TARC Report

On the Distribution of Paddy Soils in Muda Irrigation Area —A Detailed Soil Survey of ACRBD-4 Block—

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In Muda irrigation project area, double cropping of rice has spread rapidly since 1970 and the yield of rice has been nearly doubled by 1974. However, the double cropping of rice is faced with problems such as loss and shortage of irrigation water, difficulty of water management, decrease of soil bearing capacity and so on[2,11]. Since 1970 Tropical Agriculture Resarch Center (TARC) has been carrying out joint researches with Muda Agricultural Development Authority (MADA) to solve these problems. ACRBD-4 irrigation block was selected as a pilot research area in 1977 and studies on the water management, land consolidation, field adaptability of machines, cultivation practices and farm management are being conducted in the block.

A semi-detailed soil survey of Kedah/Perlis coastal plain was already carried out and the distribution of 16 soil series was illustrated on a soil map on a scale of 1 inch to 2 miles, (1: 126, 720) by the Department of Agriculture (DOA), Malaysia.[9] But the scale of this map is too small for the studies mentioned above. Therfore, the authors conducted a detailed soil survey on the ACRBD-4 block. The purpose of the present paper is to describe 1) distribution of soils in the ACRBD-4 block and 2) chemical and physical properties of the soils with special reference to soil acidity and soil bearing capacity.

Classification and distribution of soils in the ACRBD-4 block

The ACRBD-4 block lies in the center of Muda Irrigation Area, about 9 km west of Jitra. The block is about 5 km long and 1.6 km wide and covers about 760 hectares. The topography is very gently undulating. The elevation ranges from 2.0 to 3.1 m. In the center of the block extend strips of slight depressions which are supposed to be old small river channels.

The method used in this survey was that adopted in basic soil survey of agricultural land in Japan. For field work a base map on a scale of 10 inches to 1 mile (1 : 6,336) contoured at a 0.1 m vertical interval prepared by Tsuchimochi[11] was used. Taking account of topographic situation 18 sites were selected for the examination of soil profiles. The soils were classified using the concept of soil series in the soil classification system of agricultural land in Japan.[10] As all the soils in the block are considered to be derived from the same parent material, brackish water alluvial deposits, distinct differences in soil texture were not found among soils. The presence or absence of gley and muck horizons was used as criteria for differentiation of soils. Based on the consitution of soil profiles, soils in the block were divided into 4 mapping units with provisional designations as follows:

A-soil: Comparatively well drained soil, which does not have a gley or muck horizon within 1 m of the soil surface.

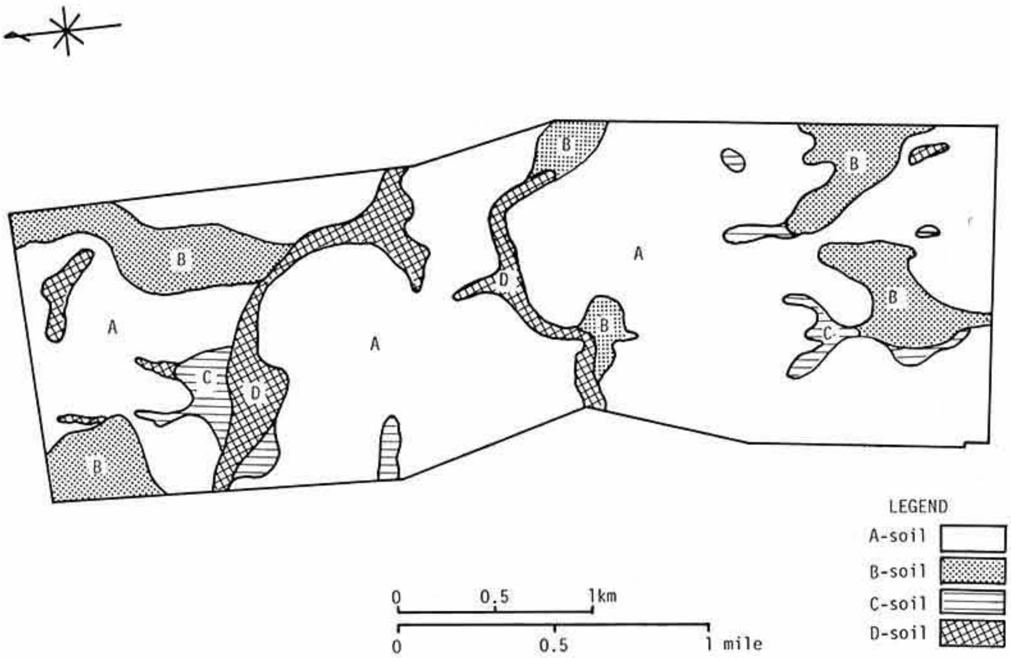
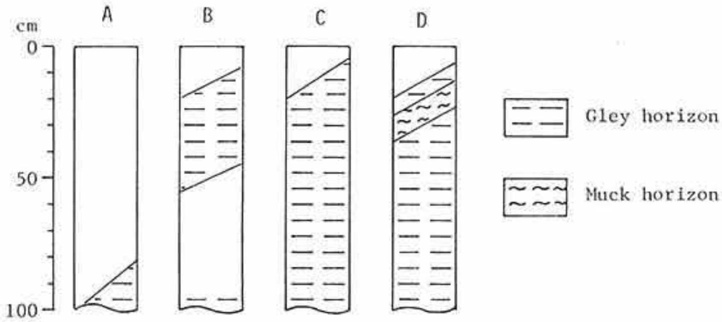


Fig. 1. Detailed soil map of ACRBD-4 block, Muda irrigation area



Remarks: A gley horizon is defined here as a horizon that has bluish gray or gray color and shows an instant and distinct color reaction with α,α'-dipyridyl solution.

Fig. 2. Diagramatic representation of profiles of mapping units

B-soil: An intergrade of A-soil to C-soil. It has a gley horizon thicker than 20 cm within 50 cm of the soil surface, and does not have a gley horizon between 60 and 100 cm in depth.

C-soil: Poorly drained soil. It has a gley horizon whose upper boundary is within 20 cm and lower boundary is deeper than 1 m of the soil surface.

D-soil: Poorly drained soil. Presence of a gley horizon is the same as C-soil. It has a muck horizon about 10 cm thick within 50 cm of the soil surface.

Fig. 2 shows profiles of soil mapping units diagrammatically.

The distribution and boundaries among them were drawn by taking boring at 69 sites and were illustrated as a soil map on a scale of 4 inches to 1 mile (1: 15,840). The soil map shown in Fig. 1 was properly reduced from the original one. The distribution of the soils is closely related to the topography. A-soil is situated on relatively high flat area and occupies about 540 ha, 71% of the total area. C- and D-soils are in slight depressions and occupy about 100ha, 14% of the total area. B-soil occurs mainly on the area adjacent to depressions and covers about 110ha, 15% of the total area.

On the semi-detailed soil map of the Kedah/Perlis coastal plain by DOA, Malaysia,[9] the distribution of only one series, Telok series, is shown in the ACRBD-4 block. It has been clarified by the present survey that 4 different soils are distributed in the block corresponding to the slight topogtaphical changes. Judging from profile descriptions in the soil survey report of DOA,[9] A-soil may be correlated to Telok series. C- and D-soils may be soils designated as "Tanah Alor" on detailed soil maps made by DOA. B-soil is presumably not distinguished from other soils by Malaysian soil surveyors.

Telok series was classified as an Acid Sulfate Soil in the soil survey report of DOA.[9] The soils of ACRBD-4 block have indeed low pH values, but the values are not lower than 3.5 and drop only slightly by air drying as mentioned later. Therefore, they have neither sulfuric horizons nor sulfidic materials defined in US system.[8] Some researchers stated, however, that the presence of jarosite is an accessory characteristic and not an obligatory property for identification of an Acid Sulfate Soil.[1,12] Relatively low acidity of the soils of ACRBD-4 block may be due to the limited accumulation of sulfidic materials before drainage and to leaching process of acidic materials during drainage and rice cultivation. Thus, these soils should be placed in a subgroup of Tropaquepts, not yet defined in Soil Taxonomy, an intergrade of Sulfic Tropaquepts to Typic or Vertic Tropaquepts. They bear some similarities to "Para or Pseudo Acid Sulfate Soil" proposed by Pons.[6]

Chemical properties

1) *Soil Acidity*

Frequency distribution of pH (1: 2.5 in water) of field moist soils is shown in Fig. 3. The pH

Table 1. Chemical and physical properties of representative profiles

Type of soil	Soil Nos. Horizon	Depth cm	pH (H_2O)		E.C.	Organic matter	Particle size distribution				Bulk density		COLE
			wet	dry			clay	silt	f. sand	c. sand	wet	dry	
					μS/cm	%	%	%	%	%	g/cc	g/cc	
A	9-Apg	0— 8	4.3	4.3	72	6.59	66.0	28.8	5.2	0.0	0.98	1.17	0.062
	-A_{12}g	8— 12	4.4	4.4	39	4.84	69.7	26.6	3.6	0.1	1.20	1.54	0.087
	-A_3g	12— 39	4.4	4.3	49	2.19	66.6	30.8	2.4	0.2	1.18	1.53	0.089
	-B_1g	39— 60	4.4	4.3	61	2.40	62.0	34.0	3.6	0.4	1.15	1.48	0.086
	-B_{21}g	60— 74	4.3	4.3	73	0.57	73.2	24.4	2.4	0.0	1.17	1.63	0.115
	-B_{22}g	74—100	4.3	4.3	81	0.47	64.7	33.2	1.7	0.4	1.12	1.71	0.152
B	7-Apg	0— 17	4.6	4.6	24	3.77	57.7	34.3	7.9	0.1	1.08	1.53	0·122
	-A_{12}G	17— 32	4.2	4.3	56	0.86	59.9	30.3	9.7	0.1	1.24	1.66	0.100
	-A_{12}G	32— 47	4.2	4.3	56	0.98	59.1	30.4	10.1	0.4	1.28	1.58	0.072
	-B_2g	47— 70	4.2	4.2	67	0.26	60.0	24.2	14.0	1.8	1.20	1.64	0.110
	-B_2g	70—100	4.2	4.2	59	0.36	59.6	24.0	13.5	2.9	1.08	1.50	0.116
C	12-Apg	0— 14	4.1	4.0	210	8.48	52.0	36.3	11.4	0.3	0.89	1.19	0.099
	-B_{21}G	14— 35	4.2	4.2	100	1.79	53.3	28.7	18.0	0.0	1.43	1.61	0.039
	-B_{22}G	35— 60	3.6	3.6	230	0.93	67.1	26.8	6.0	0.1	1.02	1.63	0.168
	-B_{23}G	60—100	3.7	3.7	230	1.22	60.1	32.1	7.8	0.0	0.94	1.56	0.187
D	6-Ap	0— 12	4.7	4.6	57	9.40	65.6	21.9	10.8	1.7	0.76	1.05	0.111
	-A_{12}G	12— 22	4.5	4.4	72	7.78	66.0	20.3	11.2	2.5	0.77	0.94	0.083
	-B_{21}G	22— 50	4.0	3.9	121	2.13	49.3	39.2	11.3	0.2	1.23	1.41	0.046
	-B_{22}G	50—100	3.8	3.8	140	1.41	59.1	33.1	7.6	0.2	0.92	1.50	0.177

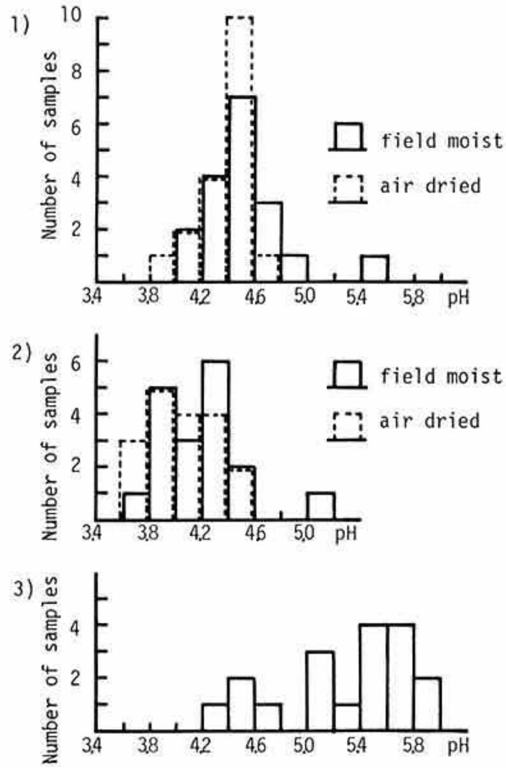


Fig. 3. Frequency distribution of soil pH
1) surface horizons
2) subsurface horizons (lowest pH within 1 m depth of each profile)
3) surface horizons after incubation under waterlogged condition for 15 days

value of surface and subsurface horizons ranges from 4.1 to 5.4 and from 3.6 to 5.1, respectively. The pH value of subsurface horizons was evidently lower than that of surface horizons. The pH of subsurface horizons in B, C and D-soils was slightly lower than that in A-soil.

Changes of pH by air drying of field moist samples were slight (0.4>) in most soils. The surest identification of potential acid sulfate soils is measurement of pH before and after incubation of samples under moist aerobic conditions while simple air drying gives inconclusive results.[12] However, it can be infered that sulfidic materials are hardly contained at least in surface horizons because they have been dried and oxidized repeatedly during dry season.

Air-dried samples of surface horizons were incubated under waterlogged conditions at 28–30°C. After 2 weeks of submergence, the pH

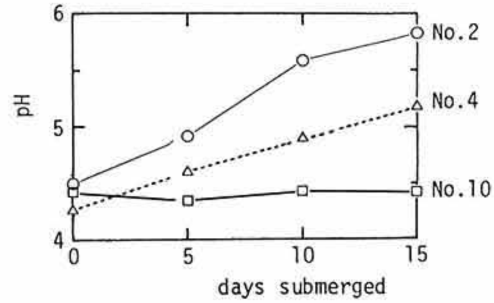


Fig. 4. Changes in pH values of submerged soils

of most soils gradually increased and exceeded 5.0, so that the acidity of the soils may pose few, if any, problems for rice plants growing under submerged conditions. But the increase of pH value of more than half of the soils was relatively slow. This fact is considered as one of the characteristics of acid sulfate soils.[3,5]

2) Electrical conductivity

Electrical conductivity of soil suspensions (1: 5 in water) ranges from 23 to 210 μS/cm in surface horizons, and from 46 to 230 μS/cm in subsurface horizons. The data mean that leaching process is in an advanced stage in the soils of ACRBD-4 block.

3) Organic matter content

Organic matter content of surface horizons ranges from 3.8 to 9.4% and has a tendency to increase in wetter types of soil as shown in Table 1. This tendency is shown more clearly in Table 2, in which organic matter content of plow soles increases in the order of A<B<C<D-soil.

Physical properties

1) Soil texture

Soil textural class of all horizons of profiles is heavy clay, containing clay fraction (2 μ>) to the extent of more than 50% of mineral particles (Table 1). There is slight difference in fine sand content between A-soil and other soils. It is considered as the influences of old small rivers.

2) Soil structure and permeability

The surface horizons had weakly developed granular structure and the subsurface horizons showed moderately well to weakly developed prismatic and angular blocky structure. A massive and compact plow sole was found just below the plowed layer.

The grade of structure of subsoil in A-soil was moderately well developed, being different from moderately to weakly developed in other types of soil. This fact may be due to the difference in experience of drying. Surface soil material and cinders of straw fallen into the cracks were found to the depth of 60–70 cm in A-soil and 45 cm or shallower in other soils. This fact also means that there was a difference in degree of seasonal drying among typees of soil.

Judging from the relatively well developed structure, presence of many old root channels and a high rate of ground water flow into profile-pits, the permeability of the subsoils in this block seems not so low that restricts the effects of subsurface drainage. Kubota reported that the structure of the subsoil was developed in Telok series better than in other soil series derived from the same parent materials in Muda area.[4] Pons[6] and Scheltema et al.[7] indicated a high structure stability and a high permeability of para or pseudo acid sulfate soils.

3) *Bulk density and coefficient of linear extensibility (COLE)*

Bulk densities of both water saturated and air dried clods were measured by kerosene immersion method and COLE values were calculated according to the following equation.

$$\mathrm{COLE} = \sqrt[3]{\text{bulk density (dry)}/\text{bulk density (wet)}} - 1$$

As shown in Fig. 5, bulk density of surface soils was lower than that of subsurface soils and decreased in the order of A>B>C>D-soil. A distinct peak of bulk density was found just below the plowed layer in only A-soil. The differences in bulk density between wet and dry clods were large, so that the COLE values were also high, ranging from 0.09 to 0.2. These high COLE values are referred not only to a high content of expanding clay minerals[8] but also to little experience of drying.

4) *Soil hardness*

Soil hardness was measured with Yamanaka's soil hardness meter at every 5 cm depth of soil profiles. Since soil hardness value is greatly influenced by soil moisture content, the values of surface horizons in A-soil were considerably higher than those in other soils, but those of subsoils deeper than 40 cm did not show distinct differences among types of soil. As seen from Fig. 5, the peaks of soil hardness just below the plowed layers were found not only in A-soil but also in B, C and D-soils. However, in the latter three soils the position of peaks was deeper than those in A-soil. The fact suggests that the influences of heavy machineries extended to the deeper part of profiles in B, C and D-soils than in A-soil.

5) *Strength and stability of plow sole*

Since plow soles play an important role in the soil bearing capacity, their strength and stability were tested. Undisturbed clods taken from plow soles were trimmed into prisms and their cutting strength was measured. Some samples, especially in A-soil, were fairly dried, as they were taken during dry season. In order to estimate properties of plow soles when soils were submerged, dried clods were allowed to be saturated capillarily with water under suction of −5 cm for 3 days before measurement. Cutting strength of plow soles in B and D-soils was lower than in other soils (Table 2). A relationship between cutting strength and organic matter content was found (Fig. 6). Cutting strength took a maximum value at organic matter content between 4 and 12%. Cutting strength of plow soles in A-soil was higher than that in other soils at the same organic matter content. Exceptional values in profile No. 12 was due to a high sand content.

Distinct difference in COLE of plow soles was found between types of soil (Table 2). COLE

Table 2. Properties of plow sole (average)

Type of soil	A	B	C	D
Bulk density (g/cc)	1.19	1.14	1.04	0.86
Organic matter content (%)	3.8	4.6	6.3	11.9
Water content (%)	41.7	49.5	55.5	90.8
Consistency index	0.87	0.74	0.73	0.70
COLE (cm/cm)	0.087	0.107	0.120	0.146
Cutting strength (kg/cm^2)	0.36	0.26	0.37	0.29

(Muda, March 1981)

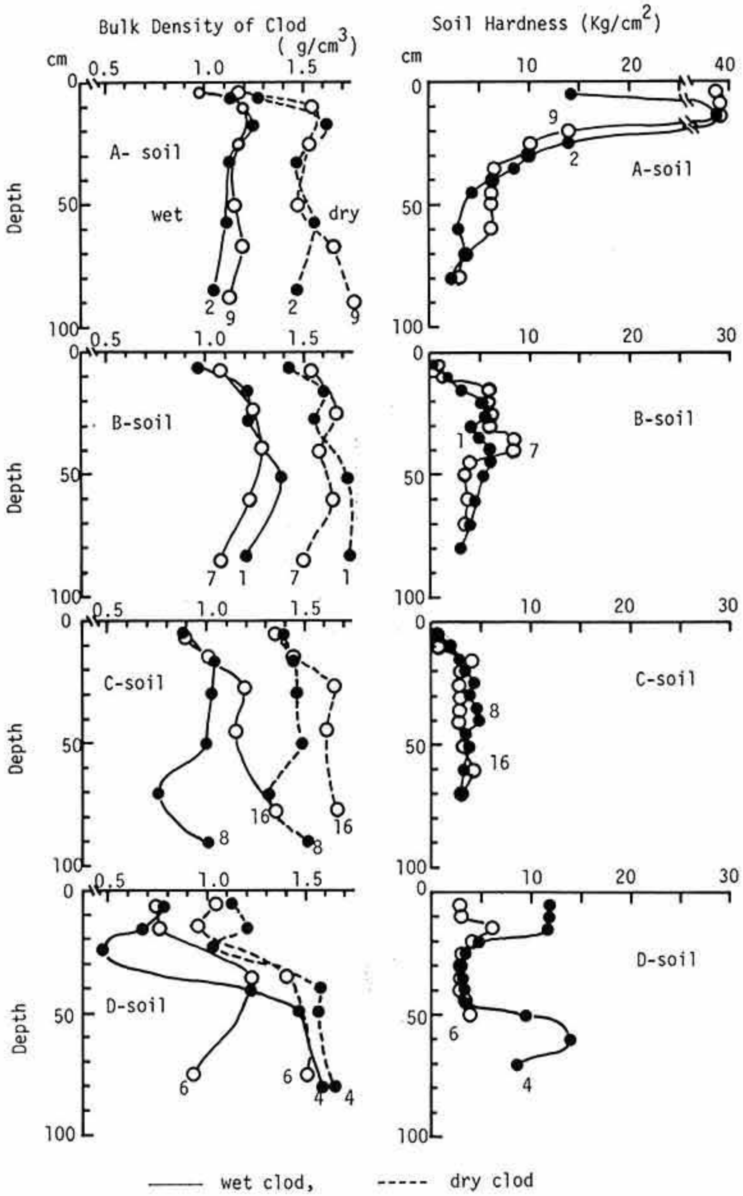


Fig. 5. Bulk density and soil hardness

of plow soles increased in the order of A<B<C<D. The results suggest that plow soles of A-soil have higher stability even under water-saturated conditions.

Moisture content of saturated test pieces was expessed in terms of consistency index. This value can be used as an index of the degree of compaction. Consistency index in A-soil was nearer to 1.0 than in other soils (Table 2). Moisture content of saturated plow sole samples was, therefore, nearer to plastic limit that is regarded as optimum moisture content for soil compaction, and stability of plow soles are higher in A-soil than in other types of soil.

Summary

A detailed soil survey of ACRBD-4 block, 760

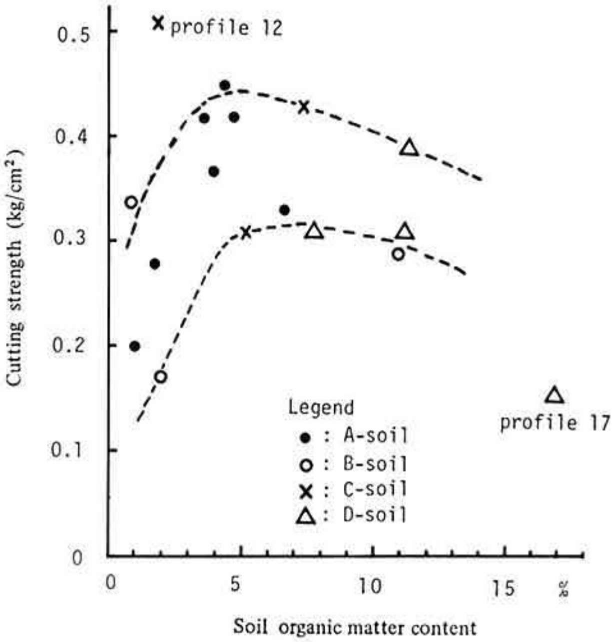


Fig. 6. Cutting strength of saturated plow sole and soil organic matter content

ha, of Muda Irrigation Area was carried out in 1981 off season. Based on the constitution of profiles, soils were divided into 4 mapping units, that is, A, B, C and D-soils, and mapped on a scale of 4 inches to 1 mile (1: 15,840).

A-soil is comparatively well drained soil. As its plow sole is shallow and stable, its suitability for mechanized farming is relatively high. The soil may belong to a subgroup of Tropaquept not yet defined, an intergrade of Sulfic Tropaquept to Typic or Vertic Tropaquept, and is similar to so-called para acid sulfate soil. The soil occupies higher topographic sites, covering an area of about 540 ha, 71% of the total area.

C and D-soils are poorly drained soils. They are characterized by low strength and stability of plow soles and weak development of structure. Therefore, drainage facilities are necessary for advancing mechanized farming on these soils. Their distribution is restricted to depressed sites, occupying as a whole about 100 ha, 14% of the total area.

B-soil is an intergrade of A-soil to C-soil. For this soil also improvement of drainage is desirable. The area occupied by this soil is about 110 ha, 15% of the total area.

Consequently total area having need of drainage facilities is estimated at about 210 ha, 29% of the total area of the block.

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