the soils of the Sambor area are classified as alluvial soils, brown alluvial soils, grey hydromorphics, red-yellow podzolic soils, plinthite podzols, and acid lithosols. Alluvial soils are on alluvial plain, widely distributed, and brown alluvial soils are on alluvial plain close to the natural levee, derived from recent alluvial origin. Grey hydromorphics are soils that are on colluvial alluvial deposits from acidic sedimentary rock sources, and that correspond to the soils of the Stung Preah and, Roha series of low-humic gley soils. The parent material of plinthite podzols is old, severely weathered sandstone colluvium. The ground water level is above 15 cm in the rainy season, and below observation depth in the dry season.

The alluvial soils are derived from young sediments deposited from the Mekong River and its tributaries. They are too young to develop marked profile. The variation in texture, and composition are related to micro or macro relief topography, and to source and kind of transported materials. Medium or comparatively coarser finer materials were found on natural levee, and on colmataged area, on the other hand, finer material were found on back marsh, swamp, and basin. Also occurring are the sorting sedimentations, alternate sedimentation of fine and coarse materials on some alluvial plains.

Most of alluvial soils are poorly drained, and of dominantly grayish color with distinct mottlings in the profiles, more marked in the upper horizons. They are characterized by the presence of weak or very weakly developed A horizon and no textural B horizon.

Lithosols are shallow or very shallow over rock and stony soils. Enough organic material has not accumuted to form a dark-colored A horizon, and this overlies C horizon or hard rock. Differences among soils in this group are mainly in texture, color, soil depth, stoniness, and weathering degree of rock or kind of rock, but there are probably also difference in mineralogy.

Low-humic gley soils are characterized by graying with distinct mottlings throughout the profile and moderately or weakly developed textural B horizon. Some soils under rice cultivation have iron and manganese accumulated layer, and with some cutans on the faces of ped.

Vertisols mapped in the Area are soils of the Prek Chamlak, and Sre Prang series. These soils are locally distributed on terraces, hill lands in Srok Prek Prasap, and on the border area in a belt transitional to alluvial plains. They formed in material from basaltic igneous rock. The vertisols are dark gray, are fine blocky in the upper part of A horizon, and are fine textured throughout. These soils develop wide cracks on drying and have some slickenside in the lower part of the A horizon. The surface horizon is a thick very dark gray in color but relatively poor in organic matter. The normal horizon sequence is Al-AC-C. Vertisols are heavy textureed, the clay content amounts to more than 40 to 80 per cent. The clays are composed mainly of montmori llonite, so that the soils are very plastic and sticky when wet. Faint or distinct mottlings generally occur in the upper part of the profile because of low permeability as well as yearly inundation and poor drainage. In the Area the intergrades to low-humic gley soils are developed on basaltic parent material over Tertiary or Mesozoic deposits.

Red-yellow podzolic soils are distirbuted on the hill lands, of which red member soils are on the higher hill land, on the contrary the yellow member soils are found on the lower hill lands transitional to alluvial plains. The red-yellow podzolic soils in this Area are mainly in part of the sub-order of Alfisols of the 7th Approximation. The soils are of coarse texture as loamy sand or sandy loam. The A horizon is distinctly differentiated into a slightly dark color A1 and a somewhat pale-colored A2. Some profiles included in this great group, have no A2 horizon. And some distributed on the boundary area between alluvial plain and hilly lands, are characterized by similar profile development as those of gray podzolic soils proposed by DUDAL and MOORMANN[5] (1960, 1961). They explained that gray podzolic soils are called terres grises or gray soils, have been referred to as ground water laterite, and are comparable to certain podzolic lateritic soils in Australia. In profiles evolved from medium textured parent materials, the Bt horizon is more pronounced, reaching to a depth of 1 m to 2 m below the surface. In many profiles, a somewhat compacted layer, not attaining the status of a hard pan, occurs just below the surface. The soils are without appreciable quantities of weatherable minerals, low pH, base saturation varies with climate, averages are low saturation, and low cation exchange capacity often less than 10 me/100 g clay. Soils recognized in this Area do not fall in gray podzolic, because of gray brown to brown in color, moderately to weakly developed Bt horizon, CEC higher than 10 me/100 g clay and pH higher than 4.5.

The alluvial soils occupy 10,900 ha corresponding to 16 per cent of the total area, the red-yellow podzolic soils take 16,600 ha corresponding to 24 per cent, and the low-humic gley soils 37,900 ha, that is 53 per cent of it.

Table 10. Relationship between soil series and great soil groups

Great soil group	Soil series	Parent material	Soil texture	Drainage class	Profile developement	Acreage (ha)
Alluvial soils	Chong Kaoh	Alluvium	S	Good	None to weak	400
	Pongro	Alluvium	SiL	Good	None to weak	2,500
	Bos Leav	Alluvium	SiCL, LiC	Good	Weak	5,300
	Moreum	Alluvium	HC	Very poor	Weak	1,000
Lithosols	Pou	Basaltic/Tertiary		Good	None	300
Vertisols	Prek Chamlak	Basaltic	HC	Moderately good	Weak	900
	Sre Prang	Basaltic/Tertiary	HC	Moderately good	Weak	1,100
Low-humic gley soils	Stung Preah	Alluvium	SL	Good	Strong	300
	Kampi	Alluvium/Tertiary	CL	Moderately good	Medium	2,500
	Roha	Alluvium	LiC	Good	Medium	4,600
	Sambok	Alluvium	HC	Moderately good	Medium	24,000
	Russei Char	Alluvium	HC	Poor	Medium	6,500
Red-yellow Podzolic soils	Krakor	Old alluvium	LS	Good	Medium	6,300
	Keng	Old alluvium	LS	Good	Medium	1,500
	Tuol	Old alluvium /Tertiary	LS/CL	Moderately good	Medium to strong	8,800

The soils were subdivided into soil series on the basis mainly of soil texture, drainage condition, and effective depth. The major soil groups recongnized in this area and the soil series subdivided as mapping unit are shown in Table 10 with indicating parent material, drainage class, soil texture, and acreage for each soil series.

Soils in the Sambor area are classified and correlated to the 7th Approximation [23)24)] as follows:

Table 11. Classification of soils according to the 7th Approximation

Order	Sub-order	Great soil group	Sub-group	Soil series
Entisols	Fluvents	Ustifluvents	Typic Ustifluvents	Pongro
			Aquic Ustifluvents	Bos Leav
				Moreum
	Psamments	Ustipsamments	Aquic Ustipsamments	Chong Kaoh
	Orthents	Ustorthents	Lithic Ustorthents	Pou
Vertisols	Usterts	Pellusterts	Typic Pellusterts	Prek Chamlak
		Chromusterts	Lithic Chromusterts	Sre Prang
Inceptisols	Aquepts	Haplaquepts	Anthropic Haplaquepts	Stung Preah
				Roha
	Tropepts	Ustropepts	Lithic Ustropepts	Kampi
			Aquic Ustropepts	Sambok
				Russei Char
Alfisols	Ustalfs	Rhodustalfs	Typic Rhodustalfs	Krakor
		Haplustalfs	Typic Haplustalfs	Keng
			Lithic Haplustalfs	Tuol

The order Inceptisols include low-humic gley soils, Aquepts and Tropepts sub-order are recognized. Anthropic Haplaquepts sub-group is the soils cultivated for rice plant, one of which Roha series is of coarse texture, with moderately developed sesquioxides accumulated horizon, influenced by rice cultivation. The Sambok and Russei Char series falling in Aquic Ustropepts are poor to very poor in drainage, and widely distributed on the alluvial flood plain of the Area.

The order Alfisols include those soils called red-yellow podzolic soils. The soils in this order fall in Ustalfs sub-order, one of which Krakor series corresponding to red podzolic soils, is included in Typic Rhodustalfs, and the other Keng series correspooding to yellow podzolic soils, is included in Typic Hapustalfs. The Tuol series, of Lithic Haplustalfs, is in high base saturation that increases with increasing depth.

The soils of the order Vertisols include Usterts sub-order, the Prek Chamlak series belongs to Typic Pellusterts, but in relatively wide range level because of not high clay content throughout the profile, and moderately low pH value.

Soils of recent origin have been classified as Entisols. Included are alluvial soils and lithosols. In alluvial soils Ustifluvents and Ustipsamments are recognized, and Aquic sub-group soils are dominant. The correlation between soil series and its corresponding sub-group of the 7th Approximation is shown in Table 11.

III. Descriptions of Soils

It describes the individual soils or mapping units in the Area: that is on the soil map, bounded by lines,. color printed and indicated by letter symbol. The approximate acreage of the soils is given in Table 10.

1) Chong Kaoh Series

In the Chong Kaoh series are excessively drained to well drained, coarse textured soils. These soils are slightly acid to neutral. They formed in material from very recent alluvium. They are alluvial soils and are included in Aquic Ustipsamments according to the 7th Approximation, These soils mostly occupy inside the natural levee of the Mekong River, in places are under water for long periods during the rainy season. Those in the inundation area are cultivated. Chong Kaoh soils are not extensively distributed, and cover 400 ha that is corresponding to 0.6 per cent of the Area.

2) Pongro Series

The Pongro series consists of well drained, deep to moderately deep, of medium textured soils that are on gentle sloping to nearly level. They are on gentle slope of natural levee, shoal delta in Ta Mau and Chhlong districts, and amount to 2,500 ha that is corresponding to 3.8 per cent of the Area. Shrubs such as kapok, kwatt, and grass make up the natural vegetation. In some places upland crops as banana, tomato, maize, and upland rice are cultivated. They are alluvial soils, and are included in Typic Ustifluvents according to the 7th Approximation.

The surface soil is dark reddish gray to dark reddish brown, slightly sticky fine sandy loam. The subsoil is reddish brown and is generally about the same texture as the surface soil, but in places it is loamy fine sand or silt loam. Pongro soils are fine granular and fine blocky, and in some places are found crotovina-like or granular formed by soil faunal activities. The presence of one to two buried horizons within 1 m which is attributable to alternate sedimentation by flooding, is one of characteristics of the soils.

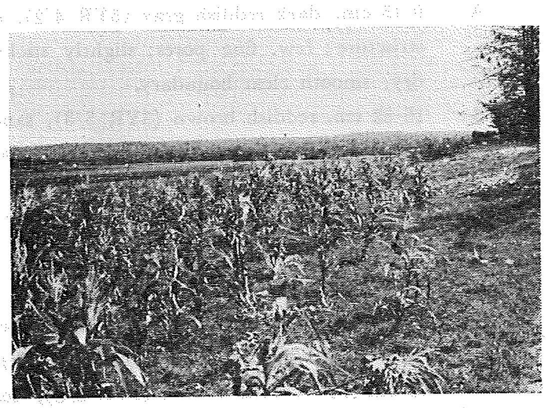


Fig. 3. Upland field on gentle slope of a natural levee.

The soil of Pongro series is the soil with weakly to very weakly developed profile, formed in two different sedimentation modes of material, and the buried horizons are very weakly developed. The buried A and B horizons are silty clay loam and clay loam, relatively finer than the upper horizons. No distinct mottlings are present throughout the profile.

The particle size distribution showed that the fine sand fraction is dominated except Ab horizon which is dominated by silt fraction, Th value of pH ranges from 6.1 to 6.4 in water extract, and exchangeable acidity is around 5 throughout the profile. Cation exchange capacity is rather low, less than 10 me except A and Ab horizons those of which are little higher, attributable to organic matter. The base saturation is more than 90 per cent, especially A horizon shows over 100 per cent. The soil has rather low content of available manganese which is below the sufficient range of 30 to 60 ppm, and rather low content of available phosphorous throughout the profile.

The micromorphological characteristics of A horizon are likely granular fabric by Brewer, with skeleton grains dominant fabric. The B horizon has nearly the same plasmic fabric as the above, and Ab horizon is with finer basic fabric than the above horizons. No distinct plasma separations are observed throughout the profile.

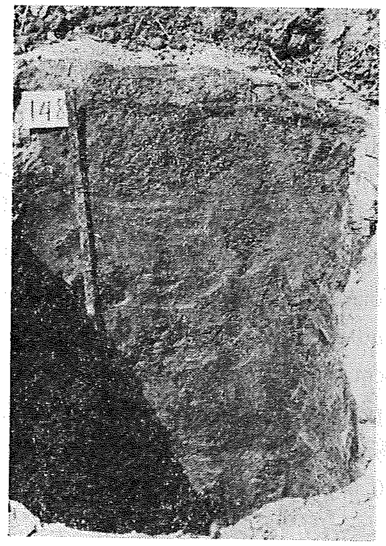


Fig. 4. A soil of Pongro series, medium textured (No. 148) that is on back slope of the natural levee.

Representative profile of Pongro series (*profile number* 148)

Area : Phum Kampong Kor, Khum Ta Mau, Sork Prek Prasap. (105°58′E. 12°16′N.)

Vegetation : Banana.

Parent material : Alluvium.

Topography : Gentle slope of natural levee, slope 3°N.

A 0-15 cm, dark reddish gray (5YR 4/2), sandy loam; weak, fine granular and fine blocky structure; few, fine pores; slightly sticky, plastic; slightly compact (17mm); few, roots; dry, smooth clear boundary.

B 15-38 cm, reddish brown (5YR 5/3), sandy loam; weak, fine granular structure to massive; few, very fine pores; slightly sticky, plastic; compact (23mm); few, roots; dry; smooth clear boundary.

Ab 38-58 cm, dark reddish brown (5YR 3/2), silty clay loam; weak, blocky structure; commn, very fine and fine pores; sticky, plastic; compact (21mm); semi-dry; few, roots; smooth clear boundary.

Bb 58-76 cm, dark reddish gray (5YR 4/2), clay loam; massive and weak, fine granular structure; slightly sticky, slightly plastic, compact (22mm); semi-dry; smooth diffuse boundary.

C 76 cm +, reddish brown (5YR 5/3), loamy sand; massive and weak, blocky structure; slightly sticky, slightly plastic; compact (22mm); semi-dry.

Micromorphological description [2) 15)] (*profile number* 155) :

A Mo-insepic likely granular fabric, with skeleton grains dominant basic fabric mainly composing of silt to fine-sand sized quartz, few plagioclases, mica, quartzite and pyroxenes; being narrow range of size of skeleton grains, it seems a random packing skeleton grains; with macro or meso-sized meta vughs and few organic fragments.

B11 Plasmic fabric same as above. (Fig. 34)

B12 Mo-insepic porphyroskelic fabric, finer basic fabric than above horizon; plasma is darker color which is attributable to organic materials possibly coming from sedimentation, with skeleton grains, macro meta vughs, few vesicles and few organic fragments.

Table 12. Chemical physical characteristics of Pongro soil (profile number 148)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc.)	pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
				Particle size distribution (mm)(%)						Soil reaction		
0-15	A	3.07	7.3	0.4	69.4	16.5	13.7	SL	1.16	6.10	5.58	5.3
15-38	B	2.35	0	0.3	75.6	19.7	4.4	SL	1.18	6.32	4.98	5.4
38-58	Ab	5.41	0	3.2	22.4	58.0	16.4	SiCL	1.12	6.38	4.94	5.3
58-76	Bb	3.27	0	0.2	57.8	26.0	16.0	CL	1.18	6.39	4.89	5.3
76+	C	1.85	0	0.5	85.7	4.7	9.1	LS	1.28	6.42	5.92	5.3

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100gm) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorp. coefficient	Available (mg/100g) MnO	P_2O_5
2.24	1.30	0.12	10.8	11.3	9.7	1.8	0.3	0.7	110	324	1.5	11.6
0.58	0.34	0.04	8.5	7.5	6.0	0.9	0	0.5	98	368	0.5	5.5
1.10	0.64	0.06	10.6	13.3	9.9	2.4	0.1	0.4	96	522	0.3	6.5
0.65	0.38	0.04	9.5	9.0	6.3	2.3	0	0.2	97	465	0	9.8
0.22	0.13	0.04	3.2	6.1	4.5	0.4	0	0.2	83	320	tr.	7.8

3) Bos Leav Series

The Bos Leav series consists of well-drained, deep and moderately deep soils formed in material from fine textured alluvium. These soils are on gently sloping to nearly level, and on back slope of natural levee of the Mekong River. They cover 5,300 ha that is corresponding to 7.7 per cent of the Area. The natural vegetation is mostly scattered hardwoods and shrubs such as cha, khtom, and kapok. In places upland crops such as peanuts, tobacoo, and maize are cultivated. A small acreage is used for irrigated upland fields. They are classified as alluvial soils, and included in Aquic Ustifluvents according to the 7th Approximation.

The surface soil, a dark brown to dark reddish gray silty clay loam to silty clay, is friable and slightly acid. The subsoil is reddish gray to reddish brown, silty clay or silty clay loam. Effective depth of soil is more than 1 m.

The soil of Bos Leav series is clay loam to light clay in texture, and with weakly to very weakly developed profile. No distinct Bt horizon, and mostly manganese mottlings are present within 1 m. Weakly developed blocky structure is in A and B horizons.

Clay content of the soil ranges from 26 to 32 per cent, without distinct differentiation throughout the profile. The value of pH (H_2O) is around 5.4, and exchange acidity is low. The ratio of C/N is rather low 7.1 for the first horizon, and decreases with depth. The base saturation varies between 83 and 92 per cent. The amount of available manganese is moderate, and that of phosphorous ranges from 4 to 9 mg/

100g soil.

The plasmic fabric is generally mo-omnisepic porphyroskelic fabric, with especially weakly developed vosepic plasma separation in BCg horizon, and weakly developed normal sesquioxidic diffuse nodules throughout.

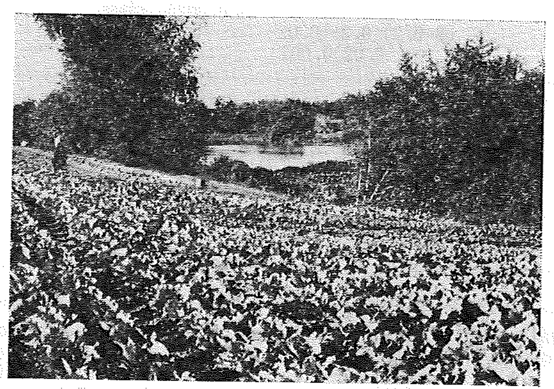


Fig. 5. Well growing cabbage on irrigated, and fertilized field. (Bos Leav series)

Representative profile of Bos Leav series (*profile number* 133) :

Area : Phum Khvien, Khum Bos Leav, Srok Kratie. (106° 02′ E. 120° 26′ N.)

Vegetation : Commn upland crops as corn or peanuts.

Parent material : Alluvium.

Topography : Gentle back slope of natural levee.

Ap 0-14 cm, dark brown (7.5YR 4/2), silty clay; weak, blocky structure; few, fine pores; very sticky, plastic; extremely compact (30mm); few, roots; semi-dry; smooth clear houndary.

Blg 14-29 cm, reddish gray (5YR 4.5/2) and reddish brown (5YR 5/3) light clay; weak, blocky structure; commn, fine and medium pores; few to common, manganese mottlings; sticky, plastic, very compact (28mm); few, roots; moist; smooth clear boundary.

BCg 29-46 cm, dark reddish gray (5YR 4/2) and reddish brown (5YR 5/3), light clay; weak, blocky structure; common, fine and medium pores; few, manganese mottlings; sticky, plastic; very compact (27mm); moist, smooth diffuse boundary.

Cg 46 cm+, dark reddish gray (5YR 4/2) and reddish brown (5YR 5/3) light clay; weak, fine blocky structure; few, manganese mottlings; very sticky, very plastic; very compact (25 mm), moist.

Micromorphological description (*profile number* 133) :

Ap Ma-silasepic porphyroskelic fabric, with basic fabric of plasma dominat with some to few skeleton grains sand-sized as quartz, plagioclases, with some pedorelicts of skeleton grains rich in brownish plasma, and weakly developed normal nodules and with some plant tissue, organic fragments, and macro to meso meta vughs.

B1g Ma-silasepic porphyroskelic fabric with some area with vosepic, and with some sand-sized skeleton grains as quartz, feldspars, and with weakly developed normal nodules diffuse to rather sharp external boundary, with some papules yellowish strong to medium birefringence. And with meso to macro meta vughs and few vesicles. (Fig. 35)

BCg Ma-mo-omnisepic porphyroskelic fabric, with some vosepic plasmic fabric, and with strongly developed papules in zones. Some to many dark colored organic fragments, fine sand-sized skeleton grains rather higher volume than the above, and with weakly developed normal sesquioxidic adhesive diffuse nodules and macro to meso meta vughs and/or possibly vesicles.

Cg Ma-mo-omnisepic porphyroskelic fabric, with many skeleton grains as quartz, feldspars, and with some areas of vosepic plasmic fabric. Few papule in matrix, and less developed diffuse normal nodules with many macro-sized meta vughs, few meso vughs.

4) Moreum Series

In the Moreum series are very poorly drained, dark reddish brown to dark

Table 13. Chemical physical characteristics of Bos Leav soil (profile number 133)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm)(%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y1)
0-14	Ap	3.93	0	1.6	15.3	51.0	32.1	SiC	1.03	5.45	4.45	0.3
14-29	B1g	5.53	0	0.7	33.6	35.3	30.3	LiC	1.12	5.32	4.12	0.7
29-46	BCg	3.17	0	0.1	41.3	32.6	26.0	LiC	1.14	5.41	4.11	0.6
46+	Cg	2.92	0	0.1	36.4	37.5	26.0	LiC	1.13	5.47	4.17	0.6

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100gm)	Exchangeable cations (me/100gm) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100gm) MnO	P_2O_5
1.60	0.93	0.13	7.1	15.9	10.9	2.2	0.4	0.5	88	983	3.0	9.3
0.65	0.38	0.08	4.7	13.7	9.8	1.2	0.1	0.3	83	905	3.1	4.2
0.49	0.29	0.07	4.1	12.0	8.2	2.2	0.3	0.3	91	790	2.9	5.3
0.27	0.16	0.07	2.3	12.5	9.1	1.5	0.6	0.3	92	880	2.2	4.8

gray, deep to very deep soils formed in fine textured alluvium. These soils are on gently sloping to slightly depression. Distributed on the back marshy lowlands of Kratie, Bos Leav, Kanhchor, Prek Prasap, Ta Mau and Chhlong, the area amounts to 1,000 ha corresponding to 1.5 per cent of the Area. Most of the soils are under submerged conditions even in the dry season, but are not remarkably affected by ground water. A considerable amount of thready and cloudy mottlings is found within a depth of 50 to 60 cm from the surface. The vegetation is mostly bushes such as roten, treng, and aquatic plants such as sarmour, and proandat. The soils are classified as alluvial soils and included in Aquic Ustifluvents according to the 7th Approximation.

Fig, 6. Aquatic plants on back marshy lowland in the dry season, near Kratie.

The surface soil, a dark reddish brown heavy clay with few thready iron mottlings, is medium acid. The subsoil is dark reddish gray or reddish brown heavy clay, with many thready and filmy iron mottlings, and is also medium acid. Most of the soils have never been used for agriculture.

The soil of the Moreum series is of weaky developed profile differentiation, and buried horizons formed in nearly the same material as the above horizons. As the texture is heavy, the soil is extremely plastic, and sticky. Although it is in very poorly drained status, the degree of gleyzation is not intensively progressed at a depth of 70 cm during the dry season. In B2g horizon distinct reaction to benzidine was observed.

Mechanical analysis showed that it is dominated by clay fraction throughout more or less 60 per cent. The value of pH(H_2O) shows 4 to 5 increasing with depth. Carbon content of Ab horizon show a little higher than upper or below horizon. Base saturation is around 60 per cent increasing with depth. The available manganese content is very low to nearly nothing, except A horizon which contains MnO 6 mg/100 gm soil. The available phosphorous content is rather low except A horizon containing 14 mg P_2O_5.

The plasmic fabric is mo-masepic porphyroskelic fabric, with plasma dominant basic fabric, and sesquioxidic normal nodules are recognized throughout the profile, with fluidal structure resulting from plasma separation for Al horizon, but not distinctly.

Representative profile of Moreum series (*profile number* 104) :

Area : Khum Sambok, Srok Kratie. (106°02′ E. 12°35′ N.)

Vegetation : Bush as roten, snay (*Streblus asper*) and aquatic plants or grass as sarmour and proandat.

Parent material : Alluvium.

Topography : Slight depression of back marsh lowland.

Ag 0-13 cm, dark reddish brown (5YR 2/2), heavy clay; weak, blocky structure; few, very fine pores; few, thready mottlings; extremely sticky, extremely plastic; very compact (27 mm); abundant, roots; moist, smooth clear boundary.

Bg 13-30 cm, dark reddish gray (5YR 4/2), heavy clay; moderate, blocky structure; few, fine pores; many, thready and filmy mottlings; extremely plastic; very compact (26mm); common, roots; moist, smooth clear boundary.

Abg 30-43 cm, dark reddish gray (5YR 4/1.5), heavy clay; massive; few, fine pores; many thready and specled mottlings; extremely sticky, extremely plastic; compact (23mm); few, roots; moist, smooth clear boundary.

Bbg 43-69 cm, reddish gray (5YR 5/2) and dark brown (7.5YR 4/4), heavy clay; massive; few, fine pores; few, thready mottlings; extremely sticky, extremely plastic; compact (20mm); few, roots, moist, smooth clear boundary.

C 69 cm+, reddish gray (5YR 5/2) and dark brown (7.5YR 4/4), heavy clay; massive; extremely sticky, extremely plastic; compact (22mm), moist.

Micromorphological description (*profile number* 111) :

A1g Mo-masepic porphyroskelic fabric, plasma dominant basic fabric with few skeleton grains silt to fine sand sized as quartz, plagioclases, macro meta vughs, skew plane and channel voids and with some papules brownish yellow in color. Some irregular fluidal structure likely to be formed from sorting sedimentation. Many to some adhesive diffuse sesquioxidic normal nodules embedded in plasma. (Fig. 36)

B2g Mo-masepic porphyroskelic fabric with some area of omnisepic, with plasma dominant basic fabric and with very few skeleton grains and meta vughs, channels and planes. Plasma is rather dense, with reddish brown yellow papules, adhesive diffuse normal nodules and some organic fragments.

C1g Essentially as above ; mo-masepic porphyroskelic fabric, with plasma dominant basic fabric with very few skeleton grains ; Plasma is rather dense, with yellowish brown papules in matrix or voids and few meta vughs and channels or plane voids and adhesive normal nodules ; with organic fragments like root remains.

C2g Mo-masepic porphyroskelic fabric ; extremely few, silt sized skeleton grains, and dense plasma dominant fabric includes meta vughs and channels, adhesive diffuse normal nodules, reddish brown sesquioxidic concretions, and dark or carbniferous and brown root organic fragments ; with pedorelicts brown in color composing dense plasmic material.

Table 14. Chemical physical characteristics of Moreum soil (profile number 104)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-13	Ag	10.49	0	tr.	3.2	37.4	59.4	HC	0.91	4.65	3.86	8.1
13-30	Bg	9.52	0	0.1	2.2	37.8	59.9	HC	1.01	4.88	3.92	5.4
30-43	Abg	2.50	0	0.1	2.0	34.3	63.6	HC	1.13	5.32	4.40	0.6
43-69	Bbg	14.15	0	tr.	2.0	34.6	63.4	HC	0.96	5.61	4.00	5.1
69 +	C	1.40	0	0.2	5.4	38.1	56.3	HC	1.14	6.13	4.81	0.8

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
3.55	2.06	0.19	10.8	21.5	7.5	3.7	1.5	0.6	61	1256	6.0	13.9
1.56	0.91	0.10	9.1	17.7	7.7	3.5	1.0	0.3	70	1094	2.9	6.6
1.68	0.98	0.09	10.8	20.0	9.0	4.7	1.3	0.3	76	969	0.9	4.0
1.41	0.82	0.08	10.2	17.9	9.2	4.6	2.0	0.5	91	1520	-	4.6
0.93	0.54	0.07	7.7	17.2	9.1	6.0	1.6	0.1	97	1004	tr.	3.8

5) **Pou Series**

In the Pou series are well drained, shallow, cobbly or gravelly soils formed in basaltic igneous material and old mixed alluvium, and overlie the Tertiary bedrock such as shale and sandston. Depth to bedrock ranges from 5 to 20 cm. A few fine roots penetrate to depth of 30 cm. Rock outcrops cover from 2 to 5 per cent of the surface area, that is stoniness class 2 according to USDA Soil Survey Manual. Pou soils are slightly undulating to hilly, and distributing on the hill lands of Bos Leav and Kanhchor districts. The natural vegetation is open forest, mainly hardwoods such as sonkar, and chlek.

The surface soil, a dark reddish gray gravelly or cobbly sandy loam, is neutral in reaction. The subsoil is also dark reddish gray and half-weathered gravelly clay loam to light clay, and it overlies Tertiary bedrock such as shale, and sandstone.

The soil of Pou series is of half-weathered basaltic gravelly whose content increases with increasing depth. The texture of the fine-earth is fine to very fine, and becomes finer with depth at a depth of bedrock. In the second horizon, no structure developed, and some faint manganese mottlings were observed.

Mechanical analysis showed that clay content increases with depth. Being affected by parent material, the base is saturated throughout the profile. The soils are characterized by rather higher phosphorous absorption coefficient and available manganese content. Cation exchange capacity is comparatively higher than other soils.

Representative profile of Pou series (*profile number* 134) :

Area : Phum Baeng Pralit, Khum Bos Leav, Srok Kratie. (106°04′ E. 12°24′ N.)

Vegetation : Open forest of sonkar (*Zizyphus oenoplia*) chenko, chlek (*Terminalia tomentosa*) and slolou (*Lagerstraemia sp.*).

Parent material : Basaltic

Topography : Flat on the hill lands.

A 0-3 cm, dark reddish gray (5YR 3.5/1), sandy clay loam; common, very fine and fine half-weathered gravel; very weak, plismatic and fine blocky structure; few, fine pores;

Tabel 15. Chemical physical characteristics of Pou soil (profile number 134)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-3	A	4.17	17.2	31.1	34.5	17.3	17.1	SCL	1.13	6.95	6.70	0.3
3-20	C1	5.26	35.6	32.5	18.7	18.5	30.3	LiC	1.16	7.11	6.39	0.3
20 +	C2	6.41	72.2	31.0	19.6	21.1	38.3	LiC	—	6.57	5.21	0.3

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
4.01	2.33	0.20	11.6	25.7	29.3	2.7	0.4	1.8	133	1126	14.1	10.7
1.82	1.06	0.07	15.1	26.8	25.6	4.9	0.8	1.2	121	1377	8.0	2.7
1.74	1.01	0.07	14.4	29.5	22.1	7.8	0.5	0.7	105	1442	1.7	2.7

slightly sticky, slightly plastic; very compact (27mm); abundant, roots; dry, smooth clear boundary.

C1 3-20 cm, dark reddish gray (5YR 3.5/1), light clay; abundant, fine and medium half-weathered gravel; massive; few, manganese mottlings; sticky, plastic; compact (22mm); commn, roots; semi-dry; smooth clear boundary.

C2 20 cm+, dark reddish gray (5YR 3.5/1), light clay; abundant, fine and medium half-weathered gravel; few, manganese mottlings on gravel; very sticky, very plastic; semi-dry.

6) **Prek Chamlak Series**

The Prek Chamlak series consists of moderately well drained, moderately deep to deep clayey soils formed in material from basaltic igneous rock. These soils are gently sloping to hilly. The characteristics of the soils are A horizon of dark brown to dark gray, of very fine texture, and the presence of whitish concretion likely coming from carbonate in the upper part of A horizon. They extend to valley plain and hill lands of Bos Leav, Kanhchor and Prek Prasap, and they occupy 900 ha corresponding to 1.4 per cent of the Area. The natural vegetation is predominantly deciduous trees such as sonkar, cha, and grass as sabou. During the rainy season, a small acreage of the soils is grown with rice, however the undulating hilly region is not cultivated. The soils are classified as vertisols, and are included in Typic Pellusterts according to the 7th Approximation.

The surface soil is dark brown heavy clay, with blocky structure, extremely plastic, and extremely sticky. The subsoil, a dark gray heavy clay, is slightly acid, and of some slickenside on the peds. Though the soil of Prek Chamlak is distributing on gentle slope of hill lands, cloudy iron mottlings are weakly developed in the upper part of A horizons, and moderately developed blocky to fine blocky are found in the A horizons, and some slickenside are on the peds. The texture is very fine throughout.

The clay content ranges from 44 to 54 per cent, rather uniform throughout the profile. The value of pH(H_2O) is rather low, around 5.4, but exchange acidity of A3 horizon is exceptionally high, 15.9. The cation exchange capacity is between 29 and 30 me, except for C horizon. The amount of available manganese and phosphorous is slightly low throughout the profile, except for the first horizon that is moderate in content of manganese, 7.8 mg/100g soil.

The plasmic fabric of A horizon is mo-ma-omnisepic, with dense plasma dominant basic fabric. In A12 horizon, some vosepic plasma separation, and with fluidal structure are observed, and normal sesquioxidic diffuse nodules are present throughout the A horizon.

Representative profile of Prek Chamlak series (*profile number* 140) :

Area : Phum Chamlak, Khum Chamlak, Srok Prek Prasap. (106°04′ E. 12°17′ N.)

Vegetation : Open forest of cha (*Butea frondosa*) and rovear (*Ficus religiosa*).

Parent material : Basaltic and Tertiary rocks.

Topography : Gentle slope of hill land.

A11g 0-14 cm, dark brown (7.5YR 3/1), heavy clay; moderate, blocky and fine blocky structure; few, fine pores; few, cloudy mottlings; extremely sticky, extremely plastic; compact (24 mm); abundant, roots; dry, smooth clear boundary.

A12g 14-30 cm, dark gray (10YR 4/1), heavy clay; moderate, blocky and fine structure; fine pores; common, cloudy mottlings; extremely sticky, extremely plastic; very compact (27 mm); few, roots; dry, smooth clear houndary.

A13 30-49 cm, dark gray (10YR 4/1), heavy clay; weak, blocky structure; extremely sticky, extremely plastic; extremely compact (29mm); few, roots; dry; smooth diffuse boundary.

C 49 cm+, dark brown (10YR 3.5/2), heavy clay; extremely plastic, extremely sticky; extremely compact (32mm).

Micromorphological description *(profile number* 140) :

A11g Medium birefringence plasma is dominant with mo-masepic dense plasma dominant basic fabric, only with silt sized skeleton grains. Some areas with argillaceous yellowish papules. With dark or strong brown organic fragments, macro meta vughs, meso vughs likely vesicles, and channels. Many, different size normal sesquioxidic nodules adhesive diffuse iregelar shaped.

A12g Birefringence little stronger than above; ma-vo-omnisepic plasmic fabric, with some areas with fluidal structure, and with different sized normal nodules rather sharp boundary to diffuse. With decomposed organic fragments in matrix, and common, meso to macro sized meta vughs and channels. Some papules yellowish in color, and few, dark brown pedorelicts.

A13 Nearly same plasmic fabric as above, mo-ma-omnisepic with some area with fluidal structure and many, different size normal nodules, very dark brown diffuse boundary to fairly sharp. Some papules in matrix, dark brown rounded pedorelicts, and some, macro to meso-sized meta vughs and channels.

C Mo-omnisepic with lattisepic fabric, intergrade to porphyroskelic fabric, and with fine sand to silt sized skeleton grains. Some, dark brown pedorelicts and macro to meso-sized meta vughs and meso channels and few, different sized normal nodules diffuse boundary to fairly sharp.

Table 16. Chemical physical characteristics of Prek Chamlak soil (profile number 140)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Partical size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-14	A11g	6.00	0	0.1	16.1	59.1	44.7	LiC	0.99	5.44	4.32	0.5
14-30	A12g	6.59	0	0.3	7.9	37.6	54.2	HC	1.04	5.42	3.51	8.9
30-49	A3	6.28	0	0.3	10.2	37.6	51.9	HC	1.07	5.40	3.33	15.9
48+	C	5.47	0	0.4	25.2	26.8	47.6	HC	0.97	5.53	3.52	5.2

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
3.39	1.97	0.17	11.5	30.6	20.7	6.4	0.8	0.9	94	1531	7.8	4.4
1.58	0.92	0.11	8.3	31.4	14.9	6.6	2.2	0.5	77	1348	2.7	2.4
1.39	0.81	0.09	9.0	29.3	12.9	6.8	2.3	0.6	77	1392	3.0	2.4
0.79	0.46	0.06	7.6	26.3	12.0	7.7	3.3	0.4	88	1237	0.8	2.9

7) Sre Prang Series

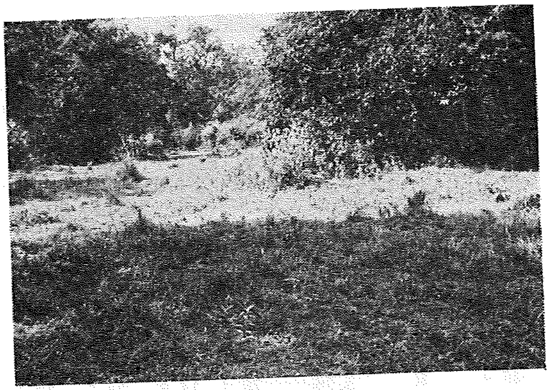


Fig. 7. Dense bush and glass on an alluvial plain close to the hill land; in the foreground Tertiary bedrock underlies.

In the Sre Prang series are moderately well draind to well drained, moderately shallow to shallow soils. These soils formed in material from basaltic mixed with alluvium over Tertiary origin such as shale and sandstone. In places a thin round gravel layer is inserted on the bedrock. The soils are on low terraces transitional to the hill lands. The area of this soils amounts to 1,100 ha that is, corresponding to 1.7 per cent of the Area. Depth to bedrock ranges from 30 to 45 cm. Faint to moderately distinct mottlings develop in the upper part of A horizons. Deciduous trees such as cha, and sonkar, and grass as sabou make up the natural vegetation. They are classified as vertisols, and are included in Lithic Chromusterts according to the 7th Approximation.

The surface soil, a very dark gray brown to dark reddish brown heavy clay textured, is fine blocky, medium acid, and mostly faint mottled. The subsoil is dark gray brown to dark brown heavy clay or clay loam, and generally faint mottled. In most places there is a small amount of shaly gravels that increase with depth.

The clay content is higher than the Prek Chamlak soils, it is likely coming from mixed with alluvial materisls. The value of pH(H_2O) is 4.5 to 6.0, and base saturation is rather low from 55 to 73 per cent, except for the bedrock. The amount of available manganese, and phosphorous in All horizon is more or less moderate.

Representative profile of Sre Prang series (*profile number* 139):

Area: Phum Prek Chamlak, Khum Chamlak, Srok Prek Prasap. (106°03′ E. 12°18′ N.)

Vegetation: Grass as sabou (*Imperata cylindrica*).

Topography: Gentle slope on hill land.

A11g 0-3 cm, very dark gray brown (10YR 3.5/1), heavy clay; weak, fine blocky structure; few, fine and medium pores; few, thready and filmy mottlings; extremely sticky, extremely plastic; compact (22mm); abundant, roots; dry, smooth clear boundary.

A12g 3-15 cm, very dark gray brown (10YR 3.5/1), heavy clay; moderate, blocky structure; few, fine and medium pores; common, thready and filmy mottlings; extremely sticky, extremely plastic; very compact (25mm); abundand, roots; dry; smooth clear boundary.

A13 15-32 cm, brown (7.5YR 5/2) and reddish brown (5YR 4/3), heavy clay; moderate, blocky and fine blocky structure; few, fine and medium pores; extremely sticky, extremely plastic; very compact (27mm); few, roots; wavy clear boundary.

A14 32-45 cm, brown (7.5YR 5/2) and dark brown (7.5YR 4/4), heavy clay; few, fine unweathered gravel; moderate, blocky structure; few, fine and medium pores; very sticky, very plastic; extremely compact (32mm); semi-dry; smooth abrupt boundary.

R 45 cm+, abundant, fine and medium unweathered round gravel in the upper part 2-3 cm thick over the half weathered shale and sandstone layer.

Table 17. Chemical physical characteristics of Sre Prang soil (profile number 139)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	(pH)KCl	Exch. acidity (y_1)
0-3	A11g	8.73	tr.	0.2	2.2	22.0	75.6	HC	0.77	4.58	3.50	15.9
3-15	A12g	9.43	0	tr.	2.1	15.9	82.0	HC	0.99	4.80	3.30	24.7
15-32	A13	11.09	35.2	0	4.5	21.7	73.8	HC	0.97	5.12	3.32	27.7
32-45	A14	7.10	14.9	1.9	8.6	19.4	79.6	HC	1.09	5.45	3.43	20.8
45 +	R	5.76	76.4	14.3	34.7	17.0	34.0	LiC	-	6.02	3.91	2.4

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
5.24	3.04	0.28	10.8	26.7	8.7	3.7	1.2	1.1	55	1380	4.2	10.1
2.86	1.66	0.18	9.2	30.2	9.1	6.5	2.8	0.6	62	1440	2.2	4.0
1.77	1.03	0.12	8.5	25.8	7.9	5.4	3.1	0.3	64	1315	1.3	2.4
1.24	0.72	0.09	8.0	21.9	6.7	5.3	3.7	0.3	73	1404	tr.	5.0
0.62	0.36	0.06	6.0	14.8	5.0	4.8	3.8	0.3	93	859	4.3	4.8

8) Stung Preah Series

The stung Preah series consists of well-drained to somewhat excessively drained, deep to moderately deep, and medium textured gray soils which formed in material from alluvium mixed with weathered old alluvium. These soils are gentle sloping to nearly level, and are distributing on valley plain in hilly lands in Ta Mau, Chhlong and Prek Prasap districts. They are classified as low-humic gley soils, and are included in Anthropic Haplaquepts according to the 7th Approximation. Being cultivated with rice for long time, many kind of mottlings such as fine tubular, filmy, spotty, and cloudy are markedly developed especially in the B21 horizon.

The surface soil, a dark gray to gray loamy, is friable, and medium acid. The subsoil is gray to brownish gray, loam to sandy loam. Permeability is moderately rapid, root penetration is deep to very deep. No irrigation facilities have been provided, rice plants are cultivated during the rainy season.

The soils are characterized by the high bulk density, 1.32 to 1.47, low cation exchange capacity less than 3.8 me/100 gm soil, low base saturation, and low content of available manganese and phosphorous. The value of pH(H_2O) is relatively low, 4.5 to 4.9, excep for IIC horizon.

Representative profile of Stung Preah soil (*profile number* 151) :

Area : Phum Stung Preah, Khum Ta Mau, Srok Prek Prasap. (105°56′ E. 12°19′ N.)

Vegetation : rice (paddy field).

Parent material : Alluvium mixed with old alluvium.

Topography : Nearly level on valley plain.

Apg 0-15 cm, dark gray (10YR 4/1), loam; very weak, blocky structure; few, fine pores; common, filmy and thready mottlings; slightly sticky, non plastic; compact (22mm); abundant, roots; dry; smooth clear boundary.

B21g 15-20 cm, gray (10YR 6/1), loam; very weak, blocky structure; few, fine pores; common, thready and specled mottlings; slightly sticky, non plastic; extremely compact (32mm); common, roots; semi-dry; smooth clear boundary.

B22g 20-30 cm, light brownish gray (10YR 6/2), sandy loam; very weak, blocky structure; few, fine pores; abundant, thready and cloudy mottlings; slightly sticky, non plastic; very compact (27mm); few roots; moist; smooth clear boundary.

B23g 30-75 cm, light brownish gray (10YR 6/2), sandy loam; massive; few, cloudy mottlings (10YR 6/8); slightly compact (18mm); moist; smooth clear boundary.

IIC 75 cm+, yellowish brown (10YR 5/8) and light brownish gray (7.5YR 6.5/2); slightly compact (18mm), moist; commn, manganese reaction by benzidine reagent.

Table 18. Chemical physical characteristics of Stung Preah soil (profile number 151) (on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-15	Apg	1.55	0	14.6	43.3	27.6	14.5	L	1.32	4.55	3.75	5.1
15-20	B21g	0.85	0	20.8	40.9	25.9	12.4	L	1.46	4.71	3.89	2.5
20-30	B22g	0.75	0.8	28.6	41.0	16.0	14.4	SL	1.43	4.93	3.97	2.2
30-75	B23g	0.62	2.2	36.9	43.4	8.3	11.4	SL	1.04	4.89	3.97	3.2
75+	IIC	0.65	7.8	4.2	78.7	7.1	10.0	SL	1.47	5.13	4.34	0.7

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
1.56	0.91	0.09	10.1	3.8	0.4	0.4	0.1	0.1	26	411	0	2.0
0.68	0.40	0.05	8.0	2.7	0.3	0.5	0	0.1	33	408	0.5	2.3
0.17	0.10	0.04	2.5	2.5	0.8	0.4	0	0	48	408	0.5	2.3
0.13	0.08	0.02	4.0	1.6	0	0.4	0	0	25	362	0	2.8
0.17	0.10	0.01	10.0	0.9	0.9	0.1	0	0.1	122	362	0.7	4.9

9) Roha series

The Roha series consists of moderately drained to poor drained, deep to moderately deep soils formed in material from very fine textured alluvium. These soils are gentle sloping to nearly level. They are mainly on the valley plain dissected in the hill lands, and are distributed in Kratie, Saop, Bos Leav and Prek Prasap districts, and on the banks of the Prek Te River. They occupy 4,600 ha that is corresponding to 7.0 per cent of the Area. They are classified as low-humic gley soils, and are included in Anthropic Haplaqepts according to the 7th Approximation. No irrigation facilities have been provided, rice is cultivated during the rainy season. The soils have sesquioxidic accumulated horizon below the surface layer, which is of fine tubular iron

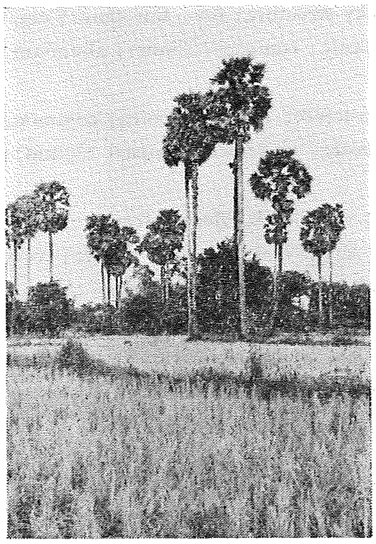


Fig. 8. Paddy field on the valley plain; in the background is a row of coconut palm trees.

dominating mottlings. In the immediate beneath horizon to the surface soil, manganese dominant mottlings, and concretions are pronouncedly developed by rice cultivation. The duration of rice cultivation is not clearly informed, but this profile developments show that A horizon elucidated under a reductive condition and B horizon with iron and manganese illuviation have developed. This corresponds to the taxonomic units of Aquorizem proposed by KAWAGUCHI and KYUMA[10].

The surface soil, a dark reddish gray to dark brown silt loam to clay loam, is nearly neutral. The subsoil is dark reddish brown to dark gray, and clay loam to light clay.

The clay content increases with increasing depth from silt loam to light clay textural class. The value of pH(H_2O) becomes high with depth, which is the same tendency as cation exchange capacity. The bulk density is 1.14 to 1.26, and the base saturation is rather high, more than 100 per cent throughout the profile. The amount of available manganese of Apg horizon show somewhat high, but very low for other horizons, and that of available phosphorous is low to very low.

Representative profile of Roha soil (*profile number* 107) :

Area : Phum Kou Leap, Khum Kratie, Srok Kratie. (106°04′ E. 12°32′ N.)

Vegetation : Rice (paddy field).

Parent material : Alluvium.

Topography : Nearly level, valley plain.

Apg 0-15 cm, dark reddish gray (5YR 4/2), silt loam; moderate, blocky structure; few, fine pores; few, mottlings; very sticky, plastic; very compact (28mm); abundant, roots; dry; smooth clear boundary.

B21g 15-20 cm, dark reddish brown (5YR 5/2.2), clay loam; massive; abundant, thready mottlings; very sticky, very plastic; extremely compact (32mm); common, roots; semi-dry; smooth clear boundary.

B22g 20-28 cm, dark reddish brown (5YR 2/2.5), light clay; massive; few, fine pores; common, thready and few, manganese mottlings; very sticky, very plastic; extremely compact (32mm); common, roots; semi-dry; smooth clear boundary.

B23g 28-55 cm, dark reddish gray (5YR 4/2), light clay; massive; few, fine pores; few, fine cloudy and specled mottlings; very sticky, very plastic; compact (22mm); moist; smooth clear boundary.

C 55 cm+, dark reddish gray (5YR 4/2), light clay; few, fine half-weathered gravel; massive; very sticky, very plastic; moist.

Table 19. Chemical physical characteristics of Roha soil (profile number 107)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc.)	pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-15	Apg	2.23	0	3.2	37.2	46.4	13.2	SiL	1.14	5.49	4.18	0.5
15-18	B21g	2.35	4.1	5.8	34.6	41.9	17.7	CL	1.25	6.45	4.94	0.3
18-28	B22g	5.12	0	6.2	27.4	39.4	27.0	LiC	1.23	7.68	6.01	0.2
28-55	B23g	4.48	0.9	5.4	23.0	34.4	37.2	LiC	1.26	8.49	6.70	0.3
55 +	C	4.82	3.5	5.6	22.4	33.3	38.7	LiC	1.26	8.71	6.99	0

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	MnO	P_2O_5
1.06	0.62	0.07	8.8	8.5	6.8	0.6	1.6	0.2	108	644	4.2	1.6
0.60	0.35	0.04	8.7	9.9	7.4	1.7	3.4	0.1	127	645	1.7	1.6
0.39	0.23	0.03	7.6	16.4	12.6	2.8	4.7	0.2	123	854	2.4	1.8
0.55	0.31	0.03	10.3	21.5	13.2	5.7	5.1	0.3	113	944	1.2	4.1
0.43	0.25	0.04	6.2	20.8	13.2	7.9	6.1	0.2	131	944	0.9	5.5

(Ca, Mg, Na, K: Exchangeable cations (me/100g); MnO, P_2O_5: Available (mg/100g))

10) **Kampi series**

The Kampi series consists of moderately well to well drained moderately deep to shallow fine textured soils. These soils formed mainly in material from alluvium over Tertiary bedrock, and in places, a thin round gravel layer of alluvial deposit, exists immediately above the bedrock. Depth to the bedrock varies from 28 to 50 cm. They are moderately developed profile. They have also fine tubular iron mottlings, manganese mottlings and concretions throughout the profile. These soils are on alluvial plain or lower terrace, and on the transitional area to the hill lands in a belt. They are classified as low-humic gley soils, and are included in Lithic Ustropepts according to the 7th Approximation. The natural vegetation is mainly shrubs such as pring, chreak, and places mixed with turf, and sabou.

The surface soil is dark brown to dark reddish gray clay loam, and slightly acid.

The subsoil is brown to dark reddish gray clay loam, friable, and slightly acid. The Kampi soils are subdivided into two soil types, Kampi-1 and Kampi-2, on the basis of thickness of top soil, that is; effective depth of soil for Kampi-1 is more than 50 cm, and Kampi-2 is shallower than 50 cm. They are mainly

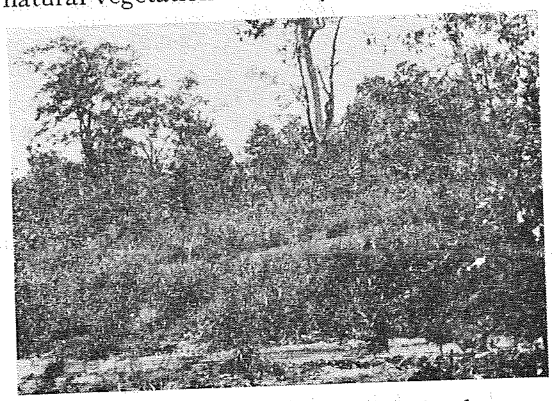


Fig. 9. A natural landscape of transitional area between hill land and alluvial plain.

distributed in Kratie, Saop, Prek Prasap, and on the right bank of the Prek Te River. They occupy the area of 2,500 ha that is corresponding to 3.6 per cent of the Area.

The soil of Kampi series is of fine texture, moderately well drained soil. The gravel increases with increasing depth as far as the Tertiary bedrock. Depth to bed-rock is 35 cm. Iron and manganese mottlings are abundant from the surface, especially are distinct in the B1g horizon. The soil is fairly hard for the surface, and with common to many manganese detection sensible to benzidine reagent throughout.

The particle size distribution is of fine texture but no distinct profile differentiation from the point of textural class. The base saturation increases with depth, indicating 73 per cent for the first horizon. Phosphorous absorption coefficient is very low, however the content of available manganese in Ag horizon is moderately high. The value of cation exchange capacity of the Ag horizon is 9.3 me/100 gm soil. These increase with depth.

Representative profile of Kampi soil (*profile number* 113):

Area: Phum Bos Prohoang, Khum Kratie, Srok Kratie. (106°02′ E. 12°36′ N.)

Vegetation: Open forest of pring (*Engenia jambolana*), klong (*Dipterocarpus tuberculatus*), chreak (*Terminalia tomentosa*) and cha (*Butea frondosa*).

Parent material: Alluvium.

Topography: Nearly level on alluvial plain.

Ag 0-8 cm, dark brown (7.5YR 4/2), silty clay loam; weak, blocky structure; common, very fine and fine pores; abundant, thready and specled mottlings; sticky, plastic; extremely compact (32mm); abundant, roots; dry; smooth clear boundary.

B1g 8-18 cm, brown (7.5YR 5/2), clay loam; few, fine round gravel; weak, blocky structure; common, very fine and fine pores; few, iron mottlings; abundant manganese mottlings; sticky, plastic; extremely compact (32mm); few, roots; dry; smooth clear boundary.

B2 18-35 cm, brown (7.5YR 5/1.5), clay loam; weak, blocky structure; few, fine pores; abundant, fine round gravel including manganese concretions; very sticky, very plastic; very compact (27mm) dry; irregular abrupt bonudary.

R 35 cm+, shaly rock, half-weathered, very compact (28mm).

Table 20. Chemical physical characteristics of Kampi soil (profile number 113)
(on oven-dry basis)

Depth	Horizon	H_2O	Gravel	Particle size distribution (mm) (%)					B. D.	Soil reaction		
cm		(%)	(%)	Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	(gm/cc.)	pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-8	Ag	1.45	3.7	3.3	31.0	48.1	17.6	SiCL	1.05	5.23	3.82	2.1
8-18	B1g	4.97	12.8	0.3	44.7	32.7	22.3	CL	1.20	5.59	4.70	0.6
18-35	B2	3.47	24.5	4.5	33.9	39.2	22.4	CL	1.16	5.68	4.76	0.7
35+	R	4.66	70.0	20.1	13.7	36.0	30.2	LiC	1.18	6.09	5.05	0.5

Humus	Organic carbon	Total nitrogen	C/N	Cation exch. cap.	Exchangeable cations (me/100g)				Base sat.	Phosphorous absorption coefficient	Available (mg/100g)	
(%)	(%)	(%)		(me/100g)	Ca	Mg	Na	K	(%)		MnO	P_2O_5
2.24	1.30	0.10	13.0	9.3	5.5	0.8	0.3	0.2	73	456	12.3	2.3
1.17	0.68	0.06	11.3	10.3	8.9	0.5	0.3	0.1	95	559	4.0	2.6
1.17	0.68	0.06	11.3	14.6	13.2	1.6	0.4	0.1	104	852	2.3	2.4
0.65	0.38	0.05	7.6	15.9	16.0	1.5	0.9	0.2	116	943	4.7	1.5

11) **Sambok Series**

The Sambok series consists of dark gray to dark brown, moderately well drained to poorly drained, deep soils that are formed from alluvium including recent material. These soils are of very fine texture, most widely distributed in the Area, mainly on alluvial plains between the natural levee and hill lands. The acreage amounts to 24,000 ha that is equivalent to 36 per cent of the Area. The ground water is rather fluctuating, and mottlings are found mainly within 30 cm from the surface. The natural vegetation is mainly shrubs such as cha, khtom, and wildgrass as sabou. Some area of the soils is utilized for upland crops during the dry season. The soils are classified as low-humic gley soils, and are included in Aquic Ustropepts of the 7th Approximation.

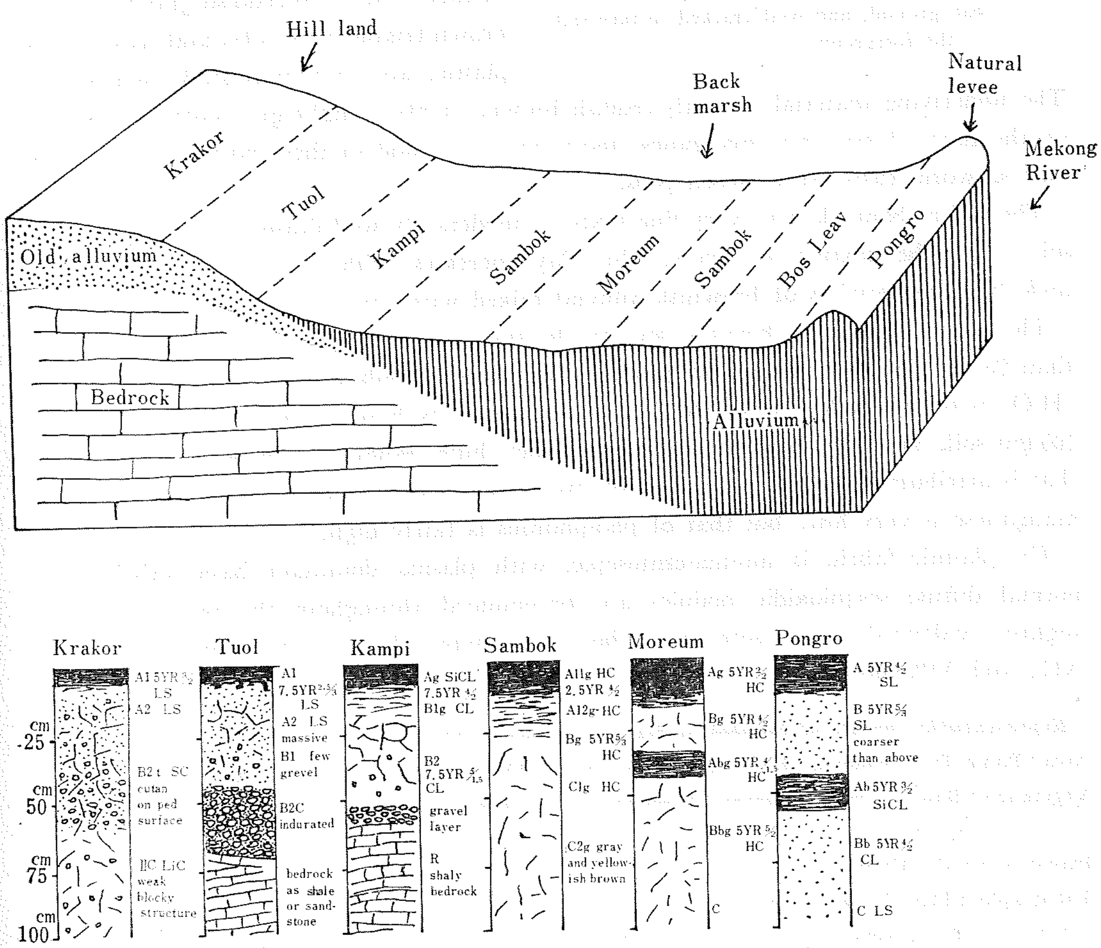


Fig. 10. Relationship between topography and soils

The soils are overflooded 3 to 4 m deep for 1 to 3 months during the rainy season, often more than 5 m deep. The A horizons are placed under reduced conditions for some time which brings about the formation of iron mottlings. As the texture is heavy, the soils are extremely plastic, and extremely sticky throughout the profile when wet. It is assumed that the subhorizons are not strongly reduced, and without

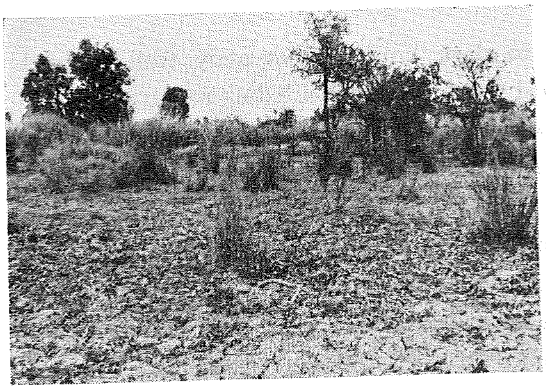


Fig. 11. A view of alluvial plain in the dry season. Scattered bushes and wildgrass in the background, and well cracked surface soil in the foreground.

distinct mottlings. The color of B and C horizons is reddish or yellowish mosaicked with grayish materials which is likely from resedimentation of weathered Tertiary materials. The compactness of the horizons increases with increasing depth.

The surface soil is dark reddish gray to dark reddish brown, friable heavy clay that is very hard when dry. The subsoil is slightly finer textured than the surface soil. It is reddish gray to reddish brown friable heavy clay and is extremely plastic, and extremely sticky when wet. The underlying material is mostly reddish brown, in places light gray cutanic material on the faces of ped, and manganese mottlings are found in these horizons. In some places, worm casts are between peds.

The soil of Sambok is of very fine texture, moderately well drained to poorly drained soil. As the texture is heavy, the clay increases with increasing depth. The underlying material is of brownish alluvial mixed with grayish shaly material.

The soil is one of the heaviest soils in the surveyed area, the clay content is more than 70 per cent throughout the profile. The value of bulk density is around 1.0, pH (H_2O) is relatively low as 4.5 to 5.1. The cation exchange capacity is 21 to 29 me/100 gm soil, and the base saturation is rather high ranging from 62 to 84 per cent that is attributable to the properties of parent materials. The amount of available manganese is very low, but that of phosphorous is fairly high.

The plasmic fabric is mo-ma-omnisepic, with plasma dominant basic fabric, and normal diffuse sesquioxidic nodules are pronounced throughout the profile. Being slightly evidenced plasma separation, however vosepic plasma separation is found in A11g and A12g horizons.

Representative profile of Sambok series (*profile number* 159) :

Area : Phum Prek Samman, Khum Kanhchor, Srok Chhlong. (106°02′ E. 12°16′ N.)

Vegetation : Bush as rang (*Garcinia hamburyi*), cha (*Butea frondosa*) and grass as sabou (*Imperata cylindrica*).

Parent material : Alluvium.

Topography : Flat alluvial plain.

A11g 0-10 cm, weak red (2.5YR 4.5/2), heavy clay ; moderate, blocky structure; few, fine pores; few, thready and cloudy mottlings; extremely sticky, extremely plastic; slightly compact (12 mm); abundant, roots; semi-dry; smooth clear boundary.

A12g 10-20 cm, reddish gray (5YR 5/2), heavy clay; moderate, blocky structure; few, fine pores; common, thready and filmy mottlings; extremely sticky, extremely plastic; slightly compact (17 mm); abundant, roots; semi-dry; smooth clear boundary.

Bg 20-33 cm, reddish brown (5YR 5/3) and reddish gray (5YR 5/2) heavy clay ; moderate, blocky structure ; few, fine pores ; few, mottlings ; extremely sticky, extremely plastic ; compact (22 mm) ; common, roots ; semi-dry ; smooth clear boundary.

C1g 33-58 cm, gray (10YR 5/1) from shale and dark yellowish brown (10YR 4/4), heavy clay ; weak, blocky structure ; few, fine pores ; few, mottlings ; extremely sticky, extremely plastic ; extremely compact (32 mm) ; few, roots ; semi-dry ; smooth diffuse boundary.

C2g 58 cm+, gray (10YR 5/1) seems to be shale, and dark yellowish brown (10YR 4/4), heavy clay ; weak, blocky structure ; few, fine pores ; few, mottlings ; extremely plastic ; extremely compact (32 mm).

Micromorphological description (*profile number* 159) :

A11g Mo-ma-omnisepic plasmic fabric, dominantly composing of plasma over skeleton grains which are very few less than 2 per cent. It has macro to meso-sized meta vughs, channels and planes, few papule yellowish brown in color and few, dark colored organic fragments with adhesive diffuse normal sesquioxidic nodules.

A12g Vo-mo-ma-omnisepic plasmic fabric and with the same basic fabric as above horizon, but morepronounced adhesive sesquioxidic normal nodules are common.

Bg Ma-mo-omnisepic plasmic fabric, dominantly composing of plasma over skeleton grains, and with macro meta vugh, channel and plane voids, 40 per cent on the area basis, with more pronounced normal nodule than the above horizon, and some segregated iron concretions with some papule in matrix.

C1g Mo-ma-omnisepic plasmic fabric, and plasma dominant basic fabric with few skeleton grains. Few, a kind of fecal pellets in vugh voids composing of silasepic isotic plasma, and some, more pronounced normal sesquioxidic nodule with concretions.

C2g Mo-ma-omnisepic plasmic fabric, and plasma dominant basic fabric. Some, organic fragments like root remains, macro-sized plane, vugh voids and meso channels, and some, pronounced normal nodules with some segregated into iron concretions.

Table 21. Chemical physical characteristics of Sambok soil (profile number 159)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	particle size distribution (mm) (%): Coarse sand (2–0.2)	Fine sand (0.2–0.02)	Silt (0.02–0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction: pH (H_2O)	pH (KCl)	Exch. acidity (y_1)
0—10	A11g	6.34	0.3	0.1	0.7	28.3	70.9	HC	1.05	4.50	3.22	22.1
10—20	A12g	6.68	0.1	0.1	0.8	25.5	73.6	HC	0.94	4.78	3.31	14.2
20—33	Bg	8.35	0.4	0.1	1.3	15.1	83.5	HC	1.11	4.99	3.37	11.5
33—58	C1g	8.37	0.1	0.2	1.0	15.2	83.5	HC	1.09	5.12	3.39	10.5
58+	C2g	8.52	2.2	0.2	2.0	11.4	86.4	HC	1.11	4.89	3.06	49.8

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap- (mg/100g)	Exchangeable cations (me/100g): Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g): MnO	P_2O_5
3.56	2.07	0.15	13.8	21.9	9.0	3.7	0.5	0.4	62	1249	1.9	5.9
2.56	1.49	0.14	10.6	23.1	10.1	5.7	0.9	0.4	74	1512	0	5.0
1.86	1.08	0.11	9.8	28.3	12.3	7.8	1.1	0.4	76	1374	0	3.0
1.63	0.95	0.10	9.5	28.6	13.2	9.0	1.7	0.4	84	1473	0	2.1
0.98	0.57	0.06	9.5	29.0	8.8	8.1	2.4	0.4	67	1328	0	0.6

Table 22. Chemical physical characteristics of Sambok soil (profile number 118)

(on oven-dry basis)

Depth	Horizon	H_2O	Gravel	Particle size distribution (mm) (%)					B. D.	Soil reaction		
				Coarse sand	Fine sand	Silt	Clay	Textural class		pH	pH	Exch. acidity
cm		(%)	(%)	(2-0.2)	(0.2-0.02)	(0.02-0.002)	(<0.002)		(gm/cc.)	(H_2O)	(KCl)	(y_1)
0—15	Ag	4.54	5.1	0	15.2	54.8	30.0	SiC	1.01	4.90	4.10	1.7
15—60	B11g	5.32	0	0.6	21.6	46.2	31.6	SiC	1.12	5.86	4.72	0.4
60—	B12g	7.21	0	0.6	7.4	39.2	52.8	HC	1.09	6.02	4.81	0.3

Humus	Organic carbon	Total nitrogen	C/N	Cation exch. cap.	Exchangeable cations (me/100g)				Base sat.	Phosphorous absorption coefficient	Available (mg/100g)	
(%)	(%)	(%)		(me/100g)	Ca	Mg	Na	K	(%)		MnO	P_2O_5
1.94	1.13	0.11	10.2	13.1	7.4	2.0	0.3	0.5	77	659	6.9	5.2
0.84	0.49	0.07	7.0	13.9	10.2	3.6	0.7	0.2	105	707	2.1	3.8
0.68	0.40	0.07	5.7	13.8	10.1	4.2	0.5	0.3	109	824	0.6	3.9

12) Russei Char Series

The Russei Char series consists of poorly drained, deep to very deep, dark reddish gray to reddish gray soils that are friable, and very hard when dry. These soils formed in alluvium and they are on nearly level to gently undulating in topography, and extended over all alluvial plains, especially on lower depression. The acreage amounts to 6,500 ha that is equivalent to 9.9 per cent of the surveyed area. Mostly bushes as taor, tamonpakoi, and wildgrass make up the natural vegetation. Russei Char soils mostly have never been used for agriculture, but a small acreage is planted to rice during the dry season. The soils are classified as low-humic gley soils, and are included in Aquic Ustropepts sub-group of the 7th Approximation.

Fig. 12. A man power irrigation for paddy field during the dry season.

The surface soil is dark reddish gray to reddish gray, iron mottled heavy clay. It is medium to strongly developed blocky, very hard when dry, and slightly acid. The subsoil, a reddish gray to reddish brown, iron mottled heavy clay, is slightly acid, and very hard when dry. It has fairly developed blocky structure, and is very compact and very hard when dry. In some places, some gravels are in the profile.

The soil of Russei Char series has moderately developed blocky structure in Ag horizon, and fine tubular or filmy mottlings are found within 50 cm from the surface, because the soil is flooded more than 2 m deep during the rainy season, and the ground water table fluctuates. The grayish color of B horizon possibly comes from the shaly parent material. There is no distinctly developed gleyzation throughout the profile during the dry season.

As described in morphology, clay is dominant throughout the profile and there is no profile differentiation from the point of particle size distribution. The soils are slightly acid, with cation exchange capacity of 20 to 24 me/100 gm soil, and with rather high base saturation ranging from 63 to 86 per cent. The available manganese content is very low to nothing, and the content of available phosphorous is fairly high.

The micromorphological characteristics are mo-masepic palsmic fabric, with plasma dominant basic fabric, and with vosepic plasma separation and some striated fluidal structure in the case of Blg and B2g horizons. Sesquioxidic normal nodules are found throughout the profile.

Representative profile of Russei Char soil (*profile number* 123) :

Area : Phum Prek Chik, Khum Saop, Srok Prek Prasap. (105°57′ E. 12°31′ N.)

Vegetation : Bushes as taor (*Terminaria chebula*), tamonpakoi and grass as sabou.

Parent material : Alluvium.

Topography : Gentle undulating lowland behind the natural levee.

Ag 0-14 cm, dark reddish gray (5YR 4/2), heavy clay ; moderate, blocky structure ; few, fine pores ; few, thready and filmy mottlings ; extremely sticky, very plastic ; compact (24mm) ; common, roots ; semi-dry ; smooth irregular boundary.

Blg 14-32 cm, yellowish red (5YR 4/6) and dark reddish brown (5YR 5/2), heavy clay ; moderate, blocky and fine blocky structure ; few, fine pores ; few, mottlings ; extremely sticky, extremely plastic ; very compact (25 mm) ; common, roots ; semi-dry ; smooth clear boundary.

B2g 32-50 cm, brown (7.5YR 4/6) and gray brown (7.5 YR 5/1), heavy clay ; moderate, blocky structure ; few, fine pores ; few, mottlings ; extremely sticky, extremely plastic ; very compact (27 mm) ; few, roots ; moist ; smooth diffuse boundary.

B3g 50 cm+, brown (7.5YR 4/6) and gray brown (7.5YR 5/1), heavy clay ; massive ; extremely sticky, extremely plastic; very compact (37mm) ; moist.

Micromorphological description (*profile number* 123) :

Ag Mo-ma-omnisepic plasmic fabric, plasma dominant basic fabric with few skeleton grains. Some more or less decomposed brownish organic fragments and root remains. With sorting structure due to sedimentation, macro to meso-sized vugh, plane, and channel voids, and some normal sesquioxidic nodules.

Blg Vo-mo-omnisepic plasmic fabric, plasma dominant basic fabric with 5-10 per cent skeleton grains on the area basis, with more pronounced adhesive normal sesquioxidic nodules than the above, weaky to moderately developed papule, and few, vosepic plasma. Some to common, macro-sized vughs and meso-sized vughs and channel voids.

B2g Ma-omnisepic plasmic fabric with some striated likely fluidal structure, and plasma dominant basic fabric having few skeleton grains. Common, macro to meso-sized meta vugh voids and many micro to meso plane voids. Some, pronounced normal sesquioxidic nodules and weakly developed papules (Fig. 37).

B3g Mo-omnisepic plasmic fabric, with striated plasma separation and few, vosepic neocutanic plasma concentration, and some papules. Common, strongly developed normal adhesive nodules including segregated iron concretions, and with macro to meso-sized meta vugh and plane voids.

Table 23. Chemical physical Characteristics of Russei Char soil (profile number 123)
(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-14	Ag	8.42	0	tr.	1.8	30.1	68.1	HC	0.91	4.48	5.01	0.3
14-32	B1g	10.47	0	0.1	6.6	23.0	70.3	HC	1.03	5.19	5.08	0.3
32-50	B2g	9.79	1.9	tr.	4.3	22.6	73.1	HC	1.11	5.21	6.09	0.6
50 +	B3g	9.91	0	tr.	0.8	30.6	68.6	HC	1.09	5.30	7.19	0.2

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
2.86	1.66	0.16	10.3	21.5	8.4	3.9	0.7	0.6	63	982	1.6	5.8
0.99	0.68	0.09	6.4	20.6	10.7	5.6	1.1	0.4	86	1005	0	3.5
1.13	0.66	0.08	8.2	23.1	9.9	6.2	1.6	0.4	78	1197	0	3.8
1.25	0.75	0.07	10.4	24.7	11.6	3.5	2.0	0.4	70	1298	0	1.5

13) Krakor Series

The Krakor series consists of well drained, moderately deep to very shallow, dark reddish brown to reddish brown and gravelly coarse textured soil that is friable, hard when dry. These soils formed in material from old alluvium overlying Tertiary and Mesozoic deposits. They are at elevation of 35 to 40 m on gentle sloping or undulating hilly lands in Prek Prasap, Kanhchor, and Chhlong districts. The acreage of these soils amounts to 6,300 ha that is equivalent to 9 per cent of the surveyed area.

Fig. 13. Hardwoods open forest on the Krakor soil in the dryseason.

The natural vegetation is mainly hardwoods such as kron, chreak, and shrubs. These lands have never been utilized for agriculture because of the lack of irrigation water.

The surface soil is dark reddish brown to reddish brown loamy sand, in some places, gravelly. It is friable and slightly acid. The subsoil is reddish brown gravelly loamy sand, it is non sticky, friable but hard when dry, and slightly acid. Underlying the subsoil, at a depth between 15 and 50 cm is gravelly indurated layer or of weathered Tertiary and/or Mesozoic material.

The Krakor soils have a thin organic-mineral A1 horizon and slightly light colored A2 horizon coarse textured. Although the B2t horizon is gravelly, it is finer textured than the above as shown in the data of mechanical analysis. It can be suggested that not all the clay in B2t horizon is translocated and accumulated, but some are from parent material *in situ*, because the argillaceous cutan is not distinctly developed, and the boundary between B2t and IIC horizons is not abrupt. They are classified as red podzolic soils, and are included in Typic Rhodustalfs subgroup of the 7th Approximation.

The soils are subdivided into two soil types (Krakor-1 and Krakor-2) on the basis of thicknees of top soil and gravel content; that is, the thickness of top soil for krakor−1 is more than 50 cm, that of Krakor-2 is less than 50 cm.

The Al horizon of Krakor soil is 12 cm thick, of coarse texture, and with low humus content. The A2 horizon is weakly developed over the B2t horizon whose color is 5YR to 2.5YR 4/4, and unweathered fine gravel content in volume increases with increasing depth. It can be noticed that parent material of IIC is different from the horizons, because of redder color and finer texture. Argillaceous cutan on the faces of ped in the B2t horizon is an evidence of high clay content and characteristics of textural B horizon.

Although the gravel content of B2t horizon is 42 per cent, the clay is much more accumulated in this horizon. With the pronouncing evidence of clay coating on the peds, it is characterized by the mechanical properties for the B2t horizon. The soil reaction of these horizons is slightly acid, the base saturation is rather high. The amount of available manganese as well as available phosphorous is very low.

The micromorphological characteristics of A horizon are of skeleton grains dominant basic fabric, with mo-masepic plasmic fabric in the A horizon, so it is like granular fabric by Brewer[2]. There is a distinct evidence of argillan sesquioxidic on their skeleton grains for B2t horizon, and for IIC horizon, and some cutans on skeleton grains are recognized. Some lithorelicts exist throughout the profile but no nodules.

Representative profile of Krakor soil (*profile number* 108) :

Area : Khum Kratie, Srok Kratie. (106°04′ E. 12°30′ N.)

Vegetation : Shrub and open forest, kron (*Dipterocarpus tuberculatus*) and chreak (*Terminalia tomentosa*).

Parent material : Old alluvium over Tertiary or Mesozoic deposit.

Topography : Flat plain on the hill, elevation 35 to 40 m.

A1 0-12 cm, dark reddish brown (5YR 3/2), loamy sand ; very weak, fine granular structure ; few, fine pores ; very compact (26mm) ; non sticky, non plastic ; abundant, roots ; dry ; wavy clear boundary.

A2 12-25 cm, reddish brown (5YR 4/3), loamy sand ; weak, blocky structure ; few, fine pores ; few, fine unweathered gravel ; non sticky, non plastic ; very compact (28mm) ; common, roots ; dry ; smooth diffuse boundary.

B2t 25-55 cm, reddish brown (5YR 4/3) and reddish brown (2.5YR 4/4), sandy clay ; weak, blocky structure ; few, clay coating on the faces of peds ; non sticky, non plastic ; very compact (25mm) ; abundant, fine and medium unweathered gravel ; few, roots ; semi-dry ; smooth diffuse boundary.

IIC 55 cm+, reddish brown (3.5YR 4/3), light clay ; weak, blocky structure ; reddish brown (5YR 5/3) on peds ; very sticky, very plastic ; compact (24mm) ; common, fine unweathered gravel ; moist.

Micromorphological description (*profile number* 108):

A1 Mo-masepic porphyroskelic fabric that is like granular fabric, with skeleton grains dominant basic fabric, with macro-sized meta vughs and channels, and with light yellowish brown plasma with some organic fragments.

A2 Plasmic fabric same as above; skeleton grains dominant basic fabric likely granular fabric by BREWER. Some plant tissue remained organic fragments and meta vughs and channels (Fig. 39, 40).

B2t Ma-vosepic porphyroskelic fabric, with some sesquioxidic argillan on skeleton grains. Plasma is more yellowish than the above horizon, medium birefringence. Few, sesquioxidic stained lithorelicts.

IIC Mo-ma-omnisepic porphyroskelic fabric that is with basic fabric of 30 to 40 per cent skeleton grains on the area basis. Plasma is yellowish brown, some weakly oriented on skeleton grains, some reddish brown pisolith like pedorelicts, some meta vughs and channels, and few, organic fragments.

Table 24 Chemical physical characteristics of Krakor soil (profile number 108)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B. D. (gm/cc.)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-12	A1	1.39	0	34.5	51.5	7.7	7.3	LS	1.39	5.45	4.48	0.7
12-25	A2	1.50	6.1	37.4	48.5	9.4	9.7	LS	1.40	5.40	4.40	0.8
25-55	B2t	5.25	42.1	33.5	24.1	6.1	36.3	SC	1.21	5.49	4.24	2.5
55+	IIC	5.34	11.0	12.4	21.8	25.9	39.9	LiC	1.29	6.82	6.02	0.6

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
1.03	0.60	0.06	10.0	2.9	2.7	0	0.3	0	103	228	1.3	1.2
0.77	0.45	0.04	11.2	5.5	3.3	0	0	0.2	63	205	0.3	0.6
0.41	0.24	0.02	12.0	16.1	13.8	0.6	0.4	0.1	94	1139	0	0.8
0.27	0.16	0.01	16.0	28.2	31.0	0.4	0.6	0.3	114	855	0	2.0

14) Keng Series

In the Keng series are somewhat excessively drained to well drained, very deep to moderately deep, dark brown to dark gray soils that are moderately acid. These soils are gently sloping to slightly undulating, and are in Saop and Kratie (on the right bank of the Prek Te) districts. The acreage amounts to 1,500 ha that is equivalent to 2.3 per cent of the surveyed area. The natural vegetation is mainly dense hardwoods, and bushes as prou, cha, and in places, mixed with wildgrass. They are formed mainly from old alluvium. The soils are classified as red-yellow podzolic soils, and are included in Typic Haplustalfs sub-group of the 7th Approximation.

The surface soil is dark brown to dark gray, very friable to loose loamy sand that is of low humus and slightly acid. The A2 horizon is dark brown slightly lighter than the above, and is generally the same texture as the surface soil, but in places, it is slightly coarser than the surface soil. It has weakly developed blocky structure, and the horizons are friable throughout, and soft when dry. The texture in the B horizon increases with increasing depth, and clay coatings are on the faces of ped, especially prominent argillaceous cutans are on the peds.

The soil of Keng series has an extremely thin A1 horizon overlying A2 horizon that is 20 cm thick. The B1 horizon is 10YR 5/4 to 5/7 in color, and of coarse texture. The B2 horizon has relatively high clay content and prominent clay skin on the ped surface. The A2 horizon is not prominently differentiated, and there are no mottlings within 1 meter. The B horizon is yellowish brown in color, with no distinct structural development. As the texture is coarse, they are not hard in compactness, the B2 horizon is a little finer in textural class then the above horizons. Being under dense forest, the soils are not completely dry during the dry season.

It is distinctly noted that the clay content of B2 horizon is much higher than the above horizons as shown in the particle size distribution. The soils are low in exchangeable acidity, and slightly acid. The value of CEC varies between 1.6 and 3.9 me/100 gm soil, and the base saturation is low, less than 50 per cent except A1 horizon showing 79 per cent. The amount of available manganese as well as phosphorous is very low to scarce.

The micromorphological characteristics of Keng soil are that mo-ma-omnisepic porphyroskelic fabric is developed in the A horizon, but B1 horizon has skel-vosepic porphyroskelic to intertextic fabric which shows pronounced argillaceous and sesquioxidic cutans, and these skel-vosepic porphyroskelic to intertextic fabric are more developed in the B2 horizon.

Representative profile of Keng soil (*profile number* 121) :

Area : Khum Saop, Srok Prek Prasap. (105°58′ E. 12°33′ N.)

Vegetation : Shrubs as prou (*Dllenia ovata*), propal (*Hopea recopei*), potrear (*Zizyphus jujuva*) and grass as sabou (*Imperata cylindrica*).

Parent material : Old alluvium.

Topography : Slightly undulating on hill land.

A1 0-4 cm, dark brown (7.5YR 3/2), loamy sand; very weak, fine granular structure; non sticky, non plastic; loose (5mm); abundant, roots; dry; smooth clear boundary.

A2 4-25 cm, dark brown (7.5YR 4/2), loamy sand; weak, blocky structure; few, fine pores; non sticky, non plastic; compact (23mm); common, roots; semi-dry; smooth diffuse boundary.

B1 25-58 cm, yellowish brown (10YR 5/7 and 10YR 5/4), loamy sand; massive; few, fine pores; non sticky, non plastic; compact (22mm); very few, roots; semi-dry; smooth diffuse boundary.

B2 58 cm +, yellowish brown (10YR 5/7 and 10YR 5/4), sandy loam; massive; few, fine pores; non sticky, non plastic; very compact (28mm); moist.

Micromorphological description (*profile number* 121) :

A1 Mo-omnisepic porphyroskelic fabric; brown plasma is very low birefringence; few, biorelict organic fragments and some, dark brown ligneous matter.

A2 Ma-isotic porphyroskelic fabric with meta macro-sized vughs and channels; yellowish brown plasma is low birefringence, with some skeleton grains and humified organic fragments (Fig 38, 41)

B1 Ma-skel-vosepic porphyroskelic to intertextic fabric, with some skeleton grains; common, macro-sized vughs, some argillaceous-ferric cutans.

B2 Skel-vosepic porphyroskelic to intertextic fabric, with some argillaceous, iron rich cutans having strong extinction band; plasma is of rather low birefringence; few to some, papules brownish yellow in color; common, meta macro-sized vughs and some skeleton grains.

Table 25. Chemical physical characteristics of Keng soil (profile number 121)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-4	A1	1.16	3.8	35.4	51.2	5.5	7.9	LS	1.33	5.49	5.04	0.4
4-25	A2	7.62	1.5	35.4	52.7	6.2	5.7	LS	1.37	4.80	4.17	2.3
25-58	B1	6.66	2.2	35.8	51.4	4.8	8.0	LS	1.43	5.08	4.19	2.2
58 +	B2	1.28	3.8	32.1	49.0	5.3	13.6	SL	1.38	4.73	4.63	4.9

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
1.62	0.94	0.08	11.7	3.9	2.8	0	0	0	79	182	3.2	2.8
0.36	0.21	0.04	5.2	2.1	0	0.4	0	0.1	23	194	tr.	2.9
0.13	0.08	0.02	4.0	1.6	0.5	0	0	0	31	192	tr.	2.9
0.13	0.08	0.03	2.6	2.6	0.3	0.3	0.1	0.2	38	182	0	3.4

15) Tuol Series

The Tuol series consists of moderately well drained to slightly poorly drained, moderately deep to shallow, dark brown to gray brown loamy sand in places gravelly that is friable and hard when dry. These soils are formed in material from old alluvium over half-weathered shale and sandstone of Tertiary bed. Depth to the bedrock ranges from 25 to 50 cm. They are at elevation of 30 to 35 m associated with lower terrace and alluvial plain in Kratie and Saop districts. The acreage of the soils amounts to 8,800 ha that is equivalent to 13 per cent of the surveyed area. The natural vegetation is mainly deciduous and shrubs such as klong, chlek, and in places, mixed with wildgrass. The soils are classified as red-yellow podzolic soils, and are included in Lithic Haplustalfs sub-group of the 7th Approximation.

The surface soil is dark brown to gray brown loamy sand, slightly gravelly, and slightly acid. It is friable but hard when dry. The subsoil is pinkish gray to light yellowish brown gravelly loamy sand. It is medium to slightly acid. The gravel content increases with increasing depth as well as the compactness increases with depth.

The A1 horizon of Tuol series is dark brown, of coarse texture, and with weakly developed granular and blocky structure. The A2 horizon is not distinctly developed morphologically, but lighter color than the above horizon. With increasing depth, clay content as well as fine unweathered gravel increase. The soil is associated with the hill lands, and alluvial plain, as a result, few fine tubular and cloudy mottlings are found in the A1 horizon, and common, in the B1 horizon. The B hroizons are very hard as much as 30 to 32 mm reading measured by YAMANAKA's cone-penetrometer. These lands are under muddy water more than 1 meter deep during the rainy season.

Fig. 14. A soil of Tuol series (No. 125), which underlies Tertiary bedrock.

Assuming the results for the soil profile number 130, it is characterized by that the exchangeable acidity is very low, nearly neutral in the case of the underlying horizon, the value of cation exchange capacity is less than 8 me/100 gm soil, and the base is saturated. The amount of available manganese and phosphorous is not sufficient throughout the profile.

Representative profile of Tuol soil (*profile number* 124) :

Area : Phum Prek Chik, Khum Saop, Srok Prek Prasap. (105°56′ E. 12°31′ N.)

Vegetation : Grass as sabou (*Imperata cylindrica*).

Parent material : Old alluvium over Tertiary or Mesozoic deposit.

Topography : Flat plain on the hill side.

A1 0-15 cm, dark brown (7.5YR 2.5/3), loamy sand; weak, fine granular structure and weak, fine blocky structure; few, mottlings; non sticky, non plastic; very compact (25mm); abundant, roots; dry; wavy clear boundary.

A2 15-27 cm, strong brown (7.5YR 5/6) and pinkish gray (7.5YR 6/2) 3 : 1; loamy sand; few, fine gravel; massive; non sticky, non plastic; very compact (27mm); few, roots; dry; smooth clear boundary.

B1 27-36 cm, light brown (7.5YR 6.5/3), sandy clay loam; weak, blocky structure; few, fine pores; common, yellowish red (5YR 5/6) thready and strong brown (7.5YR 5/6) cloudy mottlings; abundant, fine and medium rounded gravel; sticky, plastic; extremely compact (30mm); semi-dry; few, roots; smooth diffuse boundary.

B2C 36 cm+, light gray (10YR 7/2) and yellowish red (5YR 4/6) 3 : 1, sandy clay loam; abundant, fine and medium rounded gravel; weak, blocky structure few, fine pores; very sticky, plastic; extremely compact (32mm); semi-dry.

Table 26. Chemical physical characteristics of Tuol soil (profile number 130)

(on oven-dry basis)

Depth cm	Horizon	H_2O (%)	Gravel (%)	Particle size distribution (mm) (%) Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	Textural class	B.D. (gm/cc)	Soil reaction pH(H_2O)	pH(KCl)	Exch. acidity (y_1)
0-15	A	0.80	1.0	16.8	59.0	17.2	4.7	SL	1.39	5.92	4.93	0.3
15-24	B11	2.55	6.2	18.0	46.7	18.9	16.4	SCL	1.36	7.03	5.04	0.2
24-34	B22	2.08	2.2	19.2	47.6	19.9	13.3	SL	1.44	8.38	6.20	0.2
34 +	B23	3.16	1.8	16.7	45.0	17.3	21.0	SCL	1.39	9.26	7.30	0

Humus (%)	Organic carbon (%)	Total nitrogen (%)	C/N	Cation exch. cap. (me/100g)	Exchangeable cations (me/100g) Ca	Mg	Na	K	Base sat. (%)	Phosphorous absorption coefficient	Available (mg/100g) MnO	P_2O_5
1.03	0.60	0.06	10.0	3.3	0	2.6	0.6	0.1	100	136	2.0	2.8
0.68	0.40	0.04	10.0	6.2	3.2	0.8	3.4	0.1	120	230	4.6	2.6
0.18	0.11	0.02	5.5	6.0	3.1	0.7	3.7	0.1	126	242	1.1	3.6
0.12	0.07	0.01	7.0	8.1	6.2	1.0	4.6	0.2	148	326	3.5	3.8

IV. Capability Groups of Soils

The capability classification is a system of grouping to show how suitable soils are for most kinds of farming in a general way. It is a practical grouping for upland crops and paddy rice based on the physical and chemical properties of soils, on the needs and limitations of soils, on the risks of damage to them, and also on their response to management.

The soils are classified into class I, II, III and IV by its productive capability for rice, and upland crops on the basis of the suitability items and suitability decisive factors which show the restrictive and impeding factors as the following items inhering in the soil.

Upland crops	*Paddy rice*
Thickness of top soil (t)	Thickness of top soil (t)
Effective depth of soil (d)	Effective depth of soil (d)
Gravel content in top soil (g)	Gravel content in top soil (g)
Facility of plowing (p)	Permeability (i)
Wetness of land (w)	State of redox potentiality (r)
Inherent fertility (f)	Wetness of land (w)
Content of available nutriments (n)	Inherent fertility (f)
Hazards (j)	Content of available nutriments (n)
Slope of land (s)	Presence of harmful substances (h)
Erosion (e)	Frequency of accidents (a)

Note : Parenthesis ( ) indicates abbreviation of items.

Soils are graded into four groups on the basis of the existence or absence of restrictive or impeding factors against production of reasonable amount of crops or a reasonable control of the soil and the extent of possibility of the degradation of the soil. The four classes in the capability system are described as follows :

Class I : Soils are those that have the widest range of use and the least risk of damage because of having none or virtually no restrictive or impeding factors having no possibility of soil degradation. They can be cultivated with almost no risk of erosion and will remain productive if managed with normal care.

Class II : Soils can be cultivated regularly, but they do not have quite as wide a range of suitability as class I soils. Some soils need moderate care to prevent erosion, may be slightly drought, slightly wet or somewhat limited in depth.

Class III : Soils can be cropped regularly but have a narrow range of use than the soils in class II. They need even more careful management.

Class IV : Soils have greater natural limitations than those in class III but can be cultivated for some crops under very careful management.

The soils were placed in the following capability class.

For paddy field

Soil series	Simplified formula	Capability class
Moreum soils	IIIa* IIwn	II
Prek Chamlak soils	IIIa* IItw	II
Stung Preah soils	IIIfna* IIwi	III
Roha soils	IIIa* IIwn	II
Sambok soils	IIIa* IIwn	II
Russei Char soils	IIIa* IIwn	II

For upland field

Pongro soils	IIt(w)	II
Bos Leav soils	IItp(w)	II
Pou soils	IVdpg(w) IIIti	IV
Prek Chamlak soils	IIIp* IIti(w)	II
Sre Prang soils	IVd IIIpt(w) IIgfi	IV
Kampi-1 soils	III(w*)tdpfni	III
Kampi-2 soils	IVtd(w*) IIIfnie	IV
Sambok soils	IIItip IIn(w)	III
Krakor-1 soils	IV(w*) IIItfni IId	III
Krakor-2 soils	IVtd(w*) IIIfnie IIgs	IV
keng soils	IIIfn(w*) IIt	III
Tuol soils	IV(w*) IIItdfni IIpse	III

(w) indicates grade of dryness, not of wetness.

(w*) indicates that grade of dryness can possibly be raised to one grade higher class without difficulty.

a* indicates that risk of flooding can be eluded for land utilization.

p* indicates that grade of facilities of plowing can be raised to one grade higher class without difficulty.

The total acreage in each capability class is given in the list as follows :

Acreage in each capability class

For paddy field

Class	Soil series	Acreage (ha)
Class II	Moreum soils	1,000 ha
	Prek Chamlak soils	900
	Roha soils	4,600
	Sambok soils	24,000
	Russei Char soils	6,500
	Total	37,000
Class III	Stung Preah soils	300
	Total	300

For upland field

Class	Soil series	Acreage (ha)
Class II	Pongro soils	2,500
	Bos Leav soils	5,300
	Prek Chamlak soils	(900)
	Total	7,800
Class III	Chong Kaoh soils	400
	Kampi-1 soils	1,500
	Sambok soils	(24,000)
	Krakor-1 soils	3,300
	Keng soils	1,500
	Tuol soils	8,800
	Total	15,500
Class IV	Pou soils	300
	Sre Prang soils	1,100
	Kampi-2 soils	1,000
	Krakor-2 soils	3,000
	Total	5,400
	Total for the Area	66,000

Note : Parenthesis ( ) indicates soil classified in duplicate for both paddy field and upland field.

1) Paddy Field Uses of the Soils

Class II

Moreum Soils

The Moreum soils are very poorly drained, deep to very deep, fine textured soils.

The surface horizon is 15 cm thick, and effective depth of soil is as thick as 1 m. Although the area is flooded for months of the year, the soils have little effect of ground water, and no gley horizon throughout the profile during the dry season. The soils are grouped as class II when used as paddy field. It is difficult to use the soils as upland field because they are one of the poorest drained soils in the Area.

The natural vegetation is shrubs such as roten, snag, and aquatic plants as sarmour, and proandat. Nearly the whole areas have not been used for agricultural purposes. The permeability of the soils in this unit is slow to very slow. The available water holding capacity and fertility are generally slightly low. Root penetration is shallow to slightly deep. Brush control is needed on some sites to use the soil for agricultural development. Flooding is a problem in this area. It is difficult to drain perfectly the soil since it is situated in the lowland, the soils are best suited to dry seasonal rice cultivation. It is necessary to apply fertilizer that contains potassium and nitrogen to increase the yield.

Prek Chamlak Soils

The Prek Chamlak soils are moderately well drained, moderately deep to deep very fine textured, and extremely sticky soils. The surface horizon is 15 cm thick and effective depth of soil is 1 m or more. The soils contain a large quantity of clay, and as a result they have fairly large capacity for retaining available water. They have a large amount of exchangeable bases, and are high in natural fertility, except that available phosphorous is slightly deficient. Situated on a flat plain, the soils have little risk of erosion.

Use of plant residues, and animal manure increases the fertility, and improves the physical property of the soils. Brush control is needed in most places to increase agricultural potentiality for the soils. Fertility can be increased or maintained by applying commercial fertilizers. Irrigation facilities are required to increase yield of upland crops during the dry season. The soils are moderately fertile. and are suited to upland crops as well as paddy rice, but much more irrigation water is required than for upland crops.

The natural vegetation consists of thin wood such as sonkar, cha, and wildgrass as sabou. The soils are not utilized for agricultural purposes at present.

Roha Soils

The Roha soils are moderately drained to poorly drained, moderately deep, very fine textured soils. The surface horizon is 15 cm thick, and effective depth of soil is 1 m. Permeability of the soil is slow, since they are very fine textured and have a compacted layer immediately below the plow layer. As the soils contain low organic matter, they are not strongly reduced during the rainy season. Both the inherent fertility and content of available nutriments are low as those in the Stung Preah soils.

In most places rice is cultivated during the rainy season. It is possible to grow rice in the dry season, if irrigation facilities are constructed. As the soils are not fertile, it is necessary to apply organic matter, and fertilizer that contains nitrogen, and phosphate, to improve the fertility. Practices similar to those for the Stung Preah soils are required on these soils.

Sambok Soils

The sambok soils are moderately well drained, deep dark gray to dark brown soils. The surface horizon is 15 cm thick, and effective depth of soil is as thick as 1 m or more. The soils are very fine textured, and also very sticky, as a result they are difficult for the cultivation of upland crops. They do not contain much organic matter, and are not in a strongly reduced condition. The fertility of these soils is not as good as on the Russei Char soils. It is more advantageous to utilize these soils for paddy field.

The natural vegetation consists of shrubs such as tumonkantock, cha, and wildgrass. A small acreage of the soils is planted to upland crops, and to paddy rice as well. It is possible to harvest rice during the dry season on the area adjacent to streams or reservoirs. If drainage and irrigation facilities are provided, and water is controlled, rice can grow during the rainy season. This area is situated higher level in topography, since the drainage for this area is easier than for the Russei Char soils. Rice cultivation all the year round requires application of nitrogen as well as phosphorous, and potassium fertilizers. When the soils are used for upland fields, the indurated hard subsoil that is formed by alternate wetting and drying, interfere with tillage. One of possible measures which are relatively easy to practice is to disk raw rice straw with a spade year after year.

Russei Char Soils

The Russei Char soils are poorly drained, deep very fine textured, dark reddish gray soils. The effective depth of soil is thick, and strong gley horizon is not developed throughout the profile. The soils are very fine textured and extremely sticky, but with low organic matter, and may not be strongly reduced. Whereas slightly deficient in potassium and available phosphorous, the soils are slightly fertile. The soils have very high water holding capacity. Permeability is slow to very slow, and fertility is moderate to low. Root penetration is moderate to moderately deep. Many places are covered with muddy water during the rainy season from June to November. The soils as used for paddy field is classified as class II.

Bush control or the thining of dense brush in places increases the rice yield, and extends the acreage of paddy field. Careful management is required to maintain yield. The natural vegetation is mainly shrubs as taor, tamonpakoi, and wildgrass. Upland rice is cultivated in a limited place at present. Some places are heavily flooded during the rainy season, so it is required to provide drainage facilities or to provide water control. If account is seriously taken of the production increase of rice, it is necessary to provide some irrigation facilities. Upland field farming is also possible if the drainage condition is completely improved during the dry season. It is difficult however to carry out perfect drainage. It is more advantageous to utilize the soils as paddy field. First of all, fertilizer that contains nitrogen and phosphorous should be applied to increase the yield.

Class III

Stung Preah Soils

The Stung Preah soils are well drained, deep to moderately deep loamy soils. The surface horizon is 15 cm thick, medium textured, and effective depth of soil is 1 m or more. The horizon immediately below the plow layer is very fine textured, and compacted which prevent with permeability and penetration of roots. Although the soils have been cultivated as paddy fields, no gley horizons have developed noticeably. As the soils contain a small amount of organic matter, its reduction does not occur much progressively. Being low in inherent fertility and in available nutriments, the soils are classified as class **III**.

The permeability of these soils is moderate to rapid. Fertility is generally moderate to low. Almost the whole area is cultivated every year, but the soils are less fertile than that of other soils. The soils are not important from the agricultural standpoint, since they cover a small acreage, and are scatteringly distributed on valley plain in the hill lands. If these soils are well managed, and fertilizer that contains nitrogen, and phosphate is applied, the yield of rice increases. If irrigation water is available in the dry season, high production can be expected. Disking in green manure, also animal manure increases fertility and organic matter content.

2) **Upland Field Uses of the Soils**

Class II

Pongro Soils

The pongro soils are well drained, deep to moderately deep, medium textured soils. The thickness of top soil is less than 15 cm, and effective depth of soil is more than 1 m. Coarse alluvial materials which are different from place to place, are more than 1 m deep. The surface horizon is excessively dry in the dry season, but the subsoil is semi-dry, and granular structure is well developed with excrement of earthworms. The soils are almost neutral, have a high value of calcium saturation, and contain a large amount of exchangeable magnesium and available phosphorous throughout the profile. The permeability, available water holding capacity, and natural fertility is moderate to low. Root penetration is moderately deep to deep. Some places are flooded in the rainy season, but have little possibility of erosion because of flat in topography.

The natural vegetation is mainly shrubs such as kapok, and kwatt. A small acreage is planted to upland crops such as maize, upland rice, and other crops. Under good management the upland field is fairly productive. Yield of upland crops increases if fertilizer that contains nitrogen and phosphate is applied. Disking in plant residues, green manure, and animal manure increases fertility, and the content of organic matter. In most places, the soils are well suited to irrigated upland crops during the dry season.

As the soils are suitable for common upland crops, irrigation and drainage facilities must be constructed to enable upland crop to grow through the year. The soil fertility in some places is improved when flooded with muddy water, and more fertile soils may be obtained if colmatage is carried out in a large scale. But more advanced upland cropping systems are taken, when colmatage is not only the way to improve soil fertility, it is necessary to consider an intensive fertilization suitable to each crop.

Bos Leav Soils

The Bos Leav soils are well drained, deep to moderately deep, fine textured soils. The surface horizon is approximately 20 cm thick, and effective depth of soil is as thick as 1 m or more. The soils are fine textured, and so sticky that farming machines encounter with resistance not only during the dry season, but also during the rainy season. The permeability of the soil is moderate to moderately rapid. The available water holding capacity and fertility are mostly moderate to low. Root penetration is moderately deep. These soils are best suited to common upland crops, and in places they are of the most productive. Cereal crops and other upland crops on these soils respond well to fertilizer that contains nitrogen, and phosphate. The use of crop residues improves the fertility and tilth of the soils. A small acreage of these soils is irrigated.

The subsoils are moist even in the dry season, and with granular structure well developed from earthworm activities. The soils contain a large amount of exchangeable calcium and magnesium, and available phosphorous, but not contain much organic matter. Being nearly level in topography, the soil has little possibility of erosion. Natural vegetation is shrubs such as cha, song, khtom, and in some places upland crops such as peanuts, and maize are cultivated during the dry season. The problems concern these soils are the same as those in the Pongro soils, and of particular importance is to construct irrigation and drainage facilities for annual rice cultivation. At present, it is satisfactory to rely upon colmatage in order to maintain and increase fertility, but for intense high cultivation better fertilizations are required.

Prek Chamlak Soils

Refer to 1) paddy field uses of the soils

Class III

Chong Kaoh Soils

The Chong Kaoh soils are excessively drained to well drained coarse textured soils, but the soils are flooded for long periods every year because they are at a low elevation of 10 to 12 m. The permeability of the soils is rapid, but the available water holding capacity is low. As most places of this soil are in the inundation area, it is very difficult to use the soil for agricultural cultivation. Sparse wildgrasses make up the natural vegetation. The soils can be worked for few months during the dry season, but lack of irrigation water and low humus content limit use of these soils.

Kampi-1 Soils

The Kampi-1 soils are moderately well to well drained, moderately deep to shallow fine textured soils. They are subdivided into two soil types on the basis of thickness of top soil and effective depth of soil. The thickness of top soil and effective depth of soil are relatively small; the former is approximately 15 cm, and the latter not greater than 50 cm. The surface soil is fine textured, and sticky. In the dry season, the horizon immediately below the surface soil becomes so hard as to interfere with tillage, and restrict root penetration to a greater extent.

The permeability is moderately slow, and its available water holding capacity is relatively high, and the soil at a depth of approximately 30 cm is semi-dry in the dry season. The soils have a relatively high degree of calcium saturation, but are deficient in exchangeable magnesium, and available phosphorous, and they are not very fertile. The soils are on nearly flat in topography, situated on the transitional area to the hill lands, thereby erosion is not likely to happen. Shrubs such as pring, klong, chreak, and wildgrass grow on these soils.

The gravelly hard pan layer must, first of all, be destroyed or removed for normal agricultural utilization on the soils. It is necessary to apply organic matter as well as base-enriched material, and phosphorous to improve the fertility. Crops on the soils respond if fertilizer that contains nitrogen and phosphate is applied. Crop residues, and green manure crops should be returned to the soil, because they supply organic matter and maintain good tilth.

Sambok Soils

Refer to 1) paddy field uses of the soils

Krakor-1 Soils

The Krakor soils are well drained, moderately deep to very shallow, gravelly coarse textured soils. The soils are subdivided into two soil types, Krakor-1 and Krakor-2 soils, on the basis of thickness of top soil and effective depth of soil.

The thickness of top soil and effective depth of soil are approximately 15 cm and 50 cm respectively. The first horizon is coarse textured, non sticky. The soils have a good permeability, and available water holding capacity is low. The soils are likely to become dry considerably in the dry season, it is probably to a depth of 60 cm. The soils contain a small quantity of exchangeable magnesium and available phosphorous, so they are not much fertile. As the soils are on nearly flat on the hill lands, it is not flooded even in the rainy season. Being excessively dry in the dry season, the natural vegetation is mostly open forest such as klong, chreak, and the soils are not cultivated. Bush control or thinning dense stands of hardwoods is needed to extend the farming area on the soils, and to increase production of crop or hay. Careful management is required to maintain fertility and prevent erosion.

Rounded gravel layer is at a depth of 30 to 50 cm from the surface, so it must be removed for good agricultural use. Introduction of upland crops into this area requires the application of fertilizer that contains nitrogen and phosphate, and construct irrigation facilities. But these soils are not economically evaluated as they are on terraces far from water resources.

Keng Soils

The Keng soils are well drained, very deep coarse textured soils. The surface soil is approximately 20 cm thick, and effective depth of soil is more than 1 m deep. The soils have a good permeability, but are unable to hold much available water, and the surface soil is likely to become much dry. Being deficient in exchangeable calcium, magnesium and available phosphorous, the soils are not very fertile. Lack of irrigation water, dense forest and low fertility limit use of these soils. Under good management the upland field is fairly productive. The yields increase if fertilizer that contains nitrogen and phosphate is applied. Attention should paid to construction of irrigation facilities, to augmentation of organic matter content, and to application of soil improving materials that contain calcium, magnesium, and phosphate.

Tuol Soils

The Tuol soils are moderately well drained to poorly drained, moderately shallow loamy sand soils. The thickness of top soil is 10 to 20 cm. A gravel layer is at a depth of 15 to 25 cm, and effective depth of soil is small. The surface soil is coarse textured, and slightly acid. The subsoil is neutral or slightly alkaline.

The soils have a relatively good permeability, but have a small value of available water holding capacity. The soils are likely to become excessively dry as deep as 60 cm during the dry season. The soils are greatly deficient in exchangeable calcium, available phosphorous, and organic matter. Shrubs such as klong, and wildgrass as sabou make up the natural vegetation on the soils. The soils have not been utilized for agricultural cultivation. The surface layer of the soils is penetrated well by roots and water, but the subsoil restricts penetration. The use of organic matter or plant residues maintains good tilth and fertility.

Class IV

Pou Soils

The Pou soils are well drained, gravelly or cobbly shallow soils. The surface soil is 3 cm thick, and contains half-weathered basaltic gravels. The horizon immediately below the surface soil is abundant in unweathered gravels originated from shale and sandstone of the Tertiary and basaltic rock. The effective depth of soil is so thin that the soils are not suitable generally for agricultural cultivation. The permeability is moderately slow. The natural fertility of this soil is moderately high. The available water holding capacity is rather high. In most places the soils contain a large amount of subangular half-weathered gravel. The soils are suited to pasture or to crops that require a minimum of tillage. They have a high value of cation exchange capacity, and are abundant in exchangeable calcium, and magnesium, and available phosphorous. The natural vegetation is mostly thin woods, shrubs such as sonkar, and chenko.

Sre Prang Soils

The Sre Prang soils are moderately well drained to well drained shallow soils. The thickness of surface horizon is only 15 cm, and a half-weathered gravel rich layer comes immediately below the surface soil, and depth to a bedrock is 45 cm. The soils have a large value of cation exchange capacity and are good in inherent fertility, but it is difficult to utilize the soils as upland field, because the effective depth is shallow. The natural vegetation consists of shrubs and wildgrass, and the soils have never been used for agricultural purposes until now. Flooding is a problem of these soils. In some places on a gentle slope, the soils can be worked if tillage is shallow and done carefully. Fertility can be maintained by applying commercial fertilizers. Brush control is necessary to increase agricultural potentiality.

Kampi-2 Soils

The Kampi soils are moderately well to well drained, moderately deep to shallow fine textured soils. The soils are subdivided into two soil types, Kampi-1 and Kampi-2 soils, on the basis of thickness of top soil and effective depth of soil. The Kampi-2 soils are moderately well drained, shallow, fine textured.

The surface soil is approximately 15 cm thick, but the effective depth of soil is very shallow. Depth to the bedrock is 30 cm below the surface. The soils are extremely deficient in calcium, magnesium, and phosphorous. Root penetration is shallow. The soils are subject to erosion. The permeability of the soils generally moderate to moderately slow. The same kind vegetation as in the Kampi-1 soils is found, and no area of the soils is utilized for agricultural cultivation. Fertility can be maintained by applying commercial fertilizers, and animal manure. Bush control or thinning dense bush is needed to increase agricultural potential on the soils.

Krakor-2 Soils

The Krakor soils are well drained, moderately deep to very shallow gravelly coarse textured soils. The soils are subdivided into two soil types, Krakor-1 and Krakor-2 soils, on the basis of thickness of top soil and effective depth of soil.

The thickness of top soil that overlies hard gravel pan layer is 15 cm, relatively small, and effective depth of soil is nothing more than the surface soil. The surface soil is of coarse texture and slightly acid. The permeability is slightly smaller than the Krakor-1 soils and the soils are subject to much dry during the dry season. Depth to bedrock or indurated horizons is very shallow so that the growth of plant roots is heavily impeded. The natural vegetation, in most places, is thin hardwoods as in the Krakor-1 soils.

V. Microflora and Microbial Activities of Soils

Soil samples for microbiological analysis were taken in the dry season and put into a polyethylene bag and were sent to Japan by air-mail. Microbiological analysis was done as soon as possible after arrival of these samples. The soils were sampled during the middle of the dry season, and most soils in the field were in well dried that is nearly close to air-dried condition. It is assumed that microfloral change may be very small until the time of microbial analysis.

Materials and Methods

Soils are passed a 2 mm sieve, 40 gm were put into 360 ml sterilized water, and shaken for 10 minutes. Then $10^{-1} \sim 10^{-6}$ dilution series are made at 10^{-1} dilution intervals. From each dilution series 1 ml is taken into petri-dish or test tube. Microbes examined, media used, and cultural methods for the study are as follows:

Bacteria and actinomycetes: plate method using albumin agar[25]; counting was made after 7 days incubation at 28°C.

Fungi: plate method using Smith & Dawson's media[17]; counting was made after 3 and 5 days incubation at 28°C.

Dye-tolerant bacteria: plate method using albumin agar +1/80,000 crystal violet; counting was made after 7 days incubation at 28°C.

Spore-former: plate method; counting was made on albumin agar after 7 days incubation at 28°C. Before inoculation of soil suspension, each dilution series is heated at 80°C for 10 minutes.

Obligate anaerobe : deep tube method using bouillon agar +0.25% sodium thioglycolate ; counting was made after 7 days incubation at 28°C.

Sulphate reducer : the dilution method using modified STARKEY's media [19] added 0.02% yeast extract ; sealed by liquid paraffin after inoculation of soil suspension ; counting was made after 9 days incubation at 28°C.

Nitrifier : the dilution method using modified MEIKLEJOHN's media[7] ; counting was made after 28 days incubation at 28°C.

Denitrifier : the dilution method using nitrate bouillon media, sealed by liquid paraffin after inoculation of soil suspension ; counting was made after 9 days incubation at 28°C.

Azotobacter : smeared with 10^{-1}~10^{-2} soil suspension on the agar plate, using BROWN's media [3] ; counting was made after 2~3 days incubation at 28°C.

Algae : the dilution method using modified CHU's media which does not contain any nitrogen [26] ; counting was made after 28°C incubation outdoors.

In addition to these microbial analysis, microbial activity such as oxygen intake by soil, urease activity of soil as well as nitrogen mineralization of air-dried soil are determined.

Oxygen intake activity : oxygen intake by soil is determined by Warburg method which was established by TANABE and ISHIZAWA[21].

Fresh soil of 10~15 gm is placed into 60 m*l* vessel and soil moisture content is adjusted at about 50% of maximum water-holding capacity of the soil. Filter paper which is rolled up about 2 cm diameter is put on side-arm of the vessel and is wetted by 0.2~0.5 m*l* of 20% KOH solution. Vessels are incubated in a water bath which is accurately controlled to 30°C. After about 45 minutes the temperature of every part of the vessel becomes constant. Then shaking the vessel, the calibration curve is obtained by the 30 minutes interval determination.

Soil treatment is as follows : (1) control ; (2) the soil is adjusted at pH 6.5 with $CaCO_3$; (3) (2)+0.2% glucose. If pH is over 6.5, treatment of (2) is omitted. Oxygen intake rate of this treatment series for the soils of the first layer is determined.

Urease activity : it is determined by TANABE & ISHIZAWA's method [21]. Fresh soil of 10 gm on the dry soil basis is taken into 200 m*l* flask. Added 2~4 m*l* of toluene, and the flask is thoroughly shaken. After 10~15 minutes standing, 10 m*l* of *M*/5 phosphate buffer solution which is adjusted at pH 6.5 and controlled to 45°C, is added to the flask. After vigorous shaking, 10 m*l* of 10% of urea solution is added. The flask is then incubated at 40°C for 48 hours. After incubation 10 m*l* of 1% of $HgCl_2$ solution is added as soon as possible. The KCl solution is added and filled up to 200 m*l*, except for toluene. After 30 minutes, it is filtered and is then available for the determination of NH_3-N according to CONWAY-BREMNER's method [1].

Urease activity is determined for the first and second layer of each soil series.

Nitrogen mineralization of air-dried soil : soils of the first and second layer are allowed to air-dry. Air-dried soils of 25 gm on the dry basis are taken into beaker and incubated tion at 28°C. Before inoculation of soil suspension, each dilution series is heated at 80°C for 10 minutes.

Obligate anaerobe : deep tube method using bouillon agar +0.25% sodium thioglycolate ; counting was made after 7 days incubation at 28°C.

Sulphate reducer : the dilution method using modified STARKEY's media [19] added 0.02% yeast extract ; sealed by liquid paraffin after inoculation of soil suspension ; counting was made after 9 days incubation at 28°C.

Nitrifier : the dilution method using modified MEIKLEJOHN's media[7] ; counting was made after 28 days incubation at 28°C.

Denitrifier : the dilution method using nitrate bouillon media, sealed by liquid paraffin after inoculation of soil suspension ; counting was made after 9 days incubation at 28°C.

Azotobacter : smeared with $10^{-1}\sim10^{-2}$ soil suspension on the agar plate, using BROWN's media [3] ; counting was made after 2~3 days incubation at 28°C.

Algae : the dilution method using modified CHU's media which does not contain any nitrogen [26] ; counting was made after 28°C incubation outdoors.

In addition to these microbial analysis, microbial activity such as oxygen intake by soil, urease activity of soil as well as nitrogen mineralization of air-dried soil are determined.

Oxygen intake activity : oxygen intake by soil is determined by Warburg method which was established by TANABE and ISHIZAWA[21].

Fresh soil of 10~15 gm is placed into 60 m*l* vessel and soil moisture content is adjusted at about 50% of maximum water-holding capacity of the soil. Filter paper which is rolled up about 2 cm diameter is put on side-arm of the vessel and is wetted by 0.2~0.5 m*l* of 20% KOH solution. Vessels are incubated in a water bath which is accurately controlled to 30°C. After about 45 minutes the temperature of every part of the vessel becomes constant. Then shaking the vessel, the calibration curve is obtained by the 30 minutes interval determination.

Soil treatment is as follows : (1) control ; (2) the soil is adjusted at pH 6.5 with $CaCO_3$; (3) (2)+0.2% glucose. If pH is over 6.5, treatment of (2) is omitted. Oxygen intake rate of this treatment series for the soils of the first layer is determined.

Urease activity : it is determined by TANABE & ISHIZAWA's method [21]. Fresh soil of 10 gm on the dry soil basis is taken into 200 m*l* flask. Added 2~4 m*l* of toluene, and the flask is thoroughly shaken. After 10~15 minutes standing, 10 m*l* of *M*/5 phosphate buffer solution which is adjusted at pH 6.5 and controlled to 45°C, is added to the flask. After vigorous shaking, 10 m*l* of 10% of urea solution is added. The flask is then incubated at 40°C for 48 hours. After incubation 10 m*l* of 1% of $HgCl_2$ solution is added as soon as possible. The KCl solution is added and filled up to 200 m*l*, except for toluene. After 30 minutes, it is filtered and is then available for the determination of NH_3-N according to CONWAY-BREMNER's method [1].

Urease activity is determined for the first and second layer of each soil series.

Nitrogen mineralization of air-dried soil : soils of the first and second layer are allowed to air-dry. Air-dried soils of 25 gm on the dry basis are taken into beaker and incubated

under water-logged condition at 30°C for 28 days. After 28 days incubation the amount of NH_3-N of the soil is determined by CONWAY BREMNER's method[1].
The difference of amount of NH_3-N between the beginning and the end of incubation is expressed as nitrogen mineralization capacity of the soil under water-logged condition.

Results and Disccusion

1) Microflora of Soil Groups and Soil Series.

It is noted that azotobacter could not be detected in any samples. Microbial counts, pH, and water content of wet as well as air-dried soil are shown in Table 27-1, in the case of alluvial soils, lithosols and vertisols.

① **Alluvial Soils**

Pongro series: as shown in Table 27-1, moisture content of wet soil was much close to that of air-dried soil. Each microbial count of the first layer was quite high. The count of bacteria was greatest among all examined soils, and was of the order 10^7 per 1 gm of dry soil. The count of actinomycetes was almost equal to that of bacteria, and was greatest among all examined soils. The count of fungi, dye-tolerant bacteria was all of the order 10^5. The count of nitrifier, denitrifier and algae was of the order 10^4. That of bacteria and actinomycetes remarkably decreased in the second layer, but it increased again in the third layer. The count of fungi, anaerobe and sulphate reducer decreased with soil depth. The count of dye-tolerant bacteria and denitrifier increased with depth.

Bos Leav series: the soils are not so dry as Pongro series, but count of bacteria of the first layer was lower than that of Pongro series. The value of S/B (count of bacterial spore/count of bacteria) showed that percentage of bacterial spores occupied 97% of total bacterial count. Its value did not change very much towards the third layer. The count of actinomycetes was of the same order as that of bacteria. The count of fungi and dye-tolerant bacteria was of the order 10^5 and 10^6 respectively. The count of anaerobe was highest among all examined soils. The count of sulphate reducer was very low. The count of nitrifier and denitrifier was of the order 10^3 and 10^4 respectively. The count of algae was of the order of 10^5, and was greatest among all samples. All microbial count decreased with increasing depth, but only the count of denitrifier was maximum at the second layer.

Moreum series: the soils are flooded severely during the rainy season, hence the soil moisture content is considerably high. The pH of the surface soil was very low. The count of bacteria of the first layer was the lowest among alluvial soils. But the value of S/B was only 1%. The count of actinomycetes was of the same order as that of bacteria. The count of fungi was of the order 10^5, and showed highest value among alluvial soils. The count of dye-tolerant bacteria, anaerobe, sulphate reducer, nitrifier, denitrifier, and algae was of the order 10^5, 10^5, 10^3, 10^4, $>10^6$ and 10^4 respectively. Each microbial count remarkably decreased on the second layer.

② **Lithosols**

Pou series: every soil layer is remarkably dry, but the count of bacteria was highest, and was of the order 10^7. About 30% of total count of bacteria was in a state of

Table 27-1 Microflora of Cambodian soil (1)

Soil group	Soil Series	Land use	Soil depth cm	Soil moisture content: Wet %	Soil moisture content: Air-dried %	pH	Bacteria $\times 10^5$	Actinomycetes $\times 10^5$	Fungi $\times 10^4$	Dye tolerant bacteria $\times 10^4$	Spore former $\times 10^4$	Anaerobe $\times 10^3$	Sulphate reducer $\times 10^2$	Nitrifier $\times 10^2$	Denitrifier $\times 10^3$	Algae* $\times 10^3$
Alluvial Soils	Pongro	cultivated upland field	0~15	3.9	3.1	6.5	250	240	15	71	270	350	960	210	52	56
			15~38	4.3	2.4	6.5	29	12	5.6	77	$<10^4$	52	360	230	190	39
			38~58	13	5.4	6.4	130	99	5.8	110	60	20	6.8	71	360	—
	Bos Leav	cultivated upland field	0~14	12	3.9	5.9	76	65	22	110	740	500	9.0	39	27	600
			14~29	12	5.5	5.7	4.8	12	7.2	8.0	46	51	4.3	15	820	2.5
			29~46	11	3.2	5.4	5.3	9.3	6.2	3.7	33	24	**	6.8	3.5	—
	Moreum	Swamp	0~13	29	10	4.7	57	52	69	28	6.3	180	28	670	>2500	25
			13~30	21	9.5	5.1	1.6	12	4.1	$<10^4$	2.5	7.3	1.2	14	1900	**
			30~43	22	2.5	5.3	7.2	11	3.1	27	0.6	27	2.7	31	76	—
Lithosols	Pou	Open forest	0~3	4.3	4.2	7.7	140	110	110	170	400	460	1900	18	77	56
			3~20	5.5	5.3	7.8	50	120	1.8	39	96	97	70	8.8	31	1.2
			20~	6.4	6.4	7.6	35	220	0.2	33	4.4	43	1.4	9.0	2.7	—
Vertisols	Prek Chamlak	Open forest†	0~14	8.0	6.0	5.7	130	46	25	40	9.3	180	54	53	60	110
			14~30	12	6.6	5.9	2.3	5.2	3.2	1.2	9.5	77	**	13	2.9	0.02
			30~49	7.4	6.3	5.4	2.9	2.5	1.9	2.1	7.6	—	—	—	—	—
	Sre Prang	Grass land	0~3	9.5	8.7	4.9	43	46	30	22	160	25	7.1	30	40	390
			3~15	19	9.4	4.9	2.6	5.0	3.3	1.3	2.1	49	1.3	**	5.4	0.04
			15~32	21	11	5.1	1.8	4.5	1.9	2.5	3.4	52	0.2	9.1	1800	—

* Algae which can grow on nitrogen free media
** Microbe not detected at 10^{-1} dilution of soil suspension
† But flooded in the rainy season

spore. The count of actinomycetes was of the same order of that of bacteria. Both count of fungi and dye-tolerant bacteria was of the order 10^6, and was greatest among all examined soils. The count of anaerobe, sulphate reducer, nitrifier, denitrifier, and algae was of the order $10^5, 10^5, 10^3, 10^4$ and 10^4 respectively. The count of sulphate reducer was highest among all soils. Except for the count of actinomycetes, each microbial count decreased remarkably on the second layer.

③ **Vertisols**

Prek Chamlak series : soil moisture of the second layer was somewhat higher than that of air-dried soil. The soil are also flooded for a while in the rainy season. The count of bacteria was of the order 10^7, and the value of S/B was less than 1%. The count of actinomycetes was somewhat lower than that of bacteria. The count of fungi, dye-tolerant bacteria, and anaerobe was all of the order 10^5, and that of sulphate reducer, nitrifier, denitrifier, and algae was of the order $10^3, 10^3, 10^4$ and 10^5 respectively. Each count decreased in the second layer.

Sre Prang series : the second and third layers were not so dry, and bacterial count of the first layer was of the order 10^6, and about 40% was attributed to bacterial spore. The count of actinomycetes was of the same order as that of bacteria. The count of fungi, and dye-tolerant bacteria was [of the order 10^5. The count of anaerobe and sulphate reducer was of the order 10^4 and 10^2, and was the lowest among all examined soils. The count of nitrifier, denitrifier, and algae was of the order $10^3, 10^4$ and 10^5 respectively. Such microbes as bacteria, actinomycetes, and nitrifier decreased towards the third layer, but anaerobe and denitrifier increased with increasing depth.

In the case of low-humic gley soils and red-yellow podzolic soils the count of microbe is shown in Table 27-2.

④ **Low-humic Gley Soils**

Stung Preah series : the soils were, remarkably dried. They are likely to be flooded often. Bacterial count of the first layer was of the order 10^6, and the value of S/B was about 20%. The count of actinomycetes was lower than that of bacteria, and it was the lowest among examined soils. The count of fungi, dye-tolerant bacteria, and anaerobe was all of the order 10^5. The count of sulphate reducer, nitrifier, denitrifier, and algae was of the order $10^3, 10^3, 10^5$ and 10^4 respectively. The number of microbes except anaerobe and nitrifier decreased toward the third layer.

Kampi series : the soils are on hill lands, and are not often flooded, but microbial number of the soils was almost the same trend as Stung Preah series. The count of sulphate reducer and denitrifier was remarkably less than that of Stung Preah series.

Roha series : the soil are also flooded in the rainy season, but flooding is not so severe as in Russei Char series. The count of bacteria of the first layer was of the order 10^6, and on the other hand, that of actinomycetes was 10^7 and the value of A/B (count of actinomycetes/count of bacteria) become remarkably higher. The value of S/B was less than 10%. The count of fungi, dye-tolerant bacteria, and anaerobe was of the order $10^4, 10^5$ and 10^4. The count of sulphate reducer was the greatest among low-humic gley soils, and amounted to the order of 10^4. The count of nitrifier was

Table 27-2 Microflora of Cambodian soil (2)

Soil group	Soil Series	Land use	Soil depth cm	Soil moistuse content Wet %	Air-dried %	pH	Bacteria ×10^5	Actino-mycetes ×10^5	Fungi ×10^4	Dye to lerant bacteria ×10^4	Spore former ×10^4	An-aerobe ×10^3	Sulphate reducer ×10^2	Nitrifier ×10^2	Denitri-fier ×10^3	Algae* ×10^3
Low-humic gley soils	Stung Preah	Paddy field	0~15	2.9	1.5	4.8	23	18	14	56	43	170	74	35	350	62
			15~20	3.2	0.82	4.9	4.2	5.5	2.4	8.8	8.5	10	5.1	13	170	0.2
			20~30	7.5	0.75	5.4	1.5	2.8	0.8	2.5	1.7	20	2.4	22	12	—
	Kampi	Open forest	0~8	3.8	1.5	5.4	14	22	8.1	28	$<10^4$	290	1.5	20	25	96
			8~18	5.8	3.5	6.0	5.3	15	5.5	4.7	4.2	34	3.5	74	26	3.3
			18~35	12	5.0	5.7	2.6	13	3.1	7.6	0.7	170	**	**	49	—
	Roha	Paddy field	0~15	3.1	2.2	5.6	26	120	2.1	59	19	34	290	6800	890	—
			15~18	4.9	2.4	6.6	28	130	2.1	87	17	6.7	83	19	19	3.5
			18~28	7.0	5.2	7.7	24	47	4.3	20	17	23	1.5	9.9	50	—
	Sambok	Paddy field	0~10	3.0	2.4	4.0	14	35	20	11	2.4	430	35	510	190	—
			10~18	3.6	3.1	4.9	5.9	16	4.9	6.3	11	49	4.1	64	18	2.3
			18~40	7.3	5.5	4.7	1.8	4.3	5.7	0.5	1.4	28	85	57	27	—
	Russei char	Open forest†	0~14	15	8.4	4.9	18	40	6.3	2.1	1.2	35	130	0.8	11	2.6
			14~32	18	10	4.6	13	17	4.3	18	0.2	59	38	0.1	2.9	**
			32~50	18	9.8	5.2	13	12	2.5	4.3	0.1	100	0.2	0.4	13	—
Red-yellow podzolic soils	Krakor	Open forest	0~12	1.6	1.4	5.5	11	38	14	23	23	230	24	16	20	8.5
			12~25	2.5	1.5	5.4	12	41	4.0	32	14	210	23	600	10	2.2
			25~55	5.5	5.3	5.5	3.9	6.0	2.0	1.4	0.5	15	2.7	4.0	>1900	—
	Keng	Open forest	0~4	3.2	1.2	5.9	50	26	20	13	65	380	11	9.3	28	4.1
			4~25	7.6	7.6	5.1	9.0	9.8	7.2	0.7	18	320	5.0	3100	55	0.8
			25~58	6.7	6.7	5.1	2.2	5.8	0.5	2.2	0.8	22	0.8	4700	8.8	—
	Tuol	Open forest	0~15	2.4	0.8	6.2	72	51	3.3	140	88	190	20	0.4	51	160
			15~24	2.8	2.6	7.4	2.5	7.8	2.8	5.2	2.3	21	0.5	3.9	1.4	3.4
			24~34	2.1	2.1	8.4	2.2	7.1	1.5	2.0	0.2	3.6	0.2	19	36	—

* Algae which can grow nitrogen free media.
** Microbe not detected at 10^{-1} dilution soil suspension.
† But flooded in the rainy season.

highest among all examined soils, and was of the order 10^5, and denitrifier was of the order 10^6.

Sambok series: the soil are flooded during the rainy season. The value of pH of the first layer was 4.0 which was the lowest among all soils. Soil moisture content of this soil is close to that of air-dried soil. The count of bacteria was of the order 10^6 and the value of S/B was only about 2%. Actinomycetes was higher than bacteria. sulphate reducer, The count of fungi, and dye-tolerant bacteria was of the order 10^5. That of anaerobe,✓ nitrifier, and denitrifier was of the order $10^5, 10^3, 10^4$ and 10^5 respectively. Except sulphate reducer, the count of other microbes decreased towards the third layer.

Russei Char series: the soils are heavily flooded during the rainy season. The count of bacteria of the first layer was of the order 10^6. The value of S/B was less than 1%. The count of actinomycetes was greater than that of bacteria, and that of fungi dye-tolerant bacteria, anaerobe, and sulphate reducer was all of the order 10^4. The count of dye-tolerant bacteria was the lowest among all soils. The count of nitrifier, and denitrifier was very low and denitrifier was the smallest among all soils. Algae was also very few, and the count of bacteria, and actinomycetes were not different throughout the soil layer. Anaerobe increased with increasing depth.

⑤ Red-Yellow Podzolic Soils

Krakor series: the soils were dry throughout the profile. The count of bacteria was of the order 10^6, and was the smallest among all examined soils. The value of S/B was 21%, and that of actinomycetes was much higher than bacteria. The count of fungi, dye-tolerant bacteria, and anaerobe was of the order 10^5 respectively. The count of sulphate reducer, nitrifier, and algae was all of the order 10^3, and that of denitrifier was of the order 10^3.

Keng series: the number of microbes was very similar to krakor soils. But the count of nitrifier in the second and third layer was of the order 10^5, and was much higher than that of Krakor series.

Tuol series: soil moisture content was very low throughout the profile. The value of pH of the first layer was 6.2 and become higher toward the third layer. The count of bacteria was of the order 10^6.

The value of S/B was 12%. The count of fungi was of the order 10^4, the lowest among all examined soils. The count of dye-tolerant bacteria, anaerobe, and sulphate reducer was of order $10^6, 10^5$ and 10^3 respectively. Nitrifier was very few, the lowest among the soils. The count of denitrifier, and algae was of the order 10^4, and 10^5 respectively. The count of all microbes remarkably decreased in the second layer.

⑥ Comparison among Soil Groups and among Different Land Use

Because of the number of soil is limited, it is difficult to compare the microbial characteristics among the soils. It is significantly influenced by environmental conditions such as land use or flooding during the rainy season. Microflora of the soil in different land use was compared, that is between uncultivated and cultivated upland fields both of which are flooded during the rainy season, and also flooded wastelands. Uncultivated upland field is open forest except Sre Prang series, one of vertisols.

Pongro and Bos Leav series of alluvial soil are cultivated fields. Moreum series of alluvial soil, and Russei Char series of low-humic gley soil are in open forest, and

Table 28. Comparison of microflora between Cambodian and Japanese soils

Land use	Country	Bacteria ×10⁵	Actino-mycetes ×10⁵	Anaero-be ×10⁴	Fungi ×10⁴	Spore former ×10⁴	Nitri-fier ×10²	Denitri-fier ×10³	Sulpha-te reducer ×10²	A/B	An/B	S/B
Uncultivated upland Field	Cambodia	55	51	26	31	150	16	40	180	0.92	4.7	27
	Japan	120	23	83	14	—	0.8	120	0.2	0.19	6.9	—
Cultivated upland field	Cambodia	160	150	43	19	510	120	40	490	0.93	2.8	32
	Japan	220	48	150	23	—	140	710	3.2	0.43	6.7	—
Flooded field	Cambodia	45	52	15	26	14	1400	670	93	1.1	3.3	3.1
	Japan	300	26	210	8	140	180	110	370	0.08	7.0	4.6

are flooded during the rainy season. Stung Preah, Sambok, and Roha series are used for paddy field. The average microbial numbers of three soils which are uncultivated, cultivated upland field and prolonged flooded field, are shown in Table 28. As reference the average number of microbes of non-volcanogenous soil of Japan is shown in the same Table. Microbial analysis was carried out on Japanese soils collected in autumn after harvest.

As shown in Table 28 uncultivated upland soil was abundant only in fungi, and on the contrary cultivated soil was abundant in other microbes such as bacteria, actinomycetes, spore former, sulphate reducer, and algae. It seems that cultivated upland field is much fertile than uncultivated upland field. Flooded soil was adundant in nitrifier and denitrifier, but very few in sulphate reducer. It can be assumed that much vigorous nitrification and denitrification must have happened under submerged condition in the rainy season. Severe nitrogen loss may have happened under submerged condition in the rainy season, especially when nitrogen fertilizer was applied.

As for the ratio between each microbial count, the value of A/B (count of actinomycetes/count of bacteria) was nearly 1 for three land use group soils. The value of An/B(count of anaerobe/count of bacteria) was the lowest in cultivated upland field where is probably in an aerobic condition. The most significant difference could be observed between the ratio of S/B (count of bacterial spore/count of total bacteria) of the three group soils. The value of S/B of the flooded field was only 3.1%, the smallest among three group soils. About 97% of bacteria is considered to be viable under prolonged dry condition. One of the reason why flooded soil should have smaller value of S/B, can be attributed to more or less higher soil moisture content at the sampling time. The value of S/B of uncultivated as well as of cultivated upland field where the soil moisture content was very low, 32 and 27% respectively. Therefore it is possible that the soil moisture content controls the value of S/B of any soil. In the case of upland fields, about 70% of bacteria which developed on albumin agar seem to be viable under such extremely dry conditions. It must be studied further whether such a viable cell can decompose organic matter under such extremely dry condition or not. The microbial counts of Cambodian soils were compared with those of Japanese soils, which are in the temperate zone. Regardless of land use, bacteria and anaerobe were not abundant, but actinomycetes were more abundant in Cambodian soils than in Japanese soils. In the case of uncultivated upland fields, fungi, nitrifier, and sulphate reducer were much abundant, but denitrifier was not abundant. In the case of cultivated upland fields, fungi, nitrifier, and denitrifier were not abundant, but sulphate reducer was much abundant. In the case of flooded fields, fungi, nitrifier, and denitrifier were very abundant, but sulphate reducer was not abundant for the former. As a result of vigorous nitrification and denitrification, much nitrogen loss may occur under waterlogged conditions in Cambodian paddy fields, and especially when nitrogen fertilizer is applied to the soil.

As for the ratio between microbial count, the value of A/B was greater and that of An/B was smaller in Cambodian soils than in Japanese soils, whatever land use was. The value of S/B is very similar when it is flooded field. It can be suggested that the lower value of An/B and lower count of anaerobe and sulphate reducer in Cambodian soils reflect slight reduction of flooded soil under submerged condition. As a matter of fact, the development of reductive layers which are characteristics for paddy soil, was not progressed strongly in Cambodian soils than in Japanese paddy soils.

2) **Oxygen Intake Activity of Soils**

Oxygen intake activity of the soil was determined for 4 hours at an interval of

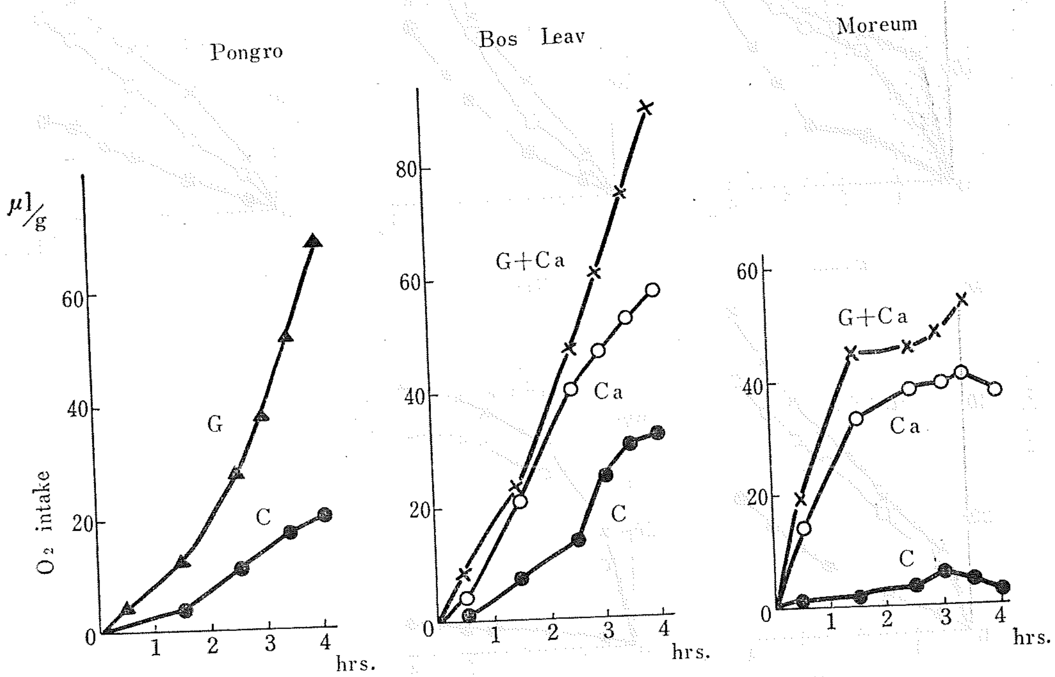


Fig. 15. Oxygen intake of surface soil of alluvial soils

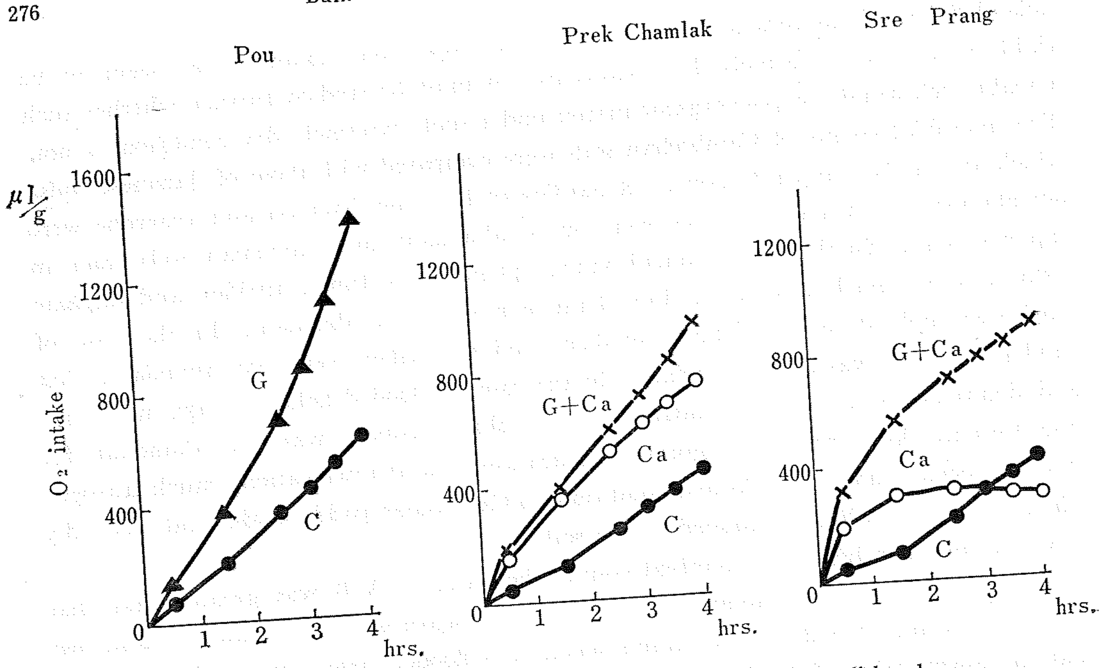


Fig. 16. Oxygen intake of surface soil of vertisols, and a lithosol

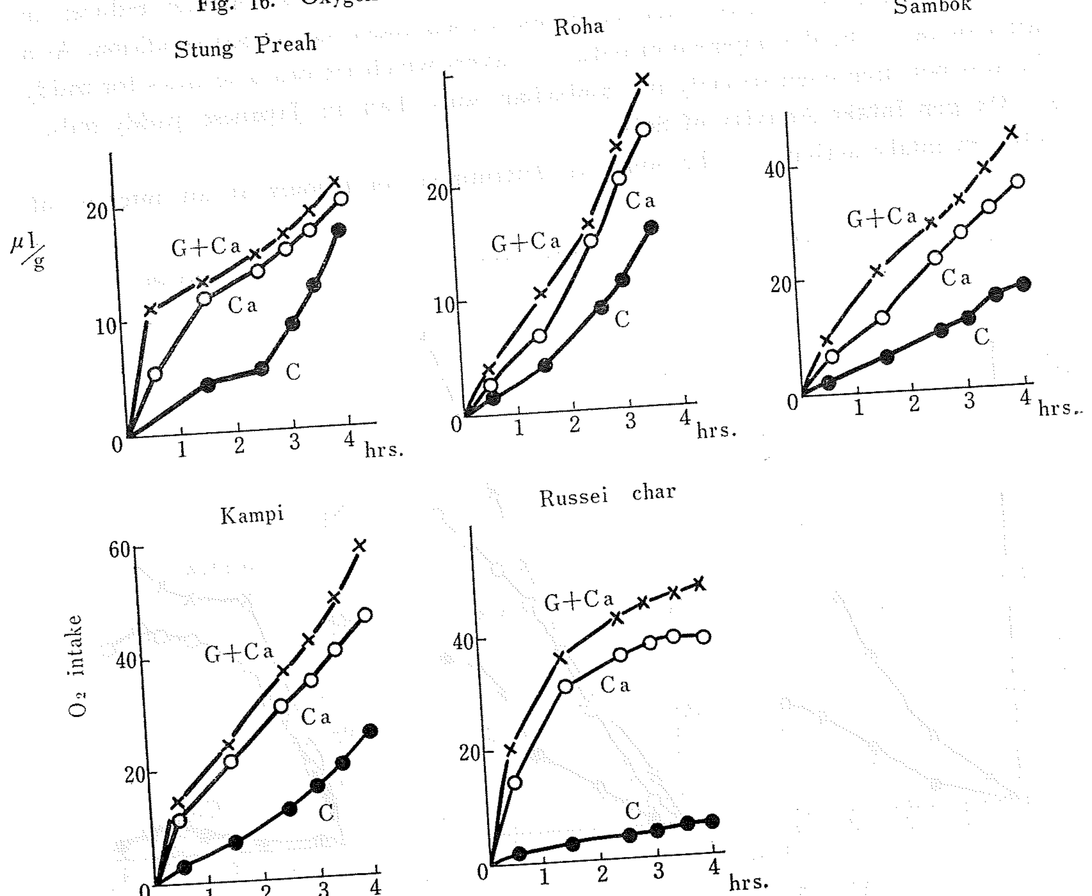


Fig. 17. Oxygen intake of surface soil of low-humic gley soils

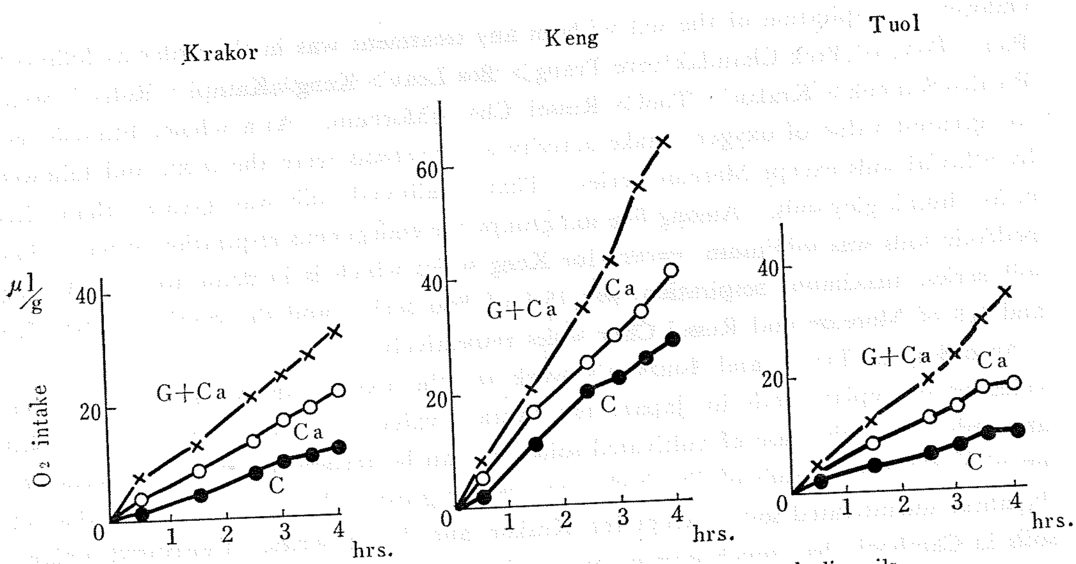


Fig. 18. Oxygen intake of surface soil of red-yellow podzolic soils

Table 29. Oxygen intake activity of the soils

(μl/g of dry soil/hr.)

Soil group	Soil Series	Land use	Control	+Lime	Glucose + Lime
Alluvial Soils	Pongro	Cultivated upland field	10.3	—	18.8*
	Bos Leav	Cultivated upland field	7.5	14.5	22.5
	Moreum	Swamp ††	1.0	12.2	14.3
Lithosols	Pou	Open forest	16.5	—	35.0*
Vertisols	Prek chamlak	Open forest †	11.0	19.0	25.0
	Sre Prang	Grass land	10.0	—	22.5
Low-humic gley Soils	Stung Preah	Paddy field †	4.0	5.0	5.5
	Kampi	Open forest	5.5	11.0	14.5
	Roha	Paddy field †	5.0	5.5	7.0
	Sambok	Paddy field †	3.8	8.5	10.5
	Russei Char	Open forest ††	1.3	12.0	14.0
Red-yellow Podzolic Soils	Krakor	Open forest	3.0	5.0	7.5
	Keng	Open forest	6.0	10.0	15.0
	Tuol	Open forest	2.5	5.0	7.5

† Not so heavily flooded in the rainy season
†† Heavily fooded in the rainy season
* Only glucose was added

half an hour. The results are shown in Fig. 15 to Fig. 18. The average value of oxygen intake activity of dry soil per hour is also shown in Table 29. As shown in Table 29, endogenous respiration of the soil without any treatment was in the order as follows: Pou >Pongro≒Prek Chamlak≒Sre Prang> Bos Leav> Keng≒Kampi> Roha >Stung Preah≒Sambok> Krakor> Tuol> Russei Char≒Moreum. As a whole, lithosols had the greatest value of oxygen intake activity and vertisols were the next, and followed by alluvial soils except Moreum series. That of alluvial soils was greater than that of low-humic gley soils. Among five soil groups, the endogenous respiration of red-yellow podzolic soils was minimum, except for Keng series which is in dense forest. Among soil series, maximum respiration was 16.5 of Pou series, and the minimum was 1.0 and 1.3 of Moreum and Russei Char series respectively.

According to TANABE and ISHIZAWA's work on the oxygen intake activity of non-volcanogeous upland soils in Japan, the average value of uncultivated soils was 4.5 and only 1.9 in the case of cultivated soils. It can be recognized that each value of uncultivated upland soils of Cambodia was rather greater than that of the value of Japanese uncultivated soils, except for Krakor and Keng series. Cultivated upland soils in Cambodia had much greater oxygen intake activity than those of Japan. The soils of upland fields in Cambodia were close to an air-dried condition. The effect of air-drying upon oxygen intake activity must be considered, because of the fact that the air-drying increased the amount of available carbon and nitrogen source.

Lime addition to the soil accelerated endogenous respiration of acid soil, especially in the case of Russei Char, and Moreum series. It is assumed that most parts of soil organic matter in both soils can not be easily decomposed by soil microbes. The acceleration of endogenous respiration by the addition of lime was not so great in the case of Stung Preah, and Roha series which are used as paddy field for long period. Potential decomposable organic matter in the soils must be consumed during the long use for paddy fields.

As shown in Table 29, glucose consumption, the difference between glucose added series and control or lime added series was greater in alluvial soils, lithosols, and vertisols, except for Moreum series. It was lower in low-humic gley soils and red-yellow podzolic soils, except for Keng series. Microflora which is able to metabolize glucose, may be very few in the above mentioned soils, and especially in Stung Preah and Roha series. From this fact, it is also assumed that the amount of easily decomposable organic matter that is already present in the soil or artificially supplied may be limited.

Comparing with the oxygen intake rate of each soil series, the rate of oxygen intake decreased with time only for Moreum and Russei Char series which are poorly drained. Glucose metabolism in the two series may be different from all other soil series.

3) Urease Activity of Soils

Rresult of the examination of urease activity of soil of the first and second layers, is shown in Table 30. Generally speaking, the order of urease activity was as follows: lithosol >vertisol >alluvial soil≒low-humic gley soil> red-yellow podzolic soil.

According to TANABE and ISHIZAWA, urease activity is in the order of uncultivated

Table 30. Urease activity and ammonia formation of air-dried soil

Soil group	Soil series	Land use	Soil depth (cm)	Urease activity NH_4-N mg/100 of dried soil	Ammonia formation of air-dried soil NH_4-N mg/100g of dried soil
Alluvial Soils	Pongro	Cultivated upland field	0~15 15~38	155 17	1.9 0.9
	Bos Leav	〃	0~14 14~29	42 19	4.3 1.6
	Moreum	Swamp	0~13 13~20	180 41	3.2 2.2
Lithosols	Pou	Open forest	0~ 3 3~20	430 32	5.3 1.3
Vertisols	Prek Chamlak	Open forest	0~14 14~30	240 64	4.3 1.8
	Sre Prang	Grass land	0~ 3 3~15	430 460	— 5.2
Low-humic gley Soils	Stung Preah	Paddy field	0~15 15~20	130 97	3.1 1.9
	Kampi	Open forest	0~ 8 8~18	87 27	5.7 2.5
	Roha	Paddy field	0~15 15~18	76 27	2.9 2.2
	Sambok	Paddy field	0~10 10~28	130 85	5.3 4.3
	Russei Char	Open forest	0~14 14~32	73 33	1.0 0.7
Red-yellow podzolic Soils	Krakor	Open forest	0~12 12~25	43 27	2.3 3.1
	Keng	Open forest	0~ 4 4~25	80 38	2.9 4.2
	Tuol	Open forest	0~15 15~24	56 31	1.8 1.5

upland field >cultivated upland field> paddy field, and is correlated with soil organic matter content. In Cambodian soils, such relationship can be observed with some exceptions. Urease activity was positively correlated with oxygen intake activity of each soil series.

(4) Ammonia Formation of Air-Dried Soil

Ammonia formation of air-dried soil was determined under water-logged condition. Hence the result cannot always be applied to nitrogen mineralization under upland field condition. The greatest nitrogen mineralization was observed in Pou, Kampi, and Sambok series. The smallest was in Russei Char series. Among paddy fields, the mineralization of nitrogen was highest for the Sambok series. It is due to the fact that this paddy field is used for paddy for only two years. It will contain much nutriment and decomposable organic matter than Stung Preah and Roha series which are using as paddy fields for a longer period.

VI. Mineralogical Characteristics of the Soils

1) Clay Mineral Composition

The X-ray diffraction pattern of the deferrated clay for the Abg horizon of Pongro soils indicated that Mg-clay shows the following spacing peaks of 3.57, 7.2, 10 and 14 Å. Some of these 14 Å minerals have the expanding property to 18 Å after treatment with glycerol. The heating treatment at 600°C identify the presence of kaolinite from disappearance of a diffracted peak at 7.2 Å. Vermiculite is recognized by NH_4NO_3 treatment and 1 : 1 HCl treatment. Chlorite is identified from a reflection of 4.75 Å and suggested its presence from heating treatment at 600°C. Treatment with $CaCl_2$ and glycerol after extracted with sodium citrate for the clay of B horizon converted partly the spacing of 14 Å to 18 Å.

The clay mineral of the clay fraction of Abg and Bbg horizons of the Moreum soil consists of kaolinite, illite and 14 Å minerals that include chlorite and montmorillonite. Chlorite is recognized from results of a little sharp reflection of 14 Å by heating at

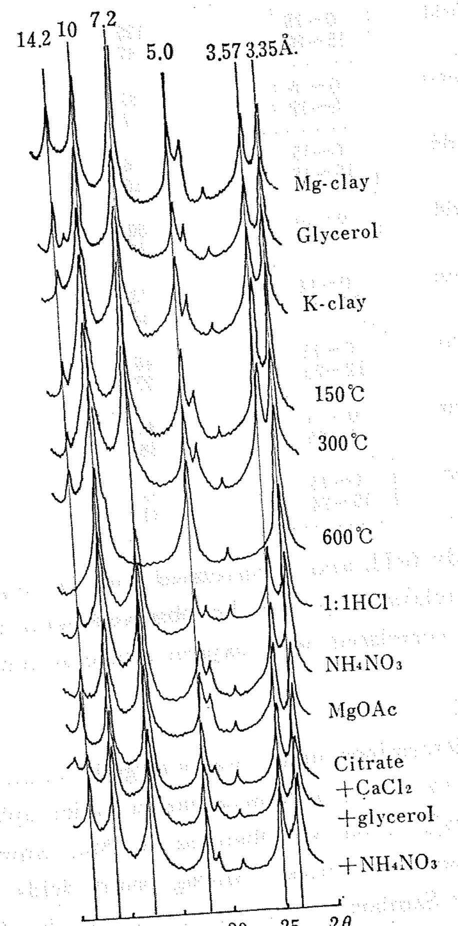


Fig. 19. X-ray diffraction patterns of clay fraction of Pongro soil (No. 148-2, B)

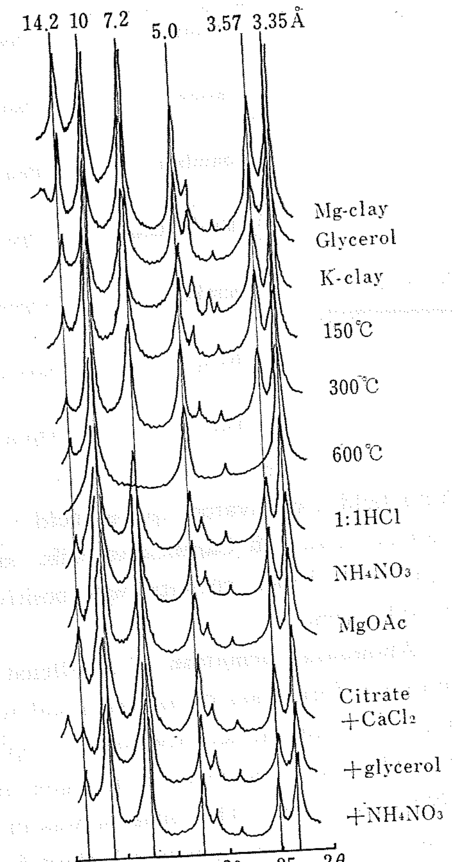


Fig. 20. X-ray diffraction patterns of clay fraction of Moreum soil (No. 104-2, Bg)

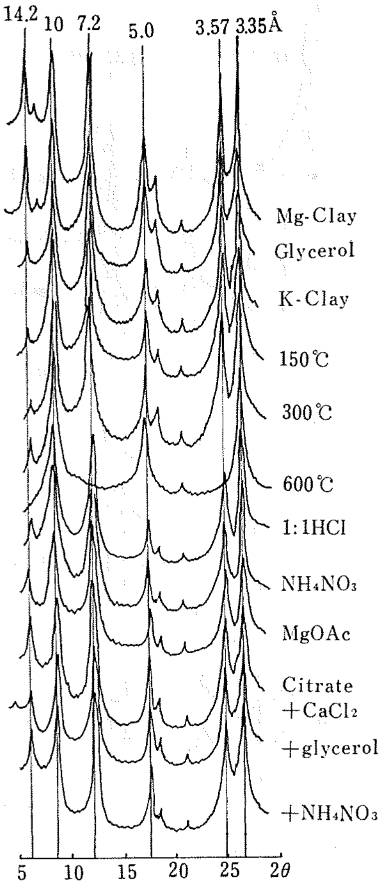


Fig. 21. X-ray diffraction patterns of clay fraction of Moreum soil (No. 104-4, Bbg)

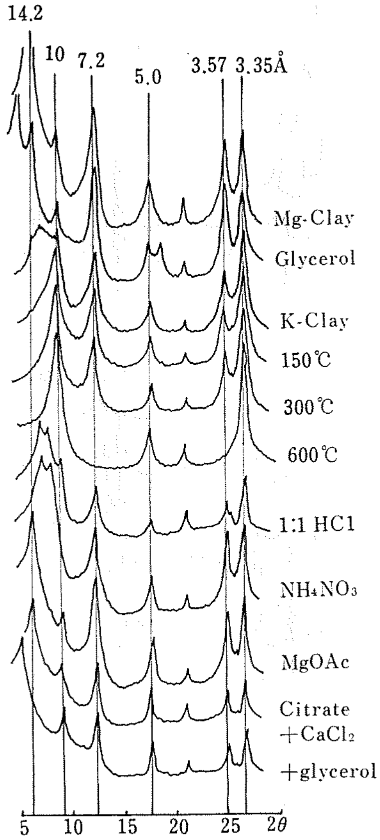


Fig. 22. X-ray diffraction patterns of clay fraction of Prek Chamlak soil (No. 140-2, A12g)

600°C, and the spacing of 4.75 Å. The 14 Å minerals include montmorillonite with metals in interlayer positions whose spacing converts to 18 Å after treatment with citrate solution, and then with $CaCl_2$ and glycerol. The differential thermal curves of the clay sample show an endothermic peak at 580°C indicating kaolinite mineral, and a weak small endothermic peak at 310°C was observed for the clay of Blg and C horizons.

The minerals of clay fraction of A13 horizon of the Prek Chamlak soil consist dominantly of 14 Å minerals, illite and kaolinite. Most part of 14 Å mineral whose basal spacing of 14 Å expanded to 18 Å after treated with glycerol. It is weakly or loosely crystallized because the spacing of 14 Å shifts to 12.8 Å after 1 : 1 HCl as well as NH_4NO_3 treatments. The spacing of 14 Å treated with sodium citrate[20] and then with $CaCl_2$ and gleycerol, shifted to 18 Å completely. It is possible that minerals with 14 Å basal spacing are montmorillonite and few with metals in interlayer positions. Mg-acetate treatment on the clay shows the dominant presence of degraded illite ; the spacing that shifts from 10 Å to 14.8 Å. The clay mineral composition of the clay fraction of A12 horizon of the Prek Chamlak soil is the same as that for the A13 horizon, except that clay of the A12 horizon contains no degraded

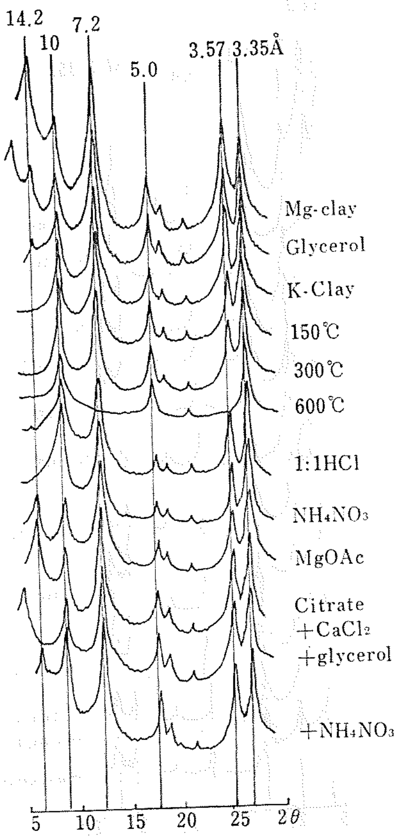


Fig. 23. X-ray diffraction patterns of clay fraction of Sambok soil (No. 159-3, Bg)

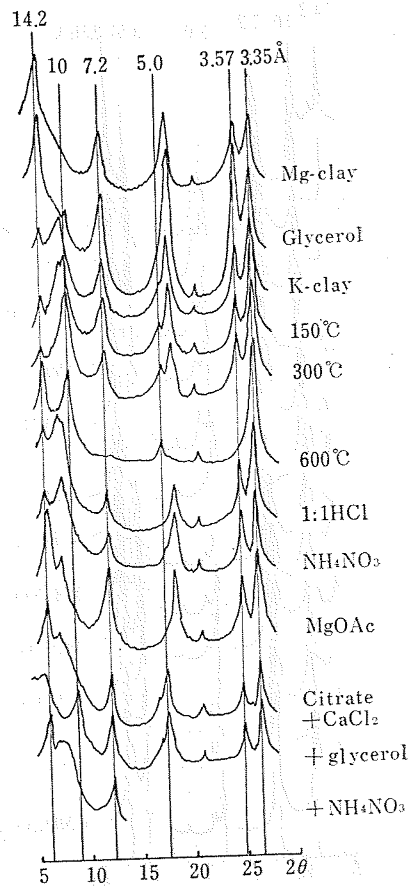


Fig. 24. X-ray diffraction patterns of clay fraction of Krakor soil (No. 108-2, A2)

illite.

The clay fraction of the Clg horizon of the Sambok soil contains kaolinite with some 14 Å minerals and illite. The spacing of 14 Å shifts to 18.5 Å spacing by gleycerol treatment, and it contracts' more or less to 13.2 Å in broad by 1 : 1 HCl treatment. Whereas the most of 14 Å shift to 10 Å reflection after NH_4NO_3 boiling treatment and some shift to 15 Å by Mg-acetate treatment. Accordingly it can be concluded that the 14 Å minerals consist of montmorillonite and vermiculite, and that it can be estimated from the differential thermal curves showing dominantly an endothermic peak at 580°C throughout the profile, as well as suggesting the presence of 2 : 1 type minerals for the A12g, Bg and Cg horizons.

The clay minerals of B2t horizon of the Krakor soil are composed mainly of 14 Å mineals with kaolinite and illite. The incomplete expansion of 14 Å spacing to 16.7 Å after being treated with gleycerol may indicate the presence of intergrade minerals to montmorillonite. The presence of chlorite may be suggested from the peak of 14 Å that become sharp by heating at 600°C, and from the diffractive peak of 4.75 Å for the Mg-clay. Vermiculite can be identified from the fact that the 10.8 Å reflection

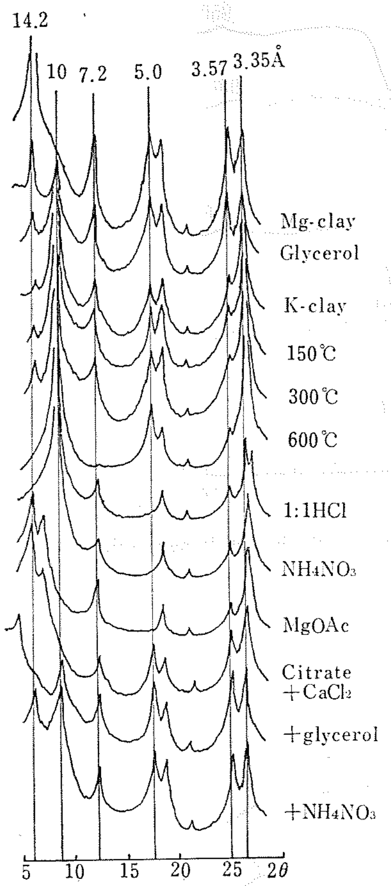


Fig. 25. X-ray diffraction patterns of clay fraction of Krakor soil (No. 108-4, IIC)

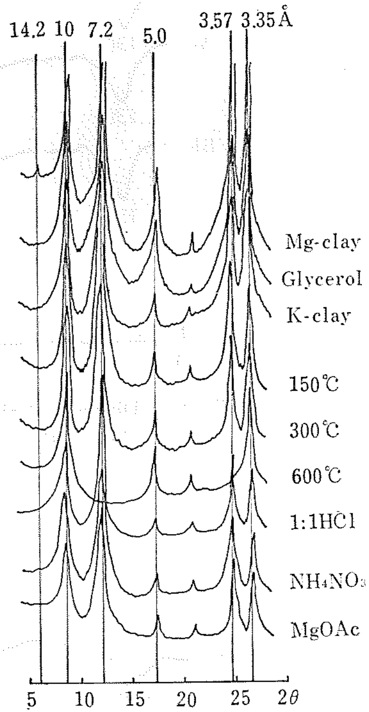


Fig. 26. X-ray diffraction patterns of clay fraction of Keng soil (No. 121-2, A2).

contracted from 14 Å by NH_4NO_3 treatment become sharp. It can be said that 14 Å minerals consist of intergrade mineral to montmorillonite, chlorite, and vermiculite. In the A2 horizon, the clay minerals are mainly composed of kaolinite, illite and 14 Å minerals. Most of the illite is degraded, caused by half-weathering. The clay mineral composition of IIC horizon consists of 14 Å minerals, illite and kaolinite. The spacing of 14 Å does not convert by the treatment with gleycerol, but it shifts completely to 18 Å spacing by the extraction with sodium citrate, and boiling treatment with NH_4NO_3 solution. Vermiculite is recognized by NH_4NO_3 treatment ; most of 14 Å reflection shifts to 10 Å. They consist of kaolinite, illite, intergrade to montmorillonite (Al interlayered), and vermiculite.

The clay mineral of B1 horizon of the Keng soil consists dominantly of kaolinite, few illite, and chlorite. The X-ray pattern shows typical peaks of 7.2, 3.57 Å for kaolinite, and peaks of 10 and 5.0 Å for illite. Illite is not degraded, and the weak reflection of 14 Å after heating at 600°C are recognized. The differential thermal curves showed a typical endothermic peak at 580° to 590°C. From the X-ray diffraction pattern no difference between A2 and B1 horizon was recognized.

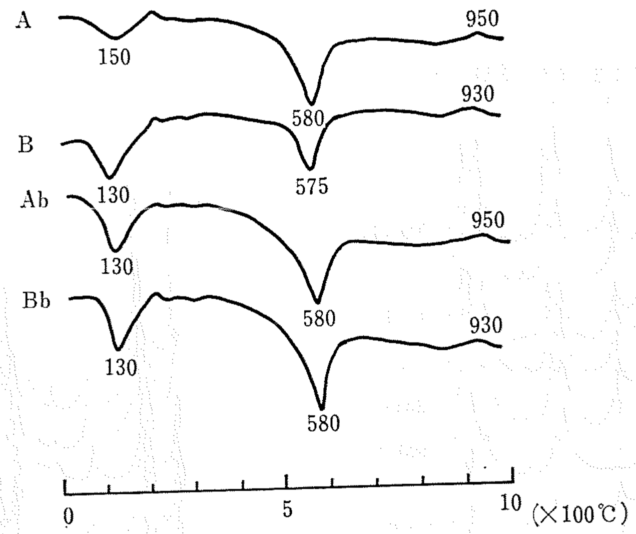


Fig. 27. Differential thermal curves of clay of Pongro soil (No. 148)

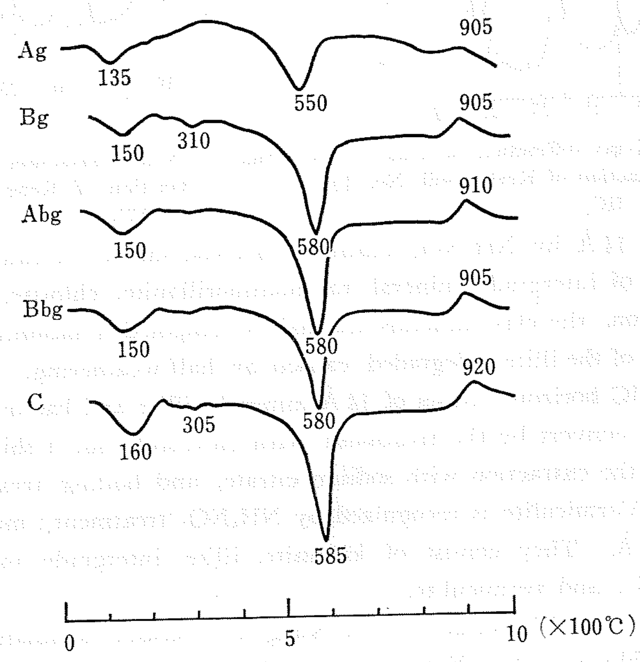


Fig. 28. Differential thermal curves of clay of Moreum soil (No. 104)

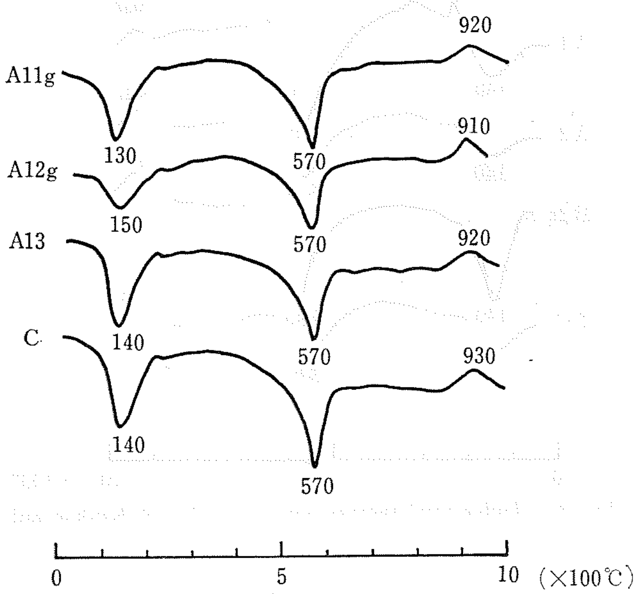


Fig. 29. Differential thermal curves of clay of Prek Chamlak soil (No. 140)

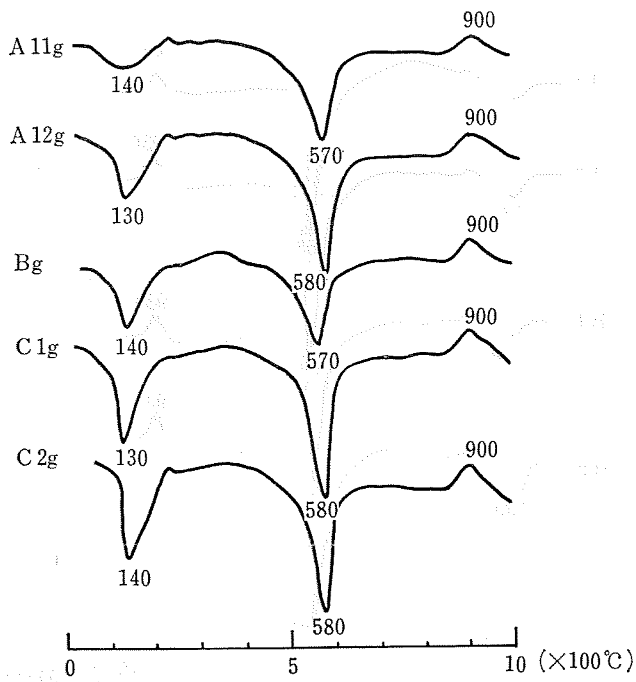


Fig. 30. Differential thermal curves of clay of Sambok soil (No. 159)

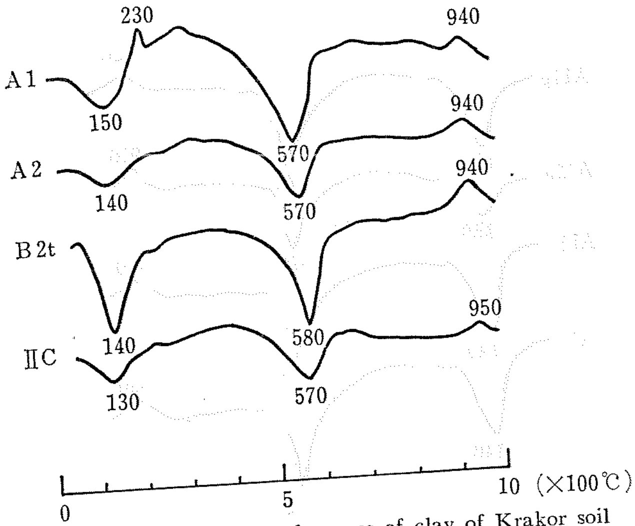


Fig. 31. Differential thermal curves of clay of Krakor soil (No. 108)

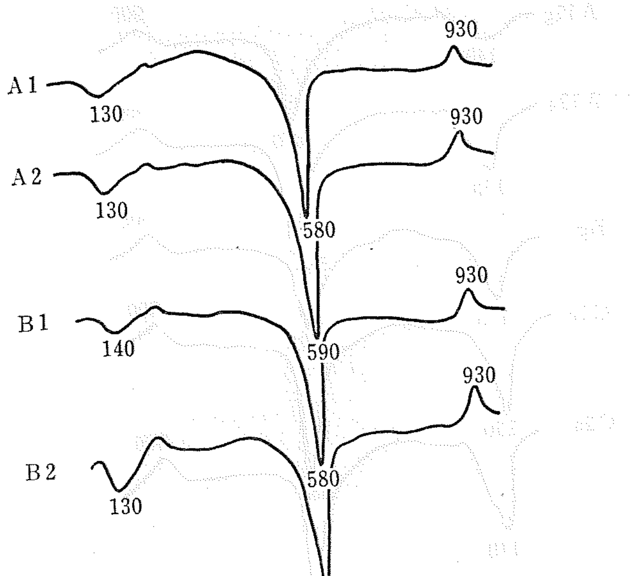


Fig. 32. Differential thermal curves of clay of Keng soil (No. 121)

The clay fraction of the Pongro soil which is dominantly composed of kaolinite, and illite, and with minor minerals of vermiculite, chlorite, and montmorillonite, is almost the same clay mineralogical composition throughout the profile. In Moreum soil, Al-interlayered montmorillonite is recognized except for C horizon, on the contrary, montmorillonite and partly interlayered are noticed for the Bg and Abg horizons of the Pongro soil.

Table 31. Clay mineral composition of some selected soils (%)

	Kaolinite	Illite	Montmorillonite	Other 14-Å minerals	Remarks
Pongro soil	60	30	+	10	14-Å minerals are vermiculite, chlorite montmorillonite.
Moreum soil	70	20	0	10	Vermiculite, chlorite, and interlayered montmorillonite are the 14-Å minerals.
Prek Chamlak soil	10	5	80	5	Interlayered montmorillonite is included in the 14-Åminerals.
Sambok soil	70	10	+	20	14-Å minerals are vermiculite, chlorite and montmorillonite and its interlayered.
Krakor soil	50	5	0	45	14-Å minerals are degraded illite and vermiculite.
Keng soil	90	10	0	0	

Note : + indicates less than 5 per cent.

The clay mineral composition of the A12 and A13 horizons of the Prek Chamlak soil is predominanted by montmorillonite, and with other minor minerals as kaolinite, illite and interlayered montmorillonite. The clay mineral composition of the B1g and C1g horizons of the Sambok soil consists of kaolinite, chlorite, montmorillonite, and its interlayered. The soils on alluvial plain, alluvial soils and low-humic gley soils, have clays whose clay minerals are dominantly composed of kaolonite, and illite, with vermiculite, chlorite, and interlayered montmorillonite as accessary minerals.

In the case of red-yellow podzolic soils, the clay of the A2 horizon is dominantly composed of kaolinite, and chlorite accompanied with vermiculite and degraded illite. The B2t horizon is of kaolinitic, with chlorite, vermiculite, and with little illite. The clay mineral composition of the Keng soil is dominantly of kaolinite and illite, there is no big difference throughout the profile.

An endothermic peak at 580~590°C of the clay of the Moreum, Sambok, and Keng soils is typical and sharp, especially for the clay of the Keng Soils along with an exothermic peak at 900~930°C. It can be suggested that sharp endothermic peak shows the presence of kaolinitic clay. The differential thermal curves of Prek Chamlak clay give an endothermic peak at 570°C, and an exothermic peak at 910°–930°C as well as some irregular flexible curves between the above two peaks. It may indicate some 2 : 1 type minerals. The differential thermal curves of Krakor clay are somewhat different from the other soil clays, that is, the two endothermic peaks for the A1, A2, and IIC horizons are shallow.

2) **Primary Mineral Composition**

Table 32. Heavy mineral composition

Soil	Horizon	Weight (%)	Magnetite	Leucoxene	Other opaque	Zircon	Epidote
Ponro (No. 148)	A1	1.34		2	8	3	8
	Ab	1.28	1	4	7	2	6
Sambok (No. 159)	A12g	1.31	13	10	3	20	20
	C1g	0.92	4	20	9	17	13
Krakor (No. 108)	A1	0.33	21	11	20	7	19
	B2t	0.64	15	10	34	27	4
Keng (No. 121)	A1	0.67	16	16	22	19	3
	B1	0.66	17	17	39	4	6

The weight percentage of heavy minerals in the fraction 0.2 to 0.05 mm in diameter, of A and Ab horizons is relatively higher than other soils, although their percentage is quite low. In the light minerals quartz dominant followed by weathered plagioclases which are darker color, and have irregular extinction pattern and some cleavage. In the heavy minerals, most of them are hornblende and altered minerals, others recognized are epidote and tremolite. It shows that two horizons are from not different materials, but from different sedimentation period.

Quartz and plagioclases are dominant minerals for the A12, and C1g horizons of the Sambok soil. The number of weathered plagioclases are rather low. The weight percentage of the heavy mineral is comparatively high. Zircon, epidote, and hornblende are dominant minerals and followed by leucoxene, and opaque minerals.

For the Krakor soil, magnetite, other opaque minerals and epidote are dominant for the A1 horizon, other opaque minerals, and Zircon are dominant for the B2t horizon. In the light mineral, plagioclases, and altered are dominant, and weathered plagioclases are next. The amount of quartz is rather low, 13 to 14 per cent. The weight percentage of heavy mineral for the A1 and B1 horizons of the Keng soil is low. Opaque minerals including magnetite, and leucoxene are dominant in the heavy mineral fraction. Zircon is next in importance for the A1 horizon. In the light minerals, plagioclases is dominant, and the half are weathered.

Table 33. Light mineral composition of fine sand fraction (0.2-0.05mm) (%)

Soil	Horizon	Quartz	Plagioclases	Weathered plagioclases	Altered	Unknown
Pongro (No. 148)	A1	30	17	22	22	9
	Ab	25	17	33	12	11
Sambok (No. 159)	A12g	28	44	17	6	5
	C1g	33	45	15	5	2
Krakor (No. 108)	A1	13	31	22	27	7
	B2t	14	23	16	41	6
Keng (No. 121)	A1	32	32	22	8	6
	B1	25	35	30	6	4

The heavy minerals of red-yellow podzolic soils are characterized by dominant composition of opaque minerals that are more than fifty per cent in the amount of mineral grains. Epidote and zircon are secondary dominating minerals.

For alluvial soils, hornblende is the dominant mineral. The low-humic gley soils have a heavy mineral composition dominated by zircon, epidote, and hornblende.

of fine sand fraction (0.2-0.05mm) (%)

Biotite	Muscovite	Hornblende	Tremolite	Augite	Hypersthene	Altered	Unknown
7	3	39	5	1		21	3
2	3	39	7	2		25	2
3		17		1		10	3
4		22				9	2
2		10		+	+	5	5
2		4		+		2	3
+		11	2	+	3	4	4
+		8	3		+	2	4

VII. A Consideration on Soil Fertility

The soils of the Area which consist of alluvial soils, low-humic gley soils, vertisols, and red-yellow podzolic soils, were examined on their soil fertility. For alluvial soils, the texture ranges from sandy loam to heavy clay, drainage class is from well drained to very poor drainage condition. The value of pH(H_2O) lowers as the texture becomes finer. There is a tendency of increasing value of total nitrogen content as the texture becomes finer, and the same increasing tendency for available phosphorous and manganese content, and cation exchange capacity is recognized.

When rice cultivation is considered, the finer texture soils, whose redox potentials are oxidative to intermediate, are more productive, because neither harmful substances nor reduced condition are expected to occur. According to the study on the paddy field soils of Northern Thailand by KAWAGUCHI and KYUMA[10], rice yield is significantly correlated to redox potential condition, total carbon content, total nitrogen content, NH_3-N produced by dry effect, ammonification, available phosphorous, exchangeable bases, available silica, and cation exchange capacity value. As for soil texture, the higher the clay content, the higher the yield of rice is obtained. The yield of rice on oxidative soil is higher than on the reductive condition.

As for low-humic gley soils, nearly the same tendency as the alluvial soils is observed; value of pH(H_2O), total carbon, total nitrogen, cation exchange capacity, and available phosphorous for the finer textured as Sambok, and Russei Char soils are higher than those of coarse textured as Stung Preah, and Roha soils. The same tendency between rice yield and chemical physical properties of the soils may be expected.

As for red-yellow podzolic soils, chemical physical properties of the Keng soils are more suited to rice cultivation as well as upland farming than other soils, from the point of analytical values of clay content, value of pH(H_2O), total carbon, total nitrogen, CEC, and available phosphorous and manganese. The permeability of these soils is rapid to very rapid, so that they are not suited to rice cultivation, along with the reason of lacking or nothing of irrigation water.

KAWAGUCHI & KYUMA stated in the report that among the correlation coefficient between chemical properties and rice yield, significant positive correlations for exchangeable magnesium content, cation exchange capacity and avilable silica content were recognized. Analytical data of available silica is not obtained for the soils of the Area, however, when the value of exchangeable calcium and magnesium content, and

Table 34. Main chemical characteristics

Great soil group	Soil series	Clay (%)	Textural class	pH(H_2O)	Total carbon (%)	Total nitrogen (%)
Alluvial soils	Pongro	13.7	SL	6.10	1.30	0.12
	Bos Leav	32.1	SiC	5.45	0.93	0.13
	Moreum	59.4	HC	4.65	2.06	0.19
Lithosols	Pou	17.1	SCL	6.95	2.33	0.20
Vertisols	Prek Chamlak	44.7	LiC	5.44	1.97	0.17
	Sre Prang	75.6	HC	4.58	3.04	0.28
Low-humic gley soils	Stung Preah	14.5	L	4.55	0.91	0.09
	Roha	13.2	SiL	5.49	0.62	0.07
	Kampi	17.6	SiCL	5.23	1.30	0.10
	Sambok	70.9	HC	4.50	2.07	0.15
	Russei Char	68.1	HC	4.48	1.66	0.16
Red-yellow podzolic soils	Krakor	7.3	LS	5.45	0.60	0.06
	Keng	7.9	LS	5.49	0.94	0.08
	Tuol	4.7	SL	5.92	0.60	0.06

of cation exchange capacity are considered, very prominent possibilities can be observed; for alluvial soils, the Moreum soils have the higher value of cation exchange capacity and exchangeable magnesium than other two soils. The Pongro, and Bos Leav soils which are grouped in class II, on the productive capability classification. When considered the chemical properties of these soils, it can be said that the Bos Leav soils are more productive than the Pongro soils.

In the case of low-humic gley soils, the finer the texture, the higher the value of CEC, and exchangeable magnesium are obtained. From these results, it can be graded that the fertility of the Russei Char, and Sambok soils are higher than that of Kampi, Roha and Stung Preah soils from the value of cation exchange capacity, and exchangeable magnesium. It can be said that the soils of Russei Char, Sambok, Roha which are grouped in capability class II, are differentiated on the basis of chemical properties of the soils in the following order; Russei Char$\geq$ Sambok$>$ Roha. Stung Preah soils are grouped in class III from the suitability decisive factors of inherent fertility and available nutriments.

With regard to the red-yellow podzolic soils, the soils which are coarse to medium textured, and are in general not fertile, but when compared these soils each other, the chemical properties of Keng soils are comparatively well suited to agricultural utilization; that is the value of CEC of Keng soils is higher than Krakor soils. The Tuol soils which are loamy textured, and are in class III on the capability classification, but they are lithic shallow soils.

If the alluvial soils are flooded once, soil particles with some nutriments and decomposable organic matter will accumulate on the surface of soil, therefore upland of the surface soil

C/N	C. E. C (me/100gm)	Exch. cations (me/100gm)		Available nutriments (mg/100gm)		Capability class	
		Ca	Mg	MnO	P_2O_5	For upland	For paddy
10.8	11.3	9.7	1.8	1.5	11.6	II	
7.1	15.9	10.9	2.2	3.0	9.3	II	
10.8	21.5	7.5	3.7	6.0	13.9		II
11.6	25.7	29.3	2.7	14.1	10.7	IV	
11.5	30.6	20.7	6.4	7.8	4.4	II	II
10.8	26.7	8.7	3.7	4.2	10.1	IV	
10.1	3.8	0.4	0.4	0	2.0		III
8.8	8.5	6.8	0.6	4.2	1.6		II
13.0	5.3	5.5	0.8	12.3	2.3	III	
13.8	21.9	9.0	3.7	1.9	5.9	III	II
10.3	21.5	8.4	3.9	1.6	5.8		II
10.0	2.9	2.7	0	1.3	1.2	III	
11.7	3.9	2.8	0	3.2	2.8	III	
10.0	3.3	0	2.6	2.0	2.8	III	

crops can grow well. When intense cultivation of upland crops with much application of fertilizer is introduced, soil acidification and loss of decomposable organic matter will proceed. Organic matter, as having an important role for the improvement of soil structure, and of soil moisture regime must be considered. Nitrification and denitrification become vigorous after the application of nitrogen fertilizer and organic matter, so technique for preventing nitrogen loss must also be considered. At present, the introduction of leguminous crops will be most advantageous for the suppy of nitrogen and decomposable organic matter to the soils.

In the case of the red-yellow podzolic soils, they are very poor in nutriment and in decomposable organic matter, and physical character of the subsoil is not good. It is better to use the soils as forest with some irrigation. Once plant root penetrate into the hard pan of subsoil, plants may grow well without irrigation.

Most places in the low-humic gley soils can be used for paddy fields, if flooding is controlled. As the amount of decomposable organic matter is not sufficient, application of organic matter is most important, especially in the case of heavy soil. In the soils, nitrification, and denitrification may be greatest, so the application of fertilizer and the control of nitrogen loss must be considered. For the soils the introduction of green manure crops is also advantageous.

VIII. Summary

The field study at Sambor area was carried out from December 1965 to January, 1966. The report includes results obtained in the field and in the laboratory: that is morphological characteristics, chemical, physical, microbiological and mineralogical properties of soils, classification of soils with soil map. Those are summaried as

follows:

(1) National agricultural statistics, and statistical investigations in the field showed that total rice production in 1964 was 2.76 million tons, the acreage of planted paddy fields was 2.3 million ha in 1964, however the unit yield was 1.165 t/ha that is the lowest among rice growing countries.

(2) In Kratie, the rice production was 31,000 tons in recent years, but it is not sufficient for the demand. The unit yield in Kratie 1.07 t/ha is still lower than the national average.

(3) About 94 per cent of the total area, 69,000 ha, is utilized for forest, but only 2.6 per cent is cultivated for agricultural production, of which 75 per cent is for paddy field in Kratie.

(4) Land forms in the Area were classified as hill lands and their piedmont, and delta surface area that is composed of natural levee, back slope, and back marshy lowlands.

(5) During the rainy season, about 80 per cent of the total area is inundated severely 3 to 5 m deep, and as a natural result, the area has been colmataged from old times. In most soils, no strong gley horizon was found during the dry season.

(6) The soils of the Sambor were classified as alluvial soils, low-humic gley soils, vertisols, red-yellow podzolic soils and lithosols. Most of the soils are low-humic gley soils which occupy about 60 per cent of the Area. These soils were classified into soil series, and 15 soil series was found.

(7) The soils were grouped on productive capability, into class II, and III for paddy fields, and capability class II to IV for upland fields were differentiated.

(8) The soils classified in class II or III can be subdivided on the basis of their soil fertility due to the texture, cation exchange capacity, and exchangeable magnesium. The finer the texture, the higher the soil fertility can be expected.

(9) Uncultivated upland soil was abundant only in fungi, cultivated upland field was abundant in other microbes such as bacteria, actinomycetes, spore former, sulphate reducer, and algae. Flooded soil was abundant in nitrifier and denitrifier, but not abundant in sulphate reducer. The value of A/B (count of actinomycetes/count of bacteria) for three group soils was nearly 1. The value of An/B (count of anaerobes/count of bacteria) was the smallest on cultivated upland fields. The value of S/B (count of spore/count of bacteria) was only 3.1% in the case of flooded soil, but about 30% in the case of upland field soils.

(10) Regardless of land use, bacteria and anaerobes were not abundant but actinomycetes were more abundant in Cambodian soils than in Japanese soils. In the case of uncultivated upland fields, fungi, nitrifier, and sulphate reducer were much abundant, but denitrifier was not abundant in Cambodian soils. In the case of cultivated upland fields, fungi, nitrifier, and denitrifier were not abundant, but sulphate reducer was abundant. In the case of flooded soils, fungi, nitrifier, denitrifier were much abundant, but sulphate reducer was not abundant in Cambodian

soils.

The value of A/B of Cambodian soils was greater than Japanese soils, but the value of An/B was smaller than Japanese soils, without any exception. The value of S/B of soils of both countries was very similar in the case of flooded soils.

(11) Microbial activity

Endogenous respiration was in the order as follows : lithosol >vertisol >alluvial soil >low-humic gley soil >red-yellow podzolic soil.

Among soil series, maximum respiration was 16.5 for Pous series, and minimum was 1.0 for Moreum series. Endogenous respiration of upland field soils in Cambodia was greater than that of Japanese soils.

Urease activity of Cambodian soil is the same order as the case of endogenous respiration.

Ammonia formation of the air-dried soil under water-logged condition was greater for Pou, Kampi, and Sambok series and smallest for Russei Char series.

(12) The dominant clay minerals of alluvial soils and low-humic gley soils are kaolinite which takes 60 to 70 per cent, and accompany with illite, 10 to 30 per cent.

(13) The Prek Chamlak soil, one of vertisols, is on valley plain dissected in hill lands, is dominated by montmorillonite in the clay fraction.

(14) The primary mineral of red-yellow podzolic soils is dominated by opaque minerals including magnetite and leucoxene, and followed by zircon, epidote and/or hornblende. The Sambok soil, a low-humic gley soil of heavy textured, and distributing on alluvial plain, is dominated by zircon, epidote, and hornblende in the heavy mineral fraction, and followed by opaque minerals.

(15) The Pongro soil derived from recent alluvium and medium textured is dominated by hornblende, and altered minerals, but contains a small quantity of opaqe minerals in the heavy mineral fraction.

Acknowledgments

The authors wish to express their sincere thanks to Dr. M. Oyama for his encouragement, and his valuable discussion in preparing this report. The authors are indebted to Dr. S. Ishizawa, Head of Dept. Soils and Fertilizers, National Institute of Agricultural Sciences, for his helpful guidance and suggestions. Grateful acknowledgment is made to Mr. Hotong Lip, Chef du Service de 1'Agriculture, and Mr. Khiou-Bonthonn, Chef du Service Météorologique du Cambodge, for their kind collaboration during the field work. The authors wish to thank Dr. L. Martine for his helpful discussions and suggestions on the manuscript, and Mr. I. Tanabe for the microbiological studies.

Thanks are given to the staff of Development Division, Overseas Technical Cooperation Agency, Tokyo, and Dr. M. Yasuo, Représentant Résidant à Phnom Penh, 1' Agence de la Coopération Technique d'Outre-Mer, for their kind cooperation and advice, and are given to Mr. K. Kubo and Mr. T. Kawai, Sanyu Consultants International, Inc., Nagoya, for their kind cooperation.

References

1) Bremner, J. M. & Shaw, K. : *J. Agri. Sci.*, **46**, 320 (1955).
2) Brewer, R. : Fabric and Mineral Analysis of Soils. John Wiley & Sons, Inc., New York (1964).
3) Brown, M. E., Burlingham, S. K. & Jackson, R. M. : *Plant Soil*, **17**, 309 (1962).
4) Chapman. H. D. & Pratt, P. F. : Methods of analysis for soils, plants and waters. Univ. of Calf. (1961).
5) Dudal, R. & Moormann, F. R. : Major soils of South-East Asia. Their characteristics, distribution, use and agricultural potential. *J. Tropical Geography*, **18**, 54-80 (1964).
6) FAO : Guidelines for Soil Profile Description (1968).
7) Fry, B. A. & Peel, J. L. : Autotrophic Microorganisms. Cambridge Univ. press, p. 75 (1954).
8) Hatakeyama, H. : Climate of Asia. Kokin-Shoin (1964).
9) Hatta, S. : Paddy in Cambodia. *Proc. Crop Sci. Soc. Japan, Special ed.*, 35-18 (1968).
10) Kawaguchi, K. & Kyuma. K. : Lowland Rice Soils in Thailand. Natural Science Series N-4, Kyoto Univ. (1969).
11) Kawaguchi, K. & Kyuma, K. : Lowland Rice Soils in Malaya. Natural Science Series N-5, Kyoto Univ. (1969).
12) Kobayashi, J. : Chemical studies on river waters of South-Eastern Asian countries. Quality of water in Thailand. *Nogaku-Kenkyu* **46**, 63-112 (1959).
13) Kobayashi, J. : Chemical study on the average quality and characteristics of river waters of Japan. *Nogaku-Kenkyu* **48**, 63 (1961).
14) Kosaka, J., Honda, C. & Iseki, A. : *Soil Plant Food*, **5**, 77 (1959).
15) Ministry of Agriculture, Cambodia, (surveyed and drafted by Charles D. Crocker) : General Soil Map with its explanation text (in mimeograph) (1963).
16) O. T. C. A. : Sambor Project Report, Lower Mekong River Basin. Vol. IV Irrigation and Agriculture. Overseas Technical Cooperation Agency, Government of Japan (1969).
17) Smith, N. B. & Dawson, V. T. : *Soil Sci.*, **58**, 467 (1944).
18) Stace, H. C. T., Hubble, G. D. et al : A Handbook of Australian Soils. Rellim Technical Publications, South Australia (1968).
19) Starkey, R. L. : *Arch. Mikrobiol.*, **9**, 268 (1938).
20) Tamura, T. : Identification of clay minerals from acid soils. *J. Soil Sci.*, **9**, 141-147 (1958).
21) Tanabe, I. & Ishizawa, S. : *Bull. Nat. Insti. Agri. Sci.* **B 21**, 115 (1969).
22) U. S. D. A. : Soil Survey Manual, U. S. Dept. Agriculture Handbook No. 18, U. S. Dept. Agriculture (1951).
23) U. S. D. A. : Soil Classification, A Comprehensive System, 7th Approximation. Soil Conservation Service, U. S. Dept. Agric. (1960).
24) U. S. D. A. : Supplement to Soil Classification System (7th Approximation). Soil Conservation Service, U. S. Dept. Agric. (1967).
25) Waksman, S. A. : Principle of Soil Microbiology. Williams and Wilkins Co., 2nd ed., p. 15 (1932).
26) Watanabe, A. : *J. Gen. Appl. Microbiol.*, **6**, 283 (1960).
27) Yokoi, H. & Mitsuchi, M. : Soil Survey Report, The Stung Chinit Area and the Area Southwest of the Great Lake in Cambodia (in mimeograph) (1970).

Appendix

A. Methods of soil profile description

1) Thickness and boundary of soil horizons.

Thickness		Measured in cm.	
Boundary			
	Shape	Smooth	
		Wavy	
		Irregular	
	Transition	Abrupt	less than 1 cm wide
		Clear	1 to 3 cm wide
		Gradual	3 to 5 cm wide
		Diffuse	more than 5 cm wide

2) Texture

The textural class used in the survey is the modified TOMMERUP's textural class that sand section is added to the TOMMERUP's scheme as shown in Fig. 41.

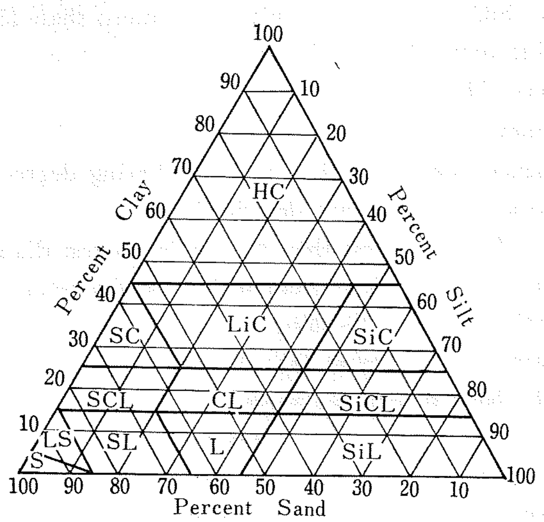


Fig. 33. Triangular chart of textural classes

Textural classes are as follows:

1. Soils containing less than 15% clay

(1)	Sand (S)	clay	less than 5%
(2)	Loamy coarse sand (LCoS)	silt+clay	less than 15%
(3)	Loamy fine sand (LFS)	silt+clay	less than 15%
		fine sand more than 40%	
		coarse sand less than 45%	
(4)	Coarse sandy loam (CoSL)	silt+clay 15~35%	
		fine sand less than 40%	
		coarse sand more than 45%	
(5)	Fine sandy loam (FSL)	silt+clay 15~35%	

	fine sand	more than 40%
	coarse sand	less than 45%
(6) Loam (L)	silt+clay	more than 35%
	silt	less than 45%
(7) Silt loam (SiL)	silt	more than 45%
2. Soils containing 15~25% clay		
(8) Sandy clay loam (SCL)	silt	less than 20%
	sand	more than 55%
(9) Clay loam (CL)	silt	20~45%
	sand	30~65%
(10) Silty clay loam (SiCL)	silt	more than 45%
3. Soils containing 25~45% clay		
(11) Sandy clay (SC)	silt	less than 20%
	sand	more than 55%
(12) Light clay (LiC)	silt	less than 45%
	sand	less than 55%
(13) Silty clay (SiC)	silt	more than 45%
4. Soils containing more than 45% clay		
(14) Heavy clay (HC)		

3) Gravels and stones

Absence or presence, size, quantity, and weathering degree of gravel and stone, and/or kind of rock if possible, are described.

Size	Very fine	less than 0.5 cm in longest diameter
	Fine	0.5~2 cm in longest diameter
	Medium	2~10 cm 〃
	Coarse	more than 10 cm 〃

Quantity (on the basis of exposed surface)

Few	less than 5%
Common	5~10
Many	10~20
Abundant	20~50

4) Color

Soil color at field moisture condition is measured by comparison with the Standard Soil Color Chart published by Nippon Shikisai-Sha, Tokyo, expressed in the same color notation as the Munsell soil color chart. Soil are not always homogeneous, often are stained and mottled showing like mosaic pattern, therefore component colors are described on Munsell color notation. Common names for soil color are based on the Soil Survey Manual[22] of U.S. Department of Agriculture.

5) Structure

Structure in the field is described on the shape, size and degree of distinctness. Size is described in millimeter, and shape is expressed in the following type of structure. Terms for the description of class and type of structure are derived from the Soil Survey Manual [22] as follows:

Platy
Prismatic
Columnar
Blocky
Subangular blocky
Granular
Crumb
Massive or single grain

Four terms are used to express the degree of distinctness as grade.

Structureless: massive if coherent, single grain if not coherent.
Weak
Moderate
Strong

6) Pores

Size	Very fine	less than 0.5 mm in diameter
	Fine	0.5~2 mm 〃
	Medium	2 ~ 10 mm 〃
	Coarse	more than 10 mm 〃
Abundance (on the basis of exposed surface)		
	Few	less than 5%
	Common	5~15%
	Many	more than 15%

7) Compactness

Compactness is measured with Yamanaka's cone-penetrometer. Value in mm shows the strength of resistance of the soil to penetration of a conical part of the tester. The grade is expressed as follows:

Loose	0~10 mm
Slightly compact	11~18 mm
Compact	19~24 mm
Very compact	25~28 mm
Extremely compact	more than 29 mm

8) Gley horizon and reducing spot

Gley horizon is defined that the hue of matrix is as blue as 10 Y or bluer than 10 Y, and with distinct pinkish coloration reaction to dipyridyl acetic solution.

9) Manganese detection

Manganese accumulated in spotty or concretionary in matrix is identified from violet tint using benzidine acetate solution.

10) Mottlings and concretions

Color, shape and quantity of mottlings and concretions are described. Color is measured by comparison with Standard Soil Color Chart, and shape is differentiated as follows:

Shape Speckled : small round shaped mottles with diffuse boundary.
Cloudy : faint mottles with three dimensional extension and diffuse boundary.
Tubular : tube shaped hollow mottles, more than 2 mm in diameter.
Thready : fine mottles like root channels, less than 2 mm in diameter.
Filmy : film like mottles with dominant two dimensional extension.
Spotty : small round shaped mottles, often slightly indurated.
Concreation : round shaped hard separation, with concentric internal structure.

Abundance (on the basis of exposed surface)

Few	less than 2%
Common	2～10
Many	10～20
Abundant	20～50

11) Wetness

The term of dry, semi-dry, moist and wet is used.

12) Degree of plasticity is mesured by rolling the soil material between thumb and finger, and is expressed as follows :

Non-plastic : no wire is formable.
Slightly plastic : wire is formable but easily deformed.
Plastic : wire as long as 2 mm in diameter is formable.
Very plastic : wire as far as 1 mm in diameter is formable.
Extremely plastic : fine wire more than 1 cm long is formable.

13) Stickiness

When soil material is pressed between thumb and finger, its adherence is noted and degree of stickiness is described as follows :

Non-sticky : after release of pressure, no soil material adheres to thumb and finger.
Slightly sticky : after pressure soil material slightly adheres to both thumb and finger.
Stikcy : after pressure, soil material adheres to both thumb and finger, and tends to stretch somewhat.
Very sticky : after pressure, soil material strongly adheres to both thumb and finger, and is decidedly stretched when it is separated.
Extremely sticky : after pressure, soil material extremely adheres to both thumb and finger, and is much decidedly stretched when it is separated.

14) Ped coatings

Clay coatings or clay skins, pressure faces, and slickenside are described.

15) Content of roots

Abundance (on the basis of exposed surface)

Few	less then 5%
Common	5~10
Many	10~20
Abundant	more than 20

B. Analytical methods and procedures

Air-dried samples are crushed with a mortar, to pass a 2 mm round-hole sieve. Material greater than 2 mm retained on the sieve is described as gravel. All determinations are performed on the less than 2 mm fraction, the results obtained are reported on that basis.

Mechanical analysis

Pipette method under dispersion with sodium hexametaphosphate and mechanical shaking; decomposing organic matter with hydrogen peroxide, and mechanical shaking for 2 hours in a medium of hexametaphosphate solution, clay and silt fraction are determined with a pipette method, the coarser fractions are determined gravimetrically.

Bulk density

Weight of 100 m*l* of less than 2 mm air-dried soil in a close-packed state is determined, using the cylinder type volume weight determination set.

pH

Glass electrode method; using 1 : 2.5 soil-water ratio denoted pH(H_2O), and using 1 : 2.5 soil-*N* KCl ratio denoted as pH(KCl).

Exchange acidity

KAPPEN method; extraction of soil with *N* KCl at pH 7.0 and titration of extract with 1/10 *N* NaOH, it is expressed as y^1 volume of NaOH.

Organic carbon

Wet combusion method by KOSAKA[14]; modification of CLARK and OGG method.

Total nitrogen

Semi-micro KJELDAHL method; digestion in a mixture of H_2SO_4 and H_3PO_4 (1 : 2), using a mixture of K_2SO_4 and $CuSO_4$ as catalyst, and steam distillation.

Cation exchange capacity

Modification of SCHOLLENBERGER's method; distillation of NH_3 from sodium chloride extract.

Exchangeable cations

Displacing soil with *N* NH_4OAc, Ca and Mg are determined by EDTA titration method, and K and Na by flame spectrophotometry.

Phosphorous absorption coefficient

Defined as the amount of fixed P_2O_5 in mg for 100 gm soil, using 2.5 per cent ammonium dibasic-phosphate adjusted to pH 7.0.

Available manganese[4]

Ammonium dihydrogen phosphate extraction method; extracting soil with ammonium dihydrogen phosphate, manganese in the extract is determined by periodate method.

Available phosphorous[4]

Sodium bicarbonate method; extracting phosphorous from soil with sodium bicarbonate, phosphorous is determined colorimetrically with ammonium metavanadate.

X-ray diffraction analysis and differential thermal analysis

After removal of organic matter by hydrogen peroxide, clay fraction less than 2μ was separated by sedimentation. The clay was centrifuged as Na-clay, and followed by deferration treatment by the dithionite method of MEHRA and JACKSON. The K-clay and Mg-clay were prepared, dried on a clean slide glass to obtain parallel clay specimens. X-ray diffraction analysis was carried out by Cu-Kα radiation, using a Geiger flex unit of Rigakudenki Co., Japan. Differential thermal analysis was carried out for not deferrated Na-clay by using an autorecording DTA apparatus of Mitamura Co., Japan.

カンボジア国　サンボールの土壌

鈴木達彦・河井完示

摘　　要

本報告はサンボール地区総合開発計画の一環として水力発電，水利，舟航などとともに農業開発計画の基本調査として1965年12月から1966年1月にかけて行なわれた土壌調査を中心にして取まとめたものである。

サンボール地区はカンボジア国の東中央部にあり，首都プノンペンの北東 150km，東径 105°50′～106°15′，北緯12°12′～12°37′，に位置する。本地区はメコン河をはさむ両岸流域およびこれにつぐ台地，谷底平野を含め約69,000 ha にわたる。

（1） 農業統計によるとカンボジア国の米の収量は水田面積とともに年々増加しているが1964年には276万トン，水田総面積は230万 ha であり，単位収量は 1,165 t/ha である。これは米生産国の中では最低の収量である。

（2） クラチエの最近の統計では米生産高は 3.1万トンで需要を充たすにいたらないが，単位収量も全国平均よりも低く，1.07 t/ha である。

（3） 農耕地は全土の16%をしめるが，本地区は 2.6 %にすぎず，そのうち75%は水田である。また森林は全土の 74% をしめるが，本地区は 94% が森林であり，農耕地としての土地利用率は極めて低い。

（4） 5月からはじまる雨期には本地区の80%は深さ 3～5 mに冠水するが，コルマタージュによって沈泥が供給される比較的肥沃な土壌には乾季に玉蜀黍，落花生，タバコなどが栽培される。乾季稲もあるが灌漑施設が整備されていないので，その面積は極めて少ない。

（5） 本地区に分布する土壌は沖積土，低腐植グライ土，ヴァーティソル，赤黄ポドゾル性土，岩屑土の5大土壌群に位置づけられ，更に15土壌統に分類された。またこのうち2土壌統（カンピ統，クラコール統）は有効土層の厚さからそれぞれ2土壌区に細分された。

（6） 本地区土壌の生産力可能性分級を昭和37年，39年に作成された基準をもとにして行なった。ただし乾湿の程度，冠水の程度については調査時の過乾は制限因子となり，冠水の危険度はほとんどの土壌について極めて高いが，両者は将来何らかの方法で軽減できることを想定して一段階づつ軽く評価しそれ以外の要因を主としてとりあげた。

これによると水田として利用する場合にⅡ等級 37,00 ha，Ⅳ等級 300 ha があり，畑地としてはⅡ等級 7,800 ha，Ⅲ等級 15,500 ha　Ⅳ等級 5,400 ha に分級された。Ⅳ等級には有効土層の浅いカンピ-2，クラコール-2 土壌区のほか浅層なヴァーティソルが含まれる。

（7） 同じ等級に分級された各土壌の表土の理化学性を比較すると極く一部の例外を除き粘土含量が

高くなるにつれて有機物含量，全窒素含量，塩基置換容量，置換性苦土，有効態燐酸含量が高くなる傾向がみられる。これは直ちに作物の生産と対応しないにしても，同等級土壌の細分を可能にすると思われる。

（8） 微生物フロラ

土壌の微生物フロラにおよぼす環境因子のうちでは，植生と雨季湛水がもっとも影響が大きいので，畑状態未耕地，既耕地土壌，雨季湛水土壌の三つのカテゴリーに分けて微生物フロラを比較した。

（i） 畑状態の未耕地では，カビのみが多く，これに対して，畑状態の既耕地では，細菌，放線菌，細菌胞子，硫酸還元菌がもっとも多かった。雨期湛水土壌（水田，雨季に湛水する疎林）では，硝化菌，脱窒菌がもっとも多く，硫酸還元菌はもっとも少なかった。

（ii） A/B（放線菌数/細菌数）は上記3グループはすべて1に近かった。An/B（嫌気性菌数/放線菌数）は，畑状態の既耕地がもっとも小さかった。S/B（細菌胞子数/細菌数）は夏期湛水土壌では3.1％であり，これに対して，畑状態の未，既耕地土壌いずれも30％前後であり著しく高かった。

（iii） 温帯の日本の土壌の畑状態の未，既耕地，水田土壌とカンボジアのそれぞれの土壌と較べると，カンボジアの土壌は上記グループとも，日本の土壌に較べて，細菌と嫌気性菌は少なく，放線菌が多かった。畑状態の未耕地では，カンボジア土壌の方が，カビ，硝化菌，硫酸還元菌が著しく多く，脱窒菌は少なかった。畑状態の既耕地では，カンボジア土壌の方が，硫酸還元菌が多く，カビ，硝化菌，脱窒菌は少なかった。これに対して，湛水土壌では，カンボジア土壌の方が，硝化菌，脱窒菌は著しく多く，硫酸還元菌は少なかった。

A/B はカンボジア土壌ですべて大きく，An/B はすべてのグループで小さかった。

（9） 微生物活性

（i） 酸素吸収：原土無処理区の酸素吸収割合（乾土1g当り，1時間の平均酸素消費量）は，概して，以下の順位であった。

岩屑土＞ ヴァーティソル＞ 沖積土＞ 低腐植グライ土＞ 赤黄ポドゾル性土

供試全土壌のうちでは，岩屑土にぞくする，ポウ統の表土がもっとも高く，平均酸素消費量は16.5，沖積土のモレアム統がもっとも小さく，1.0であった。大部分の畑状態下のカンボジア土壌は，日本の土壌よりも消費量が大きいが，大部分の畑状態下の土壌は試料採取時に，風乾土に近い土壌水分であったので，土壌の風乾による酸素消費量の増大が考慮されなければならない。

（ii） ウレアーゼ活性：各土壌群についてみるならば，酸素吸収と同じ傾向を示した。

（iii） 湛水状態下における土壌のアンモニア化成：供試土壌のうちでは，ポウ統，カンピ統，サンポック統でより大きく，ルセイチャー統でもっとも小さかった。

(8) 沖積土と低腐植グライ土の粘土鉱物はカオリンが主で粘土の60～70％を占め，イライトが10～30％であった。ヴァーティソルの粘土は大部分（80％）がモンモリロナイトであった。メコン左岸地域のうちヴァーティソル分布域以南には少量ではあるがモンモリロナイトおよび Al を層間に含むモンモリロナイト様の2：1型鉱物が混在する。これは上記の母材の影響をうけたためと考える。

(10) 赤黄ポドゾル性土の一次鉱物は不透明鉱物が優越し，つづいてジルコン，緑れん石および角閃石類が多い。低腐植グライ土ではジルコン，緑れん石，角閃石類がドミナントであった。

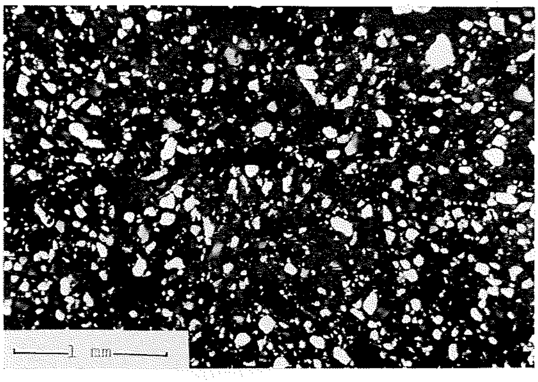


Fig. 34. Pongro soil, No. 155-2, Bll. Insepic likely granular fabric. Crossed polarisers.

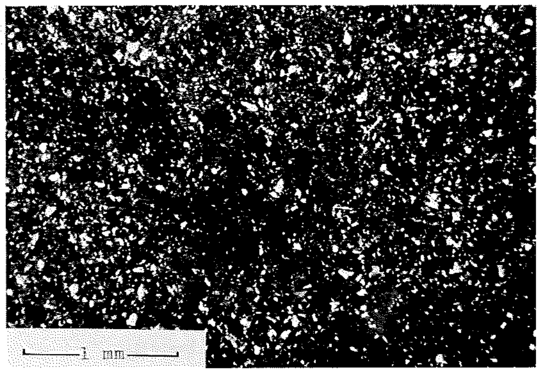


Fig. 35. Bos Leav soil, No. 133-2, Blg (14∼29cm). Ma-silasepic porphyroskelic fabric. Crossed polarisers.

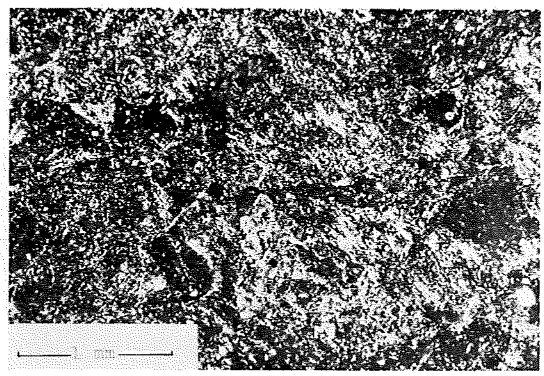


Fig. 36. Moreum soil, No. 111-1, Ag horizon. Momasepic porphyroskelic fabric with adhesive diffuse normal nodules. Crossed polarisers.

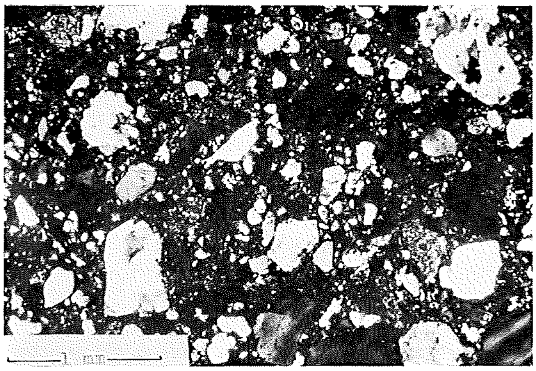


Fig. 39. Krakor soil, No. 108-2, A2 (12∼25cm). Mo-masepic prophyroskelic to granulaı fabric with meta vughs and channels. Crossed polarisers.

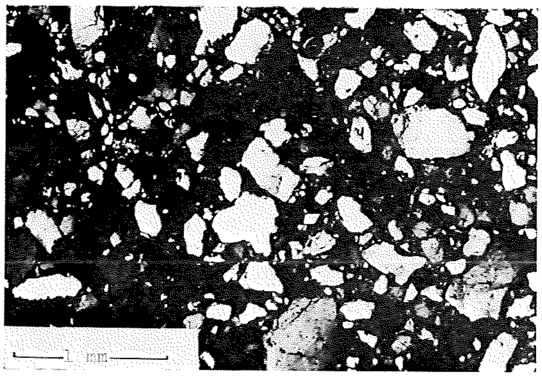


Fig. 38. Keng soil, No. 121-2, A2 horizon (4∼25 cm). Ma-isotic porphyroskelic fabric with macro vughs and channels. Crossed polarisers.

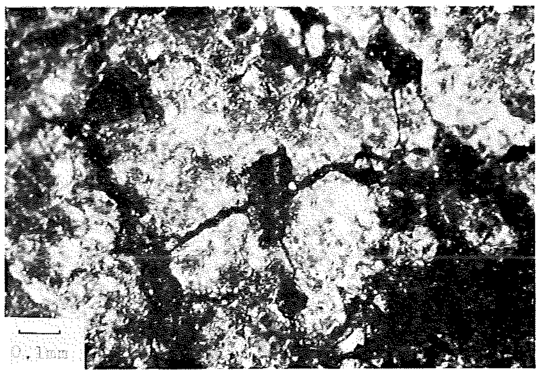
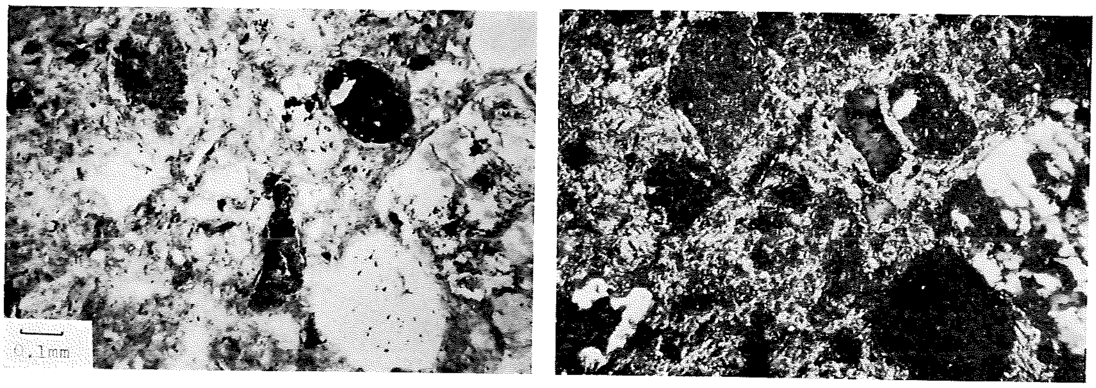
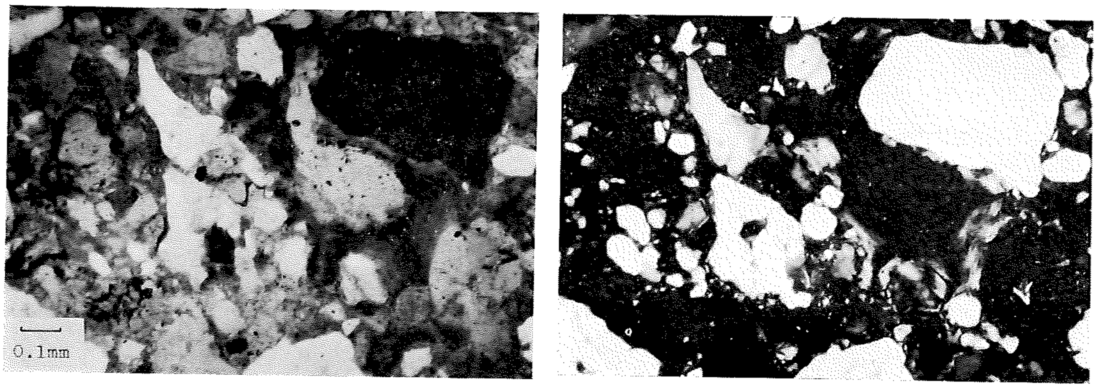


Fig. 37. Russei Char soil, No. 123-3, B2g (32∼50 cm). Ma-omnisepic plasmic fabric with pronounced normal nodules. Crossed polarisers.



(a) Plain light (b) Crossed polarisers

Fig. 40. Krakor soil, No. 108-4, B2t (25~55cm). Ma-vosepic porphyroskelic fabric with some sesquioxidic argillan on skeleton grains.



(a) plain light (b) crossed polarisers

Fig. 41. Keng soil, No. 121-4, B2 (58cm+). Skel-vosepic porphyroskelic to intertextic fabric with some iron rich argillan.