Tea Q. 49 (1) 5 - 24, 1980. Printed in Sri Lanka

SOILS OF ST COOMBS ESTATE

1 - ENVIRONMENTAL AND MORPHOLOGICAL CHARACTERISTICS

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A high intensity detailed soil survey of St Coombs Estate was carried out for purposes of (1) extrapolating the findings of soil-related research of the Institute to tea estates with similar soils and (2) improving designs and interpretations of field experiments.

This paper, the first of three, deals with the environmental and morphological characteristics of the soils of St Coombs Estate and their relationship to the factors and processes of soil formation. A detailed description of the morphology of the type-profile of each soil series is presented. Subsequent papers will deal with their physico-chemical characteristics, genesis, classification and production potentials.

INTRODUCTION

St Coombs Estate has been a research station since 1929, but information on the detailed environmental and morphological characteristics of its soils is lacking. Fertilizer and other field trials (Eden, 1933, 1937, 1938) and soil investigations related to plant growth (Lamb, 1955; Ramasamy, 1960; Tolhurst, 1961; Hasselo, 1962, 1964; Kalpage, 1967; de Silva, 1968; 1969) have been carried out from its inception and their results applied to estates but no soil surveys were done either of St Coombs or the other estates. The soils of this area were first classified by the Land Use Division under the National Soil Survey Programme in 1961 but, owing to the small scale used, the soil differences within St Coombs Estate could not be shown. The whole estate was thus mapped as consisting of one soil unit, the Red Yellow Podzolic soils.

This and the accompanying papers present the results of a high intensity detailed soil survey done in 1975. The survey was carried out as a joint project under the Co-ordinated Soil Research Programme by the Tea Research Institute and the Land Use Division of the Irrigation Department and constitutes the first step towards a survey of all tea growing areas in Sri Lanka. This will enable a better understanding of the responses obtained from field experiments and the appropriate extrapolation of the findings of the Institute to the estates.

This paper deals with the environmental and morphological characteristics of the soils of St Coombs Estate and discusses their relationships to soil forming factors and processes. Subsequent papers will deal with their physico-chemical characteristics in relation to their genesis, production potentials and management.

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GENERAL DESCRIPTION OF THE AREA

Location and Extent

St Coombs Estate is situated at an elevation of between 1310 and 1495 metres amsl (4300—4900 ft) in the Nuwara Eliya district of the Central Province. It is bounded by Mattakelle Estate on the north, Maria Estate on the east, Kowlahena and Waltrim Estates on the south and Llan Thomas Estate on the west*. The total extent of the estate is approximately 171.3 ha, (423 acre) including roads, buildings and gardens which occupy about 29.5 ha (73 acre).

Climate

St Coombs Estate is in the climatic zone commonly known as the up-country wet-zone. Some meteorological data which indicate the main features of the climate of the area are given in Table 1.

TABLE 1—METEOROLOGICAL OBSERVATIONS—ST COOMBS ESTATE, TALAWAKELE

(Average values of ten years: 1967 — 1976)

Month	*Temperatures (°C)*			*Relative humidity*		*Sunshine*	*Rainfall*	*Rainy*
	Maximum dry	*Minimum dry*	*Minimum grass*	*Maximum*	*Minimum*	*Mean hours per day*	*cm*	*days*
January ...	23.8	10.7	7.1	86	65	7.2	4.6	7
February ...	24.5	10.7	6.6	78	53	8.1	11.7	6
March ...	25.6	11.2	7.9	82	55	7.8	8.7	8
April ...	24.9	13.0	10.5	91	62	6.4	19.6	18
May ...	23.6	14.5	12.5	92	72	5.5	16.4	16
June ...	21.7	14.8	12.8	93	77	3.4	25.3	22
July ...	22.8	14.6	12.6	95	77	3.5	31.4	22
August ...	21.4	14.6	12.7	95	75	3.8	28.3	20
September ...	22.4	13.2	11.2	92	71	4.5	24.2	17
October ...	22.7	13.0	10.3	89	70	4.6	26.0	21
November ...	22.9	12.8	10.6	92	68	5.5	20.6	17
December ...	23.0	12.9	9.4	87	71	5.3	15.2	14
Means ...	23.3	13.0	10.3	89	68	5.5	—	—
Total ...	—	—	—	—	—	—	232.0	188

Landform and Geology

St Coombs Estate is a minor catchment consisting of a valley surrounded by steep mountain slopes. Four major landscape elements were identified in the survey area viz :

(a) Steep to very steep mountain slopes having gradients ranging from 25 to 60 per cent.

(b) Gently sloping to steep, rounded hills and valleys with gradients of 2 to 55 per cent.

* Survey plan of St Coombs Estate - 1961.

(c) Gently sloping to moderately steep foot slopes having gradients of 6 to 25 per cent.

(d) Level to gently sloping valley bottoms of 0 to 6 per cent slope.

Valleys in this area are generally elongated, narrow and V-shaped. The drainage pattern is dendritic, and the area is underlain mainly by metamorphic rocks of pre-Cambrian age belonging to the Highland series. The major rock type is Charnokite. A stretch of local alluvium, which is of geologically recent origin, occur in the valley bottoms. The regional strike of the area is north-west to south-west with dips varying from 15 to 50° towards the east*.

The major water source of the estate is a reservoir, built in the upper part of the valley, and having a perennial supply of water from the catchment area.

Vegetation

Part of St Coombs Estate was first opened up for Cinchona between 1876 and 1877. Tea was planted around 1881. In 1928 the estate was bought by the Board of the Tea Research Institute for its station (de Silva, 1967). At this stage, the existing land use was as follows :

Seedling tea in bearing	66.8 ha	(165	acre)**
New clearings	30.3 ,,	(75	,,)
Patna and Swamp land	74.5 ,,	(184	,,)

At present the major part of the estate is under clonal and seedling tea. However, the low-lying water-logged areas are under gum trees, vegetables and grasses. The land use pattern as at January, 1977 was as follows:

Clonal tea	57.3 ha	(141.6	acre)**
Seedling tea	54.8 ,,	(135.3	,,)
Low-lying areas	29.5 ,,	(73	,,)
Buildings, roads, etc	29.5 ,,	(73	,,)

METHOD OF SURVEY

A high intensity detailed soil survey was carried out according to the procedures described in the USDA Soil Survey Manual (1952).

Aerial photographs of the scale 1 : 25,000 taken in 1973 were used to demarcate major physiographic units. Enlarged aerial photographs of 1 : 3,168, contour maps of 1 : 3,168 with ten foot contours and the survey plan of 1961, of the same scale, were used as the base materials for this survey.

The major soil series were identified by observation of road cuts, soil pits and bores. 165 soil bores, 12 road cuts and 31 soil pits were studied and described. On the basis of these observations, 25 pits were selected for sampling for physical and chemical analysis. An average intensity of about 1.5 observations per hectare were made in this survey. Six depth phases, six rocky phases and six slope phases were identified under different series.

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* Geological Survey Department records.

** Approximate values.

Compilation of the soil map was done by the Cartographic Unit of the Land Use Division. The scale of the final published soil map is 1 : 4,000.

THE SOILS

An outline of the morphological characteristics of the different soils in St Coombs Estate are given in this section.

The well-drained soils, which occupy about 90 per cent of the estate, all belong to the Red Yellow Podzolic Great Soil Group. The imperfectly, poorly and very poorly drained soils which belong to the Alluvial, Half Bog and Bog Great Soil Groups make up the balance 10 per cent.

The soils were sub-divided into soil series and phases of soil series. It is the usual practice to give the name of the place where a particular soil was found in naming a soil series. In the case of this survey it was found that the names of estates surrounding St Coombs could not accommodate the different soils found and a departure from the usual procedure was necessary. Thus, some soil series were named after individuals viz: the first two Directors of the Institute, Mr. T. Petch and Dr. R. V. Norris and an eminent Tea Agronomist, Dr T. Eden. Some soil series were named according to the use/location of the soils concerned, *eg.* the Thavana Series (which means nursery), the Reservoir Series (occurring in the upper reaches of the reservoir) and the Agra Series (name of the nearest main river).

Classification of Soils

The soils of St Coombs Estate were grouped under the following landforms :

(i) Soils of the steep to very steep mountain slopes (25—60% slopes)

Cairness Series

(ii) Soils of the gently sloping to steep rounded hills and valleys (2—55% slopes)

Coombe Series
Waltrim Series
Kowlahena Series
Mattakelle Series

(iii) Soils of the gently sloping to moderately steep foot slopes (6—25% slopes)

Norris Series
Eden Series

(iv) Soils of the gently sloping valley bottoms (0—2% slopes)

Thavana Series
Reservoir Series
Agra-Petch Complex consisting of
Agra Series
Petch Series.

Descriptions of Soil Series

Generalized descriptions of the soil series together with detailed type-profile descriptions are given below:

CAIRNESS SERIES

The soils of this series are generally very deep to deep, well-drained, dark reddish brown to yellowish red soil, strikingly uniform in appearance throughout its depth. The soil structure is moderate subangular blocky and the whole profile is friable, slightly porous and permeable. Close examination shows a well developed textural B horizon with moderately developed cutans. Root distribution is normal with the majority of the roots occurring in the upper 50 cm. Horizon boundaries are ill-defined.

This unit occupies the convex and straight slope sites of the landscape, and occurs only in Field No. 1. Rock outcrops are fairly common in this unit. Four depth phases, three rocky phases and four slope phases were mapped. This unit occupies only 7.7 ha (19 acre) or 4.5% of the whole estate.

Type Profile (TRCP - 19)

The following type-profile of this series occurs in Field No. 1. The profile site was on a straight part of a mountain slope of 31% gradient under clonal tea.

A_p 0-18 cm :

Dark greyish brown (10 YR 4/4) moist; fine loam; weak coarse crumb; soft, very friable, very slightly sticky and very slightly plastic; many fine, few medium roots; common fine, few medium, random tubular pores; few pieces of charcoal; clear wavy boundary.

B_{1t} 18-23 cm :

Yellowish brown (10 YR 5/4) moist; clay loam; weak medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many fine, few medium, occasional coarse roots; few krotovinas; common fine, few medium and coarse random tubular inped pores; sand grains mainly of quartz; gradual smooth boundary.

B_{21t} 23-47 cm:

Strong brown (7.5 YR 5/8) moist; clay; moderate coarse subangular blocky; slightly hard, friable, sticky and plastic; common fine, few medium roots; common fine, few medium and coarse tubular random inped pores; thin patchy cutans on ped surfaces and moderate thick cutans on pore walls and roots channels; some fine quartz gravel; gradual smooth boundary.

B_{22t} 47-72 cm :

Strong brown (7.5 YR 5/6) moist; clay; moderate coarse subangular blocky; hard, slightly firm, sticky and slightly plastic; faint organic matter staining; few fine, occasional medium roots; common fine and medium and few coarse tubular random inped pores; moderately thick patchy cutans on ped surfaces and thick continuous cutans on root channels; about 5% fine quartz gravel; gradual wavy boundary.

B_{2t} 72-106/177 cm :

Reddish brown (5 YR 4/4) moist; clay; structureless, massive; slightly hard, friable, sticky and slightly plastic; common fine, few medium, occasional coarse tubular random pores; moderately thick patchy cutans; about 10% fine quartz gravel; few feldspathic fine rock fragments; gradual wavy boundary.

B_3 106/177-146/153 cm :

Red (2.5 YR 5/8) moist; clay loam; structureless massive; soft, friable, slightly sticky and very slightly plastic; few fine and medium interstitial random pores; common very fine micas; many highly weathered feldspathic rock fragments; 10% fine quartz gravel; gradual wavy boundary.

C 146/153-162 cm + :

Red (2.5 YR 5/8) moist; clay structureless massive; slightly hard, very slightly firm, slightly sticky and slightly plastic; highly weathered feldspathic rock containing many micas and a little fine quartz gravel.

COOMBE SERIES

The soils are moderately deep to deep, well drained soil having a very dark brown, thick organic matter rich, crumb structured loamy surface horizon. Sub-surface horizons are structureless massive, loamy textured and yellowish brown in colour with a thick gravel layer containing a high concentration of lateritic gravel and fine feldspathic rock fragments. Horizons below the gravel layer are yellowish red and exhibit subangular blocky structures. The whole profile is friable and the majority of the roots are within the first 50 cm or above the gravel layer.

This unit occupies the summits, convex upper slopes and striaght slopes of the rounded hill and valley landform. There are few rock outcrops in this unit. Five depth phases, five rocky phases and six slope phases were mapped. This map unit occupies 57 ha (141 acre) or 34% of the whole estate, making it the most extensive soil series in St Coombs.

Type Profile (TRCP - 16)

The following type-profile of this series was described in Field No. 10. The site was on a convex part of a hill and valley landform. The slope at the site was 12%. This place was under seedling tea.

A_p 0-26 cm :

Very dark greyish brown (10 YR 3/2) moist; clay loam; weak coarse crumb; soft, very friable, slightly sticky and non plastic; many fine and medium, few coarse roots; few fine and medium tubular and common coarse interstitial random pores; few root channels; sand grains mainly of quartz; clear smooth boundary.

A_3 26-36 cm :

Dark brown (10 YR 3/3) moist; clay loam; weak medium subangular blocky; slightly hard, friable, sticky and plastic; many fine, common medium, few coarse roots; common fine, few medium and coarse tubular random inped and exped pores; few krotovinas few coarse quartz sand grains; few root channels; gradual smooth boundary.

B_1 36-46 cm :

Dark yellowish brown (10 YR 4/4) moist; clay loam; weak medium subangular blocky; slightly hard, friable, sticky and plastic; common fine and few medium roots; few root channels; very thin patchy cutans; common fine and medium few coarse tubular random inped pores; faint organic matter staining; rare quartz gravel; few krotovinas; gradual smooth boundary.

B_{21t} 46-61 cm :

Dark yellowish brown (10 YR 4/4) moist; clay; structureless massive; slightly hard, friable, slightly sticky and slightly plastic; about 10% angular quartz gravel (4-8 mm); few ironstone gravels (2 - 5 mm); few fine feldspathic rock fragments (5-10 mm); common fine and medium tubular and few coarse interstitial random pores; common fine and medium, few coarse roots; thin patchy cutans; gravel increases with depth; few fine faint brown (7.5 YR 4/4) mottles: clear smooth boundary.

IIB_{22t} 61-84 cm :

Dark yellowish brown (10 YR 4/4) moist; clay with 40-50% gravel; soft, very friable, very slightly sticky and non-plastic; about 20% feldspathic rock fragments (5-15 mm) which appear to be coated with iron; 10% quartz gravel (2-5 mm), 10% lateritic gravel (5-15 mm); few fine and medium roots; thin patchy cutans; common medium and coarse interstitial random pores; this horizon is slightly browner than above; clear wavy boundary.

$IIIB_{23t}$ 84-98cm:

Yellowish red (5 YR 5/8) moist clay; moderate coarse subangular blocky; slightly hard, slightly firm, sticky and plastic; few fine roots; moderately thick patchy cutans; occasional decomposing feldspathic rock fragments; common fine, few medium and coarse tubular random inped pores; gradual smooth boundary.

$IIIB_3$ 98/109 - 125 cm :

Yellowish red (5 YR 4/8) moist; clay loam; structureless massive; slightly hard; slightly firm, slightly sticky and slightly plastic; few fine roots; many highly decomposed and few partially decomposed feldspathic rock fragments; gradual irregular boundary.

$IIIC_1$ 109/125 - 125/144 cm :

Red (2.5 YR 5/8) moist; clay loam; highly weathered feldspathic rock material with abundant micas: diffuse wavy boundary.

$IIIC_2$ 125/144-188 cm+ :

Similar to the above horizon with more mica and partially weathered rock material.

WALTRIM SERIES

The soils are very deep, well drained and free of gravel. The surface horizons, to a depth of 25-30 cm, are rich in organic matter, very dark greyish brown in colour, friable, and loamy textured. The structures are crumb. The sub-surface horizons

are firm, loamy to clayey, dark yellowish brown to strong brown layers with strongly developed coarse prismatic and angular blocky structures. Closer examination shows a well developed textural B horizon with moderately developed cutans. The root distribution is normal with the majority of roots in the upper 80 cm. The horizon boundaries are gradual to diffuse.

This unit occupies the lower concave slope sites below the soils of the Coombe Series. The striking feature in the Waltrim Series is the general absence of rock outcrops except in one place where the rocky area is less than 0.08 ha (0.2 acre) in extent. Two depth phases, one rocky phase and four slope phases were mapped. This series occupies 18.6 ha (46 acre) or 11% of the whole estate, making it the third most extensive unit.

Type Profile (TRCP-21)

The following type-profile occurs in Field No. 9. The site was on a long concave part of the hill and valley landform. The slope at the site was 23%. This site was under seedling tea.

A_p 0-20 cm :

Very dark greyish brown (10 YR 3/2) moist; loam; weak medium and coarse crumb; soft, very friable, very slightly sticky and very slightly plastic, high organic matter content; many fine, common medium and few coarse roots; many fine and few medium tubular random exped pores; clear smooth boundary.

A_3 20-27 cm :

Dark brown (10 YR 3/3) moist; clay loam; moderate coarse crumb; slightly hard, friable, slightly sticky and slightly plastic; high organic matter content; many fine, common medium tubular random inped and exped pores; gradual smooth boundary.

B_{1t} 27-35 cm :

Dark yellowish brown (10 YR 3/4) moist; clay; weak medium subangular blocky; slightly hard, slightly firm, sticky and plastic; common fine, few medium, and coarse roots; some organic matter staining; many fine, few medium and coarse tubular random inped pores; thin patchy cutans; gradual smooth boundary.

B_{21t} 35-47 cm :

Dark yellowish brown (10 YR 4/4) moist; clay; moderate coarse subangular blocky; hard, firm, sticky and plastic; many fine, few medium roots; common fine and medium, few coarse tubular random inped pores; thin patchy cutans; common vertical and few horizontal cracks (3-8 mm width); diffuse smooth boundary.

B_{22t} 47-76 cm :

Dark yellowish brown (10 YR 4/4) moist; clay; moderate coarse angular blocky to prismatic; hard, firm, sticky and plastic; common fine, few medium and coarse roots largely along cracks; moderately thick patchy cutans; common vertical and few horizontal cracks (5-15 mm width) common organic matter staining; many fine and common medium, tubular inped pores; gradual smooth boundary.

B_{23t} 76-98 cm :

Yellowish brown (10 YR 5/6) moist; clay; strong coarse prismatic; hard, firm, sticky and plastic; few fine and medium roots; fine roots mainly in cracks; common vertical and horizontal cracks (55 mm width); moderately thick cutans; common fine and few medium tubular random inped pores; diffuse smooth boundary.

B_{24t} 98-121 cm :

Strong brown (7.5 YR 5/6) moist; clay; very similar to the above horizon except for fewer fine roots and less cracks; diffuse smooth boundary.

B_{25t} 121-144 cm :

Strong brown (7.5 YR 5/6) moist, clay; moderate coarse prismatic; very hard, firm, sticky and plastic; thick patchy cutans; few fine tubular random inped pores; few medium dead roots; gradual smooth boundary.

B_{26t} 144-175 cm :

Strong brown (7.5 YR 5/6) moist; clay; moderate coarse prismatic; very hard, firm, sticky and plastic; thick patchy cutans; few fine and medium tubular random inped pores: few fine faint yellowish red mottles. (5 YR 5/6); diffuse smooth boundary.

B_{27t} 175-208 cm :

This horizon is very similar to above except for few medium faint mottles of 5 YR 5/6 colour; gradual smooth boundary.

B_{28t} 208-244 cm+ :

Yellowish red (5 YR 5/8) moist; clay; moderate coarse prismatic to blocky; slightly firm, sticky and plastic; few fine tubular inped pores; moderately thick patchy cutans; coarse sand grains.

KOWLAHENA SERIES

The soils are well drained, moderately deep soils having dark yellowish brown, friable surface horizons. The sub-surface horizons are generally structureless, loamy to clayey in texture and dark brown in colour with a thick gravel layer containing a high percentage of lateritic gravel and feldspathic rock fragments. The horizons below the gravel layer are yellowish red and display weak sub-angular blocky structures. The whole profile is friable and the majority of the roots are within the first 50 cm of the profile or above the gravel layer.

This unit occupies the summits, convex upper slope sites and straight slopes of the rounded hill and valley landform. There are considerable areas of rock outcrops in this unit. Three depth phases, three rocky phases and four slope phases were mapped. This unit occupies 9.6 ha (24 acre) or 5.7% of the whole estate.

Type Profile (TRCP-22)

The following type-profile of this series was located in Field No. 3. The site was on a convex slope of 13%. This pit was located in a clonal tea area.

A_p 0-23 cm :

Dark brown (10 YR 4/4) moist; loam; moderate medium crumb; soft, friable, slightly sticky and slightly plastic; many fine, common medium, few coarse roots; few vertical cracks (4-5 mm width); common fine and medium, few coarse tubular random inped and exped pores; occasional ironstone gravel; few feldspathic rock fragments (10-15 mm); few krotovinas; clear wavy boundary.

B_{21} 23-48 cm :

Dark brown to brown (7.5 YR 4/4) moist; clay loam; moderate coarse subangular blocky; slightly hard, friable; sticky and slightly plastic; many fine, few medium and coarse roots; thin patchy cutans; common fine and medium, few course tubular random inped pores; few vertical and horizontal cracks (5-8 mm width); few krotovinas; occasional ironstone gravel; few worm casts; gradual smooth boundary.

B_{22t} 48-63 cm :

Dark brown (7.5 YR 4/3) moist; clay loam to clay; moderate medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; 5% quartz gravel and 5% fine feldspathic rock fragments.

IIB_{23t} 63-89 cm :

Dark brown (7.5 YR 4/3) moist; clay with 60-70% gravel; structureless massive; loose (dry and moist), slightly sticky and non-plastic; few fine and medium roots; common fine and medium interstitial random pores; 40-50% (10-20 mm) lateritic gravel and 15-20% (30-60 mm) feldspathic rock fragments which appear to be coated with iron; clear wavy boundary.

IIB_{24t} 89-98 cm :

Yellowish brown (5 YR 4/6) moist; clay with 60-70% gravel. This horizon is very similar to the above horizon except for the matrix colour; abrupt wavy boundary.

$IIIB_{25t}$ 98-116 cm :

Yellowish red (5 YR 4/8) moist; clay; weak coarse subangular blocky; slightly hard, friable, sticky and plastic; fine feldspar gravel; common fine, few medium tubular random inped pores; moderately thick patchy cutans; clear wavy boundary.

$IIIB_{31}$ 116-165 cm :

Yellowish red (5 YR 4/6) moist; sandy clay with 20-25% gravel; structureless massive; slightly hard, friable, sticky and slightly plastic; gravel is mainly of fine feldspar in various stages of weathering; gradual wavy boundary.

$IIIB_{32}$ 165-175 cm+ :

Yellowish red (5 YR 5/6) moist; clay loam; structureless massive; friable, slightly sticky and slightly plastic; common slightly hard red (10 YR 4/6 X 4/8) plinthite domains; many highly weathered feldspars in very fine form.

MATTAKELLE SERIES

The soils of this series are very deep, well drained without a gravel layer having dark yellowish brown, friable surface horizons. The sub-surface horizons are strong brown to yellowish red, clayey textured and have blocky structures. These soils have well developed textural B horizons, and moderately thick cutans. The root distribution is confined mostly to the upper 70 cm of the profile.

This unit occupies the lower concave or straight slope sites below and adjacent to the soils of Kowlahena Series; the most striking feature in this unit is the absence of rock outcrops. Four slope phases were mapped. This unit occupies 33 ha (81.5 acre) or 20% of the total estate, making it the second most extensive unit in the estate.

Type Profile (TRCP-5)

The following type-profile occurs in Field No. 5. The site was on a concave part of the rounded hill and valley landform. The slope at the site was 23%. This pit was located in a young clonal tea field.

A_p 0-21 cm :

Dark yellowish brown (10 YR 4/4 & 5/4) moist; clay loam; weak medium, subangular blocky; soft, friable, slightly sticky and slightly plastic; many fine, common medium roots; organic matter in pockets; little quartz gravel; occasional fine feldspathic rock fragments; common medium and few fine and coarse random inped and exped pores; clear smooth boundary.

B_{21t} 21-44 cm :

Yellowish brown (10 YR 5/6) moist; clay; weak coarse subangular blocky; slightly hard, friable, sticky and plastic; many fine, common medium, few coarse; tubular random inped pores; common fine, few medium roots; thin patchy cutans; few krotovinas and worm casts; gradual smooth boundary.

B_{22t} 44-70 cm :

Yellowish brown (7.5 YR 5/5) moist; clay; moderate coarse subangular blocky; hard, slightly firm, sticky and plastic; many fine, common medium, few coarse tubular random inped pores; few fine roots, few roots channels; moderately thick patchy cutans; few krotovinas; clear smooth boundary.

B_{23t} 70-95 cm :

Dark yellowish brown (10 YR 4/4) moist; clay; very similar to the above horizon except for the matrix colour and dark brown faint mottled appearance; clear smooth boundary.

B_{24t} 95-130 cm :

Strong brown (7.5 YR 5/6) moist; clay; moderate coarse subangular blocky; slightly firm, sticky and plastic; moderately thick cutans; occasional fine feldspars; many fine, few medium and coarse tubular random inped pores; some fine quartz gravel; gradual smooth boundary.

B_3 130-170 cm :

Strong brown (7.5 YR 5/8) moist; sandy clay loam; structureless massive; friable, slightly sticky and slightly plastic; common fine, few medium tubular random pores in pockets of soil; similar soils as above with many highly weathered feldspathic rock material, few rock fragments (2-3 cm); clear wavy boundary.

C 170-180+ :

Mixed colours; sandy loam; structureless single grain; loose (dry and moist), non-sticky and non-plastic; highly weathered gneissic rock containing feldspar and a few angular quartz grains.

NORRIS SERIES

The soils are imperfectly drained, deep having very dark brown, thick organic matter-rich, crumb structured surface horizons. The textures are either clay loam or silty clay loam. The sub-surface horizons are light brownish grey to olive coloured and display blocky structures. The textures are clayey. These horizons are mottled and the lower part of the profile generally below 60 cm are completely gleyed.

This unit occupies the foot-slopes of the rounded Hill and Valley landform and occur in topographical positions below the Coombe and Waltrim Series. Two slope phases were mapped. This unit occupies about 1.0 ha (2.2 acre) or 0.5% of the total estate.

Type Profile (TRCP-9)

The following type-profile is from a pit located in Field No. 12. The site was on the concave part of a foot slope. The slope at this site was 7%. The water table was at 108 cm depth at the time of description.

A_{p1} 0-10 cm :

Dark brown (10 YR 3/2) moist; clay loam; moderate medium crumb; very hard, slightly firm, slightly sticky and slightly plastic; many fine, common medium, few fine feldspathic rock fragments; common medium, few coarse tubular pores; few pockets of brown (10 YR 4/3) soil; gradual smooth boundary.

A_{p2} 10-21/27 cm :

Very dark greyish brown (10 YR 3/2) moist; silty clay loam; moderate coarse crumb; hard, slightly firm, sticky and plastic; many fine, common medium, few coarse tubular random inped pores: few krotovinas; granular structure in places; clear wavy boundary.

B_{21t} 21/27-40 cm :

Dark brown to brown (10 YR 4/3) moist; clay; moderate coarse angular blocky to prismatic; hard, firm, sticky and plastic; common fine and medium, few coarse roots; many fine, common medium, few coarse tubular random inped and exped pores; thin patchy cutans; occasional 5 mm wide cracks; soil material from above horizons within cracks; few krotovinas; few root channels; few medium reddish brown (10 YR 5/4) mottles; clear wavy boundary.

B_{22t} 40-59 cm :

Similar to above except for less roots, moderately thick cutans and common medium faint yellowish brown (10 YR 5/4) mottles in this horizon; gradual smooth boundary.

B_{23t} 59-78 cm :

Light olive brown (2.5 Y 5/4) moist; clay moderate coarse prismatic; firm, sticky and plastic; common fine, few medium, few coarse tubular inped pores; few fine and medium roots; moderately thick patchy cutans, continuous thick cutans inside coarse pore walls and old root channels; common, medium faint dark yellowish brown (10 YR 4/4) mottles; common medium distinct grey (5 Y 5/1) colours; gradual smooth boundary.

B_{3g} 78-108 cm :

Light brownish grey (2.5 y 6/3) wet; clay; structureless massive; sticky and plastic common old root channels; few fine and medium dead roots; thin patchy cutans; many coarse prominent yellowish brown (10 YR 5/6) mottles; yellowish red (5 YR 5/5) slightly firm plinthite; gradual wavy boundary.

C_{1g} 108-160 cm :

Grey to light grey (5 Y 6/1) wet; clay; structureless massive; sticky and plastic few dead roots; very fine black mineral grains; completely gleyed horizon; water table at 108 cm depth, gradual smooth boundary.

C_{2g} 160-170 cm+ :

Grey and light grey (2.5 Y 5/0 & 7/0) wet; coarse sand; structureless, single grain; non-sticky and non-plastic; highly decomposed rock material consisting mostly of feldspar, few quartz grains and very fine black mineral.

EDEN SERIES

Imperfectly drained, deep soils, having very dark brown to brown loamy to clayey surface horizons. The sub-surface horizons are olive brown to olive in colour, clayey in texture and are often mottled. The lower-most horizons, generally below 50 cm, are completely gleyed.

This unit occupies the lower-most parts of foot slopes of the rounded Hill and Valley Landform and occur topographically below Mattakelle and Kowlahena Series. Two slope classes were mapped. This unit occupies about 0.5 ha (1.1 acre) or 0.26% of the total estate.

Type Profile (TRCP-12)

The following type-profile was in Field No. 1. The site was on a convex part of a foot slope. The slope at this site was 4%. The water table was at 135 cm depth.

A_P 0-20 cm :

Dark greyish brown and brown (10 YR 4/3.5 and 4/2) moist; clay loam; weak medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many fine and medium, few coarse roots; common fine, few medium and large tubular inped and exped random pores; occasional quartz gravel on surface; clear smooth boundary.

B_{21t} 20-37 cm :

Light olive brown (2.5 Y 5/4) moist; clay; moderate coarse subangular blocky; slightly hard, slightly firm, sticky and plastic; common fine and medium, few coarse roots; common fine, few medium tubular random inped pores; thin patchy cutans; few krotovinas; few dead roots and old root channels; gradual smooth boundary.

B_{22t} 37-53 cm :

Pale olive (5 Y 6/3) moist; clay; moderate coarse subangular blocky; slightly firm, very sticky and plastic; few fine and medium, occasional coarse roots; common fine, few medium tubular inped pores; moderately thick patchy cutans; few medium faint light olive brown (2.5 Y 5/4) mottles; diffuse smooth boundary.

B_{23tg} 53-82 cm :

Light grey (5 Y 7/2) moist; clay; moderate coarse subangular blocky; slightly firm, very sticky and plastic; few highly weathered feldspars moderately thick cutans, continuous thick cutans in side coarse pores and old root channels; few medium and occasional coarse tubular inped pores; dead medium and coarse roots; common medium, faint pale brown (10 YR 6/3) mottles; few medium distinct yellowish brown (10 YR 5/8) mottles; almost completely gleyed; diffuse smooth boundary.

B_{3g} 82-120 cm :

Pale yellow (5 Y 7/3) wet; clay; structureless massive; very similar to the above except for more weathered feldspars; less yellowish brown mottles and cutans in this horizon; clear wavy boundary.

C_g 120-164 cm+ :

Pale olive and light grey (5 Y 6/3 & 2.5 Y 7/0) wet; sandy clay loam; highly weathered feldspars with little quartz gravel; water table at 135 cm depth.

THAVANA SERIES

Imperfectly drained, deep soils having dark brown to brown, loamy surface horizons. The sub-surface horizons are either organic-rich loamy or clayey soils or both. The colours vary from greyish brown to grey or yellowish brown depending on the composition of the material. Generally the lower horizons are completely gleyed.

This unit occurs on level to nearly level valley bottom positions. The drainage of these soils has been artificially improved by raising the surface by filling to a depth of about 60-70 cm with the soils of the adjacent foot slopes, mainly to establish tea nurseries and for vegetable cultivation. This unit occupies about 10 ha (25 acre) or 6% of the total estate.

Type Profile (TRCB-97)

The following bore description in the Central Nursery in Field No. 1 typifies this series. The slope at the site was 0.5-1.0% gradient. The water table was at 75 cm depth.

A_p 0-15 cm :

Dark brown (10 YR 3/3) moist; sandy clay loam; structureless massive; friable, very slightly sticky and very slightly plastic; organic matter in pockets: transported soil; common fine, few medium roots; gradual smooth boundary.

C_1 15-45 cm :

Dark yellowish brown (10 YR 4/4) moist; sandy clay loam; structureless massive; friable, slightly sticky and slightly plastic; few fine and medium roots; gradual smooth boundary.

C_2 45-62 cm :

Dark brown (10 YR 4/3) moist; sandy clay; loam; structureless massive; friable slightly sticky and slightly plastic; some lateritic gravel; occasional feldspathic rock fragments; few fine roots, common dead roots; clear boundary.

IIC_3 62-80 cm :

Dark yellowish brown (10 YR 4/4) wet, mucky clay; faint mottling; common medium distinct dark greyish brown (2.5 Y 4/2) gleying; gradual boundary.

IIC_4 80-110 cm :

Very dark greyish brown (10 YR 3/2) wet; clay; sticky and plastic (wet): common coarse distinct greyish brown (2.5 Y 4/2) gleying; few medium dead roots: gradual boundary.

IIC_{5g} 110-125 cm+ :

Dark greyish brown (2.5 Y 4/2) wet; clay; sticky and plastic: few fine feldspars, this horizon is completely gleyed.

RESERVOIR SERIES

The soils are imperfectly to poorly drained having brown to dark brown, mucky to loamy surface horizons. The sub-surface horizons are yellowish brown to yellowish red and loamy to clayey in texture. These horizons are strongly mottled.

These soils occupy the gently sloping to nearly level sites and occur as a very narrow strip in the upper reaches of the reservoir. Generally this unit occurs topographically just below Eden, Cairness and Mattakelle Series. This unit occupies about 1.0 ha (2.6 acre) or 0.6% of the total estate.

Type Profile (TRCB-24)

The following type-profile was in Field No. 1. The bore was sited on a concave part of a foot slope. The slope at this site was about 3%. The water table at the site at 35 cm depth.

A_p 0-12 cm :

Dark yellowish brown (10 YR 4/4) moist; sandy clay loam; friable, slightly sticky and slightly plastic; about 2 cm of muck on surface; few pieces of charcoal; common fine and many fine dead roots; gradual smooth boundary.

B_{1t} 12-30 cm :

Yellowish brown (10YR 5/4) moist; clay loam; friable, sticky and slightly plastic; occasional pieces of charcoal; common fine and many fine dead roots; gradual smooth boundary.

B_{21t} 30-45 cm :

Yellowish brown (10 YR 5/6) wet; clay loam; sticky and plastic; occasional quartz gravel; little lateritic gravel; occasional feldspathic rock fragments; clear boundary.

B_{22tg} 45-60 cm :

Light olive brown and greyish brown (2.5 Y 5/4 & 5/2) wet; clay loam; sticky and plastic; clear boundary.

B_{23t} 60-80 cm :

Dark brown (10 YR 4/3) wet; clay; sticky and plastic; occasional fine gley-mottles; common; common, coarse, faint brown (10 YR 5/3) mottles; gradual boundary.

B_3 80-95 cm :

Brown (10 YR 5/3) wet; clay; similar to the above horizon except for many coarse distinct grey (5 Y 4/0) mottles; many decomposing feldspathic rock fragments; gradual boundary.

C 95-125 cm+ :

This horizon consists of highly weathered feldspathic rock material; common feldspathic gneissic rock fragments.

AGRA-PETCH COMPLEX

This unit comprises of the Agra Series and the Petch Series. It occurs on level to gently sloping valley bottoms. The two series were mapped as a complex, as they occur in an intricate pattern which prevents their being shown individually at the scale of mapping used. This unit occupies 5.4 ha (13.3 acre) or 3% of the whole estate.

AGRA SERIES

Agra Series are poorly drained, deep alluvial soils having brown to dark brown, structureless surface horizons. The textures are coarse loamy or clayey. The sub-surface horizons are dark greyish brown to grey, thin stratified sandy layers over clayey, mottled layers. The clayey sub-surface horizons have blocky to prismatic structure.

Type Profile (TRCP-7)

The following type-profile was in Field No. 12. The pit was sited on the lowest part of the level to nearly level landform. The slope at this site was 1-2%. The water table was at 95 cm depth.

A_{p1} 0-23 cm :

Very dark greyish brown (10 YR 3/2) moist; fine sandy loam; moderate coarse crumb; slightly hard, friable, slightly sticky and slightly plastic;many fine common, medium, few coarse roots; fine sand in pockets; common fine, few medium and coarse inped and exped pores; few krotovinas; gradual smooth boundary.

A_{p2} 23-41 cm :

Very dark greyish brown (10 YR 3/2) moist; fine sandy loam; structureless massive; soft, friable, very slightly sticky and very slightly plastic; common fine, few medium and occasional coarse roots; many fine roots in places; few medium and coarse interstitial pores; clear wavy boundary.

C_1 41-50 cm :

Olive brown (2.5 Y 4/4) moist; fine sand; structureless, single grain; loose, non-sticky and non-plastic; occasional coarse interstitial pores; few fine rock fragments; common medium and coarse distinct yellowish brown mottles (10 YR 5/5); diffuse smooth boundary.

IIC_2 50-60 cm :

Dark olive grey (10 YR 3/2) moist; loamy sand; structureless massive; soft, friable, non-sticky and non-plastic; few medium roots; few medium and coarse interstitial pores; very fine feldspar gravel; few subangular quartz gravel fragments at the bottom of this horizon; clear smooth boundary.

$IIIC_3$ 60-76 cm :

Very dark grey (10 YR 3/1) moist; loamy coarse sand; structureless single grain; loose, non-sticky and non-plastic; many fine feldspars; common fine subangular quartz gravel and feldspathic rock fragments at the bottom of this horizon ; abrupt smooth boundary.

IVA 76-134 cm :

Black (10 YR 2/1) moist; mucky clay loam; medium, coarse, prismatic; very hard, very firm, slightly sticky and slightly plastic; many fine, common medium dead roots; common fine and medium, few coarse tubular inped and exped pores; few 5 mm wide cracks; diffuse smooth boundary.

IVAC 134-159 cm :

Black (10 YR 2/1) wet; sandy clay loam; sticky and plastic; similar to the above horizon with common, highly weathered feldspathic rock material; high organic matter content; abrupt wavy boundary.

IVR 159 cm+ :

Hard gneissic rock containing feldspar and quartz.

PETCH SERIES

Petch Series are poorly to very poorly drained deep soils having very dark grey to black, mucky surface horizons. The sub-surface horizons are very dark grey to dark grey peat having more than 15% organic matter to a depth of 50 cm or more underlain by clayey or sandy material.

These organic soils occur on the lower most positions on the level to gently sloping valley bottoms. The following bore was studied in field No. 10. The slope at the site was 0-0.5%. The drainage was very poor. The water table was at 20 cm depth at the time of description.

Typical Profile (TRCB-3)

0-30 cm :

Very dark greyish brown (10 YR 3/2) moist; peaty muck; fair amount of undecomposed grass and other vegetative matter; little mineral matter; gradual boundary.

30-70 cm :

Very dark grey (10 YR 3/1) wet; peaty muck; less peat than above horizon; little quartz sand occasional pieces of coarse roots; approximately 20-25% organic matter; clear boundary.

70-110 cm :

Black (10 YR 2/1) wet; muck approximately 15-20% organic matter content; few undecomposed branches; clear boundary.

110-125 cm+ :

Very dark grey (5 Y 3/1) wet; mucky clay; about 10% organic matter; heavy gleying.

DISCUSSION AND CONCLUSIONS

The foregoing profile descriptions reflect the effects of the major soil forming factors. The general climatic features are relatively uniform over the entire estate. The high rainfall occurring at low intensities has caused weathering of all but the most resistant minerals in the finer fractions to considerable depths. The relatively cool temperatures (compared to the low-country) has encouraged the maintenance of moderate levels of organic matter in the surface horizons.

Micro-climatic variations within the research station arising from aspect, relief, amplitude and shading, though important for plant growth, have not impressed themselves on soil morphological characteristics.

The major variations in the soils of St Coombs Estate have, therefore, arisen from differences in parent material, past vegetation, topography and hydrology, which have influenced the soil forming processes to produce the various soil series

described in the preceding sections. Thus, the amount and kind of gravel and stones in the soils, the depth of weathering and particle size distribution have been largely dependent on the nature of the original parent materials. The contrast between soils developed from distinctly different materials is well illustrated for example by the morphology of the Kowlahena and Mattakelle series.

The accumulation of and staining by organic matter of surface horizons of the well-drained Coombe Series and Waltrim Series could be attributed to the effects of the "patana" grassland vegetation that existed on these soils in the past. The area under these series (together with the valley bottom lands which still have natural grass vegetation) coincides almost exactly with the then uncultivated area shown in old maps of 1929 as patana grassland. The high organic matter and staining of the A horizons are the effects of the thick root mat, produced under grassland vegetation in cool humid climates.

The soil moisture regime of the imperfectly and poorly drained soils in low-lying positions has resulted in the build-up of organic matter in surface horizons and mottling and gleying in the sub-surface horizons. High levels of reduced iron in percolating waters are signified by the appearance of brownish oxidized-iron stains on the surface.

Erosion of soils from hilltops and upper slopes and their deposition in lower slope positions has traditionally been considered a major process in soil formation in hilly regions. (Hasselo, 1964). However, this did not appear to be evident in the morphological studies of profiles in different slope positions. Therefore, either this process is not very pronounced under the conditions prevailing at St Coombs, or the soil material moving down is similar to and well intermixed with the soil in the depositional sites downslope. The correctness or otherwise of the latter mechanism will be revealed by detailed particle size distribution studies, to be reported in the next paper of this series.

More detailed discussions regarding the genesis of these soils and their production potentials will appear in subsequent papers.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of Dr S. Sivasubramaniam, Agricultural Chemist, TRI; Messrs L. D. Jinadasa, R. Thilakasekera and L. Amarasinghe, Soil Surveyors, Land Use Division, for their periodic participation in carrying out the survey; the laboratory staff, Agricultural Chemistry Division, TRI, for carrying out chemical analyses; the Land Use Division laboratory staff for the mechanical and water physical analyses; staff of the Cartography Section, Land Use Division, for the production of the soil map and the State Printing Corporation for printing the soil map.

Thanks are also due to Drs R. L. de Silva and R. L. Wickremasinghe, present and past Directors, respectively, of the TRI, for making arrangements to get the soil map printed.

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