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Report on a Semi - Detailed Soil Survey
of the

LAMBIR DEVELOPMENT SCHEME

4 th Division

by

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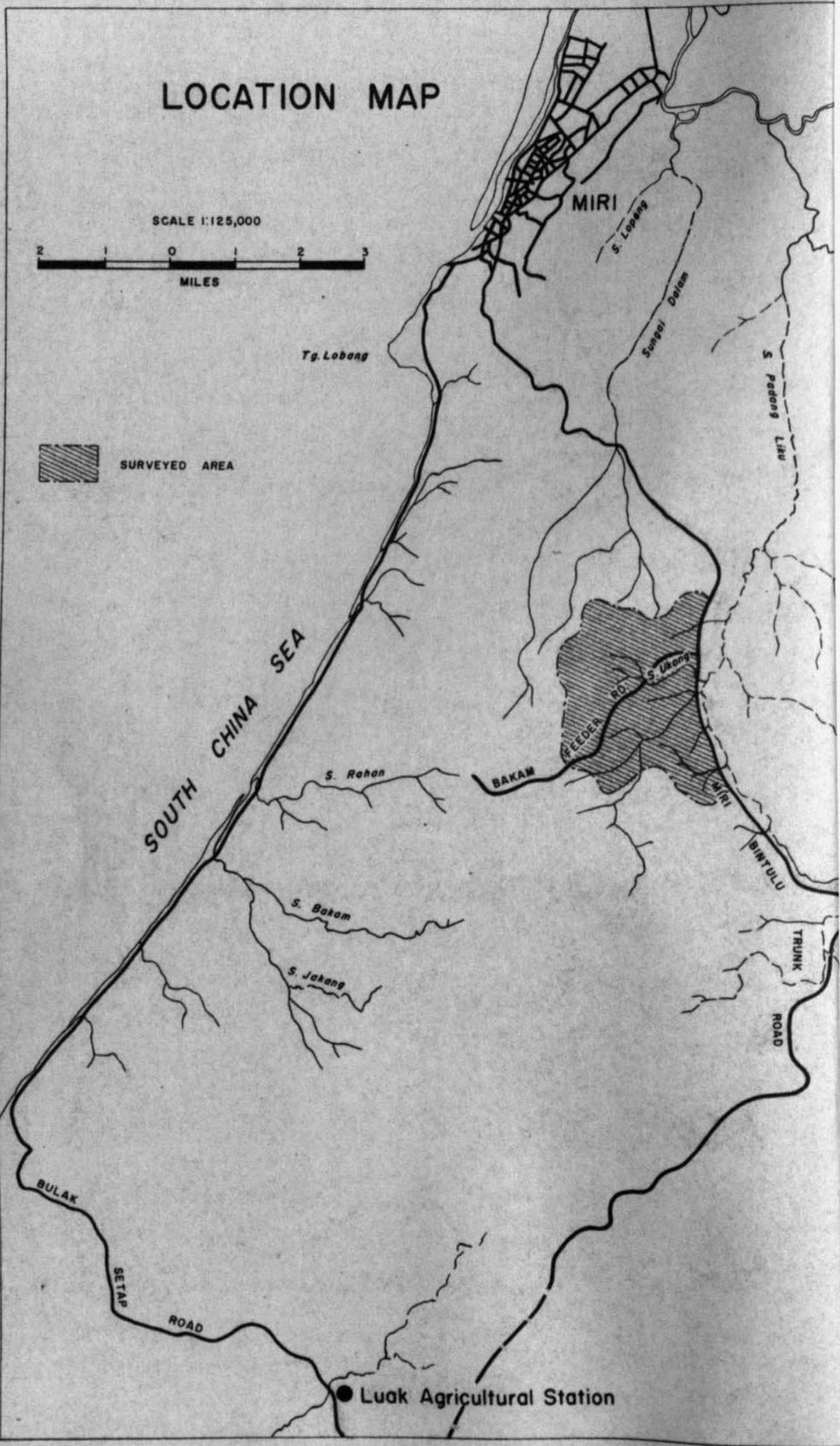
MAP I

LOCATION MAP

SCALE 1:125,000



SURVEYED AREA



REPORT ON A SEMI-DETAILED SOIL SURVEY
OF THE LAMBIR DEVELOPMENT
SCHEME

by
J.R.D. Wall.

1 INTRODUCTION

The Lambir Development Scheme area is situated at about mile $9\frac{1}{2}$ to $12\frac{1}{2}$ from Miri on the new Miri-Bintulu trunk road. The survey has resulted from several requests. Initially, the Soil Survey Section was asked by the Rubber Branch of the Department of Agriculture to examine the northern portion of the area, totalling some 1,050 acres (Area B, map 2), with the aim of determining the extent of land suitable for rubber planting. Before completion it was clear that there may be insufficient usable land and the survey was therefore extended to the south-west, covering a further 1,170 acres (Area C).

Cursory auger examinations in the part reserved for the village (map 2) revealed pockets of deep peat overlying part of the alluvial land. This prompted a request from the Planning Section of the Land and Survey Department to examine the alluvial land nearby as an alternative village site, to ensure that all peat land was excluded. This was completed, and a further rapid examination of the remaining village land (290 acres) was also made to enable soil boundaries to be drawn in that area.

Land already planted with rubber in the southeast (Area A, 630 acres) was known to be damaged by landslides prior to planting. In an attempt to determine the extent of damage the landslides were plotted, and soil boundaries drawn with the aim of locating those areas most likely to succumb to landslides in the future.

Thus, 3,140 acres were examined altogether during the period 23rd June to 5th July, by three Agricultural Assistants, Johdi bin Juko, Dahli bin Matjar and Charles Ambun, led by the Surveyor. The methods of surveying used entailed a systematic coverage of auger hole descriptions. In Areas A and B, it was found easy to walk over the area selecting auger points from a visual appraisal of the land combined with an examination of the 1:10,000 contoured map. Area C is under primary forest and, although movement is fairly easy, it was often difficult to find true locations on the map, which in addition is less accurately contoured in this area. The augerings were consequently more widely spaced in Area C, in particular on the alluvial land.

Map 2 shows the locations of all auger examination sites and Areas A, B, C and the Village Area. Landslides are located by hachuring on the soil map (Map 3). In Area A the extent and site of landslides is fairly accurate. In Area B most landslides are located fairly accurately but the extent is perhaps under-estimated. In Area C most landslides are located rather schematically, and there are probably many small ones left unmapped.

GENERAL CHARACTER OF AREA

The Lambir Development Scheme spreads over the boundaries of three reconnaissance soil surveys, the Miri-Berop Feeder Road (Wall, 1961, a), the Coastal Reconnaissance Survey (Wall, 1961, b), and the Bekenu-Niah-Suai Area, (Wall, 1962). The following descriptions are largely abstracted from these reports.

1. GEOLOGY

The geology of this area is described by Wilford (Wilford, 1961) as consisting of Tunku Formation soft sandstone, sand, clay and lignite. The sediments forming the rocks are well-sorted materials originally derived from source rocks in southwest Borneo and finally laid down, after at least two cycles of deposition and erosion, in the middle to late Tertiary. From road cuttings in the area the beds can be seen to vary in thickness from less than two feet to about fifteen feet, dipping to the north to northeast at between 10° and 20° .

2. TOPOGRAPHY

The topography consists of low to moderately high ridges rising to a maximum height of about 200 feet above local base level. The ridges vary from being slightly rounded at the summit to being sharp-edged. Those aligned close to a north-south direction tend to have equally steep flanks of between 18° to 30° , except at their northern ends where the slopes decrease to a uniform $8-18^{\circ}$. Ridges aligned close to an east west direction generally have steep southern and gentle northern slopes aligned close to the geological dip and can therefore be considered as cuestas. It is thought that the whole area once consisted of series of east-west aligned cuestas forming the foot hills of the Lambir Hills, but that subsequent dissection by the headwaters of the Padang Liku, Ukong and other streams eroding steadily southwards has resulted in a strongly ridged landscape.

Valleys penetrating the hills are all formed by tributaries of the Padang Liku River which flows to the north roughly parallel to the trunk road which is the eastern boundary of the mapped land. In the northwest the streams flow roughly northwest-southeast while in the rest of the area their general alignment is from the southwest to the northeast. The valleys are long, roughly linear and less than about four hundred feet wide, except that of the Ukong Stream which in places reaches a width of nine hundred feet. Close to permanent streams levees rise by two to four feet above the general floodplain level, and where peat occurs in the Village Area there is a weak doming effect (from Land and Survey levelling data) with the central parts of the swamp being one to two feet higher than the margins. Formerly it was thought that such doming effects were confined only to extensive swamps. Remaining parts of floodplains are almost level in valley cross section, with longitudinal gradients of between 1:140 and 1:400 in the main valleys to 1:30 and 1:100 in the smaller valleys (calculated from contour data on the base map).

Landslides have affected the whole area. They range in size from small, shallow slips of a few feet in width and length to major deep slumps of from one to two hundred feet width and two to three hundred feet length; one particularly bad slump in Area A has cut a narrow 30-40 foot deep gash into a hillside. The landslides affect land use almost as much by the choking effect of the deposited, largely sandy material as by the removal of soil. The areas of maximum deposition are included in the parts marked as landslides (in Area A mainly).

The cause of earth movements of this nature is not fully understood but there is a clear link between their occurrence and periods of unusually prolonged heavy rainfall, and steep slopes exceeding about 15° combined with permeable sandy soils. It is thought that the greater portion of the recognised landslides occurred during the notorious 'landas' season of 1962/63; few large slides have taken place since.

The affected soils mostly belong to the Nyalau and Bekenu families. They are characterized by light to heavy loamy textures, weak structures, good internal drainage and high permeability in at least the top two feet of soil, and commonly the whole depth of the soil profile.

Incoming rainfall easily penetrates sandy upper subsoils and prolonged rainfall is thought to saturate such soils, which have low water-holding capacity. Where permeable horizons overlie less permeable material, such as in Nyalau and Bekenu family soils, vertical water movement becomes impeded at the zone of textural change and soil drainage on steep slopes particularly is thought to become dominantly lateral. The presence of large amounts of water in the soil probably affects adhesion and coherence between soil particles adversely and provides lubrication for soil movement.

The combination of steep slopes with poorly structured and saturated, heavy soil overlying fairly abruptly more coherent and stable soil, stonelines or rock, favours landslide development. The process can be seen clearly in road cuttings where thin iron sheets resting on partly weathered, dense clay-shale have been exposed by erosion. Rainwater passing through highly permeable sandy soil reaches the iron sheet and flows laterally over it. Where the iron sheet slopes gently erosion of the soil above it takes the form of deep, narrow gulleys and tunnels: where the iron sheet slopes at more than approximately 15° the whole soil profile above it has commonly slipped and slumped.

3. VEGETATION AND LAND USE

Prior to selection as a development scheme most of the area was primary forest. Area A has been felled, cleared and planted with high-yielding clonal rubber. The crop is less than a year old and appears to be growing well, with the exception of a few pockets. Cover crops are well established and are competing strongly with secondary regrowth between terraces. Area B was being felled at the time of survey; parts contained old secondary forest about 15-20 years old. Area C is under primary forest apart from the belt used by the Bakam feeder road. The forest type is predominantly Lowland Dipterocarp Forest with small pockets of Swamp Forest. Timber is being or has been extracted from parts, but the density of good timber is said to be generally low.

SOILS OF THE AREA

The mapping units of the soil map (Map 3) are soil families or associations of soil families. Each unit mapped should, by definition, contain at least 85% of the soil family or families naming that unit unless otherwise stated in the text. A soil family consists of a group of soil series (the basic soil unit recognised) with similar properties such as colour, texture, structure, drainage and fertility.

The various soil families are described briefly below, and in abbreviated form on the key to the soil map.

1. MATANG FAMILY

Matang Family soils belong to the Red-Yellow Podsollic Great Soil Group. They are derived from thick sandstone and are associated with a few ridge sites of small extent. Their main characteristics are given below.

The colours of the moist soil have stronger contrasts between the horizons than the families described below. The humic topsoil is coloured dark grayish brown; the underlying A2 horizon is pale yellow to light grey and this overlies brownish yellow, commonly grading to reddish yellow, colours with increasing depth. Subsoil light grey mottles are mainly of rotting sandstone.

Beneath the thick layer of surface organic matter the textures are dominated by sand. The A1 and A2 horizons are generally sand to loamy sand, beneath which the clay content increases steadily with increasing depth, as in the Nyalau Family, to give sandy clay loam or sandy clay in the deep subsoil. Inclusions found in some Matang profiles consist of hard, iron-enriched sandstone situated in the B horizon. Weathering soft white sandstone has been noted in the C horizon in places.

No pit profiles have been examined of Matang soils in this area but it can be taken that the structure of the B and C horizons resemble those of the Nyalau Family described below, while the A horizons are almost structureless (single grain). The moist consistence ranges from loose in the upper horizons to friable or firm below. Rooting is confined to the organic-rich topsoil.

Internal drainage is good, external drainage is medium to slow. Soil analyses are not available, but it is probable that fertility levels in all respects are at least as low as those of the Nyalau Family. These soils are considered to be suitable to marginal for rubber due to their suspected low fertility within rooting depth.

The Matang Family mapping unit is admixed with small areas of Nyalau and other soils.

2. NYALAU FAMILY

The Nyalau Family is a member of the Red-Yellow Podsollic group of soils. They are widespread in the area, developed mainly from sandstone and associated with all topographic sites. Its component soils in this area have the following characteristics.

Colours (moist) are predominantly yellow or yellowish brown to reddish yellow with a distinct tendency for the colour intensity to increase with depth. Subsoil mottling is common, largely being due to weathering rock fragments rather than impeded drainage, except at foothill sites where strong gleying is a feature of the deep subsoil.

Textures are predominantly sandy, ranging from loamy sand over sandy loam (Peninjau Series) to sandy loam grading with depth to sandy clay loam or sandy clay. Inclusions are few, although stone lines are distinct features within augering depth in some areas. The soils are generally at least three to four feet deep before grading to weathering rock.

Structure is poorly developed beneath the Al horizon, but can be established as blocky (subangular) in the deeper parts of some profiles. Moist consistence varies from loose to friable in the A horizons and from friable to firm in the B horizons. There is also commonly a plastic consistence in the lower A and upper B horizons in moist soil.

Despite the high permeability and lack of obstruction, rooting is largely confined to the organic-rich topsoil. The soils are predominantly well or moderately well drained except at some foot-slope sites where subsoil gleying gives an imperfectly drained profile. External soil water run-off is slow to medium due to the rapid intake by the soil. The susceptibility to soil erosion is high on slopes exceeding about 15° , both by gullying and by landslides.

In Nyalau Family soils elsewhere the levels of plant nutrients are low except possibly of potassium in the deep subsoil. The topsoil is the richest part of the profile due to the higher amount of organic matter present which can retain exchangeable ions, thus topsoil conservation is of great importance in Nyalau soils.

All soils in this family except the Peninjau Series are considered to be suitable for rubber. Peninjau Series is excessively sandy, possibly susceptible to drought and extremely low in plant foods: the small pockets of this series are indicated on the soil map by shading within the Nyalau Family units. Although the soils can grow rubber satisfactorily it is considered that cultivation conditions become marginal where slopes exceed about 15° due to the hazard of erosion.

The Nyalau Family mapping unit contains small admixtures of other soils mainly in the Bekenu and Merit families.

3.3 3. BEKENU FAMILY

The Bekenu Family is a member of the Red-Yellow Podsollic group of soils. The family is widespread in this area, is developed largely from mixed sandstone, shale and sandy shale and is found on all topographic sites. The component soil series have the following characteristics.

Soil colours (moist) range from yellow to yellowish brown and reddish yellow. Strong colours are most common in the B horizons, which are also mottled light grey, yellow and reddish brown in places due to impeded drainage and/or the presence of weathering rock.

Textures are sandy loam to sandy clay loam in the A horizons grading with depth to clay. Hard, dark red, iron-coated sandstone inclusions are common in the B horizon which generally begins two to four feet from the surface.

Soil structure is weakly developed beneath the crumbly topsoil but can generally be determined as weak blocky in the clayey B horizon. Moist consistence grades from friable in the A to firm or very firm in the B horizon: a plastic consistence is common in moist sub soil. Permeability decreases with increasing depth: the soils are well to moderately well drained except at some foothill sites. External runoff is slow to medium. Soil erosion by both gullying and landslides is liable to be great on slopes exceeding about 15°.

Chemical analyses of Bekenu soils elsewhere reveal low levels of exchangeable and reserve plant nutrients, except possibly of reserve potassium in the lower subsoil. The topsoil holds the highest levels of plant food as the amount of organic matter is greatest there. Topsoil erosion should thus be limited as much as possible. Bekenu soils are considered to be suitable for rubber, although it is considered that conditions become marginal where slopes exceed about 15° due to the hazard of erosion.

The Bekenu Family mapping unit contains small admixtures of other soils mainly in the Merit and Nyalau families.

3.4

4. MERIT FAMILY

The Merit Family is classed in the Red-Yellow Podsollic group of soils. It is widespread here, derived mainly from shale and is associated largely with dipslope sites. The series that form the family in this area are characterized by the following features.

The moist colours range from brownish yellow to strong brown and red, the stronger colours being most characteristic of the B horizons. Light grey, yellow and reddish mottles may be common in the lower subsoil, due both to impeded drainage and to the presence of weathering multi-coloured shale.

The textures are dominated by the presence of clay giving loam to clay loam A horizons and clay loam to clay B horizons. The lower subsoil commonly contains inclusions of hard, iron-enriched sandstone and softer shale fragments. The C horizon generally begins from between two and three feet from the surface.

Structure is weak, but fine crumbly structure in the topsoil and subangular blocky structure in the subsoil as far as the C horizon are generally detectable and the subsoil peds are commonly coated by clayskins. The moist consistence ranges from friable in the shallow A2 horizon to firm or very firm below.

Roots are found predominantly in the topsoil, which is permeable as opposed to the rather dense nature of the subsoil. Internally the soils are generally moderately well drained, grading to imperfectly drained at foothill sites where the subsoil is gleyed. External runoff is medium to rapid and soil erosion is thought to be in the form of surface wash, rather than by gullying and landslides, except on the steepest slopes.

Analyses of Merit soils elsewhere show them to be less strongly leached than either the Nyalau or Bekenu families. Levels of exchangeable and particularly 'reserve' cations, although rather low, tend to increase rather than decrease with depth. It has been shown in First Division on similar soils that phosphorous fixation by iron can be a limiting factor to crop growth (Bailey, 1964, pp. 52-59). Merit soils in the area are suitable for rubber. On slopes exceeding about 25-30° however there is a danger of landslides.

The Merit Family mapping unit contains small admixtures of other soils mainly members of the Nyalau and Bekenu families.

5. MIRI FAMILY

Miri Family soils are tentatively classed as Ground-Water Podsol. They have developed in what is believed to be old alluvial-colluvial quartz sand and are found on low hill sites in three small parts of this area. Their main characteristics are described below.

The moist soil colours have low chroma throughout. The organic-rich topsoil is dark-coloured and gives way with depth to a deep, white A2 that in turn overlies abruptly dark brown or black B2h horizons. The soil textures range from sand to loamy sand; inclusions, excepting fine quartz pebbles, are rare. The consistence is loose to very friable as far as the B horizon, which is firm or very firm. The soils are virtually structureless (single grain in the A2 horizon or massive in the B2 horizon). Roots form a thick mat in the organic topsoil but a few penetrate below this level.

External drainage is slow due to the rapid intake of water at the surface and gentle slopes. Internally the profile is excessively drained as far as the B horizon, at which level drainage is strongly impeded. Analyses of similar Miri soils in adjacent areas give extremely low levels of plant nutrients except in the organic-rich topsoil and the capacity to store nutrients is equally low. This combination of unfavourable factors makes the soils unsuitable for the cultivation of rubber.

Miri Family soils form part of the Miri-Saratok Association mapping unit. Soils consisting of deep, white sand at least 48 inches deep are also included in this unit as they are believed to have a B2h horizon beyond auger depth (48 inches).

6. SARATOK FAMILY

The Saratok Family belongs to the Podsollic group of soils. Soils in the area tentatively classed as members of this family have developed in old, colluvial-alluvial quartz sand, and are found on low hill and foothill sites in association with the Miri Family described above.

Saratok soils characteristically have low chromas throughout. Beneath the thin, dark-coloured topsoil colours range from white to pale brown or light yellowish brown. Textures range between sand and loamy sand; the moist consistence is loose or very friable and there is no detectable structure apart from weak, fine crumb in the A1 horizon.

External drainage is probably slow due to the high permeability, internal drainage is good to excessive. Analyses of Saratok soils are not available but they are thought to be of low fertility and the sandiness implies a low capacity to store nutrients. They are therefore considered to be unsuitable for rubber cultivation.

It is known that in this area at least small portions of the Miri-Saratok Association mapping unit contain soils of the Silantek or Buso families (with a weakly-developed B2h horizon).

7. SEMILAJAU FAMILY

The Semilajau Family is a member of the Red-Yellow Podsollic Great Soil Group. The soils in this area tentatively classed as members of the family are limited in distribution to the levees of the Ukong Stream and have developed in recent quartzose alluvium. A few soil examinations close to the stream banks revealed extremely sandy soils which could be classed as members of either the Kayan Family (Recent Alluvial) or of the Lundu Family (Regosol). They are thought to represent only a small part of this mapping unit however.

The moist colours of Semilajau Family soils are predominantly pale yellow to yellowish brown: the deep subsoil is commonly mottled strong brown and light grey, and faint, dark, colour banding can be distinguished in the upper subsoil in places, due to the addition of fresh flood material burying old topsoil horizons.

Textures range from sand to sandy clay loam, there generally being a clear tendency for the clay content to increase with increasing depth. The soils are loose to very friable and structureless below the weakly crumb-structured A1 horizon. External drainage is slow; internally the soils are moderately to imperfectly drained. The water table may be present in the deep subsoil where gleying occurs.

Analyses of Semilajau soils in nearby areas show that the fertility levels are low except in the topsoil. They are considered to be suitable for rubber cultivation, however, provided fertilizing is adequate. Flash floods are a probable hazard to young trees.

The Semilajau Family forms apart of the Semilajau-Malang Association mapping unit, in which it is thought to be dominant. Small admixtures of Plan and Bijat families soils probably occur in places.

8. MALANG FAMILY

The Malang Family forms part of the Red-Yellow Podsollic group of soils. The members of the family in this area have a wide distribution in the valleys and have developed from recent clayey alluvium. In some respects they can be considered as intergrades to the young, weakly developed Seduau Family of the Recent Alluvial Great Soil Group.

The moist soil colours of the Malang Family range from yellow to strong brown and reddish yellow, with reddish brown to light grey mottles characterizing the lower part of the profile, in which ground water gleying is commonly present. The textures are loam in the topsoil to clay loam or clay in the subsoil. Sandier horizons may occur as bands in lower parts of the profile. The soils are friable to firm where moist, and plastic and sticky where wet; weak blockiness is usually detectable in the A and B horizons. Roots are most common in the topsoil but can be found throughout the profile above the gleyed horizon if the latter is present.

External drainage is medium to slow, internal drainage is predominantly imperfect. Analyses of similar soil in adjacent areas show the fertility levels to be moderate. The family is considered as suitable for rubber cultivation although there is a hazard of periodic flooding.

The Malang Family forms part of the Semilajau-Malang Association and the Bijat-Malang Association in which it is thought to be subordinate. It also occurs in the Bijat-Malang-Plan Association as a subordinate member.

9. BIJAT FAMILY

The Bijat Family is a part of the Low Humic Gley Soil Group. The soils of the family in this area are widespread in the valleys and are developed in recent, predominantly clayey alluvium under hydromorphic conditions.

The soil colours range from dark greyish brown to yellowish- or strong brown mottled grey or light grey in the upper few inches of soil, giving way rapidly with depth to deep, light-coloured gleyed soil. The texture in at least the upper 18 inches of the mineral soil is clay loam or clay. Above, there may be a peaty horizon up to 6 inches deep; beneath, there may be sandier horizons. The wet consistence of the clayey subsoil is plastic and sticky; the structure is massive. Roots are confined largely to the upper, ungleyed part of the profile.

External drainage is very slow, internal drainage is poor or very poor. Soil fertility is thought to be sufficiently high for rubber to be cultivated, although the inherently poor drainage qualities would need improvement first and there would be a risk of periodic flooding.

Bijat Family soils are dominant in the Bijat-Malang Association and form an important part of the Bijat-Malang-Plan, Bijat-Plan and Bijat-Anderson associations.

10. PLAN FAMILY

The Plan Family is classed as a member of the Low Humic Gley soil group. The component soils of the family are fairly widespread in parts of some valleys where they are derived from recent, mixed colluvial/alluvial material.

The soil colours are yellowish in the upper few inches with light grey and reddish brown mottles, except in some locations where there is a dark greyish brown topsoil. Beneath, light greyish brown colours predominate within the zone of the water table; reddish brown mottles occur down root channels.

Textures below the topsoil range from sand to sandy clay loam; commonly the sand is coarse in grade. The topsoil may be peaty to a depth of 6 inches. The wet consistence varies from non plastic and non sticky to plastic and slightly sticky. Structure is not detectable. Roots are found predominantly in the topsoil.

Due to the lowlying positions occupied by this family the soils have slow external and poor or very poor internal drainage. The fertility is believed to be low but if the soils can be adequately drained and fertilized they could be made marginal to suitable for rubber cultivation, the main risk being periodic flooding. Fertilizer application will probably need to be made more frequently than on more clayey soils due to the low capacity of the sand to store nutrients.

Plan Family soils form important parts of the Bijat-Plan and probably the subordinate part of the Bijat-Malang-Plan Association.

11. ANDERSON FAMILY

The peat soils of the Anderson Family are classed in the Bog Great Soil Group. The Anderson soils in this area are common in some valleys where they form in lowlying basins between river levees and hillsides. They are formed by organic accumulation in a hydromorphic environment.

The chief characteristics are dark brown to black colours, woody composition, strong acidity and low fertility. They are considered unsuitable for the cultivation of rubber. Small areas mapped as this family consist mainly of loose watery muck with peaty and clayey lenses. Thin surface skins of clay above deep peat are also included in this unit, as are small pockets of Mukah Family soil, which by definition consists of 6-36 inches of peat or muck overlying clay.

4 CONCLUSIONS

The total area of the Lambir Development Scheme as measured by planimeter amounts to 3,140 acres, excluding the disturbed roadside land. The scheme area is divided for easy reference into four parts, namely areas A, B, C and the Village Area. The break-down of suitable, marginal and unsuitable land in areas A, B and C is shown below. It should be remembered that the acreages are approximate, that the alluvial land has not been examined intensively, and that the mapping units contain admixtures of other soils, particularly in the southwest of Area B and in Area C.

Areas measured by planimeter.

Village Area	Area A	Area B	Area C	Total	
1	23	17	14	55	1. <u>Unsuitable</u> Landslides Anderson Family, Anderson-Bijat Association; low fertility and bad drainage.
24	24	22	66	136	
-	3	16	-	19	
10			12	22	Nyalau Family (Peninjau Series); low fertility, susceptible to erosion. Miri-Saratok Association; as above
-	1	-	10	11	2. <u>Marginal</u> Matang Family; low fertility, susceptible to erosion Nyalau Family; susceptible to erosion Bekenu Family; " " " Plan Family (after improvement) including parts of mixed associations containing this family
66	242	209	430	947	
5	125	268	224	622	
3	25	125	65	218	
167	167	385	331	1050	3. <u>Suitable</u> Merit, Malang, Semilajau, Bijat and parts of mixed associations containing these families (after improvement of poorly drained soils).
276	609	1042	1153	3080	

Most of the hill land of Area A is already planted with rubber, regardless of soil suitability, giving an estimated planted area of about 490 acres. The acreage is being extended slightly by putting in additional terraces at the foothills. Further expansion can be effected if necessary by using the better drained valley land (Malang Family). It is understood however that at least some of the valley land is to be used for swamp padi. The soils with the best inherent advantages for this crop are those belonging to the Bijat Family; the Anderson Family is infertile and difficult to drain, the Plan Family is of low fertility and liable to cause lodging of young rice during floods.

In Area B as much suitable hill and valley land as possible will be planted with rubber. If the Nyalau and Bekenu soils are used the risk is taken that serious landslides will occur on moderate to steep slopes during periods of prolonged rain. Excluding the existing landslides, areas of Peninjau Series and the peat of the Anderson Family, the plantable area amounts to 987 acres. The hill land will require careful terracing and much of the flat land will need draining.

Area C has been less thoroughly examined, but if as much suitable and marginal land as possible is to be planted there is an area of about 1,060 acres available. The two valleys mapped as the Bijat-Anderson Association are excluded from this amount, although it may be possible to drain parts of them adequately.

This scheme area is far from ideal for rubber planting since the physical environment is such that normal soil conservation measures cannot cope with the type of erosion experienced from time to time. This is clearly indicated in Soil Survey Report No.21 pp.16-17 (Wall, 1961) and Report No.35, pp.15-17, 20 (Wall, 1962). Despite the presence of large patches of moderately good Merit soils, the dominance of weakly structured, permeable and sandy Nyalau and Bekenu hill soils, combined with the many moderately steep and steep slopes, make the area as a whole marginal at best due to the erosion hazard.

In this respect, it is pertinent that a forested area higher up in the Lambir Hills, with the same hill soil families as here, was examined in detail and found to be scared by landslides over about 11% of the 60 acres examined. Almost all appear to have occurred in 1962-63. Thus, given sufficiently adverse climatic conditions landslides will occur on these soils whether there is a mature tree cover or not.

Under the rather special conditions of the Lambir Development Scheme area it is questionable whether the normal wide terraces, constructed along a contour and tilted slightly back into the hillside, best fulfill one of their prime functions, namely that of preventing erosion. Normally, terraces are built so that surface water runoff down slopes is checked and dissipated on the terraces: much of the water collecting on the terrace is meant to penetrate the soil at the terrace heel with the aim of preventing surface erosion and gulying. This is probably a desirable aim in the heavy, clayey, coherent Merit soils, but if the process leading to landslides in the Nyalau soils in particular is correctly understood (section 2.2) then such terrace building is likely to aggravate rather than alleviate the problem. The deliberate diversion of surface water into the soil adds to its weight, and increases lubrication and hence instability.

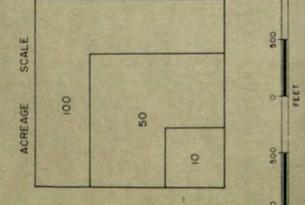
Ideally it is thought that the erosion control measures for these sandy, permeable soils should be aimed at the prevention of excessive amounts of water from entering the soil to cause it to become saturated. It has been suggested in these circumstances that terraces should be dispensed with and thick cover crops maintained to give a humus-rich water-absorbent topsoil, and to divert at least a part of incoming rainfall from entering the soil. This however would not be effective in dealing with the most damaging prolonged heavy rainfalls. Assuming therefore that some type of terrace is required, it is suggested that the terrace widths be decreased in order to minimize the amount of bare, flat soil exposed to rain and runoff. A further possible modification is that the terraces be carefully graded to tilt gently not only into the hill but also laterally around and down the hill. The danger would then be that incipient gulying of the terrace heels would be stimulated if large quantities of water were allowed to flow too fast along them. In other countries with similar severe erosion problems, stepped concrete flumes are constructed at intervals around hillsides that lead water from such terraces straight down the hillside into the valley below. This creates an additional expense which may not be justified in this case for many years when the next severe 'landas' occurs, but if the problem is judged sufficiently serious then the expense is negligible compared to the loss of several acres of high-yielding mature rubber.

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LAMBIR DEVELOPMENT SCHEME SOIL MAP

Scale 1:10,000



- LEGEND**
- Disturbed land, roads and landslides
 - Observed soil boundary
 - Tentative soil boundary interpolated between soil auger examination sites
 - Form lines at 20 feet interval
 - Streams and rivers

SOIL SURVEY DRAWING No. 154 C BASE MAP DERIVED FROM LAND & SURVEY DEPARTMENT, SARAWAK COMPILED BY J. R. D. WEL DRAWN BY Lim Dui Chong GOVERNMENT COPYRIGHT SOIL SURVEY AREA No. 78

KEY

ORIGIN	MAPPING UNITS (SOIL FAMILIES)	APPROX. ACREAGE	MAIN SOIL CHARACTERISTICS	TOPOGRAPHY	SUITABILITY FOR RUBBER AND MAIN LIMITATIONS FOR CULTIVATION
RESIDUAL SOILS	MATANG	11	Light grey loamy sand over friable yellowish to reddish sandy clay loam to sandy clay. Deep, well drained.	Ridges and upper slopes	Unsuitable, due to low soil fertility.
	NYALAU	947	Yellowish brown friable sandy loam over friable to firm yellowish to reddish sandy clay loam or sandy clay. Deep, well to moderately well drained.	Occurs on all sites but best developed on upper slopes and ridges.	Soil suitable but on slopes exceeding 15° erosion hazard is present, low chemical fertility. PENINJAU SERIES; unsuitable.
	PENINJAU	19	Yellowish loose loamy sand on friable sandy loam. Deep, well drained.		
DERIVED MAINLY FROM	BEKENU	622	Yellowish brown friable sandy loam or sandy clay loam over firm yellowish to reddish clay loam to clay. Moderately deep, moderately well drained.	Found on all topographic sites	Soil suitable, but on slopes exceeding 15° erosion hazard is present. Low chemical fertility.
	MERIT	594	Yellowish to reddish friable clay loam over firm clay. Moderately deep, moderately well drained, stony in places.	Occurs on all sites but best developed on gentle dipslopes	Soil suitable, but on slopes exceeding 25° erosion hazard is present. Low to moderate chemical fertility.
OLD ALLUVIAL SOILS DEVELOPED IN	MIRI SARATOK	22	Deep light grey to white loose sand over dark brown sand. Excessively drained.	Lower slopes only, gentle to moderate slopes	Unsuitable due to low soil fertility.
RECENT ALLUVIAL SOILS DEVELOPED IN	SEMILAJAU	34	Yellowish loose sand over friable sandy loam to sandy clay loam. Heavier textured bands in places. Deep, well drained	Levees of streams	Marginal due to low chemical fertility. Periodic flash floods occur.
	MALANG	71	Yellowish brown friable loam over yellowish to reddish firm brown clay loam or clay. Sandy bands in places. Deep, moderately well to imperfectly drained.	Levees of streams and some valley basins. Gentle slopes.	Suitable. Periodic flash floods occur.
	BIJAT	213	Yellowish brown clay loam on sticky, plastic clay. Sandy bands in places. Deep, poorly drained.	Valley basins, flat	Suitable with sufficient drainage. Periodic flash floods occur.
ORGANIC SOIL	PLAN	38	Yellowish sandy loam over greyish sand to sandy clay loam. Clayey bands in places. Deep, poorly drained.	Valley basins and colluvium from landslides. Flat to gentle slopes.	Unsuitable due to low fertility and bad drainage
	ANDERSON	23 14 28	1 3-6 feet deep. 2 6-10 feet deep. 3 > 10 feet deep.	Valley basins, flat	
MIXED ALLUVIAL AND ORGANIC SOILS		125 138 55	See above	Valley basins and colluvium from landslides. Flat and gentle slopes.	Suitable with sufficient drainage. Periodic flash floods occur.
		71	See above	Valley basins, flat.	Unsuitable due to bad drainage and presence of peat.

