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MALAYSIA

Report on a Reconnaissance Soil Survey  
of the  
BINTULU-LABANG AREA (4th Division)

by  
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Soils Division

Sarawak, Nov.1963

Dept. of Agric.

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## REPORT ON A RECONNAISSANCE SOIL SURVEY OF THE BINTULU - LABANG AREA, 4th DIVISION.

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## 1. INTRODUCTION AND SUMMARY

The Fourth Division Development Committee proposed this survey with the dual purpose of locating the most suitable route for a feeder road between Bintulu and Labang and of tapping the best agricultural land between the two places. Labang is likely to be the nearest point to Bintulu on the future trunk road between Miri and Sibiu.

Fieldwork was started in mid July, 1963, and was completed by mid August with a team comprising four Agricultural Assistants and one Soil Surveyor. Air photograph interpretation for the soil map both prior and subsequent to the field work took four to five weeks with an additional two weeks for the completion of the Terrain/Soil Suitability Map and the Agricultural Potential Map.

The total area shown on the accompanying Soil Map covers approximately 540 sq. miles<sup>1</sup> and includes 110 sq. miles of the Coastal Reconnaissance Survey (Survey Area 43) which has not been reported on in detail before. This area, surveyed in 1961, is included both to make available more information and to form a conveniently shaped block for reporting purposes<sup>2</sup>.

Of the 540 sq. miles (345,000 acres) approximately 280 sq. miles are considered topographically and pedologically suitable for agriculture, a further 90 sq. miles marginal and 180 sq. miles unsuitable for agricultural purposes with the systems in use at the present time. Technically, much higher and steeper land and poorer soils could be used but/only if the pressure for land was strong enough, agricultural practises were correspondingly improved and money was available for expensive investment in such items as terracing and fertilisers.

Land in use for permanent and shifting cultivation from 1948-51 (latest available air photographs) was largely in the agriculturally suitable and marginal land close to main rivers and streams in the southern half. Alienated land in 1963 was concentrated around Bintulu and alongside the Btg. Kemena and its main tributaries. Marginal and in places good agricultural land exists in the Nyabau and Semilajau Forest Reserves.

A reasonably easy road route between Bintulu and Labang is indicated on the Agricultural Potential Map. This route would also tap large areas of unused marginal to good agricultural land in the Sg. Sibiu valley and parts of the Nyabau and Semilajau Forest Reserves.

The following is a summary of the main soil types and their distribution. Shallow, stony, podsollic soils of the Penrissen and Nyalau Associations occur in the central area which is dominated by two high parallel ridge systems culminating in Bt. Nyabau and Bt. Entimau north of Sg. Sibiu and Bt. Takuja and Bt. Bala south of Sg. Sibiu. Similar soils derived mainly from sandstone extend north of Sg. Likau to the lower Sg. Semilajau and northeast to Bt. Tiban (outside the area) and Sg. Seran on steep-sided, dissected hills.

Deeper, less stony and more clayey podsollic soils of the Merit and Bekonu Associations are derived from mixed sandstones and shales and occur on lower, less steep hills in the middle Sg. Takau and Sg. Semilajau valleys, south of the Bt. Takuja - Bt. Bala ridges and in the Sg. Sibiu valley.

Extensive sand terraces containing poor humus podsolis are common in coastal areas, parts of the lower Sg. Sibiu valley, and in the upper Sg. Takau valley.

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1. Areas are measured by planimeter from maps at scale 1:50,000. Figures are therefore most accurate on flat land and least accurate on the most rugged and dissected country, where errors exceeding 100% are possible.

2. See Location Map inset in the Soil Map; also Wall J.R.D. (1961) Progress Report on the Coastal Reconnaissance Survey for 1961.  
Survey Area 43.

3. For an explanation of these terms see section 3, 1.

The alluvial land is widespread but not in large blocks. Riverine alluvium, mainly clayey, fringes swamps and penetrates along valleys in the hilly country. Deep peat covers riverine and estuarine clay alongside Btg. Kemena. Estuarine silty clays are restricted to the banks of Btg. Kemena and the mouths of the larger coastal rivers while poor, quartzitic beach sand lies largely behind Bintulu and as narrow belts and embayments along the coast further north.

The survey was effected by methods that are now standard for reconnaissance surveys in the country.<sup>1</sup> The transfer of data from air photographs to base maps proved difficult on the two northern 1:50,000 sheets, (3-113-9 and 10), since photo principal points are not plotted on these sheets and the topographic detail is scanty and in places inaccurate. For these reasons the plotted soil boundaries are subject to error and this is a further cause for treating acreage figures with reserve (see also footnote page 1).

Large areas in the central high hills and in the uniform lowlying land of the middle Sg. Takau and Sg. Semilajau were not examined in the field. The high steep land is not important for agriculture, although the lowlying land is potentially important. The latter areas however had similar photo characteristics to parts examined elsewhere and soil information was interpolated from the known to the unknown similar areas; this ensured a considerable saving in time as access to these remote parts is difficult. The distribution of rentis lines on the accompanying soil map (map No. 1) indicates which parts have and have not been examined in the field. The accuracy of the soil boundaries of the unvisited parts depends entirely on the accuracy of air photograph interpretation.

A total of 93 samples were collected, of which 59 have been analysed chemically in the Soils Laboratory. Field surveying was carried out along 146 miles of paths and cut rentise.

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1. Limitations and uses of reconnaissance surveys are explained in Departmental Circulars 2 and 2 (a).

## 2. GENERAL CHARACTER OF THE AREA.

### 1. GEOLOGY<sup>1</sup>

In brief, sedimentary rocks of mid Tertiary age underly the whole area and outcrop throughout the central and northern parts. Quaternary alluvium, covered by deep peat near Btg. Kemena, overlies the rock formations in the south and occurs as narrow strips in river valleys crossing the hilly country, particularly in the middle Sg. Takau, Sg. Semilajau and Sg. Sibiu valleys. Terrace alluvium is widespread in coastal districts.

The rocks, which are predominantly soft and of fine to medium texture, range from shales, argillaceous sandstone, sandy shale and fine sandstone to medium sandstone. Limestone lenses were noted in places and calcareous varieties of the rocks and lignitic bands also occur. In the Sg. Sibiu area many recent road cuttings have exposed predominantly dark grey fine sandstones and fine sandy shales.

Sandstone successions are sufficiently thick in places to form well defined escarpments and high hills. The sandstones are largely members of the Nyalau Formation which underlies all the hill land except in the northeast and along Sg. Sibiu where the Setap Formation interfingers. Shales and fine sandy shales are the main constituents of the Setap Formation and are largely responsible for the lowlying country wherever the Formation outcrops.

The regional strike is consistently southwest-northeast except for a deviation shown most clearly by the middle Sg. Sibiu valley trending east-west. Folding has caused the common occurrence, parallel to the strike, of shallow dipping synclines occupied largely by the Setap Formation, and of more steeply dipping anticlines occupied mainly by the Nyalau Formation.

Low terraces are widespread on and behind the whole coastline and inland in the Sg. Sibiu, Sg. Plan Besar, Sg. Takau and Sg. Semilajau valleys. Small patches were also noted in the field near the upper Sg. Sibop, Labang and at a higher level in the lower Sg. Sibiu. The terrace material comprises loose fine white sands resting in most places on a dark brown humus pan. Quartz gravel is said to occur in a terrace in the middle Sg. Sibiu valley and was noted in a higher level terrace remnant lower down the same valley.

The remaining alluvial land consists of mixed fine sands, silts and clays except in the upper stream courses where the banks are formed of mixed silts and fine-medium sands. The source of the alluvium is probably local, i.e. from the Nyalau and Setap Formation sandstones and shales, except for that brought downriver by Btg. Kemena which in any case is derived from similar lithological types upriver.

Reworked alluvium occupies the banks of Btg. Kemena below Sebauh where tides are still effective. Sandy marine alluvium lies behind Bintulu and further north as narrow shoreline strips and embayments. The sand is predominantly quartz and fine to medium in size except near coastal cliffs. At such places outcropping sandstone beds are subject to wave weathering and coarse sands with shell fragments are intermixed with the finer grades.

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### 1. Information in this section is largely abstracted from the memoirs listed below.

Haile, N.S. (1961) The Geology and Mineral Resources of the Suai-Baram Area, North Sarawak: Brit. Borneo Geol. Survey Mem. 13, 1962.

Kirk, H.J.C. (1957) The Geology and Mineral Resources of the Upper Rajang and Adjacent Areas: Brit. Borneo Geol. Survey Mem., 8, 1957.

Iichti, P. et al. (1960) The Geology of Sarawak, Brunei and the Western Part of North Borneo: Brit. Borneo Geol. Survey Bulletin, 3, 1960.

## 2. TOPOGRAPHY AND DRAINAGE

It will be helpful in this section to refer to the accompanying Terrain/Soil Suitability Map (map No. 2). Briefly; the central core area consists of high parallel ridges. Surrounding them are high dissected hills which project north to the lower Sg. Semilajau and Bt. Tiban, northeast to the upper Sg. Labang, west to Tg. Kidurong and form the southern limit of the hills south of the Btg. Bala ridge systems. Lower hills forming a dissected erosion surface are to be found largely in the central Sg. Takau and Sg. Semilajau area, southwest of Labang, the Sg. Sibiu valley and contiguous with flat-tapped coastal terraces. Alluvial land and swamps are most extensive in the south.

The coastal lowlands between K. Kemena and Tg. Batu, between Tg. Batu and K. Plan Besar and in the narrow strips and embayments north of Tg. Kidurong comprise gently undulating beaches parallel to the shore corresponding to series of old sand bars and infilled lagoons, now swales. The most recent beach is generally the highest at about three to four feet above normal high tide. With increasing distance inland the surface of the beaches appears to drop slowly until the water table rests at the surface and peat is able to form.

The drainage pattern is parallel reflecting the presence of a subdued sand bar-swale topography. The sand bars are rarely flooded, conversely the swales or intervening lower lying strips have a naturally high water table and are rapidly flooded after storms. Artificial drainage along swales to rivers, using existing streams in places, would be easy, but river and stream mouths on the coast tend to be blocked by sand bars at all but high tide.

Peat swamps are all lowlying and directly associated with badly drained alluvial basins. The largest flank Btg. Kemena, between Sg. Spadok and Sg. Selezu, northeast of Sebauh and north of Pandan, where depths commonly attain 20 feet. Many smaller and shallower swamps occur behind the levees of large streams such as the lower Sg. Sibiu, Sg. Selezu, Sg. Sebungan and Sg. Labang. The margins of the swamps commonly terminate abruptly at river banks and hill sides where the peat is still greater than 10 feet in depth. Small swamps occur behind Bintulu, between Sg. Plan Besar and Tg. Batu and near K. Semilajau on marine alluvium. Near Sg. Terus an encroaching sea has exposed the margins of a deep swamp on the shoreline.

Drainage of the swamps is effected by slow surface runoff, there being few visible stream courses except on the swamp perimeters. This implies that the surface is slightly domed.

Narrow strips of estuarine land occur on the banks of the lower Btg. Kemena and at the mouths of other coastal streams. The typical meandering creeks and lagoons of this landform are poorly developed. Twice daily, tides of saline to brackish water submerge the land.

Riverine land lies around the swamp fringes and penetrates the hill land alongside streams. In the northern part of this area where low hills occur many small strips of interconnected alluvium dissect the hills. The areas are not sufficiently large to develop independent distinct drainage systems. Small tributary streams are in places blocked by the high levees of a larger stream and form small poorly-drained backswamps.

Hill land is divisible into a number of distinct units which reflect differences in structure, lithology and geomorphological processes. Lying astride the centre of the area are high parallel ridge systems on either side of Sg. Sibiu. They culminate in Bt. Nyabau (541 feet) and Bt. Entimau to the north and Bt. Takuja and Bt. Bala (1,143 feet) to the south, coinciding closely with outcrops of anticlinal competent sandstone strata. The highest ridges show a strong tendency towards cuesta formation with long moderately steep dip slopes opposite steep scarp slopes. The drainage pattern is coarse and trellis-like.

Surrounding the central ridges at a rather lower general level and extending north to the lower Sg. Semilajau and Bt. Tibau, northeast to Sg. Labang, west to Sg. Likau and south of the Bt. Bala - Bt. Takuja ridges are moderately high dissected hills rising in places to about 300 feet above nearby valleys. North of Sg. Sibiu the hills are mainly underlain by sandstone. Where the dips are gentle cuestas are evident, some quite extensive as northwest of Sg. Spoh. The drainage pattern of these parts is moderately fine and angular being influenced

strongly by the strike of the rocks. All rivers north of the Bt. Nyabau - Bt. Entimau ridges drain towards the sea. South and east of the Bt. Bala - Bt. Takuja ridges are groups of hills with a similar amplitude of relief but underlain by a mixed sandstone-shale sequence which gives rise not to cuestas but to a confused dissected system of short knife-edged ridges with steep slopes between  $20^{\circ}$  and  $45^{\circ}$ . The drainage pattern is moderately fine with sub angular trends. Streams from these hills all flow towards Btg. Kemena.

The lowest hills have accordant summits at about 40 to 60 feet above local base level indicating that they are probably remnants of a former erosion surface at a time when the sea level was higher. They occur mainly behind the coast, in the middle Sg. Semilajau valley, east of Labang and in the Sg. Sibiu valley, generally coincident with the outcrop of shale and mixed sandstone-shale formations and the larger synclinal structures. Dissection has caused the partial replacement of the hills by alluvium; peat formation on the alluvium among these hills is restricted to small areas near Sg. Labang and is not common as in topographically similar areas elsewhere in the country. Hill slopes are variable but predominantly less than  $35^{\circ}$  -  $40^{\circ}$ . The drainage pattern is fine, dendritic and unrelated to the structure.

Terraces are widespread on the coastline and also occur in the upper Sg. Takau, middle Sg. Semilajau, Sg. Sibiu and Sg. Plan Besar valleys. Their surfaces are in most places contiguous with the summits of low hills described in the paragraph above and can therefore be considered as part of the same erosion surface.

The main terrace height lies at between 30 feet and 50 feet above local base level. Behind Bintulu is a low terrace with an undulating surface and maximum height above adjacent alluvium of 44 feet, (surveyed by P.W.D. Roads Branch). This is the most common level along the coast although lower terraces at 6 feet - 10 feet above sea level have been noted at K. Sg. Semilajau and K. Sg. Panapa, and at less than 6 feet above adjacent alluvium in the upper Sg. Sibop, Labang. Higher terrace remnants were also noted at 109 feet and 111 feet (surveyed) above sea level (70-80 feet above local base level) on the new road between Bintulu and Sg. Sibiu. Terrace surfaces are level to gently undulating and invariably steep sided. Surface drainage is not generally visible.

Flooding can be expected to occur throughout the alluvial areas (except on the terraces) and normally happens on three or four occasions in the "landas" lasting three or four days. The worst flooding probably occurs in the lower Btg. Kemena tributaries at times when heavy rains combine with high tides. After a particularly wet week during the survey the margins of the peat swamp at Sg. Selezu were flooded to depths of 3 feet, decreasing in depth with increasing distance towards the swamp centre. Sg. Sibiu at Rh. Labang rose by three feet after one heavy storm and needed to rise by a further 6 to 7 feet to top the banks. The 1963 floods everywhere topped river banks for several days but apparently were less serious than those experienced in the Niah, Bekenu and Btg. Baram areas.

### 3. VEGETATION AND LAND USE.

It will be useful in this section to refer to the accompanying Agricultural Potential Map (map no. 3).

Primary forest occurs throughout the Semilajau and Nyabau Forest Reserves. It also extends onto the Bt. Takuja - Bt. Bala ridges, the Btg. Kemena peat and nipah swamps and the more remote of the lower hills in the upper Sg. Sibiu and west of Labang.

Peat Swamp Forest is distinctive on the air photographs and fairly easy to map, in contrast to riverine, or Riparian, Forest which resembles Lowland Dipterocarp Forest in many respects. In the Forest Reserves there is little or no peat forest and riverine forest is confined generally to small strips alongside the streams. Kerangas vegetation is well represented on the many coastal terraces and also occupies dip slopes of cuestas and upper slopes of the higher sandstone ridges. The similar Poor Lowland Dipterocarp Forest occurs generally on the central dissected hills with sandstone strata and in places is present on what appears to be either riverine terraces or beds of near horizontally-bedded sandstone. These places are delimited tentatively on the soil map as the Penrissen Association in the upper Sg. Sibiu and in the lower Sg. Semilajau and Sg. Balim (Sg. Likau) areas. Lowland Dipterocarp Forest occurs on the lower hills and foothills, and mixed with Poor Lowland Dipterocarp Forest in the middle Sg. Semilajau and Sg. Takau area.

Most land within easy reach of Btg. Kemena and its main tributaries had been used, for shifting cultivation largely, by 1948-51 when the most recent air photographs were taken. It is reasonable to expect that even less accessible land has been cleared since then. A map showing alienated land, (1963) prepared by the Lands & Surveys Office, Fourth Division, indicates that most is confined to the margins of the main rivers except at Bintulu where large blocks extend between the Nyabau Forest Reserve boundary and Btg. Kemena. It is likely that most alienated land is used for rubber, coconut and padi holdings, and it is significant that all is within easy access of the main means of transport, streams and rivers, and on suitable to marginal agricultural land. Should a road be built between Bintulu and Labang following Sg. Sibiu the pattern can be expected to change accordingly since at the present time no land is alienated along the middle and upper Sg. Sibiu to the vicinity of Labang.

Racial division is apparent in land tenure, economy and population distribution. Chinese support practically all commercial life in towns and bazaars and own the timber mills at Bintulu and Sebauh. They are taking an increasing interest in agriculture however, and own the large Sibiu Rubber Planting Scheme block parts of which will shortly be ready for tapping, also the old rubber on peat swamps at Sebauh. Foochow support agriculture, and to a certain extent town life, while Hokkien and Teo Chew are the principal shopkeepers. Malays, some formerly Melanaus, live on the outskirts of Bintulu, the other bazaars and alongside the lower rivers practising shallow sea fishing, river fishing and the upkeep of smallholdings with rubber, rice, coconuts and vegetables as the main crops. Iban communities are scattered throughout the populated area but mainly in upstream land among the hills where shifting cultivation for hill padi can be practised. Recently the more progressive houses are taking a keener interest in the Rubber Planting Scheme and in swamp padi cultivation, actively encouraged by the Department of Agriculture.

### 3. SOILS

#### 1. CLASSIFICATION AND MAPPING

Reference in this section is made to the 'Field Classification of Sarawak Soils'<sup>1</sup> in which soil associations are classified, defined and described. A soil association is simply a convenient mapping unit which can be recognised easily both in the field and during air photograph interpretation, and which preferably contains genetically related groups of soil series. A soil series is the basic unit of soil mapping. On the accompanying Soil Map (map No. 1) can be found a key to the soil associations, their approximate acreages and main characteristics.

Some associations proved considerably easier to map than others in the present area, due to their occurrence on easily recognised geomorphic features or their presence beneath specific vegetation types or both. The residual soil associations are difficult to subdivide where thin, steeply dipping sandstone and shale strata are interbedded in roughly equal proportions. They are particularly difficult to delimit from alluvium on low hills less than about 20 feet high hidden beneath primary or old secondary forest. For these reasons many lowlying areas in the north are mapped as mixed associations and include many small patches of alluvial land that cannot be mapped at the scale used.

#### 2. SOIL ASSOCIATION DESCRIPTIONS

Associations are grouped together below for descriptive convenience and numbers in brackets refer to their numbers used in 'The Field Classification of Sarawak Soils.' In general, and unless otherwise stated, the descriptions refer to the dominant soils in the associations.

##### 1. ORGANOGENIC SOILS

###### 1. Anderson Association (31)

This association, mapped where practicable as three depth phases, is distributed widely in the southern part of the area, particularly adjacent to Btg. Kemena, as large swamps with depths commonly attaining 20 feet. Swamps smaller in area but similarly deep are found alongside the larger tributaries of Btg. Kemena and among lowlying hills particularly between the lower Sg. Sebungan and Sg. Labang. A feature of the above swamps is that the peat remains uniformly deep close to the margins so that depths of six to ten feet commonly lie within two to three hundred feet of rivers and hills.

Generally shallow swamps occur in a few coastal areas such as behind Bintulu, near Sg. Plan Besar and near the mouth of Sg. Semilajau. Near Sg. Terus however, northeast of Tg. Batu, small patches of deep peat lie among buried sand bars and former lagoons: the peat is currently being exposed on the shoreline by an encroaching sea. Peat has not been noted in the lowlying area between the middle Sg. Takau and middle Sg. Semilajau.

Coloured dark brown and black and embedded in a watery matrix the peat is raw, woody and waterlogged except near river banks where cultivation and a fluctuating water table have allowed aeration. This results in peat shrinkage, and the periodic addition of floodwater alluvium leaves skins and lenses of inorganic clay on and within the organic peat. Where a surface alluvial layer above the peat exceeds a depth of 12 inches it is regarded for practical purposes as a sub type of an alluvial association rather than of the Anderson Association.

Spore or comminuted beach debris is actively accumulating along the shore northeast of K. Btg. Kemena and near K. Sg. Semilajau as banks as much as three feet thick. In time they will become incorporated into the underlying sand as peat beds.

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1 Andriese, J.P. (1962) Field Classification of Sarawak Soils (1st Approximation) Technical Paper No. 1 (Department of Agriculture) 1962.

The peat is predominantly organic, acid and has a high exchange capacity. A profile (S.2544/47) analyzed from nearby Sg. Stulai indicated that the 'total' levels of major nutrients were low to medium for satisfactory plant growth with the exception of nitrogen and magnesium which respectively were high and medium. The peat is uniform in physical properties over large areas and it is probable that the nutrient status of the peat elsewhere is similar also. It has been noted however from other surveys that peat swamps near the coast which began as mangrove and nipah swamp tend to contain higher levels of magnesium and calcium in particular compared to inland swamps.

Until recently it has been thought that peat should not be cultivated beyond a general depth of five to six feet. It is not a good medium for growth for most crops under natural conditions, but after improvement such as draining and manuring it may be suitable for pineapples and other shallow rooted crops, in particular annuals. The only exceptions to this are sago which appears to grow happily on undrained peat as much as 10 feet deep, and jelutong whose natural habitat this is. Measures of improvement likely to be required by other crops include shallow drainage to aerate the peat and slowly lower the water table, and felling and burning before planting to release bound nutrients. Further overall fertilizing, in particular with lime to counteract acidity, at regular intervals is also likely to be necessary. Overdeep drainage would allow the surface peat to dehydrate irreversibly and may allow the incursion of brackish water up drainage channels once the peat has shrunk below high tide level.

## 2. ALLUVIAL SOILS

### 1. Tatau (11), Igan (11) and Oya (12) Associations.

The three associations have a common marine origin and sandy textures. They occur in a belt on the coast about one and a half miles wide behind Bintulu and as narrow coastal strips and embayments northeast to K. Sg. Semilajau; in many places the strips are too narrow to map.

The Oya Association (not mapped) occupies a narrow band on the shoreline, generally coinciding with the highest and most recent beach where the permanent water table lies at least 24 inches from the surface. The main soil is a pale yellow loose sand to loamy sand above the water table and grey to olive grey wet sand below. In places a dark brown firm humus pan is met with at about 30-40 inches depth. Faint brown to reddish brown mottling may be apparent above the water table.

A second soil occurs close to those headlands that are in the process of being weathered by the sea. It consists of a yellow or pale yellow sand to loamy sand with many individual sand grains coloured brown and reddish brown, intermixed with a considerable quantity of broken shells. The grade of sand is not uniform and varies from fine to coarse. It can be assumed that this soil is younger than that first described.

The surface of both soils is commonly devoid of litter under both secondary and primary vegetation. The sandy texture and common absence of humus and even topsoil render the soil extremely friable, loose, porous, and excessively drained and altogether a poor medium for plant growth. The low cation exchange capacity and excessive drainage means that easily soluble fertilizers added are rapidly lost by leaching. The bulk of the sand is quartz. Nutrient levels of soils in this association are generally low to very low, but the calcium level will probably be higher in the younger soil due to <sup>the</sup> presence of shells.

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1 No specific fertilizer recommendations are made in this report since insufficient crop yield/soil data is available.

Coconut is the crop most commonly grown on these soils. It rarely fruits well however unless considerable attention is paid to fertilizing. Water melon and other garden vegetables are tried elsewhere and appear to give satisfactory results, especially where organic refuse is mixed in with the soil.

The Tatau and Igan Association soils are fairly uniform and have in common a permanent water table within 24 inches of the surface and an acid, peaty litter and humus. Flooding after heavy rainfall occurs to depths of one or two feet for short periods.

The main soil of the Tatau Association consists of a dark greyish brown sandy loam topsoil overlying very pale brown to greyish brown loose sand. Beneath is the permanently wet zone of light grey to olive grey sand; in places the deeper subsoil is dark brown. The Igan Association main soil differs only in having a water table permanently at or near the surface and a topsoil comprising peat or muck between a few inches and three feet deep.

The subsoil has a low exchange capacity and tends to be low in all nutrients. The peaty topsoil, where present, has a higher inherent potential since the exchange capacity is greater and nutrient levels are generally not as low as in the sandy material. Crops grown successfully on similar drained and burned shallow peat in other areas include most shallow rooted vegetables, bush and certain tree crops including coconut. The fertilizer requirements are unlikely to be fully met by burning the peat and a regular fertilizing programme will therefore be necessary.

Shallow drainage is thought to be superior to deep drainage since the peat is richer than the underlying sand and it should therefore be conserved as long as possible. Also, overdeep drainage will let the surface peat dry out too completely and perhaps irreversibly.

## 2. 2. Mukah Association (112)

Small areas of this association occur between Tg. Batu and Sg. Plan Besar, and in places backing the Rajang Association of Btg. Kemena. The soils are partially desalinized old estuarine alluvium.

The main textures are clays to silty clays and the soil colours light grey to light greyish brown with reddish brown mottling commonly present in the subsoil. Peat topsoil occurs as much as three feet deep. The soils are poorly drained and hydromorphic, ideal for wet padi cultivation.

The available nutrient levels in other parts of the country are higher than usual by Sarawak standards, particularly in calcium and magnesium. It is possible however that the soils also contain high salt (sulphate and chloride) levels which cause it to be toxic for most crops.

## 3. 3. The Rajang Association (33)

This association is confined to narrow strips bordering Btg. Kemena and to small enclaves at the mouths of coastal streams. The soils are saline peaty clays and silty clays subjected to daily tidal incursions. Their potential for agriculture is high but until it is possible to keep out tidal water and partially desalinize at least the top 24-30 inches/potential cannot be realized.  
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4. Undup (21) and Sadong (23) Associations (incorporating Semilajau (211) and Malang (212) Associations.)

While it is fairly easy to distinguish areas of alluvial from hill soils and to find exactly what types of soil occur from fieldwork, it is impossible to map individual soil associations among the many narrow valleys penetrating the hills at the reporting scale of 1:100,000. In this case resource is made to composite soil associations.

The Sadong Association is the most comprehensive and includes all levee and basin soils of various textures. It is particularly appropriate to use this association for the smaller hill valleys since the soils are complex ranging on the one hand from narrow sandy levees to small patches of poorly drained basin clays.

The levee soils belong to the Semilajau Association and are generally deep brownish yellow, loose, poorly-structured fine sandy loams lying above brownish yellow fine sandy clay loams and fine sandy clays with reddish brown and pale yellow to white mottling in the deeper subsoil. The sandiness of the levees is an indication of rapidly moving water during floods, which implies that when flooding does occur it can be serious. Levees of this nature are most common near the central high hills: with increasing distance from this source of sand they tend to become lower, narrower, less sandy and less well drained until, like Sg. Semilajau, they cross other sandstone strata further downstream.

A profile was analysed of a Semilajau Association soil under primary forest from the upper Sg. Semilajau (S.2510/16). The results showed that the soil was less acid than normal and the exchange capacity was extremely low throughout due to the amount of sand present and that the 'totals' of major nutrients were all low to very low except potassium in the deeper subsoil. The 'available' analyses yielded practically nothing. The surprising feature of these very poor sandy soils is that any vegetation can exist. That it is able to do so can be attributed to the widespread rooting system of the trees and to the annual floods which must add a certain amount of plant food to the soil. Despite the poor nutrient levels in the soil the physical properties are moderately good and tree crops if fertilized a little and regularly should grow well.

Adjacent to the levees, which in places are 20 feet above normal river level, the land surface drops and the soils become increasingly more clayey, dense and poorly drained. The main association in these lowlying parts is the Malang Association, and the main soil comprises a thin topsoil overlying a brownish yellow to pale olive clay loam mottled with reddish brown and black. At greater depth in the region of the water table, at about 24-30 inches, the soil becomes a light grey clay with pale yellow to reddish yellow mottles. The consistence above the water table is friable to firm; below, plastic: the structure throughout is poorly developed. In places this soil forms the main levee.

Other soils occupying small areas are more poorly drained, and have variable textures in the subsoil.

The nutrient status as seen by a profile analysed from the middle Sg. Sibiu (S.2529/35) under primary forest is low, except in the topsoil, both as regards 'total' and 'available' levels. Magnesium only appears to have a fairly satisfactory status; the pH is medium. The nutritional difference between this clayey alluvium and the sandy Semilajau Association soil described above is a matter of degree. Both are poor, but due to their different drainage and textural properties can be treated in different ways. This soil is more suitable to shallow rooted crops, in particular swamp padi in the more poorly drained parts, palms, bush crops and vegetables, with the provision that regular fertilizing is essential to ensure satisfactory growth.

The levees of the larger tributaries such as Sg. Labang have soils containing alternating sandy and clayey layers, typical of Undup Association soils. The topsoil consists of shallow yellowish brown loam, beneath which are layers of brownish yellow, yellow or pale yellow clay loam, clay, fine sandy loam or fine sandy clay. Reddish yellow and light grey mottling usually occur towards the base of this soil, and this is succeeded by paler coloured clay loams

to clays within the range of the permanent water table.

5. Strap (22) and Bijat (221) Associations.

The Strap Association is<sup>a</sup> composite association and occurs on lowlying riverine land dominated by clayey alluvium, such as that found alongside the larger tributaries of Btg. Kemena. It is a mapping unit used where the soil areas are too small to map as more specific associations even though such associations are distinct in the field.

The principal soil belongs to the Bijat Association, which is mapped separately in places where it is fairly widespread. It consists of a brown to greyish brown friable loam overlying a grey to pale yellow, firm, slightly plastic clay mottled with reddish brown. The deeper subsoil generally lies within the permanent water table and is a strongly gleyed plastic clay; in places peat also occurs at depth. The Bijat Association occupies a belt between the river bank, where a narrow strip of Malang Association soils commonly occurs (see section 4 above), and adjacent peat swamps. On the fringe of the peat swamps lie soils of the Nyabor Association. This resembles the Bijat Association except that the internal drainage is poorer and muck or peat topsoil occurs to depths of three feet.

Analyses have not been made of the above soils, but it is probable that the inorganic material will be poorly endowed with nutrients, since it originates from the same sandstone and shale complex as the analysed Malang and Semilajau Association profiles described in sub section 4 above. The poor drainage and clayey texture are good combinations for wet padi cultivation. It may be possible to drain the shallow peat margins for padi if the gradient is suitable.

6. Buso (24) and Miri (14) Associations.

These associations are directly linked with old alluvial material on dissected terraces. Marine terraces with Miri Association soils occur throughout the coastal area. The terraces lie at a general level of between 30 and 50 feet above local base level with narrower, younger, shoreline strips at between six and ten feet above sea level. The largest area mapped is slightly less than one square mile, most do not exceed a half square mile in area being dissected by rivers and streams crossing them from hills behind.

Riverine terraces with Buso Association soils were noted in the upper Sg Takau, near Sg. Labang and in the Sg. Sibiu valley. They generally lie at levels less than 15 feet above adjacent rivers except in the lower Sg. Sibiu where two remnants were seen at 70-80 feet above local base level. The terraces form major components of the (51) and (52) Associations described below in section 3.2.4.

The soils of each association are similar and dominated by humus podsols with a firm, deep humus pan at depths varying between a few inches (eroded phase) and nine or ten feet. Textures throughout are sands to loamy sands and, due to the single grain structure and loose consistence, drainage is excessive in the white sand above the humus pan. Internal drainage tends to be laterally above the humus pan which forms a perched water table.

Leaching has removed almost all nutrients beneath the topsoil; consequently the uses for agriculture are extremely limited despite the favourable topography.

The riverine terraces tend to have slightly different soils. The colours are somewhat stronger, the texture less uniform and gravel is commonly intermixed. The agricultural value however remains low.

3. RESIDUAL SOILS

1. Nyalau (444) and Penrissen (44) Associations.

The main feature common to the two associations is their predominantly sandy parent material. The Penrissen Association is composite, derived from Bako and Matang Associations on cuesta topography. As a general rule the coarser and purer the sand, the thicker the strata, the harder, the cementing agent of the

sandstone and the gentler the dip the more the soil tends to be shallow and podsolized resembling the Bako Association. With increasing textural fineness of the sand, with softer and thinner strata and with increasing dip the more the soils resemble the red-yellow podsolics of the Nyalau and, where shale is interbedded the Bekenu Associations (see sub section 2 below).

Nyalau Association soils are predominant on the central hills with moderate to steep slopes north of Sg. Sibiu and on the Bt. Takuja - Bt. Bala ridges. They also extend northwards on similar steep hills to the lower Sg. Semilajau and Bt. Tiban, and to the upper Sg. Labang. Smaller areas occur mixed among Bekenu and Merit Associations, particularly south of the Bt. Takuja-Bt. Bala ridges, in the lowlying land of the middle Sg. Semilajau and in the coastal areas.

The soils are typically sandy, friable, sub plastic in the sub soil and well to moderately well drained. Shallow stony phases commonly occur on the steeper slopes. The main soil consists of a dark yellowish brown loamy topsoil lying on yellow to yellowish brown sandy loam. Beneath this is brownish yellow sandy clay loam giving way to brownish yellow or reddish yellow stony sandy clay at depths ranging from 18 to 40 inches. The stones comprise fragments of weathering sandstone coated and stained red and reddish brown: the fresh sandstone is generally bluish grey to white. Sand textures are commonly medium grading to fine and very fine. Minor series occur in poorly drained foothill sites; some have heavily lateritized stones in the subsoil; some truncated soils are reddish yellow directly beneath the topsoil.

A profile (S.2540/43) analysed from the middle Sg. Semilajau area under primary forest showed a low to medium pH and low or very low levels of all 'available' major nutrients; topsoil levels were slightly better than in the subsoil due to the higher organic matter content. 'Total' magnesium and potassium were medium; the exchange capacity was very low due to the predominance of inactive sand. Thus despite the good physical conditions for plant growth the chemical status of this profile implies a need for frequent liberal dressings of complete fertilizer. A further hazard is the occurrence of steep slopes: terracing would be required for cultivation on those exceeding about 15-20°. In this respect the best land use is to grow permanent tree crops rather than annuals, both to stabilize and protect the soil from degradation and to ensure maximum uptake of nutrients by means of their widespread rooting systems. However, it is worthwhile noting that at Tg. Kidurong Bintulu Malays are growing pineapples on this soil successfully, in addition to numerous bush fruit as catchcrops prior to the maturing of coconuts.<sup>1</sup> The coconuts are growing slowly, probably due to the lack of adequate fertilizer<sup>1</sup>.

The Penrissen Association is composite, consisting of the Bako Association on long gentle dip slopes and the Matang Association on opposite steeper scarp slopes of curstas, and high ridges. It is therefore most widespread among the central hills, the high ridge systems and the higher hills extending north to the lower Sg. Semilajau. Other occurrences are the lowlying syndinal areas such as in the upper Sg. Sibiu and possibly near Sg. Balim (Sg. Likau) and the lower Sg. Semilajau. At the latter two places it is possible that terrace soils are intermixed.

The Bako Association is predominant within the areas mapped as the Penrissen Association. The principal soil noted comprises thick raw humus, coloured dark reddish brown and interlaced with roots, overlying a pale yellow sandy loam horizon. Beneath this is a richer coloured horizon lying directly on solid sandstone or on weathering sandstone rubble at depths ranging from 12 - 30 inches. The soil is loose, friable, well drained and more leached than the Nyalau Association soils. Analyses have not been made of the soil but it is likely to be impoverished to judge from the kerangas vegetation growing on it.

Another soil was noted in the upper Sg. Likau and the lower Sg. Sibiu situated on gentle dip slopes and derived from dark bluish grey sandstone. It consists of a thick raw humus layer beneath which lies progressively a paler yellow sandy loam, a pale yellow sandy clay loam and finally a light grey sandy clay loam, mottled with reddish brown along pores and root channels, lying on weathering sandstone. The cause for the light colour may be due to impeded drainage, and hence gleying, leaching of iron and/or a paucity of iron colouring compounds in the parent material. Elsewhere in Sarawak similar dark grey and dark bluish grey carbonaceous rocks have been noted to weather directly to light grey soil. Rock outcrops towards the summits of hills and in gullies commonly form minor scarps.

The Matang Association is confined to scarp slopes and other steep slopes of the higher hills and is mixed with and grades imperceptibly into the richer-coloured Nyalau Association at lower levels. The sand grade tends to be medium to coarse and is part residual, part colluvial. The soil consists of pale yellow sandy loam on pale yellow sandy clay loam, commonly stony and mottled reddish brown. Drainage is moderately good to poor, the consistence friable to firm and the structure poorly developed. Leaching has probably removed most 'available' nutrients, which, combined with the high steep slopes, causes the soil to be unsuitable for agriculture.

## 2. 2. Bekenu (457) and Merit (455) Associations.

Where sandstone and shale beds occur in roughly equal proportions, the resultant soil types depend to a great extent on the dip and thickness of the strata. Generally dipping thick beds give rise to cuesta topography in which the sandstone forms the dip slope and shale outcrops as the scarp slope: this results in two distinct soils of the Nyalau and Merit Associations mappable at large scales. Where however the beds are thinner and dips steeper the situation becomes more complicated and the soil types less distinct. The main effect is that a hybrid soil results produced from mixed, weathered sandstone and shales and that only small areas occur, if any, of distinct shale or sandstone - derived soil. Where gentle dips and thin beds occur the soils tend to be both mixed and distinct, as with steep dips and thick beds and with varied dips and beds of uneven thickness. In the present area the lowlying hill land of Sg. Sibiu, the coastal areas, the middle Sg. Takau and Sg. Semilajau and the higher land south of the Bt. Bala - Bt. Takuja ridges give rise to this complex pattern of soils made up of distinct Nyalau and Merit Associations (mainly in the north) and the hybrid soil which forms the Bekenu Association. The Bekenu Association also occurs on fine sandstones and sandy shales.

The most distinct soil of the Bekenu Association consists of a yellowish-brown topsoil lying on brownish-yellow fine sandy loam or (fine sandy) clay loam, beneath which is brownish yellow or reddish yellow (fine sandy) clay generally mottled with light grey and reddish brown. Weathered iron-coated rock fragments are commonly encountered at depths varying from 18-80 inches or more. Road cuttings along the new Bintulu-Sg. Sibiu road provide good examples of fresh, deep profiles in well-lateritized soil.

The depth of the sandy upper subsoil varies but tends to be thickest on gentle slopes and hill tops. The soil is well drained and friable to firm in the rooting zone and possesses a weak prismatic structure in the textural B horizon. Analyses of a profile under primary forest from the upper Sg. Semilajau (S.2503/09) showed a moderately rich topsoil overlying subsoil with a low pH, medium to low exchange capacity and low to very low 'available' levels of major nutrients. 'Total' potassium and magnesium were medium and low to medium. A further profile (S.2556/61) from the Sg. Labang area and under two year old secondary forest was very similar. It is unlikely that any soils of this Association will be rich in nutrients.

The agricultural value exceeds that of the Nyalau Association, however, since the nutrient levels are slightly higher and the soil is better able to retain added fertilizer. The erosion hazard is similar since the topsoil and upper subsoil of both Associations is similarly sandy.

Other soils are associated largely with foothill sites where differences in drainage occur. Shallow depth phases are common on steep slopes.

Found generally on low hills with slopes not exceeding  $30^{\circ}$  -  $40^{\circ}$  is the Merit Association. Its distribution is similar to the Bekenu Association and it is also found both as fairly large separate areas and as small patches intermixed with other associations.

Several related soils occur. The dominant type consists of a thin dark greyish brown topsoil merging downwards to brownish yellow clay loam followed by reddish yellow stony clay at about 30 - 40 inches. Underneath lies a clay strongly mottled with red, light grey, pale yellow and reddish yellow which grades downwards to unweathered light grey shale at about 90 - 100 inches. Clay enrichment of the lower horizons has occurred leaving a thin lighter-textured upper

subsoil which is friable to firm and well penetrated by the root system. The stones in the deeper subsoil are hard, being coated and impregnated with iron. Iron-filled root channels are common.

Variations in drainage and the iron content of the shale are primarily responsible for the different soils present. Shallow depth phases are common in gullies and on steep slopes.

Results of a profile (S.2517/28) analysed from the middle Sg. Sibiu under five year old secondary growth showed both lateritic and podsollic tendencies. The pH is medium rising to high in the weathering shale. The levels of 'available' major nutrients are low or very low except potassium which reaches a medium level. Levels of 'total' major nutrients were: potassium - medium increasing to high with depth; magnesium - low decreasing to very low with depth; calcium - decreasing from medium to very low with depth; phosphorous - low throughout. The medium levels in general correspond to the A1 horizon. The exchange capacity was low to medium.

Although the interpolation of the above data to the whole of the Merit Association soils is not practicable, results give a general idea of the fertility of shale-derived soils. Nutrient levels on the above evidence appear to be slightly better than in the Bekenu Association which in turn appear to be slightly better than the Nyalau or Penrissen Associations. The increase in clay content compared to the other two associations also implies a better fertilizer retention capacity and a greater resistance to erosion. The structure is stronger, although the drainage and porosity poorer. In all cases the analyses of slightly weathered to unweathered rock show 'total' nutrients at the same or even lower levels than higher soil horizons, with the sole exception of potassium.

4. MIXED ASSOCIATIONS OF COMPLEX ORIGIN

1. (51) and (52) Associations.

The two associations are related by mode of origin. (51) comprises old coastal landscapes now dissected, while (52) consists of former riverine areas now dissected. It is difficult to distinguish between the two except where obvious signs of old marine terraces exist or where the soil includes gravel, which generally indicates a riverine origin.

Both types contain terrace soils, principally humus podsoils, and small white clayey patches of the Tanah Puteh Association in addition to mixed material of the Ridgeway Association. Dissection has caused the partial replacement in places of terraces by alluvial valleys and small swamps. After the terrace alluvium has been stripped by normal erosion the underlying rock weathers to produce the residual soils described in section 3.2.3. above.

The number of soil associations present are many, and it is not possible to distinguish them satisfactorily by air photograph interpretation. Generally, the dominant soils are residual and are suitable for agriculture in the present area. to marginal

Referring to maps 1 and 2 it will be seen that the worst topography coincides closely with the distribution of the Nyalau and Penrissen Associations. The lower hills with moderate and steep slopes correspond to the mixed Nyalau and Bekenu Associations, and the low hills with gentle to moderate slopes occur only where there are areas of mixed Nyalau, Merit and Bekenu, and (51) and (52) Associations. Low-lying land with gentle slopes is occupied by both good and poor soils.

## 2. AGRICULTURAL POTENTIAL

Referring to maps 1, 2 and 3 it can be seen that the bulk of the unused (see section 2.3), unalienated land suitable for agriculture lies in the Sg. Sibiu valley, the fringes of the Sg. Labang drainage basin, west of Labang and within the Nyabau and Semilajau Forest Reserves. It is clear that a reappraisal of the extent of these Reserves is necessary. The soils of these areas are nutritionally poor or very poor but physically medium to good; the topography consists of low to medium height hills with gentle to moderately steep and steep slopes. The best and largest unused areas of this type of land are indicated with generalised boundaries on map 3. Flooding may be an impediment to cultivation in the alluvial areas during the 'landas'; this must be assessed locally.

Crops grown successfully under similar conditions elsewhere and which should therefore be appropriate for cultivation here include swamp padi on poorly drained clay alluvium and peat swamp fringes, sago and jelutong on deeper peat; coffee, coconuts, fruit trees and tobacco on well to moderately well drained soils; pepper on well drained hill soils (Bekenu Association particularly appropriate) and rubber on all but the poorest and most badly drained soils.

Oil palm may be a suitable crop on the low hills and alluvium of the upper Sg. Semilajau but to maintain high yields a regular and possibly expensive fertilizer programme may have to be maintained. The results of fertilizer and cultivation experiments on the poorer sandy soils at the proposed Sg. Luak Experiment Station near Bekenu should be generally applicable to the soils in this area.

Rubber could be grown over most of the area if necessary but since it is tolerant of poor soil conditions, it is advisable to restrict new planting to the least valuable soils wherever competition occurs with other commercial, more demanding crops.

In the already settled areas, agriculture would benefit greatly by the intensification of cultivation, specifically by the introduction of tree crops on hill land, such as around Bintulu, and by the increasing adoption of swamp padi with off season crops as opposed to hill padi with catch crops. If new land within Forest Reserves is released for hill padi cultivation, the potential will be wasted and there will be the strong possibility of soil erosion through gullying on the sandy soils. If, however, the land is released for settled agriculture only, the scope and possibilities for different crops are great and the optimum use will be made of the land.

## 3. COMMUNICATIONS.

The main link within the area for trade and commerce is Btg. Kemena, which is sufficiently deep to permit large Chinese launches to travel well beyond Labang to Tubau. Smaller perahus with outboards can use the larger tributaries normally for short distances, but relying on floodwater the more remote headwaters can be reached. Coastal traffic hinges on Bintulu. A feeder road is near completion that will serve the large R.P.S. block between Bintulu and the lower Sg. Sibiu.

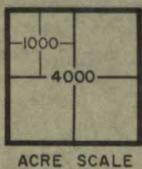
Inland areas therefore are inaccessible to motorized transport and this is doubtless the prime reason for the still quite large areas of unused agriculturally suitable land outside the forest reserves. New roads are therefore a prime requisite for development, not necessarily good roads but substantial mileages of all weather jeep tracks. The routes marked on the Agricultural Potential Map (Map 3) would serve as main feeder routes from which minor arteries could be led.

The route from Bintulu to Labang is almost bound to follow the Sg. Sibiu valley to its headwaters since on either side are high, steep ridges of very limited use for agriculture. A road to the south of the Bt. Bala - Bt. Takuja ridges, while being possible to build over the dissected hills, would be more expensive to build and would open up only small areas of unused land. A possible line for the trunk road from Miri via Btg. Suai and its southern tributary Sg. Beseri (see report No. 35<sup>1</sup>) joins the present area at the place indicated via an easy route and at the same time taps much new land in the middle Sg. Semilajau.

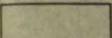
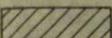
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1. Wall, J.R.D. (1962) Report on a Reconnaissance Soil Survey of the Bekenu-Niah-Suai Area, 1962, No.35.

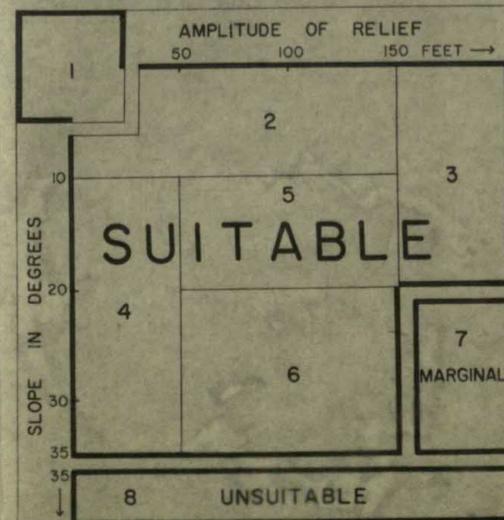
# TERRAIN-SOIL SUITABILITY MAP of the BINTULU-LABANG AREA 4th DIVISION



## KEY OF SOIL SUITABILITY

-  SUITABLE FOR AGRICULTURE
-  MARGINAL FOR AGRICULTURE
-  UNSUITABLE FOR AGRICULTURE

## KEY OF TERRAIN UNITS



N.B. Slopes and heights in units are those that are dominant.

RECONNAISSANCE SOIL MAP  
of the  
BINTULU-LABANG  
AREA  
4th DIVISION



KEY TO SOILS

BRIQUET MAPPING UNIT	ASSOCIATION NUMBER	ASSOCIATION NAME	APPROX. ACREAGE	MAIN SOIL CHARACTERISTICS	TOPOGRAPHY	TENTATIVE AGRICULTURAL SUITABILITY
ORGANIC	311	ANDERSON 1	19,011	3-6" Red peat waterlogged, old containing low levels of available nutrients except in basal layers or margins of NEJANG ASSOCIATION	Virtually flat swamps	Where drained and fertilized can perhaps be used for annual crops
	312	ANDERSON 2	2,375	6-10" Pale brown to dark brown, poor, high food with high water table	Gently undulating beaches	Where drained and fertilized can be used for annual crops and shallow-rooted tree crops
	313	ANDERSON 3	215	As for TATAU but with as much as 3" of surface peat. Very poorly drained	Virtually flat swamps margins	With appropriate drainage and irrigation highly suitable for the intensive cultivation of wet padi or most annual and perennial crops
	11	TATAU	3,87	Pale brown to dark brown, poor, high food with high water table	Low flat-topped, dissected hills	Unsuitable for cultivation
	111	IGAN	741	Light grey to bluish grey clays, rich with as much as 3" of surface peat. Very poorly drained	High levees and flat backswamps	Suitable for cultivation with appropriate fertilizing and drainage. Liable to flooding
	112	MUKAP	490	Mixed alluvium in small valleys. Consists of well drained sandy loams and poorly drained clayey backswamps, some with peat poorly drained	Virtually flat backswamps	Suitable mainly for wet padi cultivation with appropriate fertilizing and drainage. Liable to flooding
	14	MARI	9039	Humus, podsol, infertile, excessively well-drained	Low flat-topped, dissected hills	Unsuitable for cultivation
	24	BUSO	20279	Mixed alluvium in small valleys. Consists of well drained sandy loams and poorly drained clayey backswamps, some with peat poorly drained	High levees and flat backswamps	Suitable for cultivation with appropriate fertilizing and drainage. Liable to flooding
	23	SADONG	4,486	Mainly light grey clay to silty clay with as much as 3" of surface peat. Moderate fertility, poorly drained, high water table	Virtually flat backswamps	Suitable mainly for wet padi cultivation with appropriate fertilizing and drainage. Liable to flooding
	22	STRAP	626	Yellow clay loam to clay on high, very fertile, podsol, brown forest soil, well drained	Low, swampy banks, dissected hills	Mainly suitable for tree crops with appropriate fertilizing
	221	BUJAI	682	Saline, yellow clay loam to clay, well drained, moderately well-drained	Moderate to high slopes on banks of upper stream courses	Potentially fertile but at low agricultural value until reclaimed
	21	UNDUP	2009	Saline, yellow clay loam to clay, well drained, moderately well-drained	Macarthur hummocky	Unsuitable for cultivation
	33	REJANG	3,982	Pale yellow podsol, sandy loam to sandy clay loam. Commonly shallow, poorly drained	Dip slopes of siltstone	Unsuitable for cultivation
	44	PENRISSEN	12,3705	Podsol, yellow and brownish yellow sandy yellow clay loam on broken yellow or red sh. well to moderately well-drained	Mainly medium to high hills, moderate to steep slopes	Suitable for a wide range of crops with appropriate fertilizing. Erosion control necessary on slopes exceeding 15-20°
	444	NYALAU	633	Podsol, brownish yellow sandy clay loam on brownish yellow to redish yellow clay, well to moderately well-drained	Low to high hills steep and gentle slopes	As for NYALAU but erosion control is necessary on slopes greater than 25-30°
	457	BEKENU	16,54	Podsol, brownish yellow sandy clay loam on brownish yellow to redish yellow clay, well to moderately well-drained	Mainly low to medium hills, moderate to steep slopes	As for NYALAU but erosion control is necessary on slopes greater than 25-30°
	455	MERIT	11,6375	Podsol, brownish yellow sandy clay loam on brownish yellow to redish yellow clay, well to moderately well-drained	Sandy dissected marine and riverine terraces	Refer to individual associations
	51	MIRU, BUSO, BEKENU and PANTU ASSOCIATIONS	16,54	Undifferentiated marine and old estuarine alluvium and peat	Flat	Refer to individual associations
	52	3/11/112	16,54	Undifferentiated marine and old estuarine alluvium and peat	Flat	Refer to individual associations
	22/31	4447, 4547, 4548, 4549, 4550	11,6375	Undifferentiated peat and riverine alluvium	Low to high, steep to gentle slopes	Refer to individual associations
	644/645/646/647		4,771	Refer to individual association	Low to high, steep to gentle slopes	Refer to individual associations



SCALE 1:100,000

