Sime Darby Services

DETAILED SOIL SURVEY OF SARAWAK OIL PALM ESTATE

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Sime Darby Plantations

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A DIVISION OF
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SUMMARY AND CONCLUSION

1. A detailed soil survey was carried out in Sarawak Oil Palm Estate which comprises 4,360 ha. planted with oil palms.

2. The topography ranges from flat to extremely steep, low hills with occasional very steep escarpments or faults. A major part of the estate is undulating to hilly with slopes between 2 to 25^{o}.

3. A total of twelve soil series have been identified and demarcated. Their distribution is presented in the detailed soil map.

4. All the soils are acidic in reaction and are low to very low in fertility. They would require appropriate fertilization.

5. Major soil limitations to oil-palm growth encountered are poor internal soil drainage (Bijat series, Organic Clay/Muck), very sandy soil (Nyalau, Silantek and Semilajau series) and very steep topography ($>25^{o}$ slope). Together they constitute some 514 ha. (15%) of the estate.

6. Palms on Nyalau and Silantek series are stunted in growth and exhibit multiple nutrient-deficiency symptoms. These soils are extremely low in fertility and have very poor moisture-holding capacity.

1. ENVIRONMENT

1.1 Location and Extent

The estate is located about 42 km. south of Miri Town in the Miri District in the Fourth Division, Sarawak. It is accessible via the Miri-Bintulu Main Trunk Road which passes through the estate.

The total hectarage is 4,360 ha. and is divided into nine development blocks. Details of the development blocks are provided in Table 1.

Table 1: Details of Development Blocks

Block	Field	Field Hectarage	Year of Development
A	A1 - A7	195	1969
B	B1 - B12	404	1970
C	C1 - C14	810	1971
D	D1 - D13	811	1972
E	E1 - E13	914	1973
F	F1 - F13	898	1974
G	G1 - G3	101	1976
H	H1	10	Nursery
Reserve	-	217 (estimated)	1985 - 1986
		4,360	

1.2 Geology

The geology of the estate belongs to the Sibiti Formation of Miocene Epoch. Dominant geologies are sandstone, shale, mudstone, siltstone with minor limestone and conglomerate lenses.

Recent riverine alluvium occupies the alluvial flats. They are mainly of fine clay, silt and sand sediments.

1.3 Topography

The enclosed detailed soil map incorporates slope classes as phases and the distribution is presented in Table 2.

Major portions of the estate are undulating to hilly with slopes ranging from 2 to 25°. These constitute about 2,888 ha. (66%) and are scattered throughout the estate. About 956 ha. (22%) are flat and are found mainly along the rivers in Blocks A, B, C, D and E. The very steep land is mainly in the northern part of the estate, particularly Blocks D, E, F and the Reserve Area.

1.4 Climate

The estate has a hot and humid climate with little variation during the year. Generally the rainfall in all months exceeds 125 mm. (5 ins.) while the monthly temperature remains uniform at around 27°C throughout the year.

1.4.1 Rainfall

Rainfall records from 1917 to 1978 are presented in Figure 1. Annual rainfall is about 2,840 mm. with a monthly distribution varying from about 150 mm. to 330 mm. Drier months are from February to April with monthly precipitation between 125 mm. to 175 mm. Monthly precipitation from September to January is generally higher at between 200 to 330 mm. with November being the wettest month.

1.4.2 Temperature

A ten-year temperature record for Miri is presented in Figure 2. The mean annual temperature is 26.6°C. Monthly temperature is generally uniform with little seasonal variation.

Table 2: Distribution of Various Slope Classes

Block (ha)	Flat (< 2° slope)			Undulating to hilly (2 - 25° slope)	Very steep (> 25° slope)
	Very poorly drained	Imperfectly/well/somewhat excessively drained	Total flat		
A (195)	-	62(32)	62(32)	133(68)	-
B (404)	-	115(28)	115(28)	226(66)	63(15)
C (810)	-	237(29)	237(29)	556(68)	17(3)
D (811)	15(2)	179(22)	194(24)	563(70)	54(6)
E (914)	86(10)	198(21)	284(31)	551(60)	79(9)
F (898)	-	28(3)	28(3)	740(82)	130(15)
G (101)	25(25)	7(9)	32(32)	50(49)	19(19)
Reserve (217)	-	4(2)	4(2)	69(32)	144(66)
	126(3)	830(19)	956(22)	2,888(66)	506(12)

FIGURE 1

AVERAGE MONTHLY RAINFALL DISTRIBUTION

MIRI

(1917 - 1978 RECORD)

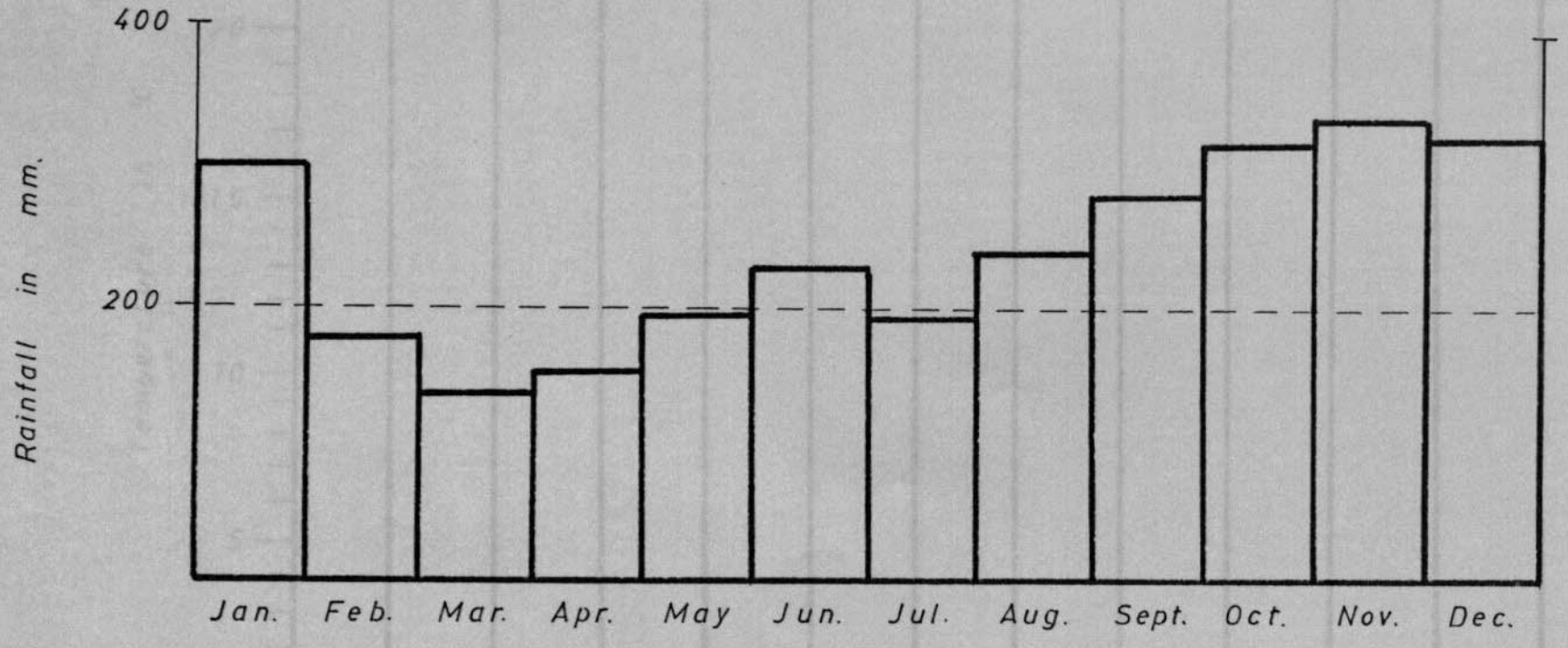
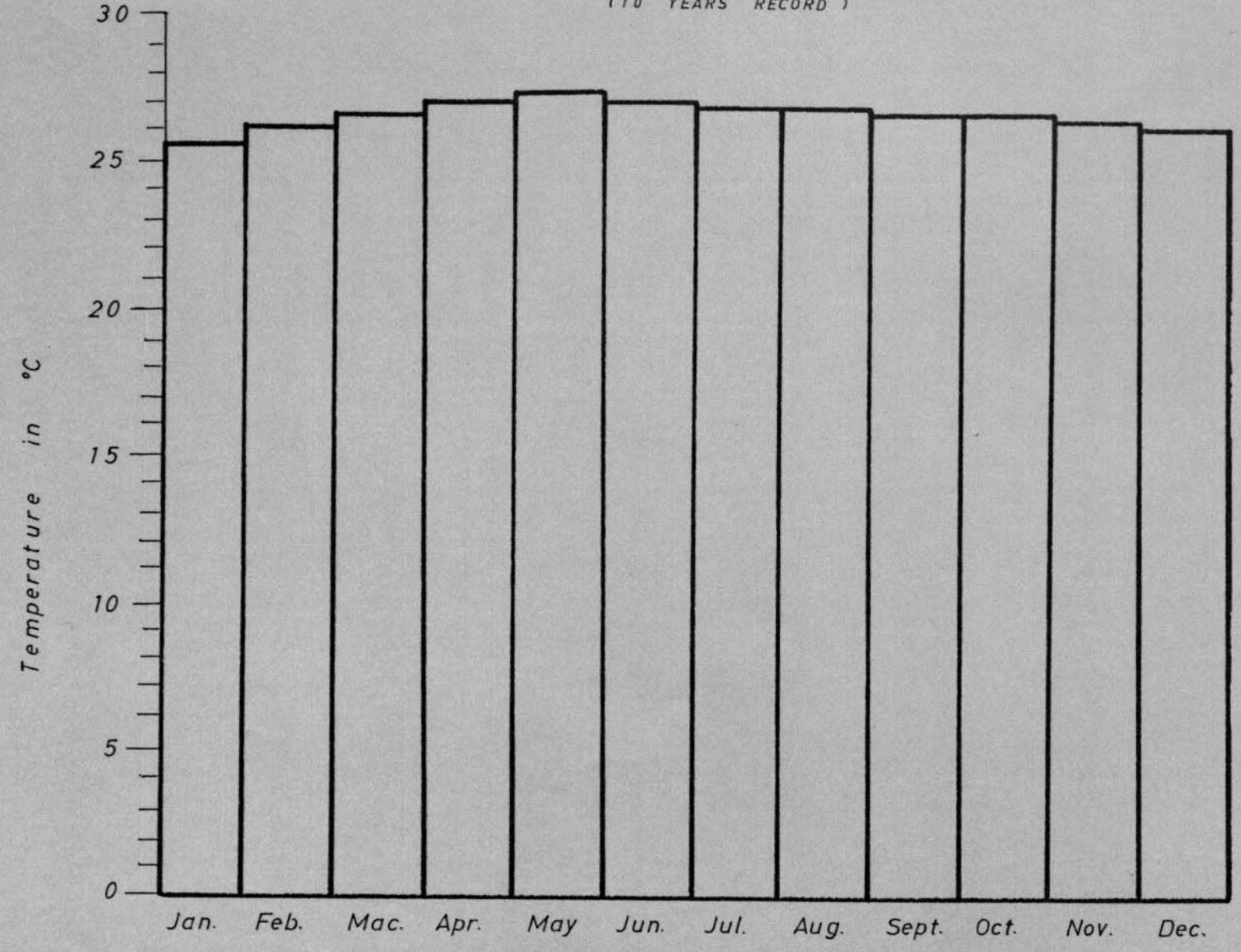


FIGURE 2

MEAN MONTHLY TEMPERATURE DISTRIBUTION

MIRI

(10 YEARS RECORD)



2. SOILS

2.1 Method of Soil Survey

The survey was carried out at detailed level of 1:8,000 ft. Free traversing system was used whereby soil examination was made at approximately 200 m. intervals using the field roads as rentices. Soil examination was made using a 3.8-cm. diameter screw auger up to a depth of 125 cm. or impediment. At each auger examination point, the following records were noted:-

- Auger examination number.
- Slope and general langform using a field clinometer.
- Texture of surface soil and sub-soil (at 50 cm. depth).
- Soil colour at field-moisture content, using the Munsell Soil Colour Chart, of soil at 50 cm.
- Drainage (through soil colour, presence/absence of mottles, topography and palm growth).
- Soil depth to impermeable layer.
- Pedological features like presence of gravels, stones, geological material, shapes of stones, etc.
- Rockiness at surface, if present, and the geology.
- Tentative soil series classification.

Representative soil profiles were dug from the dominant soils present. A total of thirty-eight soil examination profiles were dug (within frond-stack interrow spaces) and described, of which twenty-one selected profiles were soil sampled for physical and chemical analyses.

2.2 Soil Classification Units

The soils of the estate are classified according to the system used in the revised, "Soil Classification in Sarawak (TIE 1982)". The mapping units used are "soil series" which consist of soils with similar arrangement and characteristics of diagnostic horizons and formed on similar parent material. In addition to soil series, soil phases are also demarcated. They include both slope and soil depth phases.

Symbol for Slope Phase	Range of Slope in Degrees (%)
a	0 - 2 (0 - 4)
b	2 - 6 (4 - 12)
c	6 - 12 (12 - 23)
d	12 - 20 (23 - 38)
e	20 - 25 (38 - 48)
f	25 - 30 (48 - 58)
g	>30 (>58)

Symbol for Soil Depth Phase	Soil Depth (cm)
1	<25
2	25 - 50
3	50 - 75
4	75 - 100
5	>100

A Soil Mapping Unit will comprise of a series' name followed by depth and slope phases, e.g.:

Mrt-5c
Soil series: Merit
Soil depth: >100 cm.
Slope: 6 - 12°

2.3 Soils of Surveyed Area

A total of twelve dominant soil series were identified and demarcated. Their distribution is presented in the detailed soil map.

2.3.1 Merit Series (2,403 ha.)

Merit series is the most widespread soil in the estate. It is found in all the nine development blocks.

The soil is derived from non-calcareous argilaceous shale, mudstone or siltstone on gently undulating to very steep terrain. Clay content for the whole soil is between 35 - 60%. CEC is > 24 meq. per 100 g. clay in the major part of the B horizon. The soil is characterised by the yellowish brown to brownish yellow well-drained to moderately well-drained clay with well-developed structures.

The top soil consists of humus-rich Ap horizon, usually between 2 to 5 cm. thick, with brown to yellowish brown friable clay loam to silty clay loam. Structures are moderately developed with fine and medium subangular blocks and crumbs. The B1 horizon lies immediately underneath the Ap horizon and is about 15 cm. thick. It consists of yellowish brown silty clay to clay loam to clay. Structures are moderate to well-developed with mainly coarse and some medium subangular blocks. Consistency is friable and occasionally slightly firm. Coatings of illuviated organic acid are common on most of the ped surfaces. Micro-bio activities are found along coarse channels and between ped cleavages. Both the Ap and B1 horizons (about 20 cm. thick) have the highest concentration of palm roots.

Sub-soil B2 horizon is moderately deep to deep, extending to below 75 cm. or deeper. It consists of dominantly yellowish brown silty clay to clay. Structures are well-developed coarse and very coarse subangular blocks. Consistency is friable to slightly firm and occasionally the horizon may be somewhat compact. Organic acid coatings and micro-bio activities are less prominent and are confined to the upper part of the B2 horizon. Clay cutans are common and well developed on many ped surfaces. Low-grade laterised gravels of mudstone or shale may be present. They usually constitute less than 50% of the

soil volume and are loosely packed with interstices filled with clay of the overlying horizon. The gravelly layer is penetrable by palm roots.

The impermeable parent rock lies below 75 cm. or deeper. It consists of shale or mudstone with varying degrees of weathering and hardness. Oil-palm root penetration may be inhibited by this continuous impervious layer.

Merit series is strongly acidic with pH mainly between 4.1 to 5.2. Total N is low to very low at below 0.2% while organic carbon is very low at below 2%. Exchangeable Ca and Mg are very low to low while values for K are all very low. Cation exchange capacity for Merit series is medium to low with 10 to 20 meq/100 g. soil.

2.3.2 Begunan Series (255 ha.)

Begunan series is not very widespread and is found mainly in some fields of Blocks C, D and F.

This soil is similar to Merit series in most of their morphological and physico-chemical properties. The only differentiating criteria is that the sub-soil colour of Begunan series is reddish (7.5YR or redder according to Munsell Colour Chart) whereas the sub-soil colour for Merit series is yellowish.

2.3.3 Bekenu Series (232 ha.)

Bekenu series has been demarcated in parts of Blocks A, E, F and Reserve Area.

It is derived from non-calcareous arenaceous shale or sandstone on gently undulating to very steep terrain. Clay content for the whole soil is between 18 - 35%.

The Ap top soil consists of about 5 cm. thick of brown to yellowish brown loam to silty loam to sandy loam. Structures are moderately developed with fine and medium subangular blocks and crumbs. The B1 horizon is about 15 to 20 cm. thick and consisits of yellowish brown loam to silty loam to sandy clay loam. It has a moderately developed medium and some coarse blocky structures with friable to slightly firm consistency. Organic acid coatings and micro-bio activities are present. The B2 sub-soil is deep, extending to below 80 cm. It consists of yellowish brown sandy clay loam to silty clay loam to clay loam. Structures are moderately developed with coarse and some medium blocks. Consistency is friable to slightly firm. Towards the lower part of the B2 horizon the structures become weaker and coarser and the horizon is somewhat compact. Laterised gravels may be present but not common. At depth below 80 cm. or deeper lies the impervious parent rock which may inhibit palm root penetration.

Both the top soil and sub-soil of Bekenu series are strongly acidic with pH between 4.1 to 4.7. Total N % is medium to low at 0.3 to 0.1 while organic carbon is low to very low at $<4\%$ Exchangeable K and Ca are low to very low while exchangeable Mg is medium to very low. Cation exchange capacity for Bekenu series is low at between 5 to 15 meq/100 g. soil.

2.3.4 Nyalau Series (340 ha.)

Nyalau series occurs mainly in parts of Blocks A, E, F, G and Reserve Area. The soil is developed on sandstone and the topography is undulating to very steep. It is characterised by the very sandy texture with yellowish soil colour. Clay content for the whole soil is less than 18%. This soil has been classified as red-yellow podzolic soil with coarse loamy or coarse silty particle-size class.

The top soil consists of 5 to 10 cm. thick of brownish fine sandy loam with very friable consistency. Structures are moderately developed with medium subangular blocks and crumbs. B1 horizon consists of brownish yellow to light yellowish brown fine sandy loam with very friable consistency. The underlying B2 horizon consists of brownish yellow to yellow fine sandy loam. Structures are weakly developed with coarse subangular blocks and very friable consistency. Gravels are rare and uncommon. The soil has a rapid permeability with somewaht excessive drainage. Soil-nutrient loss through leaching is high. Most palms appear stunted in growth with symptoms of nutrient deficiency.

Soil pH for Nyalau series is around 4.4 and is considered strongly acidic. This very sandy soil is depleted of its soil nutrients. Levels of all major plant nutrients are very low. Cation exchange capacity for Nyalau series is very low to low at 5 to 8 meq./100 g. soil.

2.3.5 Silantek Series (47 ha.)

Silantek series is classified as podzol with non-cemented or weakly-cemented spodic horizon. The soil is developed on sandstone over rolling topography. It is characterised by the very sandy pale-coloured sub-soil with a spodic horizon below 75 cm. depth.

The top soil consists of yellowish brown to dark yellowish brown loamy sand. Structures are moderately developed with fine and medium subangular blocks and crumbs. This is underlain by an eluvial sub-soil with light grey to white loamy sand to sand. It has a weakly-developed structure with very friable to loose consistency. At depth below 75 cm. is a layer of dark yellowish brown to brown illuviated sand which is weakly cemented.

Chemical properties for Silantek series is expected to be similar to that of Nyalau series with very low levels of major plant nutrients. Oil palms on Silantek series are usually stunted in growth with symptoms of multiple nutrient deficiencies.

2.3.6 Kabuloh Series (tentative) (116 ha.)

This soil unit has been tentatively classified as Kabuloh series with high base saturation due to high exchangeable Ca and Mg. It usually occurs in scattered small pockets in Blocks A, B, C and D with dominant areas in C11, C12, C13, D12 and E3.

Top soil consists of about 5 cm. of dark brown to dark greyish brown silty clay loam to silty loam. Structures are well-developed with fine blocks and crumbs. Sub-soil is deep and consists of light olive brown silty clay to clay with strongly developed blocks and friable to slightly firm consistency. Soft manganese nodules are usually encountered at depth below 75 cm.

Soil pH is between 5.0 to 5.5 and is considered acidic to strongly acidic. Exchangeable Mg and Ca are high at around 4 and 11 meq. % respectively. Exchangeable K is around 0.4 to 0.7 meq. %.

2.3.7 Tukau Series (491 ha.*)

This is an alluvial soil which is deep and well-drained. The soil is fine loamy in texture with about 18 - 35% clay throughout.

The top soil consists of dark greyish brown to very dark greyish brown friable silty loam to clay loam with moderately-developed fine and medium blocks and crumbs. Sub-soil is deep to very deep and consists of yellowish brown silty clay loam to silty loam with 15 - 35% clay content. It has well-developed medium

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* In association with Lupar series.

and coarse block structures and is friable. No stones or pebbles are encountered within 150 cm. soil depth. Grey mottles may be present at lower depth of the sub-soil.

Top soil is acidic with pH between 5.4 to 5.9 and sub-soil is strongly acidic with pH 4.3 to 4.9. Organic carbon is highest in top soil with values between 2.0 to 2.5% while sub-soil organic carbon is less than 1%. Exchangeable cations are medium to high in the top soil and very low to low in the sub-soil.

2.3.8 Lupar Series

The morphological properties of Lupar Series are generally similar to those of Tukau series. They are separated on the basis of their soil textural class. Lupar series has a fine clayey textural class with clay content between 35 to 60% while Tukau series is fine loamy with clay content between 18 to 35%.

2.3.9 Ajoh Series (231 ha.)

Ajoh series is classified as grey-white podzolic soil with clayey particle-size class and has abundant (>20%) mottles within 100 cm. soil depth. The soil is imperfectly drained and occurs on flat valley floors.

The top soil consists of very dark greyish brown to dark brown friable clay loam to silty clay loam with moderately developed medium and fine structures. Sub-soil colour changes abruptly to light grey to grey with prominent brownish and yellowish mottles of about 5 to 15 mm. diameter. Consistency is friable to slightly firm, becoming more massive and plastic with depth. Structures are moderately developed, coarse and very coarse subangular blocky, becoming weakly developed and prismatic with depth. Soft manganese mottles may be present at the lower depth of the sub-soil.

Ajoh series has an acidic top soil with pH between 5.4 to 6.0 while the sub-soil is strongly acidic with pH between 4.1 to 5.0. Exchangeable cations for the top soil are medium to high while for the sub-soil are generally very low to low.

2.3.10 Bijat Series (122 ha.)

Bijat series is classified as gley soils that have developed on riverine alluvium from non-calcareous sedimentary rocks and have a clayey particle-size class. The soil is characterised by its poor drainage and has white to grey massive clay within 50 cm. of the soil depth. Bijat series is found mainly in the low-lying valley floors of Blocks E and G3.

The top soil is thin and consists of dark reddish brown clay loam intermixed with some organic debris. Structures are moderately developed with fine blocks and granules. Underneath the top soil is the characteristic gleyed horizon with massive to structureless clay sparsely mottled with yellowish brown or strong brown. Water-table is usually met within 50 cm. from the soil surface. In some localities, stagnant water on the soil surface is common.

2.3.11 Semilajau Series (108 ha.)

Semilajau series is alluvial soil that has a coarse loamy particle-size class with less than 18% clay content for the whole soil. It is formed in alluvium derived from non-calcareous sandstones. Its occurrence is confined mainly along the banks of some tributaries.

The top soil is about 5 cm. thick and consists of dark yellowish brown loose sand with weakly developed structures. Sub-soil is deep with pale brown to yellow loose sand and structures are weakly developed. Mottles may be present at lower depth. The soil is well-drained to somewhat excessively drained but may be subjected to short duration of flooding during the rainy days.

2.3.12 Organic Clay and Muck (5 ha.)

This is an organic soil that is found in limited extent in the low-lying areas and is very poorly drained. It consists of highly decomposed organic debris intermixed with some undecomposed plant fragments. The organic layer is usually more than 100 cm. thick.

2.4 Soil Series Differentiation

The criteria used in differentiating the various soil series of the estate is provided in Table 3. These are in accordance with, "Soil Classification in Sarawak" by Y. L. Tie, 1982.

A summary of the properties of the twelve soil series of the estate is presented in Table 4.

2.5 General Soil Properties of the Estate

- Clay content for most soils is between 18 to 60% except for Nyalau, Silantek and Semilajau series with clay content at less than 18%.

- Silt content for most soils is above 30% except for Nyalau, Silantek and Semilajau series.

- Fine gravels of laterised shale may be present in small amount in soil derived from sedimentary rocks. They do not pose limitation to root penetration. Gravels are uncommon in alluvial soils.

- Some of the alluvial soils are imperfectly to very poorly drained and are subjected to flooding during prolonged rainy days. These include Ajoh, Bijat, Semilajau series and Organic Clay/Muck.

- All the soils are considered acidic with pH generally below 6. Higher pH is generally observed in top soils.

Table 3: Criteria Used for Soil Series Differentiation

Soil Series	Parent Material	Soil Group	Series Differentiation	Particle-size Class
Merit	Shale	Red-yellow podzolic soils	1. Fine clayey particle-size class. 2. Have CEC >24 meq./100 g. clay in major part of B horizon. 3. Yellow-colour class.	35 - 60% clay
Begunan	Shale	Red-yellow podzolic soils	1. Same as Merit. 2. Same as Merit. 3. Red-colour class.	35 - 60% clay
Bekenu	Shale/ Sandstone	Red-yellow podzolic soils	1. Fine loamy or fine silty particle-size class. 2. Developed on sedimentary rocks. 3. Yellow-colour class.	18 - 35% clay
Nyalau	Sandstone	Red-yellow podzolic soils	1. Coarse loamy or coarse silty particle-size class. 2. Yellow-colour class.	<18% clay
Kabuloh	Shale	Red-yellow podzolic soils	1. Calcareous or non-acidic reaction. 2. Hue of 2.5Y within a depth of 50 cm. or throughout the control section.	Not differentiated but is mainly clayey (35% clay) in SOP
Tukau	Alluvium	Red-yellow podzolic soils	1. Fine loamy or fine silty particle-size class. 2. Developed on non-accreting alluvium.	18 - 35% clay
Lupar	Alluvium	Red-yellow podzolic soils	1. Fine clayey particle-size class. 2. Developed on non-accreting alluvium.	35 - 60% clay
Silantek	Sandstone	Podzolic soils	1. Spodic horizon is non-cemented or weakly cemented. 2. Developed in residum.	Not differentiated but is sandy (<18% clay) in SOP

(continued)

Table 3: Criteria Used for Soil Series Differentiation

Soil Series	Parent Material	Soil Group	Series Differentiation	Particle-size Class
Ajoh	Alluvium	Grey-white podzolic soils	1. Clayey particle-size class. 2. With abundant (> 20%) mottles within 100 cm. but without a contrasting textural profile.	35 - 60% clay
Semilajau	Alluvium	Alluvial soils	1. Coarse loamy or coarse silty particle-size class. 2. Developed on alluvium derived from sedimentary rocks.	<18% clay
Bijat	Alluvium	Gley soils	1. Clayey particle-size class. 2. Developed on riverine alluvium from non-calcareous sedimentary rocks. 3. Poorly drained.	35 - 60% clay
Organic Clay and Muck	Organic	Organic soils	Organic clay and highly decomposed peat	Not differentiated but the organic layer is > 100 cm. deep in SOP

Table 4: Summary of Properties of Soil Series

Soil Series	Parent Material	Topography	Clay % for Whole Soil	Soil pH		Base Saturation %		CEC		Effective Soil Depth	Soil Drainage	Remarks
				Top Soil	Sub-soil	Top Soil	Sub-soil	Top Soil	Sub-soil			
Merit	Shale	Undulating to very steep (2->35°)	35-60	5.2-4.3	4.6-4.0	55-22	13- 2	Medium to low	Medium to low	> 50 cm.	Well-drained	Shallow soil on steep slope
Begunan	Shale	Rolling to steep (6-25°)	35-60	5.0-4.1	4.4-4.3	32-26	9- 5	Medium to low	Medium to low	> 75 cm.	Well-drained	Similar to Merit series in morphological properties except reddish in soil colour
Bekenu	Shale/ Sandstone	Undulating to very steep (2->35°)	18-35	6.3-4.1	4.7-4.2	92-28	28- 3	Low	Low	> 50 cm.	Well-drained	Shallow soil on steep slope
Nyalau	Sandstone	Undulating to very steep (2->35°)	< 18	4.5	4.4-4.3	41-12	4- 2	Low	Very low	> 50 cm.	Somewhat excessively drained	Very low soil fertility; very low moisture-holding capacity
Silantek	Sandstone	Rolling to hilly (6-20°)	< 18	No analytical data available but expected to be similar to Nyalau series							Excessively drained	As for Nyalau series; grey to white soil colour; presence of spodic horizon
Kabuloh (tentative)	Shale	Hilly to very steep (12-35°)	35-60	5.0	5.5-5.0	66	87-84	Medium	Medium	> 75 cm.	Well-drained	High exchangeable Ca and Mg; medium K
Tukau	Alluvium	Flat (<2°)	18-35	5.9-5.4	4.9-4.3	68-51	41- 7	Low	Low	>100 cm.	Well to moderately well-drained	-
Lupar	Alluvium	Flat (<2°)	35-60	6.0-5.5	5.5-4.0	75-68	45- 8	Medium	Medium	>100 cm.	Well to moderately well-drained	Similar to Tukau series in morphological properties except higher clay content in Lupar series
Ajoh	Alluvium	Flat (<2°)	35-60	6.0-5.4	5.7-4.1	83-54	44-22	Medium to high	Medium to low	> 75 cm.	Imperfectly drained	High water-table during rainy days
Bijat	Alluvium	Flat (<2°)	> 35	No analytical data available						< 50 cm.	Very poorly drained	Massive clay at shallow depth
Semilajau	Alluvium	Flat (<2°)	< 18	4.6	5.0-4.7	31	25-12	Low	Very low	>100 cm.	Somewhat excessively drained	Very sandy soil; occurring along river banks
Organic Clay and Muck	Organic	Flat, low-lying (<2°)	No analytical data available								Very poorly drained	Organic layer more than 100 cm. thick

- CEC/100 g. soils are generally medium to low for most soils and very low for Nyalau, Silantek and Semilajau series. Higher CEC for most top soils is mainly due to higher organic matters.

- Base saturation is generally higher in top soils than sub-soils. In Kabuloh series, higher base saturation for whole soils is due to higher exchangeable Ca, Mg and K. Base saturation is very low for the sandy Nyalau, Silantek and Semilajau series.

2.6 Soil Correlation

Table 5 presents a simple correlation between soils of the estate and some common soils from Peninsular Malaysia. The correlation is made on the basis of their resemblances in major morphological and chemical properties.

Table 5: Correlation between SOP and Peninsular Malaysia Soils

Soils of SOP		Equivalent of Peninsular Malaysia Soils	
Soil Series	Series Criteria	Soil Series	Series Criteria
Merit	- 35-60% clay - >30% silt - deep to moderately deep - friable to firm - yellowish	Bungor	- 35-60% clay - <30% silt - deep - friable - yellowish to reddish
Begunan	- 35-60% clay - >30% silt - deep to moderately deep - friable to firm - reddish	Durian	- 35-60% clay - >30% silt - moderately deep - firm - yellowish to reddish
Bekenu	- 18-35% clay - deep to moderately deep - friable to firm - yellowish	Serdang	- 18-35% clay - deep - friable - yellowish
		Nami	- 18-35% clay - moderately deep - friable - yellowish
Nyalau	- <18% clay - deep to moderately deep - friable - yellowish	No equivalent but quite similar to Serdang/Nami series except with lower clay content (<18%)	
Silantek	- with non-cemented spodic horizon - on sandstone (sandy)	Rudua	- with spodic horizon - on beach sand (sandy)

(continued)

Table 5: Correlation between SOP and Peninsular Malaysia Soils

Soils of SOP		Equivalent of Peninsular Malaysia Soils	
Soil Series	Series Criteria	Soil Series	Series Criteria
Kabuloh	- non-acidic or calcareous - high exchangeable Ca and Mg	No equivalent due to high Ca and Mg of Kabuloh	
Tukau	- 18-35% clay - on alluvium - well to moderately well-drained	Rasau	- 18-35% clay - on alluvium - well to moderately well-drained
Lupar	- 35-60% clay - on alluvium - well to moderately well-drained	Tebok	- 35-60% clay - on alluvium - well-drained
Ajoh	- 35-60% clay - >20% mottles - imperfectly drained	Batu Hitam	- >35% clay - presence of mottles - imperfectly drained
Bijat	- >35% clay - poorly drained - massive clay at <50 cm	Binjai	- >35% clay - poorly drained - massive clay at <50 cm
Semilajau	- <18% clay - somewhat excessively drained - on river levee	Telemong	- <18% clay - well-drained - on river levee
Organic Clay/ Muck	- >100 cm. organic layer	Organic Clay/Muck	- >100 cm organic layer

Soil Profile No.:	9
Field No.:	C3
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	15^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; clay loam; moderately strong, medium and fine SBK; friable; few coarse pores; many medium and coarse roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/6 to dark yellowish brown 10YR 4/6; clay loam; moderate, medium and coarse SBK; friable; few medium and coarse pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2cn	20- 60 cm	Yellowish brown 10YR 5/6; clay; moderate, coarse and some very coarse SBK; friable; common fine and medium pores; very few platty gravelly laterised shale; few organic acid coatings; abundant coarse roots; gradual boundary.
B3cn	60-105 cm	Yellowish brown 10YR 5/6; clay; moderate, very coarse SBK; friable; few medium dark yellowish brown 10YR 4/6 mottles; few coarse pores; very few platty gravelly laterised shale; many medium and coarse roots; clear boundary.
Cu	105-150 cm	A layer of unconsolidated shale with few coarse roots.

Soil profile number: 9
Soil Series: MERIT

SOIL ANALYTICAL DATA

APPENDIX 1b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	5.0	122	28.3	43.4	11.1	9.4	2.1	2.5	0.3	nd	nd	1.61	2.76	0.17	9.47
B1	5-20	4.7	81	35.6	39.3	9.3	7.5	1.4	1.4	1.4	nd	nd	0.56	0.96	0.15	3.73
B2cn	20-60	4.4	60	42.9	31.1	6.7	6.7	2.5	3.1	1.7	nd	nd	0.48	0.83	0.12	4

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	5500	2088	206	470	9	579	63	400	79	2	12.4	0.35	1.03	4.59	0.1	0.33
B1	7500	3375	114	160	20	282	63	300	10	6	15.5	0.21	1.08	3.19	0.1	0.5
B2cn	8600	4188	39	164	14	421	76	450	9	3	16.4	0.22	0.86	0.99	0.12	1.22

nd=not determined

Soil Profile No.:	15
Field No.:	F2
Parent material:	Shale
Landform:	Rolling low hill
Physiography at site:	Upper slope
Slope at site:	12^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 3 cm	Yellowish brown 10YR 5/4; silty clay loam; moderate, fine and few medium SBK; friable; few coarse pores; many fine roots; clear boundary.
B1	3- 20 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and some medium SBK; friable; few coarse pores; many organic acid coatings; many coarse roots; gradual boundary.
B2tcn	20- 75 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and very coarse SBK; slightly firm; few fine strong brown 7.5YR 5/6 - 5/8 mottles; few coarse and fine pores; few organic acid coatings; very few platty gravelly laterised shale; few medium roots; clear boundary.
Cu	75-120 cm	A layer of decomposing shale with few platty gravelly laterised shale; slightly compact.
CR	120-150 cm	A compact, continuous layer of undecomposed shale.

Soil profile number: 15 SOIL ANALYTICAL DATA APPENDIX 2b

Soil Series: MERIT

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-3	4.5	128	32.4	51.8	4.1	3.2	2	1.9	0.9	nd	nd	1.82	3.13	0.21	8.66
B1	3-20	4.3	122	43.2	47.2	2.9	1.7	0.8	0.6	0.5	nd	nd	0.75	1.29	0.12	6.25
B2tcn	20-75	4.2	76	43.7	42.7	2.1	2.3	1.8	2.2	2.1	nd	nd	0.45	0.77	0.1	4.5

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	5700	1588	101	200	12	167	40	400	16	24	18.13	0.21	0.58	3.3	0.13	0.58
B1	9000	1913	85	126	16	98	48	225	10	20	13.2	0.16	0.32	3.28	0.09	0.72
B2tcn	11000	2025	31	125	15	91	185	275	10	6	14.93	0.19	0.18	0.7	0.09	1.72

nd=not determined

Soil Profile No.:	16
Field No.:	F4
Parent material:	Shale
Landform:	Very steep, hilly
Physiography at site:	Lower slope
Slope at site:	28^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 3 cm	Yellowish brown 10YR 5/4; silty clay loam; moderate, fine and few medium SBK; friable; few coarse pores; many fine roots; clear boundary.
B1	3- 20 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and some medium SBK; friable; few coarse pores; many organic acid coatings; many coarse roots; gradual boundary.
B2tcn	20- 75 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and very coarse SBK; friable; few coarse pores; many organic acid coatings; many coarse roots; gradual boundary.
Cu	75-120 cm	A layer of decomposing shale with few platty gravelly laterised shale; slightly compact.
CR	120-150 cm	A compact, continuous layer of undecomposed shale.

Soil profile number: 16

Soil Series: MERIT

SOIL ANALYTICAL DATA

APPENDIX 3b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-2	4.3	203	19.8	37.3	16.6	16.4	1.1	1.5	1.1	nd	nd	1.29	2.22	0.11	11.7
AB	2-33	4.0	85	42.6	34.4	6.8	5.7	1.3	2.5	1.9	nd	nd	0.37	0.64	0.1	3.7
B2t	30-75	4.6	25	46	33.8	4	3.8	1.9	2.9	3	nd	nd	0.38	0.65	0.09	4.22

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	3300	1125	63	98	7	91	24	200	12	22	9.73	0.14	0.44	0.44	0.09	0.5
AB	9800	2013	25	120	13	65	203	225	9	3	14	0.2	0.2	0.23	0.08	1.61
B2t	11300	3375	20	133	20	91	71	450	8	nd	16.67	0.21	0.21	0.41	0.09	2.84

nd= not determined

Soil Profile No.:	31
Field No.:	C11
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	18^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 2 cm	Yellowish brown 10YR 5/4; clay loam; moderately weak, medium and fine SBK; friable; many fine roots; clear boundary.
B2cn1	2- 50 cm	Yellowish brown 10YR 5/6 - 5/8; clay; moderately strong, coarse and medium SBK; friable; few medium and coarse pores; few platty gravelly laterised shale; few organic acid coatings; many coarse roots; gradual boundary.
B2cn2	50-110 cm	Yellowish brown 10YR 5/8; clay; moderately strong, coarse SBK; friable; very few mudstone fragments; few medium and coarse pores; few platty gravelly laterised shale; few organic acid coatings; many medium and coarse roots; clear boundary.
Cu	110-150 cm	A layer of unconsolidated mudstone with few medium roots.

Soil profile number: 31

Soil Series: MERIT

SOIL ANALYTICAL DATA

APPENDIX 4b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-2	4.1	199	29.8	34	13.1	9.5	1.8	2.6	1.9	nd	nd	1.72	2.96	0.09	19.1
B2cn1	2-50	4.5	36	48.7	23.5	8.5	8.9	3.3	3.4	1.1	nd	nd	0.63	1.08	0.08	7.87
B2cn2	50-100	4.4	45	49.1	28.4	7	8.4	2.8	1.4	0.2	nd	nd	0.51	0.88	0.09	5.66

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	5000	1550	38	245	11	203	45	175	18	24	13.07	0.24	0.45	0.74	0.07	0.78
B2cn1	9000	3125	14.5	150	60	181	80	200	8	2	16.27	0.21	0.13	0.037	0.08	2.17
B2cn2	9800	3563	17.5	135	17	149	146	175	9	nd	14.93	0.18	0.26	0.049	0.09	2.45

nd=not determined

Soil Profile No.:	34
Field No.:	D8
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	20^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 3 cm	Dark brown 10YR 3/3; silty clay loam; strong, medium and fine SBK; slightly hard; few coarse pores; many fine roots; clear boundary.
B1	3- 20 cm	Yellowish brown 10YR 5/4 - 5/6; silty clay loam; moderately strong, medium and coarse SBK; slightly firm; common medium pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2t	20- 70 cm	Yellowish brown 10YR 5/6; silty clay; strong, coarse SBK; slightly firm; few medium and fine pores; clay cutans on ped surfaces; many coarse roots; gradual boundary.
B3	70-150 cm	Yellowish brown 10YR 5/6; silty clay; moderately strong, coarse and very coarse SBK; slightly firm, slightly compact; common mudstone fragments; few medium and fine pores; few platty gravelly laterised shale; many medium roots; clear boundary.
Cu	150 cm+	A layer of unconsolidated mudstone.

Soil profile number: 34

Soil Series: MERIT

SOIL ANALYTICAL DATA

APPENDIX 5b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-3	5.1	224	28.3	54.8	5.8	3.6	1.5	1.1	0.9	nd	nd	2.89	4.97	0.39	7.41
B1	3-20	5.2	99	35.8	50	6.1	3.5	0.8	0.6	0.3	nd	nd	1.2	2.06	0.16	7.5
B2t	20-70	4.8	51	48.7	38.7	4.1	1.7	1	0.8	0.6	nd	nd	0.69	1.19	0.09	7.66

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	6400	3063	314	250	16	981	64	400	17	24	19.73	0.22	2.11	8.5	0.09	0.33
B1	8000	3188	214	180	15	638	60	300	10	9	14.27	0.21	1.75	5.29	0.1	0.39
B2t	7300	3313	35	145	16	230	76	250	9	nd	18.8	0.17	1.01	0.64	0.1	2.34

nd=not determined

Soil Profile No.:	12
Field No.:	C4
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Top slope
Slope at site:	18^{o}
Drainage:	Well-drained
Soil series:	Begunan

Profile Description

Ap	0- 2 cm	Dark yellowish brown 10YR 4/4; clay loam; moderately strong, fine and medium SBK; friable; few coarse pores; many fine roots; clear boundary.
AB	2- 10 cm	Yellowish brown 10YR 5/4 - 5/8; clay loam; moderately strong, medium SBK; friable; common medium and coarse pores; many medium and coarse roots; many organic acid coatings; clear boundary.
B2cn	10- 70 cm	Strong brown 7.5YR 5/6; clay; moderate, medium and coarse SBK; friable; common medium and fine pores; very few platty gravelly laterised shale; many coarse roots; very few organic acid coatings; gradual boundary.
B3cn	70-130 cm	Reddish yellow 7.5YR 6/6 and yellow 10YR 7/6; clay; moderate, coarse SBK; slightly compact; few medium pores; very few platty gravelly laterised shale; few medium and coarse roots; gradual boundary.
Cu	130-170 cm	A layer of unconsolidated shale with few medium roots.

Soil profile number: 12 SOIL ANALYTICAL DATA APPENDIX 6b

Soil Series: BEGUNAN

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-2	5.0	81	30.7	42.6	8.1	4.7	2.1	2.6	2.2	nd	nd	3.34	5.74	0.28	11.9
AB	2-10	5.1	55	34.9	39.4	8.2	5.4	2.1	4	4.9	nd	nd	1.4	2.41	0.15	9.33
B2cn	10-70	4.4	33	52.2	29	5.3	5.4	2.7	2.2	0.9	nd	nd	0.39	0.67	0.9	0.43

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	7000	1975	128	353	14	626	74	250	11	13	16.53	0.37	1.14	3.71	0.08	0.22
AB	7900	2038	104	250	17	404	66	200	8	2	13.87	0.23	0.78	2.81	0.09	0.42
B2cn	12600	3813	26	165	27	50	85	450	8	2	15.73	0.2	0.39	0.21	0.08	1.01

nd=not determined

Soil Profile No.:	24
Field No.:	E9
Parent material:	Shale
Landform:	Rolling low hill
Physiography at site:	Upper slope
Slope at site:	9^{o}
Drainage:	Well-drained
Soil series:	Begunan

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; loam; moderately strong, fine and medium SBK; friable; few coarse pores; many fine and medium roots; clear boundary.
B1	5- 35 cm	Strong brown 7.5YR 5/8; clay; moderate, coarse and very coarse SBK; firm; few medium and coarse pores; many organic acid coatings; many coarse and medium roots; gradual boundary.
B2cn	35-120 cm	Yellowish red 5YR 5/8; clay; moderate, very coarse SBK; firm; few medium and coarse pores; few platty gravelly laterised shale; few organic acid coatings; few medium roots.

Soil profile number: 24 SOIL ANALYTICAL DATA APPENDIX 7b

Soil Series: BEGUNAN

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.1	211	23.7	41.3	15.6	12.1	2	1.3	0.9	nd	nd	2.23	3.84	0.14	15.9
B1	5-35	4.3	58	42.2	36.5	9.6	7.3	0.9	0.5	0.1	nd	nd	0.42	0.72	0.06	7
B2cn	35-120	4.3	44	49	32.1	5.5	4.8	1.7	1.9	1.9	nd	nd	0.48	0.83	0.07	6.85

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	3800	1088	87	160	7	54	47	400	18	32	11.87	0.19	0.46	2.42	0.1	0.72
B1	7300	1763	30	95	9	39	38	325	8	6	11.87	0.13	0.18	0.7	0.09	1.42
B2cn	9800	2875	19	98	14	45	60	325	8	2	14.93	0.16	0.15	0.19	0.09	1.89

nd=not determined

Soil Profile No.: 6
Field No.: A3
Parent material: Shale
Landform: Hilly
Physiography at site: Mid-slope
Slope at site: 15°
Drainage: Well-drained
Soil series: Bekenu

Profile Description

Ap	0- 5 cm	Dark brown 10YR 3/3; loam; moderate, fine and medium SBK and crumbs; friable; few coarse pores; many fine roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/4; loam; moderate, medium SBK; slightly firm; common fine and medium pores; organic acid coatings on ped surfaces; abundant coarse roots; gradual boundary.
B2t	20- 80 cm	Yellowish brown 10YR 5/6 - 5/8; clay; moderate, coarse SBK; slightly firm; few fine pores; many medium and coarse roots; clay cutans on ped surfaces; clear boundary.
C	80-200 cm	Light grey 10YR 7/2 and yellowish brown 10YR 5/8; clay; moderately weak, very coarse ABK; compact; firm; presence of shale fragments.

Soil profile number:6 SOIL ANALYTICAL DATA APPENDIX 8b

Soil Series: BEKENU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	6.3	182	23.8	44.8	13.3	10.5	1.4	1	0.1	nd	nd	3.82	6.57	0.28	13.6
B1	5-20	5.4	60	25.1	32.6	17.6	17.9	1.1	0.8	0.9	nd	nd	0.78	1.34	0.14	5.57
B2t	20-80	4.7	24	38.9	30.3	11.8	11.8	1.3	1	1	nd	nd	0.41	0.7	0.08	5.12

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	4300	1525	383	250	13	229	41	250	19	13	14.13	0.66	3.39	9	0.09	0.22
B1	4600	1500	221	123	14	229	41	375	9	8	8.93	0.23	1.02	4.41	0.1	0.22
B2t	7100	2012	37	111	24	93	69	325	7	nd	15.6	0.18	0.26	0.74	0.08	1.56

nd=not determined

Soil Profile No.: 18
Field No.: F8
Parent material: Shale
Landform: Hilly
Physiography at site: Hill top slope
Slope at site: 18^{o}
Drainage: Well-drained
Soil series: Bekenu

Profile Description

Ap	0- 7 cm	Brown to dark brown 10YR 4/3; loam; moderately strong, medium and fine SBK; friable; common coarse pores; many fine and medium roots; clear boundary.
AB	7- 35 cm	Yellowish brown 10YR 5/4 - 5/6; silty loam; moderate, medium and some coarse SBK; friable; common medium and coarse pores; many organic acid coatings; abundant coarse and medium roots; gradual boundary.
B2t1	35- 70 cm	Yellowish brown 10YR 5/8; loam; moderate, coarse SBK; friable; common fine and medium pores; few organic acid coatings; many medium roots; gradual boundary.
B2t2	70-120 cm	Yellowish brown 10YR 5/8; clay loam; moderately weak, very coarse SBK; slightly compact; common fine and medium yellow 10YR 7/8 and yellowish red 5YR 5/8 mottles; very fine pores; few medium roots.

Soil profile number:18

SOIL ANALYTICAL DATA

APPENDIX 9b

Soil Series: BEKENU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-7	4.1	207	16.7	45.1	24	4.2	1.6	1.2	0.4	nd	nd	2.54	4.37	0.14	18.1
AB	7-35	4.4	104	17.8	49.9	24.2	2.5	0.8	0.5	0.3	nd	nd	0.71	1.22	0.06	11.8
B2t1	35-70	4.4	29	23.2	43.3	21.2	7.3	1.3	0.3	0.3	nd	nd	0.26	0.45	0.06	4.33
B2t2	70-120	4.2	23	27.9	46.4	20	2.1	0.8	0.6	0.4	nd	nd	0.21	0.36	0.04	5.25

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	2100	650	62	80	6	17	39	175	12	46	8.67	0.89	0.41	1.16	0.1	0.95
AB	2400	638	23	55	3	10	50	450	66	2	9.47	0.08	0.1	0.23	0.09	1.06
B2t1	3600	1038	36	73	55	71	39	325	6	nd	5.07	0.08	0.33	0.99	0.08	0.33
B2t2	3600	875	13	49	8	11	23	375	6	nd	10.8	0.12	0.47	1.14	0.09	1.11

nd=not determined

Soil Profile No.: 22
Field No.: E3
Parent material: Shale
Landform: Very steep, hilly
Physiography at site: Top steep slope
Slope at site: 35°
Drainage: Well-drained
Soil series: Bekenu

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; silty loam; moderate, medium SBK; friable; common medium pores; many fine roots; clear boundary.
B1	5- 30 cm	Yellowish brown 10YR 5/6; silty loam; moderate, medium and coarse SBK; friable; common fine and medium pores; many organic acid coatings; abundant coarse and medium roots; gradual boundary.
B2t	30- 85 cm	Yellowish brown 10YR 5/6 to light olive brown 2.5Y 5/6; silty clay loam; moderately strong, medium and coarse SBK; friable; common medium pores; very few platty gravelly laterised shale; many medium roots; few organic acid coatings; clear boundary.
Cu	85-200 cm	A layer of fragmented unconsolidated shale; slightly compact but penetrable by roots.

Soil profile number:22

SOIL ANALYTICAL DATA

APPENDIX 10b

Soil Series: BEKENU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.7	169	20.8	57	7.9	3.4	1.9	1.3	0.6	nd	nd	1.65	2.84	0.18	9.16
B1	5-30	4.7	33	24.9	57.7	7.3	3	3.1	1.9	0.9	nd	nd	0.53	0.91	0.09	5.88
B2t	30-85	4.4	39	40	47.2	4.8	2.3	1.1	3.1	1.6	nd	nd	0.3	0.52	0.07	4.28

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	4300	1663	131	158	6	138	54	400	17	20	10.13	0.16	0.99	3.8	0.09	0.44
B1	6000	1975	44	125	17	129	49	450	9	6	11.33	0.22	1.3	2.96	0.08	0.36
B2t	8600	750	13.5	113	12	139	75	525	10	nd	12.27	0.16	0.4	0.07	0.11	2.22

nd=not determined

Soil Profile No.: 28
Field No.: E13
Parent material: Shale
Landform: Hilly
Physiography at site: Mid-slope
Slope at site: 18^{o}
Drainage: Well-drained
Soil series: Bekenu

Profile Description

Ap	0- 5 cm	Yellowish brown 10YR 5/4; fine sandy loam; moderate, fine and medium SBK and crumbs; friable to loose; common coarse pores; abundant fine and medium roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/6; fine sandy clay loam; moderate, medium SBK; friable; common fine and medium pores; many medium and coarse roots; many organic acid coatings; gradual boundary.
B2	20- 85 cm	Yellowish brown 10YR 5/6; fine sandy clay loam; moderate, medium and coarse SBK; friable; slightly compact; common fine and few medium pores; many medium roots; very few organic acid coatings; gradual boundary.
B3	85-150 cm	Yellowish brown 10YR 5/6; fine sandy clay loam; moderately weak, coarse and very coarse SBK; friable; slightly compact; few fine and medium pores; many medium roots; common medium light grey 10YR 7/2 mottles.

Soil profile number:28

SOIL ANALYTICAL DATA

APPENDIX 11b

Soil Series: BEKENU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.3	152	13.6	17.2	8.1	42.5	12.3	2.5	0.6	nd	nd	1.95	3.35	0.3	6.5
B1	5-20	4.2	64	18.9	17.1	7.9	37.7	10.1	1.7	0.6	nd	nd	0.43	0.74	0.05	8.6
B2	20-80	4.3	44	23.1	17.9	5.2	39.2	10.3	0.3	0.7	nd	nd	0.29	0.5	0.05	5.8

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	2100	750	46	113	3	44	13	200	18	17	6.27	0.12	0.2	0.93	0.07	0.56
B1	3200	1038	13	70	6	22	75	275	8	8	6.13	0.19	0.06	0.1	0.09	0.72
B2	3400	1175	11	52	66	25	26	200	7	2	6.8	0.17	0.03	0.005	0.08	1.48

nd=not determined

Soil Profile No.: 14
Field No.: F15
Parent material: Sandstone
Landform: Hilly
Physiography at site: Top gently slope
Slope at site: 8^{o}
Drainage: Well-drained
Soil series: Nyalau

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; fine sandy loam; moderately strong, medium and fine SBK; friable; common medium and coarse pores; abundant fine roots; clear boundary.
B2t1	5- 25 cm	Brownish yellow 10YR 6/8; fine sandy loam; moderate, coarse and some medium SBK; friable; common medium and fine pores; abundant coarse and medium roots; many organic acid coatings; gradual boundary.
B2t2	25- 55 cm	Brownish yellow 10YR 6/8; loam; moderate, coarse SBK; friable; common fine and medium pores; few organic acid coatings; many medium roots; clear boundary.
B3	55-120 cm	Reddish yellow 7.5 YR 6/6; loam; moderately weak, very coarse and coarse SBK; slightly firm, slightly compact; common medium pale yellow 2.5Y 8/4 and yellow 2.5Y 8/6 mottles; few fine pores; few fine and medium roots.

Soil profile number:12

SOIL ANALYTICAL DATA

APPENDIX 12b

Soil Series: NYALAU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.5	120	14.9	27.3	31.4	19.2	0.9	0.5	0.2	1.04	nd	1.78	3.06	0.14	12.7
B1	5-25	4.4	44	16.5	29.9	30.8	18.7	0.8	0.1	0.2	1.28	nd	0.27	0.46	0.07	3.85
B2t1	25-55	4.3	35	17.4	28.9	30.5	17.5	0.6	0.2	0.3	1.49	nd	0.19	0.33	0.04	4.75
B2t2	55-120	4.4	24	21.3	28.5	31.3	16.7	0.9	0.2	0.3	1.56	nd	0.15	0.26	0.04	3.75

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	1400	488	23	75	4	16	9	300	10	26	8.27	0.16	0.2	0.65	0.08	0.78
B1	2100	650	13	53	8	7	13	300	6	2	5.07	0.06	0.02	0.01	0.05	0.58
B2t1	2200	675	15	45	5	9	12	300	6	nd	5.43	0.07	0.02	0.01	0.08	0.61
B2t2	3600	863	15	46	10	35	15	450	6	nd	5.6	0.07	0.03	0.005	0.07	0.72

nd=not determined

Soil Profile No.: 25
Field No.: E4
Parent material: Sandstone
Landform: Very steep, hilly
Physiography at site: Top slope
Slope at site: 4^{o}
Drainage: Somewhat excessively drained
Soil series: Nyalau

Profile Description

Ap	0- 5 cm	Very dark greyish brown 10YR 3/2; fine sandy loam; moderate, medium and fine SBK and crumbs; very friable; common coarse pores; many organic acid coatings; many fine and medium roots; clear boundary.
B1	5- 25 cm	Light yellowish brown 10YR 6/4 to 2.5Y 6/4; fine sandy loam; moderate, medium and coarse SBK; very friable; common medium and fine pores; many organic acid coatings; many medium and coarse roots; gradual boundary.
B21	25- 60 cm	Yellow 2.5Y 7/6; fine sandy loam; moderately weak, coarse SBK; very friable; common medium and fine pores; many organic acid coatings; common medium and coarse light grey to white 10YR 7/1 - 8/1 sandstone pockets; many medium roots; gradual boundary.
B22	60-150 cm	Yellow 2.5Y 7/6; fine sandy loam; moderately weak, very coarse SBK; very friable; common coarse white 10YR 8/1 sandstone pockets; common medium and fine pores; few organic acid coatings; few medium roots.

Soil profile number:25

SOIL ANALYTICAL DATA

APPENDIX 13b

Soil Series: NYALAU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.5	84	8.7	16.9	8.4	44.5	18.8	2.1	0.3	nd	nd	2.39	4.11	0.12	19.9
B1	5-25	4.4	51	11.9	17.6	8.7	42.1	15.2	1.6	0.1	nd	nd	0.39	0.67	0.05	7.8
B21	25-60	4.3	61	15.2	18.6	8.6	40	15.3	2.1	0.2	nd	nd	0.31	0.53	0.05	6.2
B22	60-150	4.4	42	16.4	15.6	7.4	39.6	16.8	2.2	0.1	nd	nd	0.23	0.4	0.05	4.6

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	1700	450	70	95	5	20	9	200	14	9	5.6	0.11	0.99	1.22	0.07	0.39
B1	2500	663	16.5	48	10	13	22	450	7	3	4.8	0.05	0.02	0.08	0.07	0.58
B21	3600	788	29	43	12	14	19	450	6	2	5.6	0.06	0.02	0.12	0.07	0.67
B22	3100	838	19	40	9	25	32	300	7	nd	8.13	0.08	0.02	0.04	0.07	0.58

nd=not determined

Soil Profile No.: 1
Field No.: B10
Parent material: Shale
Landform: Hilly
Physiography at site: Mid-slope
Slope at site: 16°
Drainage: Well-drained
Soil series: Kabuloh (tentative)

Profile Description

Ap	0- 5 cm	Very dark greyish brown 10YR 3/2; silty clay; moderately strong, fine SBK and crumbs; friable; abundant fine and coarse roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/6; silty clay; moderately strong, coarse and medium SBK; friable; few medium and coarse pores; many coarse roots; organic acid coatings on ped surfaces; gradual boundary.
B2t	20- 95 cm	Light olive brown 2.5Y 5/6; silty clay; moderately strong, coarse and very coarse SBK; friable; few fine pores; many coarse roots; clear boundary.
BC	95-140 cm	Light olive brown 2.5Y 5/6; silty clay; moderately weak, very coarse ABK and SBK; slightly massive; with common light grey 10YR 7/2 mottles and soft manganese concretions.

Soil profile number: 1

Soil series: KABULOH

SOIL ANALYTICAL DATA

APPENDIX 14b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-5	4.95	335	40.0	48.2	2.3	2.2	0.9	0.8	2.1	0.75	nd	2.93	5.04	0.39	7.51
B1	5-20	5.50	126	46.3	43.4	2.2	2.3	0.4	0.3	0.1	1.10	nd	1.01	1.74	0.18	5.61
B2t	20-95	5.00	175	51.5	39.4	1.8	1.4	1.4	0.4	0.3	1.17	nd	0.54	0.93	0.14	3.86

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	11900	5063	1502	393	31	649	74	100	17	52	23.87	0.73	3.19	11.78	0.11	0.28
B1	10100	5625	424	178	30	530	80	450	10	6	18.67	0.43	4.47	11.40	0.12	0.22
B2t	10100	5750	397	40	27	549	91	375	11	6	18.67	0.54	3.96	11.10	0.12	0.22

nd=not determined

Soil Profile No.:	2
Field No.:	B8
Parent material:	Alluvial
Landform:	Alluvial flat
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Well-drained
Soil series:	Tukau

Profile Description

Ap	0- 10 cm	Dark greyish brown 10YR 4/2; silty loam; moderate, medium and fine SBK and crumbs; friable; many fine, medium and coarse roots; clear boundary.
B1	10- 25 cm	Yellowish brown 10YR 5/6; silty loam; moderate, medium and coarse SBK; friable; common fine pores; many coarse roots; organic acid coatings on ped surfaces; gradual boundary.
B2t	25- 80 cm	Yellowish brown 10YR 5/6; silty loam; moderate, coarse and some medium SBK; friable; common fine and medium pores; many coarse roots; clay cutans on ped surfaces; gradual boundary.
B3	80-150 cm	Dark yellowish brown 10YR 4/6, yellow 10YR 7/6 and light grey 10YR 7/1; silty loam; moderate, very coarse SBK; friable.

Soil profile number: 2 SOIL ANALYTICAL DATA APPENDIX 15b

Soil series: TUKAU

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	v.f silt	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–10	5.90	134	20.6	53.8	12.1	8.1	0.8	0.5	0.3	1.06	nd	2.50	4.30	0.23	10.87
B1	10–25	4.45	122	22.9	57.6	9.6	5.5	0.5	0.3	0.2	1.28	nd	0.66	1.14	0.15	4.40
B2t	25–80	4.30	86	26.2	55.0	9.1	5.6	0.6	0.3	0.2	1.37	nd	0.39	0.67	0.10	3.90

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	5800	1888	293	278	14	549	44	300	13.0	17	13.20	0.72	1.75	6.51	0.11	0.22
B1	4400	1775	180	63	12	160	39	450	12.0	24	9.20	0.14	0.73	2.91	0.10	0.42
B2t	4400	1813	78	116	17	1414	39	475	8.5	6	8.93	0.13	0.39	1.25	0.10	0.75

nd=not determined

Soil Profile No.: 4
Field No.: A6
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Well-drained
Soil series: Tukau

Profile Description

Ap	0- 15 cm	Dark greyish brown 10YR 4/2; silty loam; moderate, medium and fine SBK; friable; common coarse and medium pores; many fine roots; clear boundary.
B1	15- 35 cm	Yellowish brown 10YR 5/6; loamy sand; moderate, medium SBK; friable; common coarse pores; many organic acid coatings on ped surfaces; many coarse and very coarse roots; gradual boundary.
B2t	35- 75 cm	Yellowish brown 10YR 5/6 to brownish yellow 10YR 6/6; loam; moderate, medium and some coarse SBK; friable; common fine pores; few organic acid coatings; many fine and medium roots; gradual boundary.
B3	75-140 cm	Yellow 10YR 7/6; loam; moderate, coarse SBK; friable; common medium yellowish brown 10YR 5/8 and yellow 2.5Y 7/6 mottles; common fine and medium pores; wavy and clear boundary.
IIc	140-200 cm	Variegated light yellowish brown 2.5Y 6/4, pale yellow 2.5Y 7/4 and light grey 2.5Y 7/2; loam; weak to structureless; somewhat loose.

Soil profile number: 4

Soil series: TUKAU

SOIL ANALYTICAL DATA

APPENDIX 16b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	v.f silt	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–15	5.40	140	22.0	50.2	17.9	1.8	2.9	0.6	0.3	1.14	nd	1.97	3.39	0.15	13.13
B1	15–35	4.90	45	21.2	45.8	13.7	11.6	1.9	0.3	0.4	1.32	nd	0.48	0.83	0.09	5.33
B2t	35–75	4.70	52	20.1	42.2	14.9	18.1	3.0	0.5	0.6	1.52	nd	0.29	0.50	0.08	3.63

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	4500	1325	144	180	9	176	33	175	16	22	8.80	0.59	0.93	2.93	0.07	0.28
B1	3900	1363	74	111	10	97	27	325	7	18	7.60	0.19	0.38	1.88	0.09	0.33
B2t	3500	1163	39	80	14	40	67	275	7	nd	19.33	0.12	0.26	1.06	0.08	0.50

nd=not determined

Soil Profile No.: 13
Field No.: D2
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Moderately well-drained
Soil series: Lupar

Profile Description

Ap	0- 2 cm	Very dark greyish brown 10YR 3/2; clay loam; moderately strong, medium and fine SBK; friable; few coarse pores; many fine roots; clear boundary.
B1	2- 10 cm	Brown to dark brown 10YR 4/3; silty clay loam; moderately, weak, coarse SBK; friable; very few coarse pores; abundant coarse roots; many organic acid coatings; gradual boundary.
B2	10- 70 cm	Yellowish brown 10YR 5/4 - 5/6; silty clay; moderate, coarse and very coarse SBK; friable; common fine and medium pores; many medium and coarse roots; gradual boundary.
B3	70-100 cm	Light grey 10YR 7/1; silty clay; moderately weak, very coarse SBK; friable; slightly massive; common medium dark, yellowish brown 10YR 3/6, 4/6 and brown 7.5YR 4/4 mottles; few fine and medium pores; many medium roots; clear boundary.
Cg	100-150 cm	Light grey 10YR 7/1; silty clay; moderately weak, very coarse SBK and columnar; slightly massive, slightly plastic; common medium reddish yellow 7.5YR 6/6 mottles.

Soil profile number: 13 SOIL ANALYTICAL DATA APPENDIX 17b

Soil series: LUPAR

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–2	5.45	405	31.0	40.8	3.2	8.0	5.8	3.9	1.5	–	nd	8.40	14.4	0.61	13.77
B1	2–10	5.50	142	31.4	54.1	3.8	5.1	1.3	0.8	0.1	–	nd	1.61	2.77	0.23	7.00
B2	10–70	4.45	120	45.5	45.6	2.5	2.9	0.6	0.2	0.3	–	nd	0.52	0.89	0.10	5.20
B3	70–100	4.40	54	46.7	42.7	1.7	3.1	1.0	0.3	0.2	–	nd	0.30	0.52	0.06	5.00

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	4600	3875	2675.0	150	16	11	79	13	29	59	36.00	0.55	5.19	18.91	0.18	0.28
B1	8300	3875	171.0	385	16	2219	80	400	11	4	16.67	0.36	1.95	5.21	0.19	0.22
B2	7500	3125	58.0	180	15	6	78	400	9	nd	20.53	0.17	1.42	1.71	0.21	1.00
B3	9900	3438	35.5	200	15	413	77	375	9	6	14.13	0.21	1.29	1.26	0.20	1.00

nd=not determined

Soil Profile No.: 36
Field No.: D9
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Well-drained
Soil series: Lupar

Profile Description

Ap	0- 7 cm	Very dark greyish brown 10YR 3/2; silty loam; moderately strong, fine and medium SBK; friable; common coarse and medium pores; abundant fine, medium and coarse roots; clear boundary.
B1	7- 40 cm	Yellowish brown to dark yellowish brown 10YR 5/4 - 4/4; silty clay loam; moderate, coarse SBK; friable; few fine pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2t	40- 90 cm	Yellowish brown 10YR 5/6 to brownish yellow 10YR 6/6; silty clay; moderately strong, medium and coarse SBK; friable; few fine pores; many medium roots; clay cutans on ped surfaces; gradual boundary.
B3	90-160 cm	Brownish yellow 10YR 6/6; silty clay; moderate, very coarse SBK; friable; slightly compact; many coarse strong brown 7.5YR 5/8 mottles; few medium roots.

Soil profile number: 36 SOIL ANALYTICAL DATA APPENDIX 18b

Soil series: LUPAR

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0-7	5.95	404	22.0	47.1	3.4	6.1	6.0	4.6	1.5	nd	nd	5.80	9.98	0.41	14.15
B1	7-40	4.40	240	37.5	51.0	3.9	2.9	0.8	0.1	0.3	nd	nd	1.10	1.89	0.17	6.47
B2t	40-90	4.40	121	43.0	42.0	4.3	2.6	0.6	0.1	0.9	nd	nd	0.42	0.72	0.09	4.67

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	5400	3000	1142	395	13	1744	83	300	22	40	23.07	0.52	3.60	13.09	0.09	0.33
B1	7300	2813	63	230	14	11	143	400	14	17	14.93	0.19	0.76	1.98	0.09	0.72
B2t	7500	2113	22	156	28	533	154	300	10	nd	14.40	0.16	0.61	0.43	0.12	0.89

nd=not determined

Soil Profile No.: 10
Field No.: C5
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Imperfectly drained
Soil series: Ajoh

Profile Description

Ap	0- 5 cm	Very dark greyish brown 10YR 3/2; silty clay loam; moderate, medium and fine SBK; friable; few coarse pores; few fine roots; clear boundary.
B21	5- 50 cm	Light grey 10YR 7/1; silty clay; moderate, coarse and very coarse SBK; slightly firm, slightly massive; common medium dark yellowish brown 10YR 4/6 and reddish yellow 7.5YR 6/8 mottles; few coarse pores; many organic acid coatings; many coarse roots; gradual boundary.
B22	50-100 cm	Light grey 10YR 7/1; silty clay; moderately weak, very coarse SBK and ABK and some columnar; slightly massive; common medium brownish yellow 10YR 6/6 mottles and dark yellowish brown 10YR 3/6 manganese mottles; very few coarse pores; very few coarse roots.

Soil profile number: 10

Soil series: AJOH

SOIL ANALYTICAL DATA

APPENDIX 19b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–5	5.95	427	28.4	46.5	1.3	4.1	3.8	2.3	1.4	–	nd	6.60	11.35	0.48	13.75
B21	5–50	5.70	39	42.8	48.4	1.0	2.3	1.2	0.4	1.2	–	nd	0.64	1.10	0.10	6.40
B22	50–500	4.95	50	47.5	39.0	2.8	3.1	2.2	1.5	0.3	–	nd	0.37	0.64	0.11	3.36

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	2800	2088	2883	373	10	602	53	200	31	50	28.53	0.55	4.32	18.75	0.11	0.22
B21	8000	3625	176	214	12	459	68	300	11	nd	19.47	0.21	2.52	5.73	0.14	0.22
B22	10300	3813	242	198	20	649	80	300	10	nd	15.73	0.20	2.62	4.12	0.18	0.44

nd=not determined

Soil Profile No.: 20
Field No.: E1
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Imperfectly drained
Soil series: Ajoh

Profile Description

Ap	0- 2 cm	Brown to dark brown 10YR 4/3; clay; moderately weak, medium SBK; friable; few medium pores; many fine roots; clear boundary.
B1	2- 15 cm	Light grey 10YR 7/1; silty clay loam; moderate, very coarse SBK; slightly firm; common medium yellowish red 5YR 5/8 mottles; few fine and medium pores; many organic acid coatings; few fine and medium roots; gradual boundary.
B2	15-100 cm	Light grey 10YR 7/1; silty clay loam; moderate, very coarse and coarse SBK; slightly firm; common medium strong brown 7.5YR 5/6 and reddish yellow 7.5YR 6/6 mottles; very few fine pores; very few fine and medium roots.

Soil profile number: 20

Soil series: AJOH

SOIL ANALYTICAL DATA

APENDIX 20b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–2	5.40	106	51.0	36.3	1.1	1.4	0.8	0.6	0.2	–	nd	4.29	7.39	0.16	26.81
B1	2–15	4.50	132	35.9	53.7	1.4	1.9	0.8	0.9	0.3	1.14	nd	0.96	1.65	0.16	6.00
B2	15–100	4.10	142	34.5	53.8	4.0	2.4	0.8	0.6	0.3	1.23	nd	0.51	0.88	0.11	4.64

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	3200	2750	422	675	19	308	83	375	28	2	25.07	0.61	2.93	10.00	0.10	0.36
B1	10500	4000	74	320	39	129	79	450	23	20	14.93	0.05	0.02	nd	0.07	1.11
B2	9100	3500	53	325	22	94	58	450	27	6	10.40	0.15	0.68	1.44	0.10	0.61

nd=not determined

Soil Profile No.: 639 (Soil auger examination)
Field No.: E10
Parent material: Alluvial
Landform: Alluvial flat
Physiography at site: River levee
Slope at site: $<1^{o}$
Drainage: Somewhat excessively drained
Soil series: Semilajau

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; fine sandy loam; very friable.
B1	5 - 20 cm	Very pale brown 10YR 7/4; fine sandy loam; loose.
B2	20-100 cm	Yellow 10YR 7/6; fine sandy loam; loose.

Soil profile number: 639

Soil series: SEMILAJAU

SOIL ANALYTICAL DATA

APPENDIX 21b

Horizon	Depth in cm	pH (1:2.5)	Electr cond. umho/cm	Particle size distribution (%) clay	silt	v.f sand	fine sand	med sand	co sand	v.co sand	Bulk den	CaCO3	Org. carbon	Org. matter	Kjel N	C/N
Ap	0–5	4.55	97	11.3	23.6	15.7	42.7	2.3	0.6	0.5	–	nd	1.75	3.01	0.08	21.88
B1	5–20	4.65	94	11.5	13.3	11.8	52.5	4.5	0.1	0.1	–	nd	0.72	1.24	0.05	14.40
B2	20–100	5.00	56	8.5	13.9	11.4	52.8	8.6	0.3	0.6	–	nd	0.45	0.77	0.03	15.00

Horizon	Perchloric digestible (ppm) K	Mg	Ca	P	Cu	Mn	Zn	Total S in ppm	Avail P in ppm	Water sol B ppm	NH4OAC CEC in meq%	Extractable cations in meq% K	Mg	Ca	Na	Al
Ap	1800	575	89	115	4	52	13	400	10	6	5.33	0.08	0.23	1.36	0.06	0.36
B1	2600	713	62	93	7	33	4	375	11	13	4.93	0.10	0.11	0.58	0.04	0.42
B2	2300	663	55	63	5	18	46	300	11	4	2.93	0.10	0.11	0.57	0.07	0.33

nd=not determined

Soil Profile No.:	3
Field No.:	B3
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	16^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 10 cm	Brown to dark brown 10YR 4/3; fine sandy loam; moderate, medium and fine SBK and few granules; friable; many fauna activities; many fine and coarse roots; clear boundary.
B1	10- 20 cm	Yellowish brown 10YR 5/6; fine sandy clay loam; moderate, medium SBK; friable; many coarse pores; many fauna activities; many coarse roots; gradual boundary.
B2t	20-105 cm	Brownish yellow 10YR 6/6; clay; moderate, coarse SBK; friable; many medium and fine pores; few fauna activities; few medium and coarse roots; few faint clay cutans; clear boundary.
C	105-200 cm	Variegated light grey 10YR 7/1, very pale brown 10YR 7/4 and yellowish red 5YR 5/6; silty clay; moderately weak, very coarse SBK and ABK; friable.

Soil Profile No.: 5
Field No.: A5
Parent material: Shale/mudstone
Landform: Hilly
Physiography at site: Lower slope
Slope at site: 18^{o}
Drainage: Well-drained
Soil series: Kabuloh

Profile Description

Ap	0- 5 cm	Brown to dark brown 10YR 4/3; silty clay loam; moderate, medium and fine SBK; friable; few coarse and medium pores; many fine roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/4; clay; moderate, medium SBK; friable; common fine pores; many organic acid coatings on ped surfaces; many coarse roots; gradual boundary.
B2t	20- 75 cm	Yellowish brown 10YR 5/6 to light olive brown 2.5Y 5/6; clay; moderately strong, coarse SBK; slightly firm; few fine pores; many coarse and medium roots; clay cutans on ped surfaces; gradual boundary.
C	75-200 cm	Variegated; silty clay; weak, coarse and very coarse SBK and ABK; slightly massive; few gravelly manganese concretions.

Soil Profile No.:	21
Field No.:	E2
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Lower slope
Slope at site:	18^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 5 cm	Yellowish brown to dark yellowish brown 10YR 5/4 - 4/4; clay loam; moderate, fine and medium SBK; friable; few coarse pores; many fine roots; clear boundary.
B1	5- 20 cm	Yellowish brown 10YR 5/6; clay loam; moderate, coarse SBK; friable; common medium and coarse pores; many organic acid coatings; many medium and coarse roots; gradual boundary.
B2cn	20- 80 cm	Yellowish brown 10YR 5/6; clay; moderate, coarse SBK; friable; common medium pores; few platty gravelly laterised shale; many medium roots; gradual boundary.
BC	80-110 cm	Yellowish brown 10YR 5/6; clay; moderate, very coarse SBK; friable; few medium very pale brown 10YR 7/3 mottles; few platty gravelly laterised shale.
CR	110-170 cm	A continuous layer of undecomposed shale.

Soil Profile No.:	29
Field No.:	E13
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Upper slope
Slope at site:	18^{o}
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 5 cm	Yellowish brown 10YR 5/4; clay loam; moderately strong, medium and fine SBK; friable; few coarse pores; many fine and medium roots; clear boundary.
B1	5- 25 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and medium SBK; friable; common fine and medium pores; many organic acid coatings; abundant coarse and medium roots; gradual boundary.
B2t	25- 80 cm	Yellowish brown 10YR 5/6; silty clay; moderately strong, medium and coarse SBK; friable; few coarse and medium pores; few organic acid coatings; many medium roots; gradual boundary.
B3cn	80-105 cm	Yellowish brown 10YR 5/6; silty clay; moderate, coarse and very coarse SBK; friable; few medium very pale brown 10YR 7/4 mottles; few coarse and medium pores; very few platty gravelly laterised shale; few medium roots; clear boundary.
Cu	105-120 cm	A layer of unconsolidated shale.

Soil Profile No.:	35
Field No.:	D5
Parent material:	Shale
Landform:	Steep
Physiography at site:	Lower slope
Slope at site:	22°
Drainage:	Well-drained
Soil series:	Merit

Profile Description

Ap	0- 2 cm	Yellowish brown 10YR 5/4; clay loam; moderate, fine and medium SBK; friable; few coarse pores; many fine roots; clear boundary.
B2t	2- 20 cm	Yellowish brown 10YR 5/6; clay; moderately strong, medium and coarse SBK; slightly firm; few fine and medium pores; many coarse roots; clear boundary.
B2cn	20- 70 cm	Yellowish brown 10YR 5/8; clay; moderately weak, coarse SBK; slightly firm, slightly compact; few fine and medium pores; very frequent platty gravelly laterised shale; few medium roots; clear boundary.
CR	70-200 cm	A compact layer of fragmented shale with very few medium roots.

Soil Profile No.:	37
Field No.:	D3
Parent material:	Shale
Landform:	Hilly
Physiography at site:	Upper slope
Slope at site:	18^{o}
Drainage:	Well-drained
Soil series:	Begunan

Profile Description

Ap	0- 3 cm	Dark yellowish brown 10YR 4/4; clay loam; moderate, fine and medium SBK; friable; few coarse pores; many fine roots; clear boundary.
B1	3- 25 cm	Yellowish brown 10YR 5/6; clay; moderate, medium and coarse SBK; friable; common coarse pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2t	25- 80 cm	Strong brown 7.5YR 5/6; clay; moderately strong, coarse SBK; friable; few coarse pores; few organic acid coatings; few medium and coarse roots; clay cutans on ped surfaces; gradual boundary.
B3cn	80-130 cm	Strong brown 7.5YR 5/6; clay; moderate, coarse SBK; friable; slightly compact; common medium light grey 10YR 7/2 and very pale brown 10YR 7/4 mudstone fragments; very few platty gravelly laterised shale; few medium roots; clear boundary.
R	130-200 cm	An impervious layer of mudstones.

Soil Profile No.: 26
Field No.: E4
Parent material: Sandstone
Landform: Hilly
Physiogrpahy at site: Top gentle slope
Slope at site: 3^{o}
Drainage: Somewhat excessively drained
Soil series: Nyalau

Profile Description

Ap	0- 5 cm	Very dark greyish brown 10YR 3/2; fine sandy loam; moderate, medium and fine SBK and crumbs; very friable; common coarse pores; many organic acid coatings; many fine and medium roots; clear boundary.
B1	5- 25 cm	Light yellowish brown 10YR 6/4 to 2.5Y 6/4; fine sandy loam; moderate, medium and coarse SBK; very friable; common medium and fine pores; many organic acid coatings; many medium and coarse roots; gradual boundary.
B21	25- 60 cm	Yellow 2.5Y 7/6; fine sandy loam; moderately weak, coarse SBK; very friable; common medium and fine pores; many organic acid coatings; common medium and coarse light grey to white 10YR 7/1 - 8/1 sandstone pockets; many medium roots; gradual boundary.
B22	60-150 cm	Yellow 2.5Y 7/6; fine sandy loam; moderately weak, very coarse SBK; very friable; common coarse white 10YR 8/1 sandstone pockets; common medium and fine pores; few organic acid coatings; few medium roots.

Soil Profile No.:	17
Field No.:	F9
Parent material:	Sandstone
Landform:	Rolling low hills
Physiography at site:	Foot hill adjacent to ravine
Slope at site:	6^{o}
Soil series:	Colluvial

Profile Description

Ao	10- 0 cm	A thick mat of roots.
Ap	0- 10 cm	Dark reddish brown 5YR 3/2; sand; moderate, medium SBK; friable; many fine roots; gradual boundary.
Ae	10- 50 cm	Greyish brown 10YR 5/2; sand; moderately weak, medium SBK; friable; many coarse and fine roots; clear boundary.
B1	50- 60 cm	Brownish yellow 10YR 6/6; loamy sand; moderate, medium SBK; friable; common fine brown 7.5YR 4/4 streaks; many medium roots.
R	60 cm+	An impenetrable layer of sandstone.

Soil Profile No.:	8
Field No.:	C6
Parent material:	Alluvial
Landform:	Valley floors
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Well-drained
Soil series:	Tukau

Profile Description

Ap1	0- 5 cm	Very dark greyish brown 10YR 3/2; clay loam; moderately strong, fine and medium SBK and granules; friable; few coarse pores; abundant fine and medium roots; clear boundary.
Ap2	5- 15 cm	Brown 10YR 5/3; silty clay loam; moderately strong, medium SBK; friable; few fine and medium pores; many organic acid coatings; many medium roots; clear boundary.
B2t1	15- 30 cm	Yellowish brown 10YR 5/4 - 5/6; silty clay loam; moderately strong, medium and coarse SBK; friable; common fine and medium pores; many organic acid coatings; many medium roots; gradual boundary.
B2t2	30- 90 cm	Yellowish brown 10YR 5/6; silty clay loam; moderate, coarse SBK; friable; few fine pores; many medium roots; gradual boundary.
B3	90-150 cm	Yellowish brown 10YR 5/6; silty clay loam; moderate, coarse and some very coarse SBK; friable; common fine pale yellow 2.5Y 7/4 mottles; very few fine pores; few medium roots.

Soil Profile No.:	11
Field No.:	C5
Parent material:	Alluvial
Landform:	Valley floors
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Well-drained
Soil series:	Tukau

Profile Description

Ap1	0- 5 cm	Very dark greyish brown 10YR 3/2; clay loam; moderate, medium and fine SBK; friable; few coarse pores; many medium and coarse roots; clear boundary.
Ap2	5- 20 cm	Yellowish brown 10YR 5/4; silty clay loam; moderately strong, medium and some coarse SBK; friable; common medium and coarse pores; many organic acid coatings; many coarse roots; gradual boundary.
B2t	20- 70 cm	Yellowish brown 10YR 5/6 to brownish yellow 10YR 6/6; silty clay loam; moderately strong, medium and coarse SBK; friable; common fine and medium pores; few organic acid coatings; few medium roots; gradual boundary.
B31	70- 90 cm	Very pale brown 10YR 7/4; silty clay loam; moderate, coarse and very coarse SBK; friable; common medium yellowish red 5YR 5/6 mottles; few medium pores; few medium roots; clear boundary.
B32	90-150 cm	Variegated white 10YR 8/2, yellowish brown 10YR 5/6 and yellowish red 5YR 5/6; silty clay loam; moderately weak, very coarse SBK and ABK; friable; few medium roots.

Soil Profile No.:	19
Field No.:	E7
Parent material:	Alluvial
Landform:	Valley floors
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Moderately well-drained
Soil series:	Lupar

Profile Description

Ap	0- 5 cm	Dark yellowish brown 10YR 4/4; clay loam; moderately strong, fine and medium SBK; friable; common medium and coarse pores; many fine and coarse roots; clear boundary.
B1	5- 20 cm	Strong brown 10YR 5/8 and yellowish brown 10YR 5/4; silty clay loam; moderately strong, medium and coarse SBK; friable; common fine and medium pores; many coarse roots; many organic acid coatings; gradual boundary.
B2t	20- 60 cm	Dark yellowish brown 10YR 4/6 to yellowish brown 10YR 5/8; silty clay; moderate, coarse SBK; friable; common medium very pale brown 10YR 7/3 - 7/4 mottles; common fine and medium pores; many medium roots; few organic acid coatings; gradual boundary.
BCg	60-120 cm	Light grey 10YR 7/2; silty clay; moderately weak, very coarse SBK; slightly massive; common medium yellowish brown 10YR 5/8 mottles; few fine pores; few fine and medium roots.

Soil Profile No.: 30
Field No.: D13
Parent material: Alluvial
Landform: Valley floor
Physiography at site: Flat
Slope at site: $<1^{o}$
Drainage: Moderately well-drained
Soil series: Lupar

Profile Description

Ap	0- 8 cm	Dark brown 10YR 3/3; clay loam; strong, fine and medium SBK; friable; common medium and coarse pores; abundant fine and medium roots; clear boundary.
B1	8- 25 cm	Yellowish brown 10YR 5/4; clay; moderately strong, medium SBK; friable; few fine and coarse pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2t	25- 60 cm	Yellowish brown 10YR 5/6; clay; moderate, coarse and some medium SBK; friable; few fine pores; very few organic acid coatings; few coarse roots; gradual boundary.
B3	60-160 cm	Variegated yellowish brown 10YR 5/6, olive yellow 2.5Y 6/6 and strong brown 7.5YR 5/6; clay; moderate, very coarse SBK; slightly firm, slightly compact; few fine pores; few medium roots.

Soil Profile No.:	32
Field No.:	C14
Parent material:	Alluvial
Landform:	Valley floor
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Moderately well-drained
Soil series:	Lupar

Profile Description

Ap	0- 8 cm	Dark brown 10YR 3/3; clay loam; strong, fine and medium SBK; friable; common medium and coarse pores; abundant fine and medium roots; clear boundary.
B1	8- 25 cm	Yellowish brown 10YR 5/4; clay; moderately strong, medium SBK; friable; few fine and coarse pores; many organic acid coatings; abundant coarse roots; gradual boundary.
B2t	25- 60 cm	Yellowish brown 10YR 5/6; clay; moderate, coarse and some medium SBK; friable; few fine pores; very few organic acid coatings; few coarse roots; gradual boundary.
B3	60-160 cm	Variegated yellowish brown 10YR 5/6, olive yellow 2.5Y 6/6 and strong brown 7.5YR 5/6; clay; moderate, very coarse SBK; slightly firm, slightly compact; few fine pores; few medium roots.

Soil Profile No.:	7
Field No.:	B2
Parent material:	Alluvial
Landform:	Valley floors
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Imperfectly drained
Soil series:	Ajoh

Profile Description

Ap	0- 10 cm	Very dark greyish brown 10YR 3/2; clay loam; moderately strong, fine SBK and granules; friable; few coarse pores; many fine roots; clear boundary.
AB	10- 25 cm	Dark greyish brown 10YR 4/2; clay loam; moderately strong, medium SBK; friable; common coarse and medium pores; many organic acid coatings on ped surfaces; abundant coarse and medium roots; clear boundary.
B21	25- 80 cm	Grey to light grey 10YR 6/1 - 7/1; silty clay loam; moderate, coarse SBK; friable; common medium yellowish brown 10YR 5/6 and strong brown 7.5YR 5/8 mottles; few fine and medium pores; very few organic acid coatings; few medium roots; gradual boundary.
B22	80-140 cm	Grey to light grey 10YR 6/1 - 7/1; silty clay loam; moderately weak, coarse SBK; slightly firm; many coarse mottles as above; very few medium roots; gradual boundary.
BC	140-180 cm	Grey to light grey 10YR 6/1 - 7/1; silty clay loam; moderately weak, very coarse SBK and ABK; slightly firm, slightly compact; with many coarse mottles as above.

Soil Profile No.:	38
Field No.:	D3
Parent material:	Alluvial
Landform:	Alluvial flat
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Imperfectly drained
Soil series:	Ajoh

Profile Description

Ap	0- 5 cm	Dark brown 10YR 3/3; silty clay loam; moderate, fine SBK and granules; friable; few medium and coarse pores; many fine roots; clear boundary.
B1	5- 20 cm	Light grey 10YR 7/2; silty clay; moderate, very coarse SBK; friable; common medium yellowish red 5YR 5/8 and brownish yellow 10YR 6/8 mottles; few fine and coarse pores; many organic acid coatings; many medium and coarse roots; gradual boundary.
B2	20- 80 cm	Light grey 10YR 7/1; silty clay; moderate, very coarse SBK; friable; common medium strong brown 7.5YR 5/8 and brownish yellow 10YR 6/8 mottles; few coarse pores; few fine and medium roots; gradual boundary.
Cg	80 cm+	A layer of massive gleyed silty clay horizon.

Soil Profile No.:	23
Field No.:	E10
Parent material:	Alluvial
Landform:	Valley floor
Physiography at site:	Flat
Slope at site:	$<1^{o}$
Drainage:	Well-drained (subject to short duration flooding)
Soil series:	Semilajau

Profile Description

Ap	0- 4 cm	Dark yellowish brown 10YR 4/4; sand; weak, fine and medium SBK; loose; many fine and medium roots; clear boundary.
B1	4- 20 cm	Very pale brown 10YR 7/3; sand; moderately weak, medium SBK; loose; many medium and coarse roots; clear boundary.
IIB2	20- 70 cm	Yellowish brown 10YR 5/6; fine sandy clay loam; moderate, medium and coarse SBK; friable; many coarse roots; common medium yellowish red 5YR 5/6 mottles.