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SOIL PROFILES OF A HYDROMORPHIC SEQUENCE ON A TYPICAL RIDGE SAND

BY

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SOIL PROFILES OF A HYDROMORPHIC SEQUENCE ON A TYPICAL RIDGE SAND

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From the Atlantic coast to the Brazilian border Surinam is roughly divided into four formations:

The Demerara formation
The Coropina formation
The Zanderij formation
The Old Cristalline basement.

In the Demerara formation two main landscapes are distinguished:

the young sea clay landscape
the ridge landscape.

Sandy ridges alternate with clay swamps in the ridge landscape.

In the experimental Citrus plantation "Dirkshoop", situated in the Demerara formation (4) on the Saramaccariver, an investigation was carried out to study the different morphological, physical and chemical characteristics of the sandy ridge soils. On the sandy ridge soils morphologic units of a hydromorphic sequence differing in texture occur from the ridge crests to the ridge foot. For this study each morphologic soil unit is called a drainage phase. The texture of the topsoil of the more elevated phases is sand; near the base of the ridge the texture of the topsoil becomes a sandy loam.

METHODS OF INVESTIGATION

A trench, 50 meters long and 1 meter deep, was dug from the ridge crest to the ridge foot. Morphologic studies were carried out and samples for physical and chemical analyses were collected. Of some samples colours after ignition were determined. Elevation differences between the drainage phases were measured by means of a levelling instrument.

DESCRIPTION OF SOILS

Four texture-drainage phases were distinguished (3), namely: ridge crest sand A, ridge crest sand B, ridge flank sand and ridge foot sandy loam.

The drainage phases have the following profiles:

Ridge crest sand A

0 - 15 cm dark brown (10YR4/3) sand with some bleached grains;
15 - 25 cm transition zone to:
25 - 43 cm yellowish brown (10YR5/8) to brownish yellow (10YR6/8) sand with some small iron concretions and some faint, few and fine gray (10YR6/1) mottles;
43 - 53 cm yellowish brown (10YR5/8) to brownish yellow (10YR6/8) loamy sand with many iron concretions of about half a centimeter in diameter. The layer has prominent, many, coarse strong brown (7.5YR5/8) mottles;
53-100 cm yellowish brown (10YR5/8) to brownish yellow (10YR6/8) sandy loam with some weak iron concretions along the root channels;

100 - ? yellowish brown (10YR5/8) to brownish yellow (10YR6/8) loamy sand with prominent, many, coarse yellowish red (5YR4/6) and distinct, few, medium gray (10YR6/1) mottles.

Groundwater level at about 1.40 m below the surface.

Ridge crest sand B

0 - 20 cm dark brown (10YR4/3) sand;

20 - 30 cm mottled sand; mottles are prominent, many, coarse and of a brownish yellow (10YR6/6) to yellowish brown (10YR5/8) and gray (10YR6/1) colour;

30 - 40 cm mottled sand; colours of the mottles as in the layer 20 - 30 cm, only gray a little more pronounced;

40 - 65 cm brownish yellow (10YR6/6) sandy loam with distinct, common, medium strong brown (7.5YR5/8) and gray (10YR6/1) mottles;

65 - ? loamy sand; colours as in the layer 40 - 65 cm.

Groundwater level at about 1.20 m below the surface.

Ridge flank sand

0 - 5 cm brown (7.5YR5/2) sand;

5 - 15 cm pale brown (10YR6/3) sand;

15 - 25 cm dark yellowish brown (10YR4/4) sand;

25 - 38 cm light yellowish brown (10YR6/4) to brownish yellow (10YR6/6) sand with prominent, many, coarse strong brown (7.5YR5/8) mottles; some weak iron concretions;

38 - 60 cm light yellowish brown to brownish yellow (10YR6/4 - 6/6) sand with prominent, many, coarse yellowish brown (10YR5/8) and gray (10YR6/1) mottles;

60 - 90 cm yellowish brown to brownish yellow (10YR5/8 - 6/8) loamy sand with prominent, numerous, coarse strong brown (7.5YR5/8) and faint, few, fine gray (10YR6/1) mottles;

90 - ? brown to strong brown (7.5YR5/4 - 5/6) loamy sand with faint, few, fine gray (10YR6/1) mottles; some very dark gray (7.5YR3/0) manganese mottles.

Groundwater level at 1.00 m below the surface.

Ridge foot sandy loam

0 - 5 cm dark brown (7.5YR4/2) sandy loam;

5 - 20 cm grayish brown to brown (10YR5/2 - 5/3) sandy loam with distinct, few, fine yellowish brown to brownish yellow (10YR5/8 - 6/8) mottles;

20 - 40 cm dark gray (10YR4/1) sandy clay loam, prominent, common, medium brownish yellow (10YR6/6 - 6/8) mottles;

40 - ? light gray to gray (10YR5/1-6/1) sandy clay loam with prominent, common, medium strong brown (7.5YR5/8) and brownish yellow (10YR6/6 - 6/8) mottles.

Groundwater level at 65 cm below the surface.

EXPERIMENTAL METHODS

Mechanical analysis of the fractions smaller than 35 mu was made by the pipet method of Robinson (1). The fraction larger than 35 mu was determined by the sieving method. Core samples of some horizons were collected to obtain information concerning the pore space and the air-water ratio in

Table 1 — Results of the mechanical analysis

Drainage phase	Depth in cm	Clay <2 mu (%)	Silt 2 — 53 mu (%)	Sand 53 — 74 mu (%)	74 — 105 mu (%)	105 — 149 mu (%)	149 — 210 mu (%)	210 — 297 mu (%)	297 — 420 mu (%)	420 — 590 mu (%)	590 — 840 mu (%)	840 — 1190 mu (%)	1190 — 2000 mu (%)	>2000 mu (%)
Ridge crest Sand A	0-15	4.4	3.1	3.3	69.2	17.4	1.5	0.3	0.2	0.1	0.2	0.2	0.1	1.0
	25-43	4.9	4.7	3.3	67.0	16.7	1.3	0.3	0.1	0.2	0.2	0.6	0.7	—
	43-53	8.2	4.8	3.0	64.6	16.2	1.4	0.3	0.2	0.2	0.3	0.6	0.2	5.7
	53-100	14.1	6.0	2.7	62.2	12.6	1.5	0.5	0.3	0.1	0.0	0.0	0.0	16.3
	100-120	11.1	5.0	2.1	64.2	15.7	1.2	0.4	0.2	0.1	0.0	0.0	0.0	—
Ridge crest Sand B	0-20	4.1	3.9	3.3	69.6	17.2	1.4	0.2	0.1	0.0	0.1	0.1	0.0	0.5
	20-30	3.4	5.6	3.0	67.2	18.3	1.5	0.2	0.1	0.1	0.1	0.3	0.2	3.3
	30-40	4.1	4.6	2.8	68.3	18.1	1.5	0.3	0.1	0.1	0.1	0.0	0.0	—
	40-65	13.3	4.8	2.4	65.0	13.2	1.0	0.2	0.1	0.0	0.0	0.0	0.0	—
	65-90	11.2	4.6	2.5	66.5	13.2	0.9	0.4	0.4	0.3	0.0	0.0	0.0	—
Ridge flank Sand	0-5	4.2	5.3	3.6	69.0	16.0	1.6	0.2	0.1	0.0	0.0	0.0	0.0	—
	5-15	3.5	5.0	3.2	69.7	16.7	1.4	0.3	0.1	0.1	0.0	0.0	0.0	—
	15-25	3.6	5.8	3.0	68.7	17.0	1.4	0.3	0.1	0.1	0.0	0.0	0.0	—
	25-38	3.6	5.2	2.9	69.0	17.5	1.4	0.3	0.1	0.0	0.0	0.0	0.0	—
	38-60	8.4	5.0	2.2	64.5	17.6	1.5	0.4	0.1	0.1	0.1	0.1	0.0	—
	60-90	11.6	4.7	2.4	63.4	15.1	1.2	0.4	0.5	0.5	0.1	0.1	0.0	—
	90-100	11.0	4.5	2.4	64.2	16.0	1.3	0.2	0.2	0.1	0.1	0.0	0.0	—
Ridge foot Sandy loam	0-5	10.3	18.4	4.7	56.1	9.7	0.6	0.1	0.1	0.0	0.0	0.0	0.0	—
	5-20	16.4	16.3	3.5	51.9	10.7	0.8	0.2	0.1	0.1	0.0	0.0	0.0	—
	20-40	28.2	14.7	2.8	43.3	9.6	0.8	0.2	0.2	0.1	0.1	0.0	0.0	—
	40-65	23.9	9.4	2.8	50.7	11.7	0.8	0.3	0.3	0.1	0.0	0.0	0.0	—

the soil. After moisture determinations, the pore space and the percentage air, water and solid matter were calculated.

The following chemical analyses were carried out in the laboratory of the Agricultural Experiment Station: organic matter determination by the method of Kurmies; pH(H_2O) and pH(KCl) were determined by means of the glass electrode pH meter (Electrofact, type $6C_2$); the hydrolitic acidity; the S value: the real amount of exchangeable bases carried by the colloidal complexes; this value is expressed in me./100 g dry soil; and the T value or maximum adsorption capacity, also expressed in me./100 g dry soil. The amounts of K_2O, Na_2O and CaO were determined by two methods; in the first method the soil was treated with 0.1 N HCl and in the second method the soil was treated with 25% HCl. After treatment, in both methods the amounts were determined by means of the flamephotometer of Kipp. MgO was estimated colourimetrically by means of titan yellow. Determinations of P_2O_5 were carried out in 25% HCl soil extracts and in 2% citric acid extracts (Lorenz method). The total amount of iron was determined in the Laboratory for Food Control. After treatment with sulfuric, nitric and hydrochloric acid the total amount of iron was obtained by titration (2). To determine if a correlation exists between the total amount of iron and soil colours after ignition, some samples were ignited in the Laboratory (6). The samples were placed in an oven and heated to ± 850° C.

RESULTS

Table 1 presents the results of the mechanical analysis. Each profile has a horizon with a relatively maximum amount of clay. The sand fraction is concentrated between 74 and 105 mu. The clay accumulation horizons tend to have the smallest amount of pore space (table 2).

Table 2 — Relative volume percentages of pore space, solid matter, water and air

Drainage phase	*Depth in cm*	*Pore space %*	*Solids %*	*Water %*	*Air %*
Ridge crest Sand A	5-15	51.3	48.7	18.9	32.4
	25-43	49.2	50.8	18.9	30.3
	43-53	41.6	58.4	24.7	16.9
	53-100	44.5	55.5	33.8	10.7
	100-110	47.2	52.8	44.4	2.8
Ridge crest Sand B	5-15	52.8	47.2	22.7	30.1
	40-65	46.1	53.9	29	17.1
	65-75	46.1	53.9	32.8	13.3
Ridge flank Sand	0-5	55.5	44.5	30.8	24.7
	5-15	48	52	18.8	29.2
	15-25	48.7	51.3	21.4	27.3
	25-38	48.5	51.5	26.9	21.6
	38-60	44.4	55.6	29.7	14.7
	60-90	44.3	55.7	36	8.3
Ridge foot Sandy loam	0-5	53.3	46.7	39.6	13.7
	5-20	49.5	50.5	31.9	17.6
	20-40	43.8	56.2	33.1	10.7
	40-65	42.7	57.3	34.2	8.5

The relative volume percentages of solid matter, water and air are presented in figure 1. The moisture content of the topsoil increases from the ridge crest to the ridge foot. There is also a gradual increase in moisture content from topsoil to subsoil within each profile, while at comparable depth the air content tends to decrease from the ridge crest to the ridge foot.

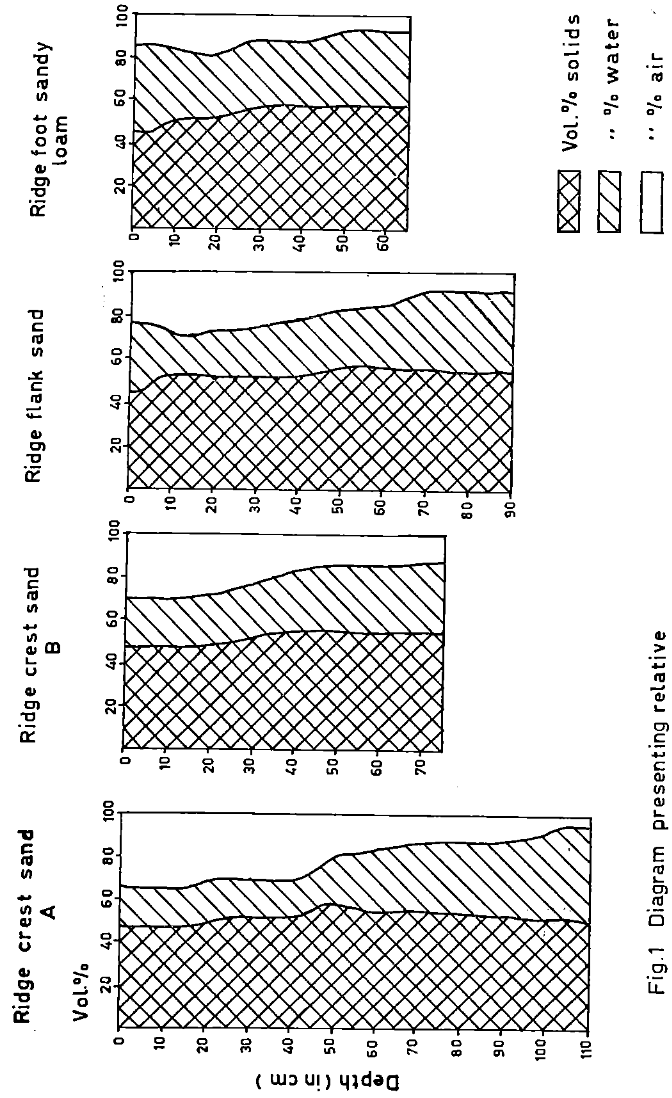

Fig.1 Diagram presenting relative volumes of solid matter, water and air

Table 3 and figure 2 show some chemical properties of the drainage phases. Generally, the organic matter content is low. The highest amount is determined in the topsoil (A_1 horizon) of the ridge foot sandy loam. The pH of the profiles is low. The ridge foot sandy loam has the highest pH. With exception of the ridge foot sandy loam profile, within the profile of each individual drainage phase, the clay accumulation horizon tends to have the lowest pH, while the immediately underlying layer indicates an increase of the pH.

Generally, the highest T values are obtained in the A_1 horizons and in the horizons with the greatest amount of clay. The layer underlying the topsoil (the A_2 horizon) shows an increase in thickness and a decrease in the amount of K_2O, MgO and P_2O_5 from ridge crest to ridge flank. These compounds tend to accumulate in the layer underlying the clay accumulation horizon. The K_2O compounds are more or less uniformly distributed through the profile of the ridge foot sandy loam; the MgO compounds are strongly concentrated in the subsoil, while the P_2O_5 compounds show a strong decrease in the layer underlying the A_1 horizon of this drainage phase. The amount of iron is strongly influenced by the position of the drainage phase. There is an increase in the amount of Fe_2O_3 from topsoil to subsoil, within each drainage phase. Relatively, the amount of iron decreases from ridge crest to ridge foot. The amount of iron is also very low in the ridge foot sandy loam

Table 3 — Results of the chemical analysis

Drainage phase	Depth in cm	Organic matter (% dry matter)	pH H_2O	pH KCl	T value (me./100 g dr.)	25 % HCl (mg / 100 g dr.) K_2O	MgO	P_2O_5	Fe_2O_3 (% dry matter)
Ridge crest Sand A	0-15	2.0	5.2	3.8	10	9	15	24	1.5
	25-43	0.3	5.0	4.0	4	8	16	21	2.3
	43-53	0.2	4.7	3.9	6	17	20	29	4.4
	53-100	0.1	4.3	3.8	11	31	51	53	7.3
	100-120	<0.1	5.1	3.7	11	45	96	104	6.4
Ridge crest Sand B	0-20	2.0	4.9	3.7	9	4	15	14	0.4
	20-30	0.6	5.0	4.1	5	5	12	11	1.9
	30-40	0.3	5.3	4.0	4	7	10	8	1.6
	40-65	0.1	4.3	3.7	10	20	33	15	4.5
	65-90	<0.1	4.4	3.8	6	24	31	18	4.7
Ridge flank Sand	0-5	2.0	5.0	3.5	7	4	17	13	0.3
	5-15	0.7	4.9	3.8	4	2	8	8	0.3
	15-25	1.0	4.9	4.2	7	10	10	7	0.5
	25-38	0.2	4.6	4.1	4	7	7	4	0.8
	38-60	0.0	4.7	3.8	5	13	8	2	1.0
	60-90	0.0	4.6	3.6	8	20	39	4	1.5
	90-100	0.0	4.8	3.8	9	43	108	15	4.7
Ridge foot Sandy loam	0-5	4.2	5.1	3.9	15	12	39	24	0.6
	5-20	0.5	5.1	3.6	10	10	58	5	1.0
	20-40	0.3	5.3	3.6	18	11	168	3	1.8
	40-65	0.0	6.0	4.1	15	10	174	2	1.8

profile; however it is slightly higher than in the ridge flank profile at comparable depth.

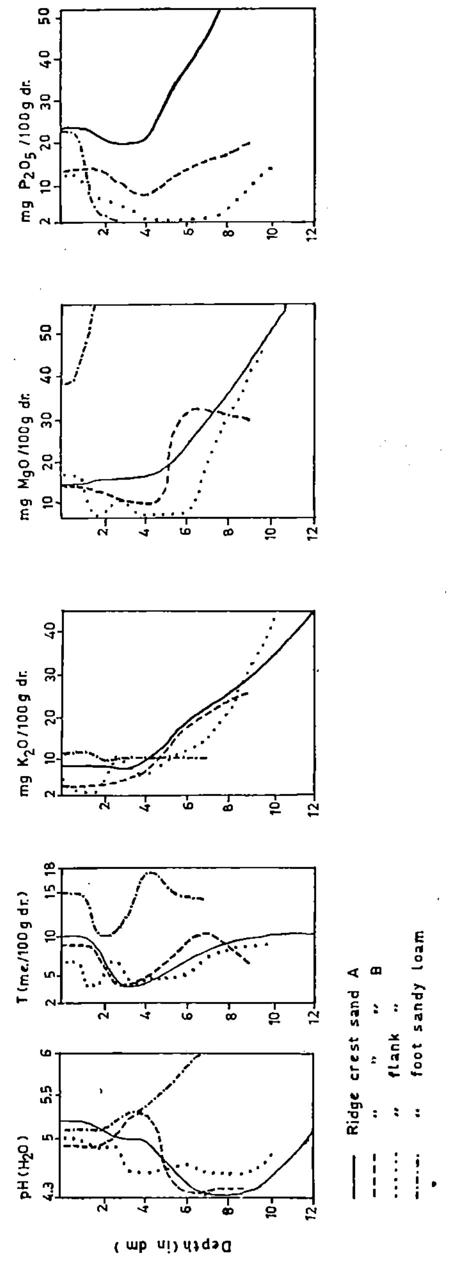

Fig.2 pH(H_2O), T-value, mg K_2O, MgO, and P_2O_5 of the drainage phases

During the ignition process the reduced forms of iron are changed intc the oxidized stage.

Figure 3 and table 4 indicate a correlation between the amount of Fe_2O_3 and the colours after ignition. The ridge crest profiles are characterized by 2.5YR hue ignition colours (Fe_2O_3% from 0.4% - 7.3%). In the ridge flank profile 2.5YR and 5YR hue colours occur after ignition, while 5YR hue iginition colours (Fe_2O_3% from 0.6% - 1.8%) are typical for the ridge foot sandy loam profile.

DISCUSSION

Each drainage phase has its own morphological, physical and chemical characteristics. These characteristics are to a large extent determined by the position of the drainage phase in relation to the groundwater level. The water hazard increases from the ridge crest to the ridge foot.

The study was carried out during a dry period. In the rainy season the groundwater rises to 50 cm below the surface of the ridge crest, while under natural conditions the ridge foot is slightly inundated during the rainy season. An increase in moisture from ridge foot to ridge flank results in an increase of the reduction period, which is associated with an increase of reduction symptoms at shallower depth in the profile (an increase in "reduction colours" and thickness of the A_2 horizon). In the A_2 horizon the loss of Fe_2O_3, K_2O, MgO and P_2O_5 compounds increases with an increase in moisture. If the amount of moisture increases, the iron changes more readily from the oxidized into the reduced form and becomes mobile (4).

The study suggests that the rate of change is also strongly determined by the amount of organic matter (6). In the topsoil most of the biological processes take place. For these processes a good supply of oxygen is necessary. When the supply of oxygen becomes insufficient as the result of an increase of moisture, the oxygen will be obtained from oxidized iron compounds. This will result in an increase of reduced iron. The reduced iron will move with the fluctuating groundwater level and will be oxidized only in those layers, where sufficient oxygen occurs; that is in those layers in which practically no oxygen is required for biochemical processes, consequently, in layers with a low amount of organic matter. This may explain the more oxidized yellow and orange colours in the B horizon below the dominantly gray A_2 horizon (4). In the A_1 horizon the gray colours are masked by the colour of the organic matter. In the subsoil reduction colours again become more pronounced.

Compared to the topsoil, the requirement for oxygen for biochemical processes in this subsoil is very low. Most of the year, as a result of the high moisture content the amount of oxygen is very low at this depth. This results in increased reduction symptoms. The reduction symptoms in the subsoil cannot be explained as the result of a loss of iron as in the A_2 horizon. On the contrary, an increase of the total amount of iron occurs at this depth. Therefore, reduction symptoms in the subsoil point to an accumulation of iron in the reduced form (5).

From the data, the increase of the amount of clay in the subsoil cannot be attributed to pedogenic processes. The relatively low amount of pore space in this layer indicates a translocation of finer material from the toplayers into this layer. Particularly, in the ridge foot sandy loam profile a sediment with

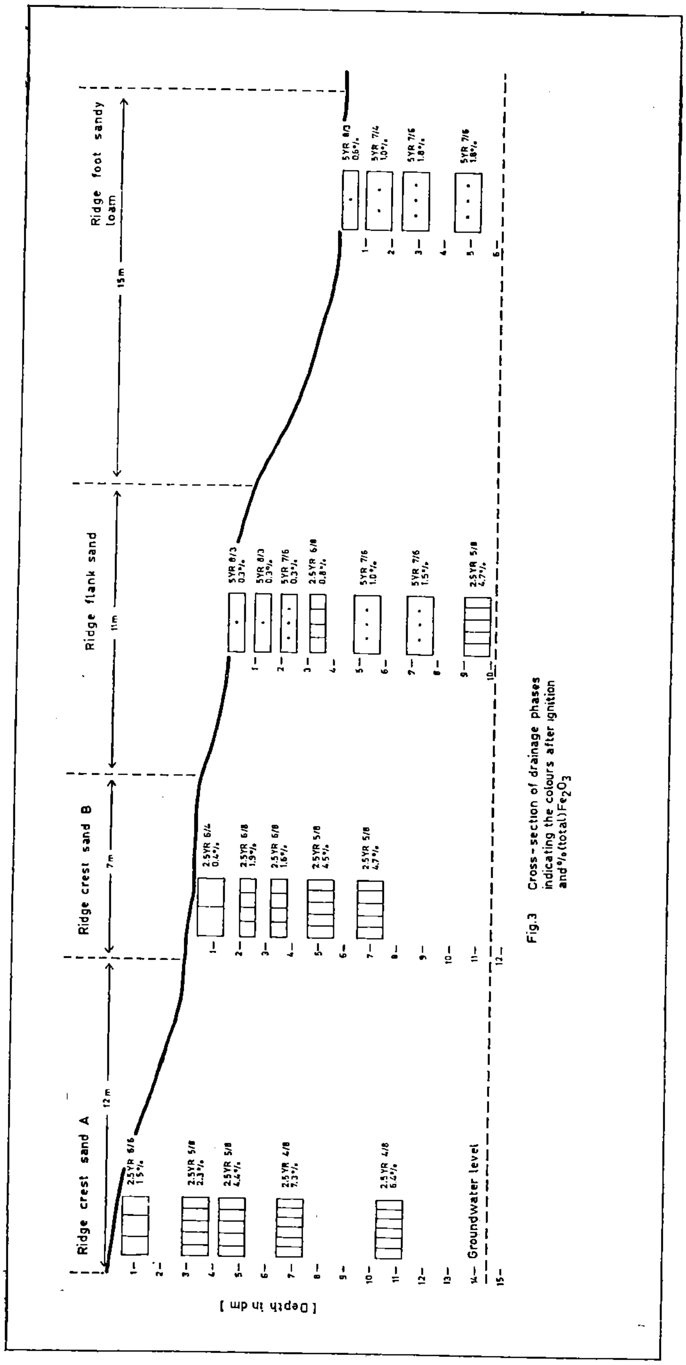

Fig.3 Cross-section of drainage phases indicating the colours after ignition and % (total) Fe_2O_3

Table 4 — Ignition colours and amount of iron

	Ridge crest sand A			Ridge crest sand B			Ridge flank sand			Ridge foot sandy loam	
Depth (in cm)	Ign.col.	Fe_2O_3%	Depth (in cm)	Ign.col.	Fe_2O_3%	Depth (in cm)	Ign.col.	Fe_2O_3%	Depth (in cm)	Ign.col.	Fe_2O_3%
0-15	2.5YR6/6	1.5	0-20	2.5YR6/4	0.4	0-5	5YR8/3	0.3	0-5	5YR8/3	0.6
25-43	2.5YR5/8	2.3	20-30	2.5YR6/8	1.9	5-15	5YR8/3	0.3	5-20	5YR7/4	1.0
43-53	2.5YR5/8	4.4	30-40	2.5YR6/8	1.6	15-25	5YR7/6	0.5	20-40	5YR7/6	1.8
53-100	2.5YR4/8	7.3	40-65	2.5YR5/8	4.5	25-38	2.5YR6/8	0.8	40-65	5YR7/6	1.8
100-120	2.5YR4/8	6.4	65-90	2.5YR5/8	4.7	38-60	5YR7/6	1.0			
						60-90	5YR7/6	1.5			
						90-100	2.5YR5/8	4.7			

more clay enriched with finer material must be considered (5). The texture of the sandy loam probably also interferes with the general trend of the chemical status of the A_2 horizon from ridge crest to ridge flank.

CONCLUSIONS

The results of this study lead to the following conclusions:

1. The morphological, physical and chemical characteristics change from the ridge crest to the ridge foot.
2. The A_2 horizon increases in thickness from the ridge crest to the ridge flank. This is associated with symptoms of reduction at shallower depth and a decrease in the physical and chemical fertility level.
3. The subsoil of each drainage phase has a higher chemical status than its top layer.
4. The ridge foot drainage phase has a very low physical, but a relatively high chemical fertility compared with the ridge crest and ridge flank drainage phases.
5. Soil forming processes are strongly related to the amount of moisture. Eluviation of finer material increases with moisture and water fluctuations.
6. To obtain information about the distribution of iron within soil profiles. it would be useful to study the colours after ignition of soils, with the same textural range as the drainage phases studied.
7. It is suggested by this study that reduction colours occur when iron has actually been removed (A_2 horizon) or when iron accumulates in the reduced form (subsoil).
8. The mobility of iron tends to be influenced not only by the amount of moisture, but also by the organic matter content.
9. In the field the drainage phases occur as small strips from ridge crest to ridge foot. This involves a differentiation in crops at short distances, unless different drainage and fertilizer practices are applied for each crop on each drainage phase.

The study was carried out in 1958. Afterwards, a more detailed classification of the drainage phases of the sandy soils has been introduced. At present the following drainage phases are distinguished: ridge crest sand A, B and C and ridge flank sand A, B, C. The differences between the drainage phases are based upon the rate of eluviation, which correlates with the intensity of gray colours in the A_2 horizon. Mapping of all the various phases is not always possible. Particularly, in the case of the ridge flank sand and the ridge foot sandy loam strong morphologic and textural differences may occur at very short distances. For mapping purposes grouping into drainage phase-associations is then necessary.

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