Report No. F2

Report on a Reconnaissance Soil Survey
of the

PELAGUS

Protected Forest

3rd DIVISION

by

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Report on a reconnaissance soil survey of the Pelagus Protected Forest, 3rd Division

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Introduction:

Project S1 of the 1966-70 Sarawak Forest Research Development Plan is the investigation of the possibility of afforestation using fast-growing softwood exotic or idigenous species. The Silvicultural Research Section has accordingly laid down experimental plots at 7 sites in the State. The soils of these sites have been surveyed in detail (Baillie, 1970 (b)) and are found to include areas of most of the important mineral soil types of lowland Sarawak, except for the Saline Gleys (mangrove soils). However the shallow and stony Red Yellow Podsolic and associated Skeletal soils which cover most of the hilly interior and probably account for over 60% of the total area of the state are not represented.

The Pelagus Protected Forest is an area of this rugged, interior hill country that is fairly accessible to the Silvicultural Research Section, based in Sibu, and it is under the permanent control of the Forest Department. Accordingly this reconnaissance soil survey was undertaken to locate the best site in the Forest for further afforestation trials, should they be required in this type of country.

1. The Area

1.1 Location and Access

The Forest is located on the true right bank of Batang Rajang, about 1½ hours upstream of Kapit by longboat (see inset to Map 1). Of the true right bank tributaries of the Rajang in the area, only Sungai Pelagus and Sungai Merit are navigable by longboat, the latter with difficulty at low water.

Medium-sized longboats can get up Sungai Pelagus to well beyond Nanga Arak, but none of its true left bank tribaries are navigable. However, the people of Rumah Kalup and Rumah Tujan are frequent visitors to the Forest and there are several well marked paths, of which the most important are those following Sungai Angkawat - Sungai Sawai and Sungai Arak - Sungai Dayat (see Map 1).

River access from the Merit side is poor, as Sungai Termulan is always choked with logs. However there are paths into the Forest area from the Rajang, and it was by one of these that the soil survey party reached Rentis 5 (see Map 3).

1.2 Cadastral

The Pelagus Protected Forest was constituted in 1936 and covered about 20,000 acres (S.G.G. Notification No.469 of 19.5.1936). Since then there have been two excisions. In 1955 about ⅓ acre was excised at Nanga Pelagus to legalise the existence of a shophouse that has been licensed and in business for over two years (S.G.G. Notification No.171 of 22.7.1955). In 1957 about 2300 acres of the damun land of Rumahs Tujan and Kalup on the T.L.B. of Sg. Pelagus was excised (S.G.G. Notification No.1905 of 14.12.1956).

An area of about 5000 acres in the southern part of the Forest, where it abuts onto Btg. Rajang, is under consideration as a National Park. If it is constituted, the area cannot be considered as a possible site for afforestation trials.

The original boundaries of the Forest and the boundaries of the 1957 excision and the proposed National Park area shown on Map 1.

1.3 Climate

The nearest medium-term meteorological stations are Kapit and Belaga. The rainfall and evaporation data of these two stations are summarised in Tables 1 and 2.

Table 1

Rainfall at Kapit and Belaga

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Kapit (24 years to 1968)													
Mean	15	13	14	12	12	9	8	10	12	14	12	14	144
Maximum	59	29	27	18	20	15	19	19	26	21	18	21	170
Minimum	7	6	5	3	7	4	1	1	6	6	6	8	107
Belaga (12 years to 1968)													
Mean	13	14	13	15	11	11	12	7	10	13	13	13	142
Maximum	22	18	23	18	17	23	16	12	18	21	19	18	157
Minimum	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes

(1) Figures are to the nearest inch.

(2) The figures are taken from Seal (1958), and from the Hydrological Yearbooks for 1962-8 of the Drainage and Irrigation Department.

Table 1 shows that the rainfall is seasonal, with the heaviest precipitation in October-March but, in comparison to West Sarawak, this effect of the Northeast monsoon is muted. The mean precipitation for all months is greater than 100 mm (ca 4 inches) so that both stations fall into Class 1A (continuously wet) in the system of Mohr and van Baren (1954).

Table 2

Evaporation at Kapit and Belaga

Kapit		J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean	)	5	5	6	6	6	5	6	6	6	6	6	6	67
Maximum	) 1963-8	6	5	11	7	6	6	6	6	6	6	6	6	71
Minimum	)	4	4	5	4	5	5	5	6	5	5	5	5	62
Belaga														
Mean	)	6	5	6	6	6	6	5	5	5	6	5	6	)
Maximum	) 1963-7	7	6	7	7	6	6	7	6	6	6	6	6	) 67(2)
Minumum	)	5	4	4	6	5	5	5	5	5	5	5	5	)

Notes:

(1) Evaporation is measured with a Class A pan at both stations and the monthly total is given to the nearest inch.

(2) There is only one complete year of readings for Belaga, so that the annual maximum, minimum and mean cannot be determined.

(3) The figures are taken from the Hydrological Yearbooks for 1962-8 of the Drainage and Irrigation Department.

Table 2 shows that the evaporation is relatively invariable from month to month within the year and from year to year. Fluctuations in the moisture balance are almost wholly attributable to variations in the rainfall. As precipitation exceeds evaporation on average for every month of the year, the soils are probably being strongly leached at present.

1.4 Geology

1.4.1 General

The findings of the localised economic geological investigations in the area of the Forest by Powell Duffryn Technical Services Ltd. in 1947-8 and by the Sarawak Shell Oilfields Ltd. in the postwar period were incorporated into the general geological description of the upper Rajang (Kirk, 1957). In the later description of the geology of the whole state, Kirk's classification and boundaries were adopted, but the nomenclature and estimated thicknesses of the deposits were revised (Leichti, 1960).

The southern part of the Forest is underlain by the Palaeogene geosynclinal sediments of the Belaga Formation. The northern section is underlain by younger shallow basin sediments of an outlier of the Nyalau Formation. The topography, vegetation and soils are all subject to strong lithological control, so that the geological boundary also separates different landscape types, forest types and soil associations.

1.4.2 Belaga Formation

The southern part of the Forest is underlain by the clastic sediments of the Belaga Formation. These were laid down on the southwestern flank of the Northwest Borneo Geosyncline in Early Tertiary times. They have been subject to severe faulting and folding since deposition and vertical or very steep angles of dip are normal. The formation consists of a succession of shales and sandstones. The argillaceous rocks are

dominant throughout, and the sandstone beds account for fractions of the total thickness that vary from 10% to 35%. The proportion and thickness of the sandstone beds is one of the main criteria for the subdivision of the Formation into members or stages. The main characteristics of those Belaga Formation rocks that outcrop within the Forest are summarised in Table 3. The basal Layar (upper Cretaceous) and the uppermost Bawang (Eocene - Oligocene) members are not included.

1.4.3 Nyalau Formation

The northern part of the Forest is underlain by sedimentary rocks of Neogene age. These have been referred to as the Long Formation, or the Pila Coal Formation, but are now regarded as an outlier of the Nyalau Formation (Leichti, 1960). They were laid down in shallow water environment, possibly an isolated basin, during Oligocene or Early Miocene times.

Since deposition they have been slightly folded and now have a shallow synclinal structure. The axis of the syncline runs parallel to the strike of the underlying Belaga Formation. The axis lies close the southern boundary of the outcrop (see Map 2) so that the syncline is asymetrical. The northwards dipping southern limb deeps more steeply than the northern limb, in which angles of dip greater than 20° are uncommon. The angular unconformity with the underlying nearly vertical strata of the Belaga Formation is as much as 90° in places.

The base of the formation consists of alternating poorly consolidated siliceous coarse sandstone and hard conglomerates. These give way to a succession of consolidated but friable sandstones and coal seams, and the formation is capped with stratified, unconsolidated conglomerates. The whole succession is shot through with thin beds of shale, mudstone and siltstone. Lenticular boulders of sideritic ironstone are concentrated in layers in some of the shale beds. Fragments of some of these boulders were noted at the surface between Sg. Latong and Sg. Berdai in the course of the soil survey.

1.5 Landform

1.5.1 General

The topography of the area shows strong lithological control and the landscapes of the Belaga and Nyalau Formation outcrops appear distinctly different, both on the ground and in stereoscopic examination of the aerial photographs.

Table 3

Belaga Formation in Pelagus P.F.

Name	Age	Estimated total thickness (feet)	Sandstone as fraction of total thickness	Thickness of sandstone beds	Lithology of argillaceous rocks	Extent of outcrop in Pelagus (see Map 2)
Metah member (Leichti) or Stage IV (Kirk)	Tb (Upper Eocene) (Leichti) or Middle - Upper Eocene (Kirk)	4,450 (Leichti) or 4,500 (Kirk)	15 - 25%	Usually < 3 feet	Dark grey Shales	Northern half of Belaga Formation outcrop (between Sg. Angkawat and Sg. Ensawi)
Pelagus member (Leichti) or Stage III (Kirk)	Tb (Middle-Upper Eocene) (Leichti) or Lower-Middle Eocene (Kirk)	10,600 (Leichti) or 15,500 - 20,000 (Kirk)	ca 35%	Up to 300 feet	Dark grey Shales	Southern half of Belaga Formation outcrop (South of Sg. Angkawat)
Kapit member (Leichti) or Stage II (Kirk)	Ta (Paleocene and lower Eocene) (Leichti) or Paleocene - Lower Eocene (Kirk)	10,900 (Leichti) or 10,000 - 22,000 (Kirk)	< 10%	Rarely > 12 feet	Multicoloured green, red, purple and grey shales	Small area between Bukit Wong and Nanga Pelagus

1.5.2 Southern section

The terrain of the southern section is typical of large areas of the Rajang hinterland underlain by rocks of the Belaga Formation. The alternation of steeply dipping beds of soft shale and harder sandstone has given rise to a marked ridge and vale topography. The thick sandstone beds form the spines of the high ridges which are aligned along the strike and which sometimes persist over long distances. The crests may be over 1000 feet high. These ridges are commonest in the outcrop of the Pelagus member, in the southern part of the outcrop, but they also occur on the Kapit and Metah members. The ridges exert strong control over the drainage, which has a trellis pattern with the first order streams running parallel to the strike. The second order streams that cut across the grain of the strike, such as Sg. Pelagus and Sg. Lebau, are often aligned along oblique regional faults.

The strike lineation of the topography between the major sandstone ridges is less conspicuous. The interfluves lack the spines of the thick sandstone beds and are lower and less persistent than the major ridges.

Most of the smaller streams are cut into solid rock and it is only along a few of the larger streams such as Sg. Pelagus, Sg. Angkawat and Sg. Lebau that there are small, discontinuous strips of alluvial deposits which are often very stony. The section of the Rajang along the southern boundary of the Forest is occupied by the Pelagus Rapids and there is no alluvium.

The absence of extensive alluvial deposits and the narrowness of the ridge crests means that the proportion of flat and gently sloping land is very small. The dominant facets of the landscape and the flank slopes of the ridges, the gradients of which range from 20° to 45°.

1.5.3 Northern section

The terrain of the Nyalau Formation outcrop is much less rugged than that of the Belaga Formation, and is atypical for most of the Rajang hinterland.

The topographic differences between the outcrops can be attributed to:

(i) the relative softness of the Nyalau Formation sandstones and (ii) the shallower angles of dip of the Nyalau sediments.

The softness and poor consolidation of the sandstones renders them more vulnerable to erosion. However, despite the general low competence, there are differences between adjacent beds which give rise to lithologically

controlled relief features. The form of these features depends upon the angle of dip of the rocks. Where the dip is shallow, cuesta features are formed. As the angles of dip are generally lower in the northern arm of the syncline, the cuesta form is best expressed north of Sungai Berdai. But even there, the low relief and the dissection of dipslopes means that the scarp and dip facets are not readily apparent on the ground.

South of Sungai Berdai, the dips are steeper and most of the ridges are homoclinal, although lower and less steep than those of the Belaga Formation. However there are places where the dip is shallow enough for cuesta formation, especially in the higher hills along the Latong-Berdai watershed. The distribution of the cuesta and homoclinal ridges most easily distinguished on the aerial photographs is shown in Map 2.

In its upper reaches Sg. Berdai follows the axis of the syncline. The valley is straight, although the stream itself is fairly sinuous within the confines of a narrow floodplain. Downstream it is not so constrained, as it flows through an extensive area of alluvial deposits.

In contrast to the southern part of the Forest, there are considerable areas of alluvium. The low competence of the Nyalau Formation rocks provides the volume of mass waste and the low relief that are necessary for extensive alluvial deposition. In addition to the current floodplain there is a low terrace, which is only about 10 feet higher. As they are both under thick forest, such a small height difference cannot be distinguished on the aerial photographs. The hiatuses in base level associated with the deposition of the terrace and the floodplain material are thought to be localised, and not to be related to changes in sea level.

1.6 Vegetation

1.6.1 General

The vegetation of the Forest shows the same clear division into the northern and southern sections that is found in the geology, topography and soils.

1.6.2 Mixed Dipterocarp Forest

The southern section is covered with Mixed Dipterocarp Forest, similar in structure and, probably, floristic composition to that covering large areas of the Rajang hinterland. There are small areas of young secondary growth within the present boundaries of the Forest in places where the larger streams such Sg. Lebau and Sg. Ensawai give relatively

easy access. There may also be areas of old secondary forest close to these streams, judging from the high proportion of geronggang (Cratoxylon arborescens) found on Rentis 1 to the north of Sg. Angkawat (see Map 3).

1.6.3 Kerapa Forest

The hill forest in the northern section is known locally as 'kerapa bukit'. In structure it appears to be transitional between coastal kerangas and Mixed Dipterocarp Forest, with a higher density of relatively small stems than is found in the latter. No collection or botanical identification was attempted during the course of this survey, but the composition of a 'kerapa bukit' inventory sample in the Ulu Anap (also underlain by sandstones of the Nyalau Formation) show this type of forest is transitional between kerangas and Mixed Dipterocarp Forest floristically as well as structurally. The 'kerapa bukit' is in fact a very heterogeneous assemblage, becoming more like kerangas on the podsolised dipslope soils and more like Mixed Dipterocarp Forest on the shale - derived soils or on steeper slopes.

The forest on the moderately and strongly podsolised soils on the alluvium in the northern section is known locally as 'kerapa paya'. This is very distinctive on the aerial photographs, with an even dense canopy of small crowns. On the ground it appears to be very similar, both structurally and floristically, to the kerangas forest found on the marine terraces in coastal areas.

1.6.4 Empran Forest

On the heavier textured and non-podsolised alluvium in the northern section, especially along the upper reaches of Sg. Berdai, and on the small areas of deep alluvium in the southern section there are areas of 'empran' forest. This has an even, large-crowned canopy and is quite distinct on the aerial photographs. On the ground it is found to have a high proportion of engkabang.

1.7 Previous soil survey coverage

No previous soil surveys have been carried out in the Forest, but nearby similar areas were examined on a broad reconnaissance scale by Andriesse (1961). Two of the profile descriptions from that survey are reproduced in the Appendix, as they illustrate the characteristics of soils found in the Forest.

The semi-detailed survey of the Nanga Merit area is wholly concerned with soils developed in the Rajang alluvium, and is not relevant to most of the Forest (Scott, 1969).

The Soil Map of Sarawak (Sarawak Soil Survey Staff, 1968) shows most of the Forest to be covered by shallow Red Yellow Podsolic and associated Skeletal soils. There are patches of deeper Red Yellow Podsolic soils shown in the northern part of the Forest. Apart from the surveys mentioned above there is no ground coverage and the boundaries in this part of the map were determined by aerial photograph interpretation.

2. Methods

2.1 Field

Prior to fieldwork, the 1967 aerial photographs were examined, and rentises planned so that they would cover the main landscape types within the Forest. In fact, due to poor navigation on the ground, two of the rentises were mislocated. The rentises actually cut, rather than those planned, are shown on Map 3.

Field work was carried out for two weeks in September 1969 by the writer and Assistant Forest Officer Abdul Manaf bin Sairi. The soil was examined at slope-corrected measured 2 or 3 chain intervals along the rentises, using a 48 inch auger with a 2 inch Edelmann head. 5 profile pits were dug, described and sampled to illustrate the characteristics of some of the more widespread soils. Because of the large number of profiles of the shallow and stony Red Yellow Podsolic soils found on the Belaga Formation that have been examined elsewhere in the Upper Rajang, attention was concentrated on the soils found on the rocks of the Nyalau Formation.

2.2 Maps and Aerial Photographs

The new series of 1:50,000 contoured sheets covering the Forest are unfortunately not yet available. The 1958 series (sheet numbers 2/113/9 and 2/113/13) are not form lined and contain several errors and uncertainties with regard to stream courses, especially in the northern part of the Forest. The Forest Department Working Plans Office 1:50,000 Map of the Forest (W.P.O. Map No.254) is based on the old series and inevitably incorporates their errors. However, in the absence of anything more recent, this was taken as the base for Maps 1-3 in the end folder, although it was amended and added to where possible.

The different landscape and forest types and the soil associations were delineated by extrapolation from the rentis data by stereoscopic examination of the recent 1:30,000 panchromatic vertical aerial photographs (Land and Survey Dept. Sortie No.26/67).

3. Soils

3.1 General

For the southern part of the Forest, the photo-interpretation of the soils for the Soil Map of Sarawak is confirmed, as shallow Red Yellow Podsolic and associated skeletal soils predominate. In the northern part, in addition to the deeper Red Yellow Podsolic soils indicated on the Soil Map, there are also fairly large areas of Podsols and Grey White Podsolic Soils.

The lower proportion of shales and the siliceous, rather than feldspathic, nature of the sandstone makes the rocks of the Nyalau Formation a more base - deficient parent material than those of the Belaga Formation. However all the soils have been subject to strong leaching and nutrient contents are generally low.

The soil mapping units in Map 3 are associations. These are geographical groupings of soils that occur in distinctive landscapes and under distinctive types of forest, and are therefore easily distinguished on the aerial photographs. The soils within an association may be quite easy to separate in the field and may not be closely related genetically or taxonomically, but if the boundary is not readily distinguishable on the aerial photographs, no attempt has been made to delineate it.

The different soils found in each association are classified according to the current Sarawak classification (Sarawak Soil Survey Staff, 1966), with the modifications and assumptions detailed below (section 3.2). As soils of some of the classification units are found in more than one association, all the soils encountered are listed together and summarised in Table 4.

3.2 Soil Classification

3.2.1 General

In applying the current Sarawak classification to the soils found in the Forest, certain assumptions and modifications were necessary, and these are described below (sections 3.2.2-3.2.6). Otherwise the definitions in Table 4 are those of the classification.

3.2.2 Soil depth in the Skeletal and Red Yellow Podsolic soils

In the 1966 classification the Skeletal soils are defined as those in which the rock, weathered or hard, is found with 10 inches of the soil surface. However, as can be seen in the description of Profile F3AE (see Appendix), there are Red Yellow Podsolic soils in which there are abundant subsoil stones, in all stages of weathering, set in a soil

matrix before the rock is reached. However it is difficult to distinguish between the stony horizon and the weathering rock when the soil is being examined with a 2 inch Edelmann auger, as is usually the case. The Skeletal soils are therefore redefined in terms of augering characteristics, and include all those soils with weathering rock or abundant stones in the top 10 inches.

Those Skeletal soils in which it is not possible to auger beyond 10 inches because of hard rock are classified as Meluan family. Those in which the rock is augerably soft are classified as Kapit family. This family is split into light and heavy textured variants, with the usual 15% clay content as the dividing line.

The Red Yellow Podsolic soil families are subdivided into deep and shallow phases, with those in which rock or abundant stones begin between 10 and 20 inches defined as shallow or stony. This subdivision at 20 inches has previously been applied to the heavy textured Merit family (Scott, 1967), but is here extended to the medium textured Bekenu and light textured Nyalau families.

3.2.3 Rocky stream bed soils

The low order streams, especially in the southern part of the forest, are extremely juvenile and, for most part of their courses, are cut into the country rock. Such sites are regarded as an extreme from of the skeletal morphology and come into Meluan family in Table 4. However, there are small discontinuous patches of poorly sorted gully wash alluvium. Where this material is very stony, or is less than 10 inches thick over rock, the soils are classified as Skeletal, either in the Kelupu (gleyed within top 10 inches) or Binatang (well drained for at least 10 inches) family.

Where the fine earth material is deeper than 10 inches, the soils are classified as Recent Alluvial or Gley soils, according to the drainage of the top 20 inches. They are further subdivided into families on textural criteria (see Table 4).

3.2.4 Podsolic features in the Red Yellow Podsolic soils

The main definitive characteristic of the Red Yellow Podsolic soils is the presence of a textural B horizon i.e. an significant increase in clay content with depth. Generally other podsolic features such as incipient humus and/or sesquioxide segregation are not found. However on very base-deficient parent materials and on gentle or moderate slopes, the beginnings of an eluvial albic A_2 horizon are found. Soils with such a horizon are separated out as Matang family within the group. Within the Forest, such soils are found in some dipslope sites on material derived from the Nyalau Formation siliceous sandstones.

However a thin surface layer with grey and pale yellow mottling is a fairly common feature in Sarawak forest soils (Baillie 1970 (a)). The distinction between thick surface mottling of this kind and a thin albic A_2 horizon is arbitrary. In this survey a minimum depth of 3 inches was fixed for an albic horizon. However the presence of an incipient organic illuvial B horizon also qualified a soil for Matang family, no matter how thin the A_2, e.g. Profile F3AJ (see Appendix).

3.2.5 Floodplain and terrace soils

There are considerable areas of recent and subrecent alluvium in the northern part of the Forest. Where this is coarse textured, Podsols, Gleys, and Grey White Podsolic soils predominate. However in the upper valley of Sg. Berdai, there are areas of heavy textured alluvium. The soils developed in this material are classified as Gleys if grey matrix colours are found within 20 inches of the surface. In the current classification, the better drained soils are subdivided into Red Yellow Podsolic and Recent Alluvial soils on the presence/absence of a textural B horizon. However it is quite possible that an increase in clay content with depth can be found which is not due to pedogenic textural segregation within the parent material, but which is inherited from fortuitous layering at the time of deposition. This ambiguity is noted, but no attempt was made to clarify it in this survey, as the distinction did not affect mapping unit boundaries.

3.2.6 Podsols and Grey White Podsolic soils

In the iron - and base - deficient coarse textured alluvium derived from the Nyalau Formation sandstones, the well drained soils are separated into Podsols and Grey White Podsolic soils on the presence/absence of an illuvial humic pan. However a thick impenetrable bed of rounded boulders is commonly encountered whilst augering. Soils in which no pan is found within auger depth, even if this is less than the normal 48 inches, are classed as Grey White Podsolics, even though it is quite possible a pan is present at greater depth.

Table 4

Soils of the Pelagus P.F. - Classification

Sarawak Classification[1]		Brief Description	Occurrence[2] (Association)	Representative Profiles (see Appendix)
Great Soil Group	Family			
Skeletal	Meluan	Very shallow reddish-brownish yellow stony loamy sand - sandy clay loam over hard rock or stones. Unaugerable below 10 inches. Bare rock falls in this family. Includes hill and stream bed soils.	(Kapit)	-
	Kapit (L)	Reddish-brownish yellow residual-colluvial hill light textured soil (< 15% clay) with abundant stones or soft rock in top 10 inches, but augerable to below 10 inches.	Kapit ((Matang))	-
	Kapit (H)	As above, but fine earth texture is heavy (> 15% clay).	Kapit	-
	Kelupu	Alluvial soil with abundant rock material in top 10 inches, but augerable to below 10 inches. Gley (grey)colours dominant in top 10 inches.	(Kapit)	-
	Binatang	As Kelupu but better drained with reddish and brownish yellow colours dominant in to 10 inches.	(Kapit)	-
Red Yellow Podsolic	Matang	Reddish-brownish yellow residual-colluvial hill soil with an albic (pale coloured) horizon > 3 inches, but rarely > 6 inches, deep at, or just beneath, surface. Texture becomes heavier with depth (i.e. textural B horizon). Subsoil texture from sandy clay loam - clay loam. Rock material rare within top 10 inches.	Matang	F3AJ JPA 5117-21
	Nyalau	Reddish-brownish yellow residual-colluvial hill soil with textural B horizon. Subsoil texture is heavy sandy clay loam, heavy sandy loam, or lighter. If any pale coloured horizon at the surface, then < 3 inches deep. Rock material rare in top 10 inches. Shallow phase has abundant rock material 10-20 inches, but deep phase is rock-free for 20+ inches.	Kapit Matang	F3AE (shallow) F3AG (shallow)

Table 4 contd.

Red Yellow Podsolic	Bekenu	As Nyalau except that subsoil texture is silty clay loam, clay loam, sandy clay or silty clay.	Kapit Matang	-
	Merit	As Nyalau and Bekenu except that texture is normally clay loam or heavier throughout, with clay in subsoil.	Kapit	-
	Semilajau	Reddish-brownish yellow alluvial soil with textural B horizon. Subsoil textures light (< 15% clay). No gley horizon in top 20 inches.	Malang	-
	Malang	As Semilajau but subsoil texture is heavier (> 15% clay).	Malang	-
Grey White Podsolic	Saratok	Pale yellow, light grey, white, very pale brown residual-colluvial hill soils with a textural B horizon. Subsoil textures are clay loam, silty clay loam or lighter. No gley horizon in top 20 inches. Rock material rare in top 10 inches. No humus pan within auger depth.	(Matang)	-
	Triboh	As Saratok but found on alluvial parent material. Often has unaugerable boulder bed within auger depth.	Buso	-
Podsol	Silantek	Pale-coloured residual-colluvial hill soils with litter mat up to 3 inches thick and with an augerable illuvial humus pan within auger depth. Textures in the illuvial pan horizon vary from sand to sandy loam, but may be as heavy as sandy clay loam below that.	(Matang)	5131 - 35
	Buso	Similar profile to Silantek but developed on alluvial parent material. Illuvial pan horizon often overlies boulder bed, but interstitial fine earth fraction may be as heavy as sandy clay.	Buso	F3AF (F3AH)
	Miri	Similar to Buso, but illuvial humus pan is thicker, more indurated and not penetrable by auger.	(Buso)	(F3AH)
Gley	Bijat	Poorly drained alluvial soil with wet gley horizon (grey colours dominant or codominant) in top 20 inches. May show alluvial stratification, but dominant texture in top 20 inches is heavy (> 15% clay). May have abundant rock material at depth, but not in top 10 inches.	((Kapit)) ((Matang)) (Malang) ((Buso))	-

Table 4 contd.

Gley	Tatau	As Bijat, but top 20 inches is dominantly light textured (< 15% clay).	((Kapit)) (Matang) ((Malang)) ((Buso))	-
Recent Alluvial	Seduau	Reddish and brownish yellow alluvial soils, with no gley horizon in top 20 inches. May have abundant rock material at depth but not in top 10 inches. May show alluvial stratification, but no textural B horizon formed. Top 20 inches dominantly heavy textured (> 15% clay).	Malang (Buso)	-
	Kayan	Similar to Seduau, but top 20 inches is dominantly light textured (< 15% clay).	(Malang) (Buso)	-

Notes:

(1) Classification according to current Sarawak classification (Sarawak Soil Survey Staff, 1966) except as noted in sections 3.2.2 - 3.2.7 of text.

(2) Column 4 - Occurrence - indicates in which of the mapping units (associations) in Map 3 the soils of the family are found. No parentheses indicate that the soils of the family are extensive within the association, single parentheses that the family is of minor importance and double parentheses that soils of the family are rare. These estimates of relative extent are very approximate.

3.3 Soil Distribution

3.3.1 General

The distribution of the various soils listed in Table 4 in each of the photogrammetrically distinct soil associations is described in sections 3.3.2-5 below and summarised in Table 5.

3.3.2 Kapit Association

This covers the whole of the southern section of the Forest and is associated with the rocks of the Belaga Formation. Similar topography, forest and soils are found over large areas of the Rajang hinterland.

The commonest soils on the steep ridge slopes are those of Kapit family and the shallow phases of Nyalau, Bekenu and Merit families. These are developed on parent material that is not wholly residual. Stone lines between the solum and the underlying soft in situ rock are common, but it is not known if all the soils are colluvial.

The soils on the ridge crests are often deeper, with the deep phase of Nyalau family common on the crests of the major sandstone ridges. On the minor ridge crests the soil depth is more variable, but where deeper soils are found, they are of Bekenu and Merit families as well as Nyalau. The area of these deeper ridge crest soils is small because the ridges are usually very narrow.

The very shallow soils of Meluan family are found in all parts of the landscape. They are common in the beds of the minor streams, which are incised into the country rock. They also occur on the ridge slopes, especially on the sites of minor landslips. Although there are probably many separate occurrences of this type of soil, their total area is thought to be small.

There are small discontinuous patches of gully wash and alluvial deposits along the streams. They are normally shallow or very stony and the soils formed fall into the Kelupu and Binatang families. There are patches of deeper alluvium where soils of Bijat, Tatau, Seduau and Kayan families are found, but even these are rarely augerable to 48 inches.

3.3.3 Matang Association

This association is found on the non-alluvial terrain of the Nyalau Formation outcrop in the northern section of the Forest. From observations in the Ulu Anap, it is known that the association is quite extensive beyond the Forest. The natural vegetation is the 'kerapa bukit' type of forest described above (see section 1.6).

The topography is much lower and less rugged than in the Kapit association and, on some of the dipslope, the gradients are gentle (10° and less). The low proportion of shales and the absence of greywacke type sandstones in the Nyalau Formation means that the soil parent materials have a lower initial content of bases than those derived from the Belaga Formation.

The combination of imperfect subsoil drainage and highly siliceous, base-deficient coarse textured parent material are conditions which favour the mobilisation of humus and sesquioxides (if any) in the surface horizons and their redeposition as a pan in the subsoil i.e. podsol formation (Andriesse, 1969). In this area, the iron content of the parent material is insufficient for the formation of iron podsols but there are some weakly developed humus podsols. In some of the flatter dipslope sites, soils with a true podsol morphology are found although the humus pan is very rudimentary. These soils fall into the Silantek family (e.g. JPA 5141-5 in Appendix) if the humus pan occurs within auger depth. Those with no humus pan within auger depth are classified as Saratok family in the Grey White Podsolic G.S.G., even though a pan is suspected to be present at depth. The soils of these two families carry the most extreme form of 'kerapa bukit' forest i.e. that with the smallest and closest stems and with thickest undergrowth.

Generally however this stage of pedogenesis has not yet been reached and the evidence of podsol formation is restricted to an albic surface horizon and organic staining in the subsoil (e.g. F3AJ and JPA 5117-21 in Appendix). Such soils fall in the Matang family of the Red Yellow Podsolic G.S.G. and carry a forest which is transitional between 'kerapa bukit' and the Mixed Dipterocarp Forest.

In areas where the topography is more broken and the slopes are steeper (up to 30°) or where there is a sufficient shale component in the parent material, no podsol characteristics are found and the soils fall into Nyalau and Bekenu families of the Red Yellow Podsolic group. These are generally deeper than the soils of the same families in the Kapit association, although Profile F3AG from this area falls in the shallow phase of Nyalau family. The shale beds are too thin and their effect too dilute for the formation of Merit family soils. The forest on these soils is much more akin to the M.D.F. than that found on the podsolised Matang and Silantek family soils of the dipslopes.

The valley bottoms are wider than in the Kapit association and the alluvial deposits in them are more extensive and continuous. They are also deeper and few soils of the Melaun, Kelupu or Binatang families are found. The alluvium is predominantely coarse textured and most of the soils fall in the Kayan or Tatau families according to the drainage of the top 20 inches.

3.3.4 Malang Association

This association is found on the better drained and heavier textured alluvium. The largest areas are in the northern section of the Forest, but there are also small patches along Sg. Pelagus and Sg. Angkawat in the southern section. The undisturbed vegetation of this association is empran forest.

Most of the soils are not gleyed in the top 20 inches, but in many of them there is a gleyed horizon between 20 and 48 inches. They fall in Red Yellow Podsolic and Recent Alluvial great soil groups. As noted above (3.2.5), distinction between these can be difficult. Within the groups, the soils are further subdivided into families on grounds of subsoil texture. The heavy textured Malang and Seduau families are the most widespread and only small areas of the lighter textured Semilajau and Kayan families are found.

In depressions in the alluvium poorly drained soils with a gleyed horizon in the top 20 inches are found. As with the better drained soils, subsoil textures are predominantly heavy and most of the soils fall into the Bijat family.

3.3.5 Buso Association

This association is found on the poorly drained coarse textured alluvium of the floodplain and low terrace in the northern section of the Forest. It is very distinct on the aerial photographs as it is covered by the very dense, small crowned 'kerapa paya' forest.

The alluvial parent material is mostly derived from the Nyalau Formation. At depths of 24-36 inches there is frequently a unaugerable bed of boulders, which are mostly sandstone but there are also fragments of sideritic ironstone. This ironstone is not of recent formation and is derived from the shale beds in Nyalau Formation (Kirk, 1957). As is to be expected from an area of coarse textured siliceous parent material and intermittently high ground water table, the most extensive soils are Podsols and related Grey White Podsolics.

Pale coloured soils with an augerable humus pan within auger depth fall into Buso family. These are the most extensive Podsols, and the area of Miri family soils, in which the pan is sufficiently developed and indurated to be unaugerable, is small. Those soils in which the humus pan is not encountered within auger depth are classified as Grey White Podsolic soils of Triboh family.

There are very thin strips of soils of Kayan and Seduau families along some of the streams. In a few patches of heavier textured alluvium, the wet gleyed soils of Bijat family are found.

4. Suitability as afforestation trials site

4.1 Considerations

The topography, natural vegetation and soils of the Kapit association area in the Forest are very similar to those found over large areas in the upper Rajang. This is in contrast to the Matang, Malang and Buso associations. The Matang association is thought to be restricted to outliers of the Nyalau Formation such as Gunong Spali and the foothills of the Hose Mountains. The Malang and Buso associations are restricted to alluvial parent materials, which are not extensive in the interior of the State.

On grounds of applicability of results, the northern part of the Forest can therefore be excluded as a possible site. Within the area covered by the Kapit association in the southern part there are no pedologically preferable sites, so ease of access and administrative convenience can be the main criteria.

Because of the proposed National Park, the southern end of the Forest cannot be considered, and the choice is restricted to the central section. Access to this section is easier from the west, as Sg. Pelagus is larger and more navigable than Sg. Merit, and the passage through the Pelagus rapids is avoided. As none of the T.L.B. (east) tributaries of the Pelagus are navigable, final access to the Forest has be on foot, and the path along Sg. Angkawat is preferred.

4.2 Conclusions:

The above considerations suggest that the best site is on the western boundary close to Sg. Angkawat and just north of the proposed National Park. An area of about 400 acres is delineated in this locality on Map 3.

However the necessity of walking and the distance from Sibu may weigh against the siting of any trials in the Forest. There are possible areas in the Balleh which are even further from Sibu, but which can reached entirely by boat. The other alternative is to acquire suitable land nearer to Sibu, but this is expensive and troublesome, and is only be justified if the extension of the afforestation trials into this type of country is to be given high priority.

Appendix

Profile Descriptions and Analyses

The five profiles from this survey and the two from the J.P. Andriesse's 1961 survey were described and sampled along the lines laid down in the Soil Survey Manual (Soil Survey Staff, 1951). The Munsell system is used for soil colours, which were determined in the field moisture condition at the time of sampling.

The chemical analyses were carried out at the laboratory of the Semongok Research Centre of the Department of Agriculture, according to the methods described in Sim (1965). The mineralogical analyses for profile JPA 5117-21 were carried out at the Royal Tropical Institute, Amsterdam.

Profile J.P.A.: 5131-35

Mapping unit: Matang association

Sarawak classification: G.S.G. Podsol Family Silantek

Location: N. bank of Rajang, near Bt. Arang (see Map 3).

Topography: Crest of low flat-topped rise in very gently undulating terrain.

Parent material: Nyalau Formation sandstone.

Vegetation: Kerapa bukit.

1-0	Litter.
0-2	Brown sand with highly decomposed organic matter, friable - loose, moist, charcoal present.
2-16	Yellow and distinct light grey, reddish yellow mottles, fine sand, crumb, moist, friable.
16-36	Light yellowish brown and faint grey mottles and organic (brown and dark brown) staining, sand.
36-66+	Light grey and faint yellow, dark brown mottles, faint rusty root channels, fine sand, moist, loose.

Profile JPA: 5117-21

Mapping unit: Matang association

Sarawak classification: G.S.G. Red Yellow Podsolic — Family Matang

Location: T.L.B. (South) of Btg. Rajang, apposite Nanga Merit bazaar, about ½ mile from river (see Map 3).

Topography: Gently undulating.

Parent material: Nyalau Formation sandstone, with some shale.

Vegetation: Primary forest with dominant keladang, resak.

1-0 Root mat.

0-1 10YR 5/3 (brown) with intensive grey mottling, with grey colours codominant for part of horizon; sandy loam, crumbly, well rooted.

1-14 10YR 7/6 (yellow) with intensive grey mottles, and weak brown mottles 9-14, sandy loam, friable, sticky.

Gradually merging to

23-43 7.5YR 6/8 (reddish yellow) with intensive 2.5Y 7/6 (yellow) mottles, silty clay, moist, sticky, plastic, compact. Light grey and brownish mottles, sandy clay loam in one corner of pit from 23-43.

Sample No.	Fine sand fraction: Light minerals										Differential Thermal Analyses
	Opaques	Altermites	Tourmaline	Zircon	Rutile	Anatase	Andalusite	Sillmanite	Actinolite	Corundum	
5117	72	5	16	44	8	6	9	10	1	5	Mostly kaolinite, with some limonite. Goethite. Organic matter.
5118	64	5	15	51	9	3	4	13	2	3	Mostly kaolinite, with some limonite. Goethite.
5119	15	31	23	57	9	7	-	1	1	-	Mostly kaolinite, with some limonite. Goethite. Organic matter.
5120	62	6	12	52	13	9	2	5	5	1	Mostly kaolinite, with some limonite. Goethite.
5121	43	10	14	36	8	16	3	15	5	1	- ditto -

Profile F3AE

Mapping unit: Kapit association.

Sarawak classification: G.S.G. Red Yellow Podsolic — Family Nyalau (Shallow)

Location: North bank of Sg. Angkawat (see Map 3).

Topography: Crest of minor ridge (zero gradient).

Parent material: Belaga Formation sandstone.

Vegetation: Very old secondary forest with high proportion of geronggang (Cratoxylon arborescens).

1-0 Litter.

0-1 10YR 5/3 (brown) with few fine faint 10YR 7/6 (yellow) mottles, sandy loam, very weak fine subangular blocky, moist, friable, abundant roots.

Clear regular boundary

1-9 10YR 7/8 (yellow) with few fine faint 7.5YR 7/8 (reddish yellow) mottles, sandy loam, weak medium subangular blocky, moist, slightly firm, roots frequent.

Gradual wavy boundary

9-26 7.5YR 7/8 (reddish yellow), sandy loam - sandy clay loam, moderate medium subangular blocky with strong discontinuous 10YR 7/8 (yellow) clay skins, moist, slightly firm, roots rare, common angular - subangular fragments of soft light grey and pale red medium sandstone.

Clear wavy boundary

26-46+ 7.5YR 6/8 (reddish yellow), sandy clay loam - sandy loam, in small pockets between abundant angular - subangular large fragments of fairly hard red, light grey, strong brown medium sandstone. Weak discontinuous reddish yellow clay skins on stone faces. No roots.

Depth (inches)	pH H_2O	% Org. C	% Total N	Conc. HCl Extract P ppm	Ca ppm	Mg ppm	K ppm	Group III %	% of fine earth Coarse sand	Medium sand	Fine sand	Silt	Clay	Texture
0 - 1	3.6	2.1	0.20	120	90	290	1110	3.7	1.7	11.3	51.9	11.0	21.2	Sandy clay loam
3 - 7	4.0	0.4	0.16	50	90	490	1990	6.3	1.1	9.0	54.4	13.1	23.3	-ditto-
15-18	4.5	0.1	0.03	40	90	540	2880	7.4	1.7	9.2	54.9	13.3	21.4	-ditto-
40-44	5.2	Tr	0.02	30	100	350	2890	6.4	4.4	16.6	55.5	14.0	8.6	Weathering rock

	Exchangeable me/100gms. Ca	Mg	K	Na	CEC
Sample 1	0.1	0.2	0.2	Tr	12.6
2	Tr	Tr	0.1	Tr	8.1
3	0.3	Tr	Tr	Tr	5.5
4	0.1	Tr	Tr	Tr	3.2

Profile F3AF

Mapping unit: Buso association

Sarawak classification: G.S.G. Podsol — Family Buso

Location: Between Sg. Berdai and Sg. Sangong (see Map 3).
Topography: Low subrecent terrace (gradient 0-1°).
Parent material: Coarse textured alluvium derived from Nyalau Formation sandstones.
Vegetation: Kerapa paya forest.

1-0 2.5YR 3/2 (dusky red) litter.

0-2 2.5YR 4/2(weak red), sandy clay loam - sandy clay, very weak fine subangular blocky, moist, friable, abundant roots.

Clear slightly wavy boundary

2-9 Mixed 10YR 6/2 (light brownish grey) and 10YR 7/2 (light grey), sandy loam, very weak moderate subangular blocky, moist, soft, many roots, occasional fine angular quartz grit.

Clear wavy boundary

9-14 10YR 4/3 (brown - dark brown) with few medium very faint 10YR 7/4 (very pale brown) mottles, loamy sand - sandy loam, very weak medium subangular blocky breaking to structureless - single grain, moist, soft, roots rare, scattered fine angular quartz grit, scattered fragments of damar.

Clear wavy boundary

14-21 7.5YR 4/4 (dark brown) and common medium distinct 5Y 4/2 (dark reddish grey), 5YR 3/1 (very dark grey) mottles, sandy loam, weak coarse subangular blocky, moist, hard - indurated, no live roots but common dead tree roots, frequent fine angular quartz grit.

Clear wavy boundary

21-34 7.5YR 4/2 (dark brown), loamy sand - sandy loam, very weak medium subangular blocky breaking to structureless - single grain, moist - slightly wet friable, no roots, abundant fine bleached angular quartz grit and many fine rounded quartz pebbles and common medium sized fragments of coal.

Clear wavy boundary

34-41 10YR 4/3 (brown - dark brown), loamy sand, structureless - single grain, wet. loose, no roots, many medium rounded quartz stones, much sandstone - derived grit, few fragments of charcoal (? lignite) and wood.

Clear regular boundary

41+ Impenetrable sandstone and quartz boulder bed.

ple o.	Depth (inches)	pH H_2O	% Org. C	% Total N	Conc. HCl Extract P ppm	Ca ppm	Mg ppm	K ppm	Group III%	% of fine earth Coarse sand	Medium sand	Fine sand	Silt	Clay	Texture
	0 - 2	3.5	5.7	0.32	160	70	Tr	330	0.2	2.3	6.1	43.0	27.1	12.9	Sandy loam
	4 - 8	4.2	1.5	0.05	60	40	Tr	60	0.8	1.3	10.8	57.4	23.6	5.3	" "
	10-13	4.1	3.7	0.08	120	60	50	320	1.1	15.0	1.8	43.1	21.5	13.6	" "
	16-19	4.1	1.6	0.04	30	50	280	1550	2.4	2.5	30.7	66.7	8.3	11.8	Loamy sand
	26-30	4.5	1.1	0.02	30	60	480	1100	1.7	19.4	46.3	64.8	2.0	4.8	Sand
	36-40	4.7	0.8	0.03	40	60	480	1010	1.6	13.4	36.0	64.7	6.5	6.4	Sand

	Exchangeable me/100gms. Ca	Mg	K	Na	CEC
Sample 1	1.0	0.7	0.3	Tr	16.0
2	0.2	Tr	Tr	Tr	3.6
3	0.1	Tr	Tr	Tr	7.0
4	0.1	Tr	Tr	Tr	9.2
5	0.1	Tr	Tr	Tr	7.2
6	0.1	Tr	Tr	Tr	3.6

Profile F3AG

Mapping unit: Matang association

Sarawak classification: G.S.G. Red Yellow Podsolic — Family Nyalau (shallow phase)

Location: Between Sg. Latong and Sg. Sangong (see Map 3).
Topography: Midslope in gently undulating terrain.
Parent material: Nyalau Formation sandstone and conglomerate.
Vegetation: Kerapa bukit forest with high proportion of kapur bukit.

½-0 Dark brown litter.

0-1 10YR 5/4 (yellowish brown), sandy loam, very weak fine subangular blocky, moist, friable, many roots.

Clear regular boundary

1-4 10YR 7/8 (yellow) with many medium distinct 5Y 8/3 (pale yellow) mottles, sandy loam, moderate medium - fine subangular blocky, moist, firm, many roots, much fine angular quartz grit.

Clear wavy boundary

4-14 As above but mottles become few and faint, and roots decrease to rare.

Gradual regular boundary

14-25 10YR 7/8 (yellow) with few fine faint 5Y 8/4 (pale yellow) mottles, sandy loam - sandy clay loam, moderate medium - coarse subangular blocky, few discontinuous clayskins along old root channels, moist, firm, roots very rare, many medium round - subrounded quartz stones.

Gradual regular boundary

25-40 2.5Y 7/6 (yellow) with many medium distinct 5Y 7/4 (pale yellow) and 7.5YR 6/8 (reddish yellow) mottles, sandy clay loam, moderate coarse - medium subangular blocky, moderate discontinuous clayskins on stone faces and in root channels, moist, firm, roots very rare, many hard subangular coarse fragments of yellow, red medium sandstone and few medium subrounded quartz pebbles.

Diffuse boundary

40-57+ 10YR 7/8 (yellow) with many coarse distinct 5Y 7/4 (pale yellow) and 2.5Y N7/. (light grey) mottles, sandy clay loam, weak medium subangular blocky, with moderate discontinuous 10YR 6/3 (pale brown) clayskins, moist, firm, slightly plastic, slightly sticky, no roots but few old root channels, many stones - as above.

Sample No.	Depth (inches)	pH H_2O	% Org. C	% Total N	Conc. HCl Extract					% of fine earth					Texture
					P ppm	Ca ppm	Mg ppm	K ppm	Group III%	Coarse sand	Medium sand	Fine sand	Silt	Clay	
1	0 - 1	4.1	0.8	0.06	60	80	110	460	2.2	5.5	12.0	52.5	17.8	10.4	Sandy loam
2	1 - 4	4.5	0.3	0.03	40	90	180	570	3.0	7.4	10.3	51.4	28.4	7.1	" "
3	7 -10	4.9	0.2	0.02	40	160	510	1390	7.0	6.9	8.8	45.9	19.6	18.3	" "
4	18-21	4.9	0.1	0.02	40	170	1290	2910	8.9	4.9	7.0	42.0	21.3	21.9	Sandy clay loam
5	32-35	5.1	0.1	0.02	40	150	580	2940	7.6	5.5	11.8	43.6	16.9	22.8	-ditto-

	Exchangeable me/100gms.				
	Ca	Mg	K	Na	CEC
Sample 1	0.1	0.1	Tr	Tr	3.8
2	0.1	Tr	Tr	Tr	1.7
3	Tr	Tr	Tr	Tr	1.6
4	Tr	Tr	Tr	Tr	3.3
5	Tr	Tr	Tr	Tr	2.5

Profile F3AH

Mapping unit: Buso association

Sarawak classification: G.S.G. Podsol — Family Miri

Location: T.L.B. of lower Sg. Termulan Betis (see Map 3).
Topography: Low subrecent terrace (gradient 0-1°).
Parent material: Coarse textured alluvium derived from Nyalau Formation.
Vegetation: Very dense Kerapa paya forest.

1½-0 2.5YR 3/2 (dusky red) litter.

0-2 7.5YR 4/2 (dark brown), loamy sand - sand, structureless - single grain, wet, soft, abundant roots.

Clear wavy boundary

2-9 Mixed 7.5YR 8/1 (white) and 10YR 7/1 (light grey) with many medium faint 10YR 7/3 (very pale brown) mottles, sand, structureless - single grain, moist - wet, soft - friable, occasional roots.

Clear slightly wavy boundary

9-19 5YR 3/2 (dark reddish brown) and many coarse distinct 7.5YR 4/4 (dark brown) mottles, sand, moderate medium - coarse subangular blocky, moist - dry, indurated - very hard, no roots.

Clear wavy boundary

19-37+ 10YR 5/4 (yellowish brown), sand, moderate medium - coarse subangular blocky, moist - dry, indurated - hard, no roots.

Depth (inches)	pH H_2O	% Org. C	% Total N	Conc. HCl Extract P ppm	Ca ppm	Mg ppm	K ppm	Group III%	% of fine earth Coarse sand	Medium sand	Fine sand	Silt	Clay	Texture
0 - 2	5.1	1.9	0.11	70	170	30	70	0.2	0.4	12.8	72.4	8.9	4.9	Sand
4 - 7	5.9	0.1	0.01	10	30	Tr	Tr	0.1	2.0	17.5	71.2	8.8	0.7	Sand
13-16	3.9	3.1	0.05	20	50	100	330	1.7	1.6	14.5	59.2	10.1	15.5	Sandy loam
33-37	4.2	1.6	0.03	30	30	260	1090	3.2	1.3	13.1	60.8	9.0	16.7	Sandy loam

	Exchangeable me/100gms. Ca	Mg	K	Na	CEC
Sample 1	2.2	1.1	0.1	Tr	5.3
2	1.1	Tr	0.1	Tr	0.3
3	1.5	Tr	Tr	0.1	11.5
4	Tr	Tr	Tr	0.2	13.0

Profile F3AJ

Mapping unit: Matang association.

Sarawak classification: G.S.G. Red Yellow Podsolic — Family Matang

Location: Between Sg. Temulan Bedgom and Sg. Termulan Betis (see Map 3).
Topography: Midslope on south facing dipslope (gradient ca 4°).
Parent material: Nyalau Formation sandstone.
Vegetation: Kerapa bukit (possibly very old secondary).

2-0 2.5YR 3/4 (dark reddish brown) litter.

0-½ Mixed 10YR and 7.5YR 4/2 (both brown - dark brown), silty clay loam, moderate - weak fine crumb, moist, friable, abundant roots.

Clear regular boundary

½-3 Mixed 10YR 6/3 (light reddish brown), 2.5Y 7/2 (light grey) and 2.5Y 8/4 (pale yellow), sandy loam - sandy clay loam, weak fine subangular blocky, moist, friable, many roots.

Abrupt wavy boundary

3-7 Mixed 2.5Y 8/6 (yellow), 10YR 7/4 (very pale brown) and 10YR 5/4 (yellowish brown) with common fine - medium distinct 7.5YR 4/2 (dark brown) and 5YR 3/3 (dark reddish brown) mottles, sandy clay loam, moderate medium subangular blocky, moist, slightly firm, common roots.

Gradual wavy boundary

7-15 Mixed 2.5Y 8/4 and 5Y 7/4 (both pale yellow) with common medium distinct 7.5YR 4/4 (dark brown) mottles, 10YR 6/4 (light yellowish brown) stains on ped faces and down root channels, sandy clay loam, moderate medium subangular blocky, moist, friable - slightly firm, common roots.

Gradual wavy boundary

15-31 2.5Y 8/6 (yellow) with many fine - medium very faint 2.5Y 8/4 (pale yellow) and 10YR 7/8 (yellow) mottles, sandy clay loam - sandy clay, moderate coarse subangular blocky with moderate discontinuous 2.5Y 7/4 (pale yellow) clayskins, moist, firm, roots rare.

Diffuse boundary

31-40+ Mixed 2.5Y N8/. (white), 10YR 7/4 (very pale brown), 5YR 6/8 (reddish yellow) and 2.5Y 8/4 (pale yellow), clay, weak-moderate coarse subangular blocky with strong continuous 10YR 7/4 (very pale brown) clay skins, moist, firm, slightly plastic but not sticky, roots very rare, many medium subangular-rounded white quartz stones.

Sample No.	Depth (inches)	pH H_2O	% Org. C	% Total N	Conc. HCl Extract P ppm	Ca ppm	Mg ppm	K ppm	Group III %	% of fine earth: Coarse sand	Medium sand	Fine sand	Silt	Clay	Texture
1	1 - 3	4.1	1.1	0.08	70	40	180	920	2.7	0.9	3.9	50.5	26.1	13.2	Sandy loam
2	3 - 6	4.0	0.6	0.06	70	60	340	1560	4.0	0.9	2.6	50.7	29.6	14.4	Sandy loam
3	9 -12	4.3	0.6	0.05	60	70	370	1930	4.5	0.8	2.5	52.4	25.2	18.7	Sandy loam
4	21-25	4.8	0.2	0.03	50	60	480	2530	6.0	1.1	7.4	47.9	22.5	25.1	Sandy clay loam
5	35-39	4.7	0.1	0.03	61	60	710	3970	7.5	1.0	5.2	42.9	22.2	33.3	Sandy clay loam

	Exchangeable me/100gms. Ca	Mg	K	Na	CEC
Sample 1	1.0	Tr	0.1	Tr	6.6
2	0.9	Tr	Tr	Tr	8.0
3	1.2	Tr	Tr	Tr	6.0
4	2.9	Tr	Tr	Tr	4.5
5	1.0	Tr	Tr	Tr	9.8