Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1

Soils and Land Suitability of the Agricultural Development Areas

Contract: LTN/6/31/2003(10)

CSIRO Land and Water
Department of Agriculture
2008

Brunei Darussalam
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Sam Grigg of URS Pty Ltd provided invaluable field assistance during the field survey. Rob Kingham, Mark Grant and Tania Laity of Bureau of Rural Sciences, Canberra provided database and geographic information system (GIS) support and Alan Marks, CSIRO Land and Water provided remotely sensed imagery.

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Bernie Powell and Phil Moody, Queensland Department of Natural Resources and Water, thoroughly reviewed this work and suggested many improvements that have enhanced the project outcomes.
Summary

The Department of Agriculture of Negara Brunei Darussalam commissioned the project Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam to assist the country’s commitment to achieve a significant degree of food security. This commitment requires increases in the level of self-sufficiency in rice, fruit, vegetables and animal production. This could be achieved through yield increases per hectare, having more crops per year, and by developing new areas for agricultural production. The overall objectives of the project were:

- To provide information on the properties of Soil Types of the Agricultural Development Areas (ADAs) and their suitability for crop cultivation that will facilitate the matching of land to uses that are profitable for farmers, sustainable and meet the country’s requirements.
- To recommend soil and nutrient management practices for the sustainable management of soil resources in Brunei that improve productivity and minimize adverse effects on the environment.

A field survey was conducted of 27 ADAs to characterise, classify and map the soils. The fertility limitations of the identified Soil Types were assessed and their suitability evaluated for a range of crops. An assessment was made of the spatial distribution of Soil Types within the ADAs, together with an assessment of which crops are suitable for different parts of the landscape.

Soil management approaches were recommended to address the various soil limitations to cropping identified for each Soil Type. This allows soil management for each crop to be tailored to the individual Soil Types for which it is suitable. A fertilizer and lime calculator was developed to recommend sustainable nutrient management practices for a range of crops.

The occurrence and properties of acid sulfate soils were investigated in detail because they have some special characteristics that make them difficult to manage for agriculture without causing damage to the environment. Management recommendations were made that allow them to be safely used for cropping without releasing acid and other pollutants.

Methods

Field Survey

The strategy was to determine the pattern of Soil Types that occurs within soil map unit boundaries from previous soil surveys. 295 sites were selected to determine toposequences (regular sequences of Soil Types from hill crest to valley bottom) within different landscapes. The soil profiles at sample sites were described to allow classification and provide the information required for the subsequent land evaluation. In addition, samples were taken from 214 soil layers in 60 soil profiles for laboratory analyses of chemical, physical and mineralogical properties. Whilst sample sites were limited to the ADAs, the ADAs are spread throughout the districts, and it is likely that the majority of Soil Types occurring in Brunei were identified.

Soil Classification

The soil classification system used was Soil Taxonomy. This is an internationally recognized system that allows international technology transfer, because similar soils anywhere in the world can be easily identified and successful management practices can be adapted for local use with minimal need for local field trials.

However, Soil Taxonomy requires considerable expertise and experience, and often involves laboratory analysis. Therefore a simplified Soil Identification Key, specific to the soils that occur in Brunei Darussalam, was developed. It is based on easily observable or measureable soil characteristics. The Soil Identification Key separates out the same soil classes as would occur if Soil Taxonomy was to be used. It recognises 10 Soil Types and 24 Soil Subtypes.
Land Evaluation

The suitability of the Soil Types was evaluated for 69 field, fruit and fodder crops, organised in 27 groups, that are currently grown or have the potential to be grown in Brunei. Suitability was determined within the FAO (1976) Framework for Land Evaluation and involved 4 steps:

1. Assessment of Soil Types in terms of attributes that affect sustainable crop production and that only change over the medium to long term using the Fertility Capability Classification (FCC) of Sanchez et al. (2003). Attributes included:
   - Soil texture (organic, sand, clay, loam)
   - Waterlogging
   - Slope
   - Erosion risk
   - Sulfidic material
   - Soil acidity/aluminium toxicity
   - Low nutrient reserves
   - High P fixation and/or iron toxicity
   - Cracking clays
   - High leaching potential

2. Assessment of the limitations posed by FCC attributes on each crop in terms of their impact on crop production or the degree of amelioration required to overcome them.

3. For each Soil Type × crop combination, rating the limitations posed by each FCC attribute by applying the crop requirements from step 2 to the FCC attributes of the Soil Type from step 1.

4. Determining the overall suitability of each Soil Type for each crop using the rating of the most limiting attribute (assuming negligible climate variability across Negara Brunei Darussalam, and crop pre-selection for its wet equatorial climate).

The definitions of the land suitability classes are as follows:

1. **Highly suitable land** with no significant limitations to sustained application of the specified use.

2. **Suitable land** with minor limitations to the sustained application of the specified use that will cause a minor reduction of productivity and will not raise inputs above an acceptable level.

3. **Moderately suitable land** with major limitations to the sustained application of the specified use that reduce productivity and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be significantly less than from Class 1 or 2 land.

4. **Marginally suitable land** with severe limitations to the sustained application of the specified use that so reduce productivity and benefits, or increase required inputs, that this expenditure will be only marginally justified.

5. **Unsuitable land** with such severe limitations that they preclude the sustained application of the specified use.

It is most important to appreciate that land suitability classes cannot be used as the only factor to determine which crop is the best choice for a particular location, because the assessment involves no economic or policy information. The suitability class informs decision makers about the bio-physical limitations for a particular crop.

Soil Database and Geographic Information System (GIS)

All field and laboratory data gathered during the project are stored in a database, with tables for site description data for 295 sites, soil layer description data for 1257 soil layers, soil layer laboratory data for 214 soil layers, and extra soil layer laboratory data relating to acid sulfate soils for 30 soil layers.

A GIS was developed for the project that includes base data (road, rivers, contours), together with ADA boundaries. Sample site locations and soil map unit polygons from previous soil surveys are also included. The map units are linked to both soil classification information and to information on land suitability and acid sulfate soil hazard. This allows maps showing the suitability of map units for a particular crop or the acid sulfate soil hazard to be presented for each ADA.
Description of Major Soil Types

Ten major Soil Types were identified during the field survey and included in the Soil Identification Key with their Fertility Capability Classification (FCC) attributes and their suitability for a range of crops.

Organic Soils (Sapristis)

The Organic soils occur on alluvial flats. They occupy about 10% of the surveyed area, mainly in the broad alluvial plains of ADAs in Brunei-Muara and Belait. They consist of a thick layer of organic material near the soil surface, sometimes with layers of mineral soil. They are a dark grey to black colour, very poorly drained, and the watertable is near the surface. They are acid sulfate soils, and either have sulfidic material (pH >3.5, but decreases to <3.5 on incubation) or a sulfuric layer (pH <3.5) in the upper 50 cm.

The attributes that influence land use for Organic soils are their organic topsoil texture, prolonged waterlogging, shallow sulfidic/sulfuric material, acidity, and high potential for P fixation and iron toxicity. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Vegetables (marginal where sulfidic material is at &lt;20 cm depth)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grasses, and fodder legumes adapted to wet areas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unsuitable or marginally suitable for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
</tr>
<tr>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td>All fruit crops assessed</td>
</tr>
<tr>
<td>Fodder legumes adapted to well drained areas</td>
</tr>
</tbody>
</table>

White Soils (Aquods)

The White soils occur on old sand dunes from a previous coast line. They occupy less than 3% of the surveyed area, mainly in Tungku ADA in Brunei-Muara and Km 26, Jalan Bukit Puan Labi ADA in Belait. They consist of a thick whitish or pale grey sandy layer overlying a black organic layer that occurs within two meters of the soil surface. They are usually very deep (>150 cm) and poorly drained.

The attributes that influence land use for White soils are waterlogging (sometimes prolonged) and low nutrient reserves. Some Subtypes have a sandy texture and are susceptible to nutrient leaching. These attributes affect their suitability for cropping according to Subtype as follows:

<table>
<thead>
<tr>
<th>Loamy poorly drained white soil</th>
<th>Sandy poorly drained white soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable or moderately suitable for:</td>
<td>Vegetables</td>
</tr>
<tr>
<td>Rice</td>
<td>Ginger and turmeric</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Grasses, and fodder legumes adapted to wet areas</td>
</tr>
<tr>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
<td></td>
</tr>
<tr>
<td>Most fruit crops (except those listed below)</td>
<td></td>
</tr>
<tr>
<td>Grasses and fodder legumes</td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>All fruit crops assessed</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes adapted to well drained areas</td>
</tr>
</tbody>
</table>

Cracking Clay Soils (Aquerts)

The Cracking clay soils occur on alluvial flats. They occupy about 10% of the surveyed area, mainly in Wasan, Si Tukak and Limpaki ADAs in Brunei Muara. They consist of very deep
(>150 cm), heavy clay soil that cracks when dry. They are grey coloured with orange/yellow spots in the upper subsoil, and are poorly drained. They are acidic (pH <4.5) and some are also acid sulfate soils with sulfidic material.

The attributes that influence land use for Cracking clay soils are their heavy clay texture, prolonged waterlogging, moderate acidity, and high potential P fixation and iron toxicity. Some Subtypes have shallow sulfidic material. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables (except root vegetables)</td>
</tr>
<tr>
<td></td>
<td>Grasses, and fodder legumes adapted to wet areas</td>
</tr>
<tr>
<td>Unsuitable or marginally suitable for:</td>
<td>Root vegetables</td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>All fruit crops assessed</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes adapted to well drained areas</td>
</tr>
</tbody>
</table>

**Texture Contrast Yellow Soils (Udults)**

The Texture contrast yellow soils occur on slopes of hills. They occupy less than 1% of the surveyed area, mainly on steep slopes in Tungulian, Malayan A and Km 26, Jalan Bukit Puan Labi ADAs in Belait. They consist of very deep (>150 cm), yellowish brown soil, with a sandy layer overlaying a loamy or clayey layer. They are well drained.

The attributes that influence land use for Texture contrast yellow soils are sandy topsoil texture, steep slopes, erosion hazard, acidity, low nutrient reserves and susceptibility to nutrient leaching. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>Most fruit crops (except those listed below)</td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
<tr>
<td>Unsuitable or marginally suitable for:</td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Durian, Langsat-duku and mangosteen</td>
</tr>
</tbody>
</table>

**Very Deep Yellow Soils (Humults)**

The Very deep yellow soils occur on slopes of hills or on river terraces. They occupy about 24% of the surveyed area and are widespread in most ADAs containing sloping land. They consist of very deep (>150 cm), yellowish brown soil. They generally have loamy or clayey subsoil texture, and are well drained to somewhat poorly drained.

The attributes influencing land use for Very deep yellow soils are acidity and low nutrient reserves. Some Subtypes have waterlogging, others have moderate to steep slopes and an erosion hazard. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>Most fruit crops (except those listed below)</td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
<tr>
<td>Somewhat poorly drained Subtypes</td>
<td>Other Subtypes</td>
</tr>
<tr>
<td>Vegetables (unsuitable on steeper slopes)</td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato (unsuitable on steeper slopes)</td>
</tr>
<tr>
<td>All fruit crops assessed (marginal on steeper slopes)</td>
<td>Grasses and fodder legumes</td>
</tr>
</tbody>
</table>
Yellow Soils (Haplohumults)

The Yellow soils occur on slopes of hills. They occupy about 32% of the surveyed area and are widespread in most ADAs containing sloping land. They consist of deep (100-150 cm), yellowish brown clayey or loamy soil overlying weathered rock material. They are well drained.

The attributes that influence land use for Yellow soils are steep slope, erosion hazard, acidity, low nutrient reserves, and high potential for P fixation. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Vegetables (unsuitable on steeper slopes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato (unsuitable on steeper slopes)</td>
</tr>
<tr>
<td></td>
<td>All fruit crops assessed (marginal on steeper slopes)</td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
</tbody>
</table>

Yellow Soils (Haplohumults)

| Unsuitable for: | Rice |

Brown Over Grey Soils (Aqualfs)

The Brown over grey soils occur on flats of alluvial valleys. They occupy about 10% of the surveyed area, mainly in alluvial valleys in ADAs in Tutong and Temburong, but also in Sg Tajau and Luahan ADAs in Brunei-Muara and Merangking ADA in Belait. They consist of a yellowish brown clay or loamy layer with red/orange spots overlying a grey clay layer. They are deep (>100 cm) and poorly drained to somewhat poorly drained.

The attributes that influence land use for Brown over grey soils are clayey texture, waterlogging (sometimes prolonged), acidity, low nutrient reserves and high potential for P fixation and iron toxicity. These attributes affect their suitability for cropping according to Subtype as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Somewhat poorly drained brown over grey soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>Most fruit crops (except those listed below)</td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for:</th>
<th>Poorly drained brown over grey soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Ginger and turmeric</td>
</tr>
<tr>
<td></td>
<td>Grasses, and fodder legumes adapted to wet areas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unsuitable or marginally suitable for</th>
<th>Durian, langsat-duku, citrus, and papaya</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>All fruit crops assessed</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes adapted to well drained areas</td>
</tr>
</tbody>
</table>

Sulfuric Soils (Aquepts)

The Sulfuric soils occur on alluvial flats. They occupy about 9% of the surveyed area, mainly in the broad alluvial plains of ADAs in Brunei-Muara. They consist of very deep (>150 cm), grey, clay or loamy soil, with a sulfuric layer (pH <3.5). They are poorly drained.

The attributes that influence land use for Sulfuric soils are waterlogging, shallow sulfidic/sulfuric material, acidity. Some Subtypes have sandy texture, low nutrient reserves
and are susceptible to nutrient leaching. Others have clayey texture and high potential for P fixation. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for</th>
<th>Rice <em>(unsuitable where topsoil is sandy)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables <em>(unsuitable where sulfuric layer is at &lt;20 cm depth)</em></td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato <em>(unsuitable where sulfuric layer is at &lt;20 cm depth)</em></td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
</tbody>
</table>

| Unsuitable or marginally suitable for | Most fruit crops assessed |

**Sulfidic Soils (Aquents)**

The Sulfidic soils occur on alluvial flats. They occupy less than 4% of the surveyed area, mainly in the broad alluvial plains of ADAs in Brunei-Muara, but also in Km 26, Jalan Bukit Puan Labi ADA in Belait. They consist of very deep (>150 cm), grey, clay or loamy soil, with sulfidic material (pH >3.5, but decreases to <3.5 on ageing). They are poorly drained.

The attributes that influence land use for Sulfidic soils are clayey topsoil texture, prolonged waterlogging, shallow sulfidic material, acidity, low nutrient reserves and high potential for P fixation and iron toxicity. Some minor Subtypes have sandy topsoil texture and are susceptible to nutrient leaching. Others have organic topsoil texture. The attributes of the major Subtype affect its suitability for cropping as follows:

**Soft poorly drained sulfidic soil**

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Ginger and turmeric</td>
</tr>
<tr>
<td></td>
<td>Grasses, and fodder legumes adapted to wet areas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unsuitable or marginally suitable for</th>
<th>Groundnuts, soya and mung bean, maize, cassava and sweet potato</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All fruit crops assessed</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes adapted to well drained areas</td>
</tr>
</tbody>
</table>

**Grey Soils (Aquents)**

The Grey soils occur on alluvial flats. They occupy less than 1% of the surveyed area, mainly in the broad alluvial plains of ADAs in Brunei-Muara. They consist of very deep (>150 cm), grey, sandy to clayey soil, with no diagnostic horizons or characteristics. They are poorly drained.

The attributes that influence land use for Grey soils are clayey or sandy topsoil texture, waterlogging, acidity, low nutrient reserves, and high potential P fixation. These attributes affect their suitability for cropping as follows:

<table>
<thead>
<tr>
<th>Suitable or moderately suitable for</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>Most fruit crops (except those listed below)</td>
</tr>
<tr>
<td></td>
<td>Grasses and fodder legumes</td>
</tr>
</tbody>
</table>

| Marginally suitable for: | Durian, langsat-duku, citrus and papaya |
Land suitability in the Agricultural Development Areas

Soil maps of the ADAs show the geographical extent of soil map units. The map units partition the landscape into areas that have similar soils and landforms. These can then be interpreted in terms of land suitability and management. In this section ‘suitable’ refers to suitability classes 1 (highly suitable), 2 (suitable) and 3 (moderately suitable).

Brunei-Muara

The landscape in most of the surveyed ADAs in Brunei-Muara can be divided into four components:

**Broad, low-lying alluvial plains with Organic, Sulfuric and Sulfidic soils** occupy all of Betumpu (474 ha), Si Bongkok Parit Masin (127 ha), Lumapas (38 ha) and Pengkalan Batu (45 ha) ADAs, and parts of the Si Tukak Limau Manis (157 ha) and Limpaki (72 ha) ADAs. The main limitations are prolonged waterlogging, shallow acid sulfate material, and soil acidity. The peaty texture of the Organic soils is also a limitation. Most of this area is suitable for vegetables, grasses and fodder legumes suited to wet areas. About 65% of the area is suitable for rice where the soil type is not Organic. However, the intricate pattern of Soil Types may make it difficult to delineate large enough areas of suitable soils. Where waterlogging is less severe (about 40% of the area), groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato may be grown.

**Broad, low-lying alluvial plains with Cracking clay soils** occupy all of Wasan ADA (372 ha), and parts of the Si Tukak Limau Manis (57 ha) and Limpaki (19 ha) ADAs. The main limitations are the heavy clay texture and prolonged waterlogging. These areas are suitable for rice, vegetables (except root vegetables), grasses, and fodder legumes adapted to wet conditions.

**Narrow, alluvial valleys** comprising Brown over grey soils occupy part of in Luahan ADA (25 ha). The main limitation is prolonged waterlogging. These areas are suitable for rice, vegetables, ginger, turmeric, grasses and fodder legumes adapted to wet conditions.

**Hilly areas** comprising Yellow soils on steep slopes occupy parts of Si Tukak Limau Manis (41 ha) and Luahan (48 ha) ADAs. The main limitation is the steep slope. They are suitable for grasses and fodder legumes. Where the slope is less than 35% they are also suitable for vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato. A wide variety of fruit crops can be grown where the slope is less than 65%.

Tungku ADA has a different landscape. There are slopes with Yellow soils similar to the hilly areas described above (102 ha). There are also dunes with White soils (79 ha) that may be suitable for rice, short duration crops and most of the fruit crops assessed except durian, langsat-duku and papaya. In the flats between the dunes (80 ha) are Sulfuric soils that are only suitable for grasses and fodder legumes due to shallow acid sulfate material.

The landscape in Sungai Tajau ADA is similar to that in Tutong (see below).

Tutong

All the ADAs surveyed in Tutong together with Sungai Tajau ADA in Brunei-Muara have similar landscapes. There are two groups of landscape components.

**Alluvial valleys and lower slopes** with Brown over grey soils and Somewhat poorly drained clayey very deep yellow soils, respectively, occupy parts of Kupang (12 ha), Maraburong (21 ha), Padnunok/Sg Burong (33 ha), Batang Mitus (Buah) (29 ha), Batang Mitus (Halaman) (109 ha), Birau (P.P. Muda) (24 ha), Birau (Penyelidikan) (32 ha) and Sg Tajau (37 ha) ADAs. The main limitation is waterlogging. The area is suitable for rice, vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato, and most fruit crops assessed except durian, langsat-duku, citrus and papaya. They are also suitable for grass and fodder legumes.
Mid slopes, upper slopes and hill crests with Yellow soils and Sandy very deep yellow soils occupy parts of Kupang (48 ha), Maraburong (37 ha), Padnunok/Sg Burong (97 ha), Batang Mitus (Buah) (488 ha), Batang Mitus (Halaman) (476 ha), Birau (P.P. Muda) (57 ha), Birau (Penyelidikan) (165 ha) and Sg Tajau (94 ha) ADAs. The main limitation is their steepness. They are suitable for grasses and fodder legumes. Where the slope is less than 35% they are also suitable for vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato. A wide variety of fruit crops can be grown where the slope is less than 65%.

Belait

There are a wide variety of landscapes in the Belait ADAs. In terms of their land suitability there are five groups of landscape components:

Low lying swamps with Organic soils cover parts of Tungulian (10 ha), Merangking (27 ha), Melayan A (8 ha), Labi Lama (40 ha) and Km 26 Jalan Bukit Puan Labi (12 ha) ADAs. The main limitations are the peaty texture, prolonged waterlogging and shallow acid sulfate material. They are only suitable for vegetables, grasses and fodder legumes adapted to wet conditions.

Alluvial valley bottoms with Brown over grey soils occur in Merangking ADA (146 ha), and dunes with White soils in Km 26 Jalan Bukit Puan Labi ADA (14 ha). In both situations the main limitation is prolonged waterlogging. They are only suitable for rice (not on White soils), vegetables, ginger, turmeric, grasses, and fodder legumes adapted to wet areas.

Alluvial plains with Sandy very deep yellow soils occur in Rampayoh (42 ha) and Labi Lama (10 ha) ADAs and flats between dunes with Sulfidic soils occur in Km 26 Jalan Bukit Puan Labi ADA (11 ha). Their main limitation is waterlogging. They are suitable for rice (except the Sulfuric soils), vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato. Most of the fruit crops assessed can be grown except durian, langsat-duku, papaya and, in the case of Sulfuric soils, mangosteen. They are all suitable for grasses and fodder legumes.

Alluvial terraces with Clayey very deep yellow soils occur in Merangking ADA (140 ha). They are suitable for rice, all the short duration and fruit crops assessed, and grasses and fodder legumes.

Slopes with Texture contrast yellow soils, Very deep yellow soils and Yellow soils occupy parts of Rampayoh (62 ha), Tungulian (82 ha), Merangking (173 ha), Melayan A (6 ha) and Km 26 Jalan Bukit Puan Labi (15 ha) ADAs. The main limitations are their steepness and soil erosion hazard. They are suitable for grasses and fodder legumes. Where the slope is less than 35% they are also suitable for vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato. A wide variety of fruit crops can be grown where the slope is less than 65%.

Temburong

The soil-landscape patterns in the ADAs surveyed in Temburong are similar although the proportions of various landscape components differ between them.

Alluvial flats with Brown over grey soils occur in Labu Estate (14 ha), Selangan (19 ha), Bakarut (3 ha) and Selapon (19 ha) ADAs. The main limitation is prolonged waterlogging. They are suitable for rice, vegetables, ginger, turmeric, grasses, and fodder crops adapted to wet conditions.

Alluvial terraces with Clayey very deep yellow soils occur in Selangan (37 ha), Bakarut (6 ha) and Selapon (28 ha) ADAs. They are suitable for rice, all the short duration and fruit crops assessed, and grasses and fodder legumes.

Slopes with Yellow soils occur in Labu Estate (83 ha), Bakarut (29 ha) and Selapon (34 ha) ADAs. Their main limitation is steepness and soil erosion hazard. They are suitable for grasses and fodder legumes. Where the slope is less than 35% they are also suitable for vegetables, groundnuts, soya and mung bean, maize, ginger, turmeric, cassava and sweet potato. A wide variety of fruit crops can be grown where the slope is less than 65%.
Sustainable Soil and Nutrient Management

The process of evaluating the suitability of land for different crops involves identifying land attributes that are limitations for each crop. In Brunei most serious limitations were:

- Soil acidity
- Sulfidic material
- Waterlogging
- Steep slopes

Whilst different crops are limited to different degrees by each attribute, it is possible to recommend some generic management strategies to ameliorate the limitations. These strategies are discussed below after a consideration of climate.

Climate

Brunei has a humid, equatorial climate characterised by high rainfall, high temperatures and humidity, lack of definite seasons and limited changes in day length through the year. The mean annual rainfall at Kilanas is 2700 mm/year. October to January have the greatest mean monthly rainfall of around 300 mm/month. February to April are usually the driest months with 150 mm/month. However, there is considerable variation in the annual pattern of rainfall. There is no distinct dry season. Thus it is not possible to define a reliable time of year when it is possible to grow dry season crops.

Soil Acidity

Soil Types affected: All soils except Sandy poorly drained white soils.

Soil acidity is widespread in Brunei with pH values typically between 4.2 and 4.9. However, 25% were more acidic than this and 7% had pH less than 3.5. Soil acidity affects crop production mainly through aluminium toxicity, because Al becomes increasingly more soluble below pH 5.5. Other effects are manganese toxicity, and deficiencies of calcium, magnesium, potassium and some micronutrients. For most crops, pH should be maintained above 5.5.

Lime should be applied to raise the pH to the target value. The amount of lime required depends on the difference between current and target pH values, the pH buffering capacity (pHBC), the depth of soil to be treated and the bulk density. There are no pHBC data for Brunei, and priority should be given to generating pHBC data so that lime can be applied efficiently. In the interim there are various methods available to estimate pHBC.

In addition to liming, the rate of soil acidification should be minimised to increase the residual value of lime and decrease the frequency and/or rate of lime applications. Practices include avoiding over liming, minimising removal of crop residues, minimising nitrate leaching, and using less acidifying forms of fertilizer.

Sulfidic Material

Soil Types affected: Organic, Sulfidic poorly drained cracking clay, Sulfuric and Sulfidic soils.

See section below on acid sulfate soils.

Waterlogging

Soil Types affected: Organic, White, Cracking clay, Somewhat poorly drained very deep yellow, Brown over grey, Sulfuric, Sulfidic and Grey soils

The climate, landscape and soils of Brunei predispose much of the country to waterlogging. The major causes are high rainfall, shallow groundwater (often <0.5 m from the surface), perched watertables (overlying unsaturated soil) due to low subsoil permeability, poor surface drainage due to low gradients on flat lowlands, and convergent runoff where hills with steep slopes shed rainfall into narrow valley floors as runoff. Waterlogging is alleviated by aerating the soil root zone, using the following methods:
Lowering the watertable using a network of deep drains. This method is not recommended in Brunei because of the widespread occurrence of acid sulfate soils (see below).

Improving surface drainage to remove excess rain and prevent it from infiltrating. It requires a well maintained network of furrows, farm drains and public drains. The furrows and farm drains should not be deep enough to lower the watertable and cause oxidation of any sulfidic material.

Artificial subsurface drainage: using a network of buried pipes. Such systems are not recommended in Brunei, because they lower the watertable (see above).

Improving soil permeability helps water drain through the soil more rapidly. It is achieved by loosening the soil with tillage, but only when the soil is dry enough not to cause compaction; maintenance of organic matter; and minimizing tillage to conserve soil structure.

Raised beds to increase the depth of soil above the watertable. Good soil structure should be maintained in the beds by avoiding traffic and tillage when wet; incorporating manure; and retaining crop residues. Care must be taken not to use sulfidic material.

Organic soils are common in the lowland of Brunei. A consequence of using these soils for agriculture is that when they are drained, either by lowering the watertable or by making raised beds, the organic matter oxidizes and the soil resource is depleted. This causes subsidence and has several serious consequences. The watertable becomes closer to the surface, whilst flooding becomes more difficult to control. Any layers with sulfidic material come closer to the surface, and it becomes increasingly difficult to find non-sulfidic material with which to replenish raised beds. Large quantities of greenhouse gases are released. Drained peat is prone to fire that is very difficult to extinguish. Whilst the rate of subsidence can be slowed by careful water management to allow economic use of peatlands, these processes are nevertheless inevitable and irreversible, and place severe limitations on the long-term sustainable use of these soils.

Water Erosion

Soil Types affected: Texture contrast yellow, Well drained very deep yellow, and Yellow soils

Farming on steep land is common in Brunei. However, the soils on steep land are generally sandy, deep and well drained, which encourages infiltration and lowers the risk of erosion. The humid climate encourages growth of ground cover which protects the soil from erosion. Nonetheless, steps should be taken to reduce the risk of soil loss.

Maintain plant cover to protect the soil surface from raindrop impact and crust formation, and slow the velocity of runoff. Pasture should be grown under perennial fruit trees. Annual crops should be grown on raised beds along the contour with only the top of the bed cultivated, and grassy cover maintained elsewhere. When clearing new areas of land, only clear narrow strips a few metres wide.

Retain crop residues to help to protect the soil surface from raindrop impact, and maintain soil organic matter, which increases soil structural stability.

Minimise tillage since loose, bare soil is prone to erosion.

Construct mini-terraces for fruit trees to locally reduce the slope and reduce runoff.

Maintain grassed waterways on natural waterways and other areas that tend to accumulate water, such as farm tracks, to minimize the risk of gullies forming.

Nutrient Management

The soil limitations discussed above reduce the ability of crops to use nutrients effectively. Therefore successful nutrient management has three prerequisites:

- Do not grow crops on unsuitable land.
On suitable land, identify the soil constraints to a particular crop, and ameliorate them as much as possible. It is normally not possible to fully ameliorate all soil constraints, in which case actual production will be less than potential production.

Aim to maintain nutrient levels in the soil by replacing those removed during the cropping cycle. Replacement should take into account actual crop production rather than potential production. Assuming potential production will lead to over application of nutrients, which is both economically wasteful and likely to result in off-site pollution by excess nutrients.

**Nutrient Management Components**

The nutrient management strategy recommended for Brunei has three components:

1. **Ameliorating low soil nutrient reserves** is required on undeveloped land with no history of fertilizer use, because many soils of the humid tropics (especially Texture contrast yellow, Very deep yellow, Yellow and Brown over grey soils) are highly weathered and naturally low in nutrients. Where soil levels of P, K, Ca and Mg are below critical thresholds for successful cropping, slightly more fertilizer than the crop needs should be applied to gradually increase soil nutrient levels. These nutrients can accumulate in the soil, so this incremental approach allows the cost of amelioration to be spread over several years.

2. **Minimising nutrient losses** is desirable both financially and environmentally. The major losses are as follows:
   - **Gaseous losses** of nitrogen occur due to a) denitrification of nitrate by soil microorganisms in waterlogged soils and b) volatilisation of ammonia. They are likely in the warm, wet conditions in Brunei, but can be minimized by:
     - Controlling waterlogging to minimize denitrification;
     - Using an ammonium form of fertilizer to minimize denitrification;
     - Waiting after liming before using ammonium fertilizers to minimize volatilisation,
     - Incorporating fertilizer and manure to minimize volatilisation;
     - Using polymer coated nitrogenous fertilizer to minimize volatilisation.
   - **Leaching** is more prevalent in coarse textured soils with high permeability (e.g. White, Texture contrast yellow, and Sandy very deep yellow soils), especially in high rainfall environments like Brunei. Leaching is more important for mobile nutrients that are either not adsorbed (nitrate) or weakly adsorbed (potassium). Leaching can be minimized by:
     - Ameliorating other soil constraints to optimize the crop’s ability to take up nutrients;
     - Using deep-rooted crops in the farming system to capture sub-soil nutrients;
     - Avoiding over-application of fertilizers;
     - Splitting fertilizer applications to apply N in small doses;
     - Avoiding over-irrigation.
   - **Erosion** results in nutrient loss and should be managed as described above.
   - **Removal of crop residues and manures** represents a loss of nutrients. Removal of crop residues should be minimised.

3. **High P fixation** occurs in some Soil Types that strongly adsorb applied P, making much of it unavailable to crops. The Soil Types affected are Organic, Cracking clay, Clayey very deep yellow, Yellow, Brown over grey, Sulfuric, Sulfidic, and Grey soils. Under prolonged waterlogging these soils also have potential to cause iron toxicity in rice. The effects of P fixation can be minimized by:
   - Placing fertilizer in bands beside/below the crop seeding line;
   - Using citrate soluble fertilizers such as rock phosphate;
   - Maintaining soil organic matter content.

3. **Maintenance of soil nutrients** is required once the soil nutrient status has been improved above critical thresholds for each nutrient. This is achieved using a nutrient budget.
approach that offsets the amount of nutrient removed by crop and that lost from the soil by leaching, volatilisation, runoff, etc. with maintenance applications of fertilizer and manure.

Nutrient sources to improve and maintain the soil nutrient status include fertilizers, manure and biological nitrogen fixation. Whilst fertilizers are a cost effective means to apply nutrients, it is important that they meet international standards to avoid contamination with heavy metals. Manures have the additional advantage of adding organic matter.

The build-up phase to improve nutrient deficient soils has been completed in most farmed soils in the ADAs, and many now have very high P and K status. This suggests fertilizer is being over applied to the extent that crops no longer respond economically. This happens either when the soil nutrient status is increased above that required to reach the potential yield for the crop or, more likely, when the crop yield is limited by other constraints that have not been fully ameliorated.

**Nutrient Balance-Based Fertilizer Calculator**

Fertilizer recommendations should be based on calculating the nutrient budget. Nutrient inputs include additions of fertilizer and manure and biological N fixation. Outputs include product removal, and nutrient losses through mechanisms discussed above.

At this stage there is uncertainty about many components of the nutrient budget in Brunei because of limited information. To encourage the use of nutrient budgeting where there are such uncertainties, a fertilizer calculator has been developed as part of this project. The calculator should assist Department of Agriculture to make fertilizer recommendations for individual situations. It requires minimal user inputs by gleaning as much information as possible from the literature. However, since the relevance of much of this information to Bruneian conditions is unknown, it leaves open the option of using inputs of locally derived information as it becomes available. Indeed it is intended that, as well as assisting fertilizer recommendations directly, it will help prioritise those topics that require data gathering by the Department.

The principle of the calculator is to recommend amounts of fertilizer to replace those nutrients removed by previous crops and that will be lost during the current crop. In addition, it assesses the nutrient status of the soil at sowing and where the status of individual nutrients is low it includes extra inputs to build up fertility.

The components of the calculator and the inputs it requires are as follows.

- **Nutrient removal by the previous crop** is determined from its yield (which must be measured by the user) and the nutrient content of the harvested crop. All crop residues are assumed to have been returned to the soil.

- **N requirement by the current crop** is determined from the expected yield (based on previous measurements by the user for similar crops) and the N content of the crop.

- **Fertilizer efficiency** is used to account for nutrient losses during the current crop and is adjusted according to the Soil Type (which must be determined by the user).

- **A fertility factor** is used to build up soil nutrient reserves if they are below critical thresholds for the current crop. If reserves are very high due to over application of fertilizer, the fertility factor will draw down nutrient reserves. If the nutrient status is unknown, the calculator assumes it is below the critical thresholds for each nutrient if the site has no history of regular fertilizer application. Otherwise it assumes the status of each nutrient is above the threshold.

This information is used to calculate the amount of fertilizer required after allowing for additions of manure. The calculator also estimates the amount of lime required based on the measured pH of the soil.
Acid Sulfate Soils

Acid Sulfate Soils (ASS) are soils in which sulfuric acid has or may be produced. ASS form from the interaction of sulfates, usually from seawater, iron from sediments and abundant organic material under permanently waterlogged conditions. These conditions lead to the formation of sulfide-containing minerals, predominantly iron pyrite (FeS$_2$). Soil that contains sulfides (sulfidic material) produces sulfuric acid if exposed to air, and its pH falls to 3.5 or less to form a sulfuric layer. During this process, acid drainage water is produced, together with toxic elements. If this water enters waterways and it can kill fish, pollute drinking water, and can corrode concrete and steel in buildings and underground pipes. The acidity in these soils includes actual acidity and acid generating potential (AGP). AGP is related to the amount of sulfides in the soil.

ASS are widespread in Brunei, mainly occurring on the broad, low-lying alluvial plains of Brunei-Muara and Belait. They were found in 9 of the ADAs. 27 sites were inspected and 7 were sampled for detailed analysis. Samples from 30 soil layers were collected and analysed for chemical, mineralogical and physical properties. Of the ten Soil Types identified, Organic, Sulfuric and Sulfidic soils are ASS, as well as the Sulfidic poorly drained cracking clay Soil Subtype. Most ASS sampled were already acidic in the surface layers (0-50 cm depth). However, the AGP of these layers was low because most of the sulfidic material had already oxidised, probably because drainage has been used to lower shallow watertables. Deeper layers had moderate levels of acidity but very high AGP.

Recognition of Acid Sulfate Soils

Successful management of ASS, requires that they are first recognised as such. ASS are included in the Soil Identification Key to allow the easy identification of those Soil Types that are ASS. ASS contain either a sulfuric layer or sulfidic material. Sulfuric layers have pH <3.5. Sulfidic materials are recognized by testing their pH before (>3.5) and after (<3.5) ageing or incubating a sample. There are simple field and laboratory methods for inducing ageing.

Whilst the soil at a lowland site should always be tested, the likelihood of encountering an ASS in one of the surveyed ADAs can be seen in the acid sulfate soil hazard maps produced by the project.

Management Options

Management of ASS is intimately linked to the overall management of the hydrology. Poor management of the watertable will result in increased acidification, poor production, environmental degradation and ultimately the loss of the soil resource itself. There are three options for ASS management.

Avoid Disturbance

Where tests show high levels of sulfidic material the preferred option is not to develop them, since the economic and environmental risks of doing so are severe. In the case of Organic soils there is a substantial risk of subsidence and eventually complete loss of the resource.

Minimize Disturbance

Where tests show low levels of sulfidic material, ASS can be safely used by careful management of the watertable to prevent further oxidation and acid generation. Both the climate and hydrology in Brunei are favourable in this regard.

Watertables must be maintained above the level of sulfidic material.

Drains should be shallow and carefully levelled to rapidly remove surface water rather than lower the watertable.

Irrigation may be necessary during dry spells since root development is always restricted in ASS. It also helps maintain the water level above the sulfidic material.
Raised beds to create a favourable root environment should be made with non-ASS material, which requires identifying the depth to sulfidic material. Where insufficient material is available, additional soil can be provided by treating sulfuric layers with lime, and/or accelerating oxidation of sulfidic material, provided the acidic leachate can be managed. Shallow rooted annual crops are preferable to deeper rooting, perennial tree crops.

Managed oxidation of ASS may be viable provided leachate can be controlled by collecting and liming it.

Rehabilitation

Rehabilitation is used where tests show a sulfuric layer or acid water. The basic principles are to curtail sulfide oxidation and to neutralise or leach existing acidity.

Re-flooding halts pyrite oxidation. It also causes reduction of Fe, Mn, S and N, which has some neutralising effect on acid soil. Re-flooding of rice paddies can have the same effect, but may cause plant nutrition and toxicity problems.

Liming the soil neutralises acidity. The surface soils (0–50 cm) tested generally require 40 – 100 t CaCO₃/ha to neutralise actual acidity and 0 – 42 t CaCO₃/ha to neutralise potential acidity. The sub-soils tested require >500 t CaCO₃/ha for a 50 cm depth interval to neutralise potential acidity.

Liming drains neutralises acid leachate.

Leaching is only possible using a water management system that discharges acidic surface water, usually at times of high flow to reduce the environmental impact. However, discharge of acidic surface water containing toxic elements may not be an acceptable option for Brunei.

ASS Occurrence and Management in the ADAs

The greatest problem with actual or potential ASS is in ADAs in the low-lying areas of Brunei-Muara and, to a lesser extent, Belait. Their occurrence in Tutong and Temburong ADAs is negligible.

Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumapas, Limpaki and Pengkalan Batu ADAs are almost entirely covered by ASS, requiring high or very high levels of treatment. Since these ADAs are already developed for agriculture, it is important that the treatment recommendations are followed to prevent further oxidation of sulfidic material, which would acidify the soil and could lead to acid being leached into nearby waterways.

Wasan also has extensive areas of ASS, but because they are Cracking clay soils they require only low to moderate treatment. If used for rice they can be cultivated with almost no special treatment, since it is kept waterlogged for most of the year.

Tungku has only moderately extensive ASS requiring moderate levels of treatment.

Tungulian, Melayan A, Labi Lama and Km26 Jalan Bukit Puan Labi have extensive ASS in lowland areas, that require very high levels of treatment. Since much of the area with ASS is currently undeveloped for agriculture and would require very high treatment levels for development, consideration should be given to leaving them undeveloped.

Merangking Bukit Sawat has isolated pockets of ASS that would best be left undeveloped, since they require a very high treatment level.
On-farm Experiments and Monitoring to Improve Soil Management

Nutrient management

The fertilizer and lime calculator uses data derived from the literature which are not necessarily correct for the conditions in Brunei. These data include the amounts of nutrients removed by particular crops, critical soil thresholds for each nutrient, fertilizer efficiency, and nutrient content of manure. There should be a program to gradually replace these data with data derived from field experiments in Brunei Darussalam.

Soil Acidity

The pH buffering capacity of different Soil Types needs to be measured so that the application rates of lime can be calculated more effectively. In addition, a program of liming trials should be conducted on a range of important Soil Types to investigate the effectiveness of amelioration. These investigations should be conducted before, or at least in tandem with, the nutrient experiments outlined above.

Watertable Behaviour

A major cause of waterlogging in Brunei is the combination of high rainfall and shallow watertables, combined with low gradients in many ADAs. The watertable should be monitored in a few lowland locations to improve understanding of the behaviour of the watertable, for example how sensitive it is to wet periods and how quickly it recedes during dry periods. Understanding watertable behaviour is critical to understanding crop water requirements. Watertable behaviour also affects the acidification of sulfidic materials.

Acid Sulfate Soils

Two aspects of acid sulfate soils require further investigation. First, the amount of acid being brought into the topsoil of acid sulfate soils by fluctuating watertables should be investigated to enable better estimation on annual lime requirements. Second, more detailed information about the depth to the sulfidic material in common situations is required so that farmers can ensure this material does not acidify to the detriment of both production and the environment.

Organic Soil Subsidence

The subsidence of peat is a major concern in the lowlands of SE Asia, especially Borneo. Development of Organic soils for agriculture necessarily leads to aeration of peat, its oxidation and eventual subsidence. The scale of the problem is unknown in Brunei, but many of the areas with the most intensive horticulture occur on Organic soils. Monitoring the subsidence of such soils in the period immediately after clearing will provide baseline data, with which to develop policy on utilisation of Organic soils. The recently cleared area at Labi Lama would provide one possible monitoring site.

Soil Distribution and Improving the Utility of the GIS

This soil survey study characterised and mapped soils in 27 ADAs covering 4422 hectares out about 576,500 hectares for the entire country. To maximise the benefits of the soil suitability and management knowledge gained by this project, the information needs to be applied to parts of Brunei outside the studied ADAs. The main vehicle for transferring this knowledge should be the Soil Types. The soils of the entire country, concentrating on areas of greater interest for agriculture, should therefore be mapped in a manner consistent with the methods and classification used in this study. At the same time, the GIS, database and maps commissioned by this soil fertility study should be expanded and enhanced.
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Part 1 Introduction

The Department of Agriculture of Negara Brunei Darussalam commissioned the project Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam to assist the country’s commitment to achieve a significant degree of food security. This commitment requires increases in the level of self-sufficiency in rice, fruit, vegetables and animal production. This could be achieved through yield increases per hectare, having more crops per year, and by developing new areas for agricultural production. The overall objectives of of the project were therefore:

- To provide information on the properties of major Soil Types of the Agricultural Development Areas (ADAs) and their suitability for crop cultivation that will facilitate the reallocation of land use to that most appropriate to meet the country’s requirements. The use of this land is controlled and gazetted, and farmers working these areas take advice from the Department of Agriculture.

- To recommend soil and nutrient management practices for the sustainable management of soil resources in Brunei that improve productivity and minimize adverse impacts on the environment.

This project consolidates current international knowledge and approaches so that the Department of Agriculture can provide the best advice to farmers in the ADAs. Volume 1 of this report describes how the project characterises soils according to an international soil classification, Soil Taxonomy (Soil Survey Staff 2003). The soil survey was conducted in 27 Agricultural Development Areas that were selected by staff of the Brunei Department of Agriculture. They are located throughout the districts of Brunei-Muara, Tutong, Belait and Temburong as shown in Table 1 and Figure 1. Individual survey areas ranged from 13 to 585 hectares.

The project uses an internationally developed, robust system for allocating soil attributes relevant to soil fertility assessment, the Fertility Capability Classification (Sanchez et al. 2003). The project also draws on a large volume of international scientific literature to identify soil attribute constraints for growing a variety of crops including rice, vegetables, other short duration crops, fruits and animal fodder. 68 crops were selected by staff of the Department of Agriculture for assessment and a further four were added by the project team (Table 2). They were evaluated in 27 groups, with two groups not being evaluated due to lack of information. The soil fertility assessment and soil constraints for cropping are integrated using the FAO Framework for Land Evaluation (FAO 1976) to rate the suitability of Soil Types for each crop.

Volume 2 (Soil Management in the Agricultural Development Areas) addresses soil management strategies to overcome the constraints to cropping identified in Volume 1. It also describes a strategy for nutrient management that makes allowance for the particular conditions in Brunei. Specific soil and nutrient management recommendations are made for a smaller selection of crops (Table 2). These crops are either grown in Brunei, have good potential as commercial crops in Brunei or are considered to be high priority by the Department of Agriculture.

The project investigated the occurrence of a particular class of soils – acid sulfate soils – in Brunei and the problems associated with them. These investigations are described in Volume 2, together with management options for acid sulfate soils.
Table 1: The Agricultural Development Areas surveyed with their district and area. Also shown are the survey area number assigned during the survey and the soil map sheet(s) for the ADA in *Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam* Report P1-1.2 – *Soil Maps* (Grealish *et al.* 2007b).

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<td>Merangking, Bukit Sawat</td>
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**Total area surveyed** 4422
Figure 1: Location of the surveyed Agricultural Development Areas in Negara Brunei Darussalam.
Table 2: The crops assessed using the Fertility Capability Classification.
Crops grouped together were assessed together. Crops with an SI number were listed by Department of Agriculture for assessment. Those without an SI number were added as potentially suitable. Those marked * could not be assessed due to lack of information. Soil management recommendations are given for a subset as indicated in the right-most column. Those marked + are also included in the fertilizer and lime calculator. Soil and nutrient management recommendations were not made for those marked -.

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<th>Scientific name</th>
<th>Section</th>
<th>Land suitability</th>
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<td>A01</td>
<td>A19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A00</td>
<td>A19</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
<table>
<thead>
<tr>
<th>SI No</th>
<th>Crop</th>
<th>Scientific name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>E12</td>
<td>Citrus</td>
<td>Sweet Mandarin (Limau manis)</td>
<td>A.2.4</td>
</tr>
<tr>
<td>F06</td>
<td></td>
<td>Musk lime (Limau kasturi)</td>
<td>6.4.3</td>
</tr>
<tr>
<td>F07</td>
<td></td>
<td>Common lime (Limau Kapas)</td>
<td>6.4.3</td>
</tr>
<tr>
<td>F08</td>
<td></td>
<td>Pomelo</td>
<td>6.4.3</td>
</tr>
<tr>
<td>E14</td>
<td></td>
<td>Banana (Pisang)</td>
<td>A.2.5</td>
</tr>
<tr>
<td>E09</td>
<td></td>
<td>Coconut</td>
<td>A.2.6</td>
</tr>
<tr>
<td>E15</td>
<td></td>
<td>Papaya (Kelapa)</td>
<td>A.2.7</td>
</tr>
<tr>
<td>E16</td>
<td></td>
<td>Pineapple</td>
<td>A.2.8</td>
</tr>
<tr>
<td>E08</td>
<td></td>
<td>Mango (Mangga)</td>
<td>-</td>
</tr>
<tr>
<td>F02</td>
<td></td>
<td>Belunu</td>
<td>-</td>
</tr>
<tr>
<td>F03</td>
<td></td>
<td>Membangan</td>
<td>-</td>
</tr>
<tr>
<td>F09</td>
<td></td>
<td>Cashew nut (Kacang Jagus)</td>
<td>-</td>
</tr>
<tr>
<td>E06</td>
<td></td>
<td>Cempedak</td>
<td>A.2.10</td>
</tr>
<tr>
<td>E07</td>
<td></td>
<td>Jackfruit (Nangka)</td>
<td>6.4.8</td>
</tr>
<tr>
<td>F01</td>
<td></td>
<td>Tarap</td>
<td>6.4.8</td>
</tr>
<tr>
<td>F05</td>
<td></td>
<td>Asam Aur-aur</td>
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<td>F12</td>
<td></td>
<td>Longan</td>
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<tr>
<td>F04</td>
<td></td>
<td>Kembayau</td>
<td>-</td>
</tr>
<tr>
<td>F11</td>
<td></td>
<td>Water apple (Jambu air)</td>
<td>-</td>
</tr>
<tr>
<td>Fodder crops</td>
<td></td>
<td>Grasses for wet areas</td>
<td>A.3.1</td>
</tr>
<tr>
<td>B02</td>
<td></td>
<td>Para grass</td>
<td>6.5.1+</td>
</tr>
<tr>
<td>Humidicolca</td>
<td></td>
<td>Brachiaria mutica (Forsk.) Staph</td>
<td>6.5.1+</td>
</tr>
<tr>
<td>B01</td>
<td></td>
<td>Signal grass</td>
<td>-</td>
</tr>
<tr>
<td>B03</td>
<td></td>
<td>Napier or Elephant grass</td>
<td>6.5.2+</td>
</tr>
<tr>
<td>B04</td>
<td></td>
<td>Guinea grass</td>
<td>6.5.2+</td>
</tr>
<tr>
<td>B05</td>
<td></td>
<td>Guatemala grass</td>
<td>-</td>
</tr>
<tr>
<td>B06</td>
<td></td>
<td>Molasses grass</td>
<td>-</td>
</tr>
<tr>
<td>Fodder legumes for wet areas</td>
<td></td>
<td>Centro</td>
<td>A.3.3</td>
</tr>
<tr>
<td>B07</td>
<td></td>
<td>Calapo</td>
<td>-</td>
</tr>
<tr>
<td>B08</td>
<td></td>
<td>Stylo</td>
<td>-</td>
</tr>
<tr>
<td>B09</td>
<td></td>
<td>Pinto peanuts</td>
<td>6.5.3+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indian jointed vetch</td>
<td>6.5.3+</td>
</tr>
<tr>
<td>Fodder legumes for well drained areas</td>
<td></td>
<td>Apil-Apil</td>
<td>A.3.4</td>
</tr>
<tr>
<td>B10</td>
<td></td>
<td>Leucaena leucocephala Lam. de Wit.</td>
<td>6.5.4+</td>
</tr>
</tbody>
</table>
The outputs from the project are:

- This report which has two volumes:
  
  

- A simple soil identification key for the major Soil Types presented as a manual for field use in English and Malay:
  
  

- Field and laboratory data, in a Microsoft Access® database, for sample locations within the ADAs.

- A geographic information system (GIS), in ESRI ArcGIS®, showing the spatial distribution of Soil Types, land suitability for a range of crops and acid sulfate soil hazard in the ADAs.

- A land evaluation system in Microsoft Excel®.

- A fertilizer and lime calculator in Microsoft Excel®.

The information in the above outputs is also presented in the following series of activity reports. Note that all the information in these activity reports can be found in the project outputs listed above.


The two phases of the project are summarized in:


Part 2 Soil Survey

2.1 Introduction

Part 2 of this report summarises the outcomes of the field work conducted to characterise, classify and map the extent of soils that occur in selected Agricultural Development Areas of Negara Brunei Darussalam. The soil information provides the base data for agricultural land use evaluations to determine crop suitability in Part 3 and for fertiliser and nutrient management recommendations (Volume 2).

This soil survey was conducted in 27 Agricultural Development Areas that were selected by staff of the Brunei Department of Agriculture. These survey areas occur throughout the districts of Brunei-Muara, Tutong, Belait and Temburong as shown in Table 1. Individual survey areas ranged from 13 to 585 hectares. The locations of the surveyed Agricultural Development Areas are shown in Figure 1.

2.1.1 Background

Previously, three general purpose soil surveys of Negara Brunei Darussalam have been conducted in various parts of the country at a variety of scales. The *Soil Survey of Brunei, British Borneo* (Blackburn and Baker 1958) covered areas near the main city Bandar Seri Begawan at a scale of 1:50,000 scale and near Tutong at a scale of 1:100,000. A *Land Capability Study* (Hunting Technical Services 1969) covered nearly the entire country at a scale of 1:100,000. The *Brunei Agricultural and Forestry Development Study* (ULG Consultants 1982, 1983) covered parts of the Belait and Temburong Districts at scales of 1:12,500, 1:25,000 and 1:50,000. The approach to classifying soils was to adopt the Sarawak Soil Classification System which allowed comparison with soils in other parts of Borneo. This system was a genetic one that recognised great soil groups and families.

This project builds on the mapping work conducted by these soil surveys and characterizes the soils of the Agricultural Development Areas according to Soil Taxonomy (Soil Survey Staff 2003), an international soil classification system. This will allow the soils to be correlated world-wide to assist with information and knowledge transfer about how these soils behave. Soil data collected and presented here will be used as inputs to a fertility capability soil classification that will assist with evaluating the crop land use and fertiliser management recommendations.

2.1.2 Objectives and Outputs of this Study

The ultimate goal is providing soil information to assist with ensuring that agricultural land-use in Negara Brunei Darussalam is sustainable. The overall objective is to provide soil-related information for decision makers and to promote sustainable and planned development through enhancing the available knowledge of soils.

The primary objective of this project activity is to identify the field observable, physical and chemical soil properties of major soil types within each of the Agricultural Development Areas and develop a soil identification key. In addition, it was found necessary that this report should also include a description of the soil map units to assist with interpretation of the accompanying maps and to assist with an understanding of the soil relationships.

The outputs of this project activity presented in this report include:

- A soil identification key.
- Description of the major soil types.
- Soils classified according to Keys to Soil Taxonomy (Soil Survey Staff 2003).
- Data from field measurements, observations and soil samples collected for laboratory analysis (see project database).
• Description of a representative soil for each of the major soil types, including photographs (see Part 4).
• Presentation of the soil classification legend for the maps (Part 5).
• Generalised soil-landscape cross-sections (Part 5).

2.1.3 Field Data Quality Objectives
The field information to be collected is dictated by the project objectives. The field data quality objectives are to provide information that will:

• Classify soils to the Subgroup Level according to Keys to Soil Taxonomy (Soil Survey Staff 2003),
• Allow verification of the existing soil map boundaries and the soil composition within these existing soil map units, and
• Provide the soil property information required for interpretations for the soil fertility evaluation.

2.2 Methods

2.2.1 Strategy and Rationale
The strategy was to use existing soil map unit boundaries from previous soil surveys and to determine the major soil types that occur within those boundaries. The soil types were described in sufficient detail so that they could be classified according to Soil Taxonomy and provide the soil information required for the subsequent soil fertility evaluation.

The locations of the sites were determined by reviewing existing soil map information, recent satellite imagery and contour data to identify landscape position. Sites were often selected to form traverses across the landscape or clusters so that would allow a catenary concept of soil variation to be developed. Resource, access and time constraints meant that areas selected for sampling were to be representative of the surveyed Agricultural Development Areas.

Data collected in this soil survey are limited to investigations conducted in the Agricultural Development Areas, and therefore the soils characterised and the soil key developed may not cover the entire population of soils in Negara Brunei Darussalam. However, because the Agricultural Development Areas are spread throughout the districts and cover a range of soil parent materials and landscape positions, it is probable that the majority of soils have been identified.

2.2.2 Field Survey

2.2.2.1 Operational Standards
The terms of reference specify that soils are to be described and classified according to standards of the United States Department of Agriculture – Natural Resource Conservation Service. The key references are:

• Soil Survey Manual (Soil Survey Division Staff 1993) – for describing and collecting field information
• Field Book for Describing and Sampling Soils (Schoeneberger et al. 2002) – for describing and collecting field information,
• Keys to Soil Taxonomy, 9th Edition (Soil Survey Staff 2003) – for classification,
These accepted standards are not repeated: only activities specific to this project are elaborated.

2.2.2.2 General Approach

The general approach to characterizing the major soil types and the collection of representative soil samples for laboratory analysis involved:

- Preliminary reconnaissance survey of landscapes and soils.
- Gathering base information, satellite imagery, topographic maps, and review of literature.
- With Brunei Department of Agricultural staff locating the survey boundary perimeters for each of the Agricultural Development Areas using a combination of survey maps, Geographical Positioning System and local knowledge.
- Establishing a project Geographic Information System database.
- Preparing satellite data including LandSat 2001 imagery, which provided complete coverage, and QuickBird 2004 imagery, that provided coverage of the Brunei-Muara Agricultural Development Areas and some of those in Tutong.
- Using satellite imagery to update historical maps and use this to provide information on current land cover and access, and to determine site locations.
- Geo-referencing of all field survey and sampling sites with a Geographical Positioning System unit. Readings were given to within one meter however the accuracy provided is about 10 meters. Where the Geographical Positioning System unit could not obtain location information because of dense overhead tree cover, distance and direction from a known location were measured using compass and hip-chain. This was then plotted on a map to obtain the site coordinates.
- Describing the sites and soil profiles in the field according to the Field Book for Describing and Sampling Soils (Schoeneberger et al., 2002), focussing on horizon depths, texture, structure, colour, redoximorphic features, field pH, and consistency.
- Photographically documenting every site using digital cameras to record the soil profile and the surrounding landscape. These photos will form part of the project database.
- Obtaining soil samples for laboratory analysis by sampling throughout the soil horizon thickness and bulking the sample. Soil samples were air-freighted to Australia for processing and analysis.
- Collecting small soil samples into plastic chip-tray containers from most sites. These have been photographed and the soil sample trays stored for future viewing and investigations.
- Revisiting sampled representative sites with laboratory data to confirm or amend their preliminary field Soil Taxonomy classification. All other sample sites were then allocated a final classification.
- Identification and reporting on the major soil types and their characteristic features.
- Developing a soil identification key based on features that are relatively easy to assess to assist users identify and classify soils.
- Allocating major soil types to the previously delineated map units using the limited field data set and a conceptual understanding of the soil distribution in the landscape.
- Preparing a soil classification to describe all of the map units that occur within the Agricultural Development Areas.
2.2.2.3 Site Identification and Sample Identification Numbers

A logical numbering system is essential so that all sites and samples can be uniquely identified and located spatially. The Site Identification Number consists of two parts to form a six digit number – the first two digits are a project-allocated number for each Agricultural Development Area and the last four digits are a unique number for each site. For example Site Identification Number ‘24 0005’ indicates site number 0005 within Agricultural Development Area Number 24.

Soil sample identification numbers were provided by the CSIRO laboratory on preprinted labels and consisted of a unique number for the 06 year at the ADL laboratory (Adelaide), for example ‘06 ADL 0850’.

2.2.2.4 Soil Laboratory Analysis

The full set of sample analysis results and methods used are described in a separate report that should be referred to, Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.1 – Laboratory Analysis of Soil Chemical and Physical Properties (Beech et al. 2006).

2.2.3 Soil Taxonomic Classifications

2.2.3.1 Soil Taxonomy

Soils are classified to make it easier to remember and communicate their significant characteristics. Classification assembles knowledge about soils, reveals their relationship to one another and the whole environment, and develops principles that help understanding of their behaviour and their response to land use. If an internationally recognized soil classification is used, international technology transfer is possible, as similar soils anywhere in the world can be easily identified and successful management practices can be copied without the need for extensive local trials.

The soil classification system used in this soil survey is the United States Department of Agriculture Soil Taxonomy, 2003 revision (Soil Survey Staff 2003). Although this was first developed for use in the United States, it is now considered to be an international classification. Revisions of sections of the classification are conducted by international committees with knowledge derived from experience of the section being reviewed.

Soil Taxonomy is an evolving classification system that changes as the store of knowledge accumulates. It is based on soil properties observed in the field or inferred from those observations and confirmed by laboratory measurements. Soil Taxonomy accounts for the morphological, physical and chemical characteristics of the soil, as well as soil temperature and soil moisture.

2.2.3.2 Diagnostic Horizons and Soil Characteristics

Soils consist of a sequence of layers. If these layers are considered in conjunction with soil-forming processes they may be recognized as genetic soil horizons (A, E, B, C). In addition to these genetic horizons, Soil Taxonomy defines a number of diagnostic horizons. The criteria that define these diagnostic horizons are much more specific than those used to identify genetic horizons. Diagnostic horizons may encompass one or more genetic horizons. Different diagnostic horizons are not necessarily mutually exclusive; they may overlap and do not have to form a continuous sequence. They are used to identify the essential features of a soil. In the higher categories of Soil Taxonomy, definitions of classes are based largely on the presence or absence of diagnostic horizons.

Chapter 3 of Keys to Soil Taxonomy (Soil Survey Staff 2003) should be referred to for the specific definitions and a complete list of diagnostic horizons and soil characteristics. The following were recognized in this soil survey as being important to the classification of the soils and a brief description is given here.
Diagnostic Surface Horizons:

*Anthropic Epipedon:* a surface horizon that shows some evidence of disturbance by human activity.

*Histic Epipedon:* a surface horizon that consists of organic soil material that is saturated and reduced for some time during normal years.

*Umbric Epipedon:* a surface horizon that is dark coloured with organic material.

Diagnostic Subsurface Horizons:

*Argillic horizon:* normally a subsurface illuvial horizon which contains significant accumulations of layer-lattice silicate clays (phylllosilicate clay) than the overlying soil material.

*Kandic horizon:* normally a subsurface horizon that has more clay than the overlying soil material and a CEC of 16 cmol or less per kg clay.

Other Diagnostic Soil Characteristics:

*Aquic Conditions:* soils with aquic conditions are those that currently undergo continuous or periodic saturation and reduction.

*n Value:* characterizes the relation between the percentage of water in a soil under field conditions and its percentages of inorganic clay and humus. It is used to predict whether a soil can support loads and what degree of subsidence would occur after drainage. A value of 0.7 or greater indicates that the soil is soft and would subside under a load.

*Slickensides:* are polished and grooved surfaces that are produced when one soil mass slides past another. Slickensides result directly from the swelling of clay minerals and shear failure. They are very common in swelling clays that undergo marked changes in moisture content.

*Spodic Materials:* show evidence that organic materials and aluminium, with or without iron, have been moved from an eluvial horizon to an illuvial horizon.

*Sapric Soil Material:* highly decomposed organic material.

*Sulfidic Material:* contains oxidisable sulfur compounds. They are mineral or organic soil materials that have a pH value of more than 3.5 that will, under moist aerobic conditions, show a drop in pH of 0.5 or more units to a pH value of 4.0 or less. Sulfidic materials accumulate as a soil or sediment that is permanently saturated, and if drained or exposed to aerobic conditions, the sulfides oxidize and form sulfuric acid.

*Sulfuric Horizon:* is 15 cm or more thick and is composed of either mineral or organic soil material that has a pH value of 3.5 or less or shows evidence that the low pH value is caused by sulfuric acid.

2.2.3.3 Categories of Soil Taxonomy

The soil classification system defined in Soil Taxonomy is a hierarchical system with mutually exclusive classes and rigidly defined boundaries. There are six categories with each category progressively having more classes and including more descriptive features than the one above. The highest category is the *order*, then the *suborder*, *great group*, *subgroup*, *family*, and *series*. In this survey, soils are classified to the subgroup level.

2.2.4 Simplified Identification of Soils

Using Soil Taxonomy to classify soils requires experience in describing soil features; often involves laboratory analysis and calls for an understanding of soil classification. Most users do not have this high level of experience, access to analytical data or understanding of the complexity of using Soil Taxonomy as a soil classification system to identify soils. Therefore
a very simplified Soil Identification Key, specific to the soils that occur within this soil study of Brunei Darussalam, was developed.

The Soil Identification Key is based on easily observable soil characteristics. These are not a direct replacement of the specific diagnostic horizons and diagnostic soil characteristics outlined above that are used for Soil Taxonomy classification. The Soil Identification Key has been constructed to separate out the same soil classes as would occur if Soil Taxonomy was to be used. However, because the Soil Identification Key is a simplification and does not use the detailed, technically-defined diagnostic characteristics, it may occasionally lead to errors in identification of soils in the field. Also it should only be used in the areas for which it was developed, namely the surveyed ADAs (see Table 1) or in similar landscapes in Brunei Darussalam.

This Soil Identification Key works on the basis that the soil is allocated to the first available decision (even though it may also fit later decisions), and the questions are related to observable soil characteristics. A collection of plain language soil type and subtype names was developed to correspond to the major Soil Taxonomy Suborder and Subgroup classes found in the survey. These names are intended to provide some assistance in understanding the intent and general nature of the soil groups as defined using the Soil Taxonomy classification.

2.2.4.1 Using the Soil Identification Key

1. Dig a small pit in the soil using a spade. The hole should be sufficiently large to allow a vertical face (side of the pit) to be observed to a depth of about 50 cm from the soil surface or to the depth at which free water flows into the pit. Then use a soil auger to obtain soil samples below the pit noting the depths that the soil is retrieved from. Auger to a depth of at least 100 cm on flat areas or 150 cm on sloping areas, or until the auger refuses to go deeper because of the underlying bedrock.

2. Determine layers in the soil by observing the depths where the appearance or ‘feel’ of the soil changes, such as colour or texture or consistence. Generally there is a topsoil layer that is about 10 to 25 cm thick and usually a darker colour than the soil below, and at least two subsoil layers below the topsoil.

3. Record the major observable soil characteristics that will be used in the soil identification key on a field sheet. These characteristics are for both the soil profile as a whole and for individual layers. Whole profile characteristics include slope, slope position and drainage. Soil layer characteristics include the depth and thickness of the layer and its colour, texture, consistence and soil reaction (pH). The information required is described in more detail below.

4. Using this soil information work through the Soil Identification Key to determine the Soil Type or Subtype.

2.2.4.2 Observable Soil Characteristics

There are many text books and manuals available (e.g. Schoeneberger et al. 2002) that provide detailed information on how to describe soils. These should be referred to if a better understanding is required. However, the soil characteristics explained below are simple to describe and provide sufficient information to allow the Soil Identification Key to be used.

Soil Depth

Using a tape measure, determine the soil depth by measuring from the soil surface to the maximum depth from which soil was obtained. This measurement may have to be done by measuring the soil auger and how far it penetrated down into the soil. Record the depth in centimetres.

Soil depth provides information on the maximum depth for plant roots to explore.
Soil Layer Thickness

By observing the soil, identify the soil layers by determining where changes occur in soil colour, texture or consistence. Using a tape measure determine the upper and lower depths of each layer by measuring from the soil surface. Record the depths in centimetres. The soil layer thickness can be determined as the difference between the lower and upper depth for each layer.

Soil layer thickness provides information on the volume of different soil materials available.

Soil Moisture

Soil moisture content can be determined by the ‘feel’ of the soil in the hand. It will vary over time depending on rainfall or irrigation frequency and proximity to the water table.

Soil moisture provides information on the soil drainage and the potential water table depth (wet soil).

<table>
<thead>
<tr>
<th>Soil Moisture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Hands remain dry when holding sample, soil readily absorbs moisture when applied.</td>
</tr>
<tr>
<td>Moist</td>
<td>Hand will feel damp when holding the sample but no free water visible</td>
</tr>
<tr>
<td>Wet</td>
<td>Free water easily visible</td>
</tr>
</tbody>
</table>

Soil Texture

Soil texture is determined by the proportions of organic material, sand, silt, and clay in a soil. If a soil is dominated by decomposed plant fibres (volume >75% organic material) then it is called an organic soil (or commonly known as peat). Mineral soils generally have a small amount or no organic material, and are composed of sand, silt and clay.

Texture can be determined in the field by taking a half hand-full of soil, adding some water so that the soil binds and can be moulded. The soil is then rolled into a ball and texture determined.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>Dominated by decomposed plant fibres. Often soft and easily squeezed when moulded in the hand.</td>
</tr>
<tr>
<td>Sandy</td>
<td>The soil stays loose and separated. It cannot be moulded into a ball or rolled into a ribbon.</td>
</tr>
<tr>
<td>Loamy</td>
<td>The soil becomes slightly sticky, and can be moulded into a ball that does not break apart. It can be rolled into a ribbon between 15 and 50 mm long that will break when bent.</td>
</tr>
<tr>
<td>Clayey</td>
<td>The soil is sticky, and is initially firm and resistant to moulding into a ball. It can be rolled into a ribbon that is greater than 50 mm long and bends without breaking.</td>
</tr>
</tbody>
</table>

Soil texture provides information on water holding capacity, aeration, resistance to root penetration, and nutrient holding capacity.

Soil Colour

Soil colour is an easily observed characteristic for determining different types of soil materials. Usually Munsell colour charts are used to place a soil into a colour grouping. For the purposes of this Soil Identification Key a few broad groups are used. To determine the soil colour find a clean sample, moisten the surface and match to Munsell colour chips or examples provided here.

Soil colour provides information on the soil drainage, organic matter content, and sometimes soil fertility when used with soil texture can be inferred.
<table>
<thead>
<tr>
<th>Soil Colour</th>
<th>Typical Munsell hue/value/chroma</th>
<th>Description</th>
<th>Example soil colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>5YR/ &lt;3/ 1-2 7.5YR/ &lt;3/ 1-2 10YR/ &lt;3/ 1-2</td>
<td>Peat / organic soils – high in organic matter</td>
<td>![Image of Black Soil]</td>
</tr>
<tr>
<td>White</td>
<td>-/ 8/ &lt;4</td>
<td>Sandy / quartz</td>
<td>![Image of White Soil]</td>
</tr>
<tr>
<td>Red</td>
<td>10R/ -/ 6-8 2.5YR/ -/ 6-8</td>
<td>Presence of iron oxides</td>
<td>![Image of Red Soil]</td>
</tr>
<tr>
<td>Yellow</td>
<td>7.5YR/ &gt;6/ &gt;6 10YR/ &gt;6/ &gt;6 2.5Y/ &gt;6/ &gt;3 5Y/ &gt;6/ &gt;2</td>
<td>Some iron oxides</td>
<td>![Image of Yellow Soil]</td>
</tr>
<tr>
<td>Brown</td>
<td>2.5YR/ &lt;7/ 3-4 5YR/ &lt;6/ 3-4 7.5YR/ &lt;6/ 3-4 10YR/ &lt;6/ 3-8 2.5Y/ &lt;5/ 2-6</td>
<td>Moderate soil organic matter content, and some iron oxides</td>
<td>![Image of Brown Soil]</td>
</tr>
<tr>
<td>Grey</td>
<td>Gley charts/ -/ 3-7/ 1</td>
<td>Near permanent waterlogging; anaerobic conditions</td>
<td>![Image of Grey Soil]</td>
</tr>
<tr>
<td>Mottles</td>
<td>Orange, yellow, red spots throughout the dominant soil colour</td>
<td>Intermittent waterlogging; intermittent anaerobic conditions</td>
<td>![Image of Mottles Soil]</td>
</tr>
</tbody>
</table>

**Soil Consistence**

Soil consistence describes the strength and coherence of a soil.

Soil consistence can be determined in the field by taking a spade sized block of soil and gently breaking the soil apart by hand. If the soil is structured it will separate into aggregates. If the soil has no structure then the break will be jagged and there will be no identifiable aggregates. Soil consistence describes the force required to break, crumble or squeeze the soil.

<table>
<thead>
<tr>
<th>Soil Consistence</th>
<th>Description</th>
<th>Implied Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>Soil is easily squeezed by hand and there is no resistance when pressure is applied to the soil block between the thumb and forefinger</td>
<td>Usually organic material and occasionally sandy soils that are saturated.</td>
</tr>
<tr>
<td>Loose, weak</td>
<td>Soil block crumbles under slight force applied between thumb and forefinger.</td>
<td>Usually sandy soils</td>
</tr>
<tr>
<td>Friable, firm</td>
<td>Soil block crumbles under moderate to strong applied force applied by the hand.</td>
<td>Usually loamy soils</td>
</tr>
<tr>
<td>Strong to rigid</td>
<td>Soil block cannot be crumbled by hand force.</td>
<td>Usually clayey soils</td>
</tr>
</tbody>
</table>

Soil consistence provides information on the ease of root penetration, weight bearing capacity of the soil, and indicates the soil texture.
**Soil pH**

Soil pH measures the concentration of hydrogen ions in the soil. A pH of 7 is neutral, pH less than 7 is acidic, and pH greater than 7 is alkaline. Soil pH can be measured by a number of different methods and instruments. In the field pH paper sticks provide a good indication. Place the pH stick on a moistened soil sample: the colour will change to indicate the pH level.

For the Soil Identification Key, pH is used to determine if a soil has a sulfuric layer (when the pH <3.5) or sulfidic material (pH >3.5 which changes on ageing to pH 3.5).

**Sulfidic Material**: contains oxidisable sulfur compounds. They are mineral or organic soil materials that have a pH value of more than 3.5. However, if exposed to moist, aerobic conditions, their pH will drop by 0.5 or more units to a pH value of 4.0 or less. This drop in pH is referred to as aging, and occurs over an 8 week period or can be accelerated by mixing the soil sample with hydrogen peroxide. Sulfidic materials accumulate in a soil or sediment that is permanently saturated, and if drained or exposed to aerobic conditions, the sulfides oxidize and form sulfuric acid.

**Sulfuric Horizon**: is 15 cm or more thick and is composed of either mineral or organic soil material that has a pH value of 3.5 or less or shows evidence that the low pH value is caused by sulfuric acid.

Soil pH provides information on the type of acidity which will impact on the use of the soil, plant growth will vary depending on the crops tolerance to acidity.

**Soil Cracks**

Soil cracks are features that are difficult to determine as they occur only when the soil is dry and often in the soil layers below the surface. Knowledge about the soil behaviour during the year will be required to determine if these features exists.

Soil cracks occur only in clayey soils when they are dry. If the cracks cannot be observed then it may be possible to observe in the subsoil slikensides which are polished and grooved surfaces between aggregates.

Soil cracks provide information that the soil material contains shrink/swelling clays.

### 2.3 Soil Classification and Identification

#### 2.3.1 Soil Taxonomy Classes Identified

A list of parts of the Soil Taxonomy Classifications identified as being relevant to the Agricultural Development Areas of Negara Brunei Darussalam is outlined below in Table 3. Seven soil Orders were identified leading to 24 Subgroups.

#### 2.3.2 Soil Identification Key

To assist users identify these soil classes a soil identification key was developed (Table 4 and Table 5). The soil classes in the Soil Identification Key are largely in the same order as occurs in the Keys to Soil Taxonomy (Soil Survey Staff, 2003).
Table 3: Soil Taxonomy classifications of surveyed Agricultural Development Areas in Negara Brunei Darussalam.

<table>
<thead>
<tr>
<th>Order</th>
<th>Suborder</th>
<th>Great Group</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histosols</td>
<td>Saprists</td>
<td>Sulfosaprists</td>
<td>Terric Sulfosaprists</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Sulfosaprists</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sulfisaprists</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Terric Sulfisaprists</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Sulfisaprists</td>
</tr>
<tr>
<td>Spodosols</td>
<td>Aquods</td>
<td>Epiaquods</td>
<td>Ultic Epiaquods</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Umbric Epiaquods</td>
</tr>
<tr>
<td>Vertisols</td>
<td>Aquerts</td>
<td>Sulfaquepts</td>
<td>Sulfic Sulfaquepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Sulfaquepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dystraquerts</td>
<td></td>
</tr>
<tr>
<td>Ultisols</td>
<td>Humults</td>
<td>Kandihumults</td>
<td>Aquic Kandihumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Kandihumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Palehumults</td>
<td>Aquic Palehumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxyaquadic Palehumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Palehumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Haplohumults</td>
<td>Oxyaquadic Haplohumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Haplohumults</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paleudults</td>
<td>Arenic Paleudults</td>
</tr>
<tr>
<td>Alfisols</td>
<td>Aqualfs</td>
<td>Epiapualfs</td>
<td>Aeric Epiapualfs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Epiapualfs</td>
</tr>
<tr>
<td>Inceptisols</td>
<td>Aquepts</td>
<td>Sulfaquepts</td>
<td>Hydraquentic Sulfaquepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typic Sulfaquepts</td>
</tr>
<tr>
<td>Entisols</td>
<td>Aquents</td>
<td>Sulfaquepts</td>
<td>Haplic Sulfaquepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thapto-Histic Sulfaquepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluaquents</td>
<td>Sulfic Fluaquents</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Endoaquents</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Humaqueptic Endoaquents</td>
</tr>
</tbody>
</table>
**Table 4: Summary soil identification key for major soil types in surveyed Agricultural Development Areas of Negara Brunei Darussalam.**

Bracketed words are the corresponding Soil Taxonomy classification. ‘No *’ indicates to restart the key or consider that a new soil has been identified that is not classified in this identification key.

<table>
<thead>
<tr>
<th>Diagnostic features for Soil Type</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the upper 80 cm of soil consist of more than 40 cm of organic material (peat)?</td>
<td>Organic soil (Saprast) (see page 54)</td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a whitish to light grey coloured soil layer overlying a dark brown coloured (organic) layer that is within 2 m of the soil surface?</td>
<td>White soil (Aquod) (see page 67)</td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the soil develop cracks at the surface</td>
<td>Cracking clay soil (Aquert) (see page 75)</td>
</tr>
<tr>
<td>OR in a clay layer within 100 cm of the soil surface</td>
<td></td>
</tr>
<tr>
<td>OR have slickensides (polished and grooved surfaces between soil aggregates),</td>
<td></td>
</tr>
<tr>
<td>AND is the subsoil uniformly grey coloured (poorly drained or very poorly drained)?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a dominantly yellowish colour</td>
<td>Texture contrast yellow soil (Udult) (see page 83)</td>
</tr>
<tr>
<td>AND a texture contrast (sandy surface layer above loamy or clayey subsoil)?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the upper subsoil have a dominantly yellowish or brownish colour,</td>
<td>Very deep yellow soil (Humult) (see page 88)</td>
</tr>
<tr>
<td>AND is the soil depth greater than 150 cm?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a dominantly yellowish or brownish colour,</td>
<td>Yellow soil (Haplohumult) (see page 103)</td>
</tr>
<tr>
<td>AND is the soil depth less than 150 cm?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a yellowish brown coloured layer with red/orange mottles (spots) overlying a grey layer that has its upper boundary within 50 cm of the soil surface?</td>
<td>Brown over grey soil (Aqalf) (see page 111)</td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does a sulfuric layer (pH&lt;3.5) occur within 150 cm of the soil surface,</td>
<td>Sulfuric soil (Aquept) (see page 119)</td>
</tr>
<tr>
<td>AND is the subsoil uniformly grey coloured (poorly drained)?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does sulfidic material (pH&gt;3.5 which changes on ageing to pH&lt;3.5) occur within 100 cm of the soil surface,</td>
<td>Sulfidic soil (Aquent) (see page 126)</td>
</tr>
<tr>
<td>AND is the subsoil uniformly grey coloured (poorly drained)?</td>
<td></td>
</tr>
<tr>
<td>No ↓  Yes →</td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a greyish colour and no other diagnostic features within 150 cm of the soil surface?</td>
<td>Grey soil (Aquent) (see page 137)</td>
</tr>
<tr>
<td>No *  Yes →</td>
<td></td>
</tr>
</tbody>
</table>
**Table 5: Full soil identification key for major soil types and subtypes in surveyed Agricultural Development Areas of Negara Brunei Darussalam.**
Bracketed words are the corresponding Soil Taxonomy classification. "No *" indicates to restart the key or consider that a new soil has been identified that is not classified in this identification key.

<table>
<thead>
<tr>
<th>Diagnostic features for Soil Type</th>
<th>Soil Type</th>
<th>Diagnostic features for Soil Subtype</th>
<th>Soil Subtype</th>
<th>Soil Taxonomy Subgroup</th>
<th>Representative Profiles – Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the upper 80 cm of soil consist of more than 40 cm of organic material (peat)? No ✅  Yes ✓</td>
<td><strong>Organic soil</strong> <em>(Saprist)</em> <em>(see page 54)</em></td>
<td>Does a sulfuric layer <em>(pH&lt;3.5)</em> occur within 50 cm of the soil surface? No ✅  Yes ✓</td>
<td><strong>Sulfuric organic soil</strong> <em>(Sulfosaprist)</em></td>
<td>Terric Sulfosaprist</td>
<td>230001 - Labi Lama <em>(see page 58)</em></td>
</tr>
<tr>
<td>Does a sulfuric layer <em>(pH&lt;3.5)</em> occur within 50 cm of the soil surface? No ✅  Yes ✓</td>
<td><strong>Sulfuric organic soil</strong> <em>(Sulfosaprist)</em></td>
<td>Does a sulfuric layer <em>(pH&lt;3.5)</em> occur within 100 cm of the soil surface? No ✅  Yes ✓</td>
<td>Terric Sulfosaprist</td>
<td>210007 - Merangking, Bukit Sawat <em>(see page 60)</em></td>
<td></td>
</tr>
<tr>
<td>Does a sulfuric layer <em>(pH&lt;3.5)</em> occur within 100 cm of the soil surface? No ✅  Yes ✓</td>
<td><strong>Mineral sulfuric organic soil</strong></td>
<td>Terric Sulfosaprist</td>
<td>030002 - Si Tukak, Limau Manis <em>(see page 62)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mineral sulfuric organic soil</strong></td>
<td>Terric Sulfosaprist</td>
<td>230004 - Labi Lama</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sulfuric organic soil</strong> <em>(Sulfisaprist)</em></td>
<td>Terric Sulfisaprist</td>
<td>300002 - Lumapas</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>White soil</strong> <em>(Aquod)</em> <em>(see page 67)</em></td>
<td>Poorly drained white soil <em>(Epiaquod)</em></td>
<td>Ultic Epiaquod</td>
<td>090012 – Tungku <em>(see page 70)</em></td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a whitish to light grey coloured soil layer overlying a dark brown coloured (organic) layer that is within 2 m of the soil surface? No ✅  Yes ✓</td>
<td><strong>White soil</strong> <em>(Aquod)</em> <em>(see page 67)</em></td>
<td>Does an unsaturated soil <em>(dry to moist)</em> layer occur over saturated <em>(wet)</em> layers? No ✅  Yes ✓</td>
<td>Loamy poorly drained white soil <em>(Epiaquod)</em></td>
<td>050004 - Lumapas 210010 - Merangking, Bukit Sawat</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Poorly drained white soil</strong> <em>(Epiaquod)</em></td>
<td>Is the subsoil texture loamy AND is its consistency firm? No ✅  Yes ✓</td>
<td>Sandy poorly drained white soil <em>(Epiaquod)</em></td>
<td>240004 - KM 26, Jalan Bukit Puan Labi 240006 - KM 26, Jalan Bukit Puan Labi <em>(see page 72)</em></td>
<td></td>
</tr>
<tr>
<td>Diagnostic features for Soil Type</td>
<td>Soil Type</td>
<td>Diagnostic features for Soil Subtype</td>
<td>Soil Subtype</td>
<td>Soil Taxonomy Subgroup</td>
<td>Representative Profiles – Agricultural Development Area</td>
</tr>
<tr>
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</tr>
<tr>
<td>Does the soil develop cracks at the surface OR in a clay layer within 100 cm of the soil surface OR have slickensides (polished and grooved surfaces between soil aggregates), AND is the subsoil uniformly grey coloured (poorly drained or very poorly drained)?</td>
<td>Cracking clay soil (Aquert) (see page 75)</td>
<td>Does a sulfuric layer (pH&lt;3.5) or do sulfidic materials (pH&gt;3.5 which changes on ageing to pH&lt;3.5) occur within 100 cm of the soil surface?</td>
<td>Poorly drained cracking clay soil (Aquert)</td>
<td>Sulfidic poorly drained cracking clay soil</td>
<td>Sulfic Sulfaquert 080003 - Wasan 080004 - Wasan 080015 - Wasan (see page 78)</td>
</tr>
<tr>
<td>No ↓ Yes →</td>
<td></td>
<td>No * Yes →</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poorly drained cracking clay soil (Aquert)</td>
<td>Acid poorly drained cracking clay soil</td>
<td></td>
<td>Typic Dystraqueort 080012 - Wasan (see page 80)</td>
</tr>
<tr>
<td>Does the subsoil have a dominantly yellowish colour AND a texture contrast (sandy surface layer above loamy or clayey subsoil)?</td>
<td>Texture contrast yellow soil (Udult) (see page 83)</td>
<td></td>
<td></td>
<td></td>
<td>Arenic Paleudult 220005 - Melayan A (see page 86) 220007 - Melayan A</td>
</tr>
<tr>
<td>Diagnostic features for Soil Type</td>
<td>Soil Type</td>
<td>Diagnostic features for Soil Subtype</td>
<td>Soil Subtype</td>
<td>Soil Taxonomy Class</td>
<td>Representative Profiles – Agricultural Development Area</td>
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<tr>
<td>----------------------------------</td>
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</tr>
<tr>
<td>Does the upper subsoil have a dominantly yellowish or brownish colour, <strong>AND</strong> is the soil depth greater than 150 cm?</td>
<td><strong>Very deep yellow soil</strong> <em>(Humult)</em> <em>(see page 88)</em></td>
<td>Does the subsoil have a sandy texture?</td>
<td>Sandy very deep yellow soil <em>(Kandihumult)</em></td>
<td>Somewhat poorly drained sandy very deep yellow soil</td>
<td>Aquic Kandihumult</td>
</tr>
<tr>
<td>No → Yes →</td>
<td></td>
<td></td>
<td>Is the lower part of the subsoil a greyish colour (somewhat poorly drained)?</td>
<td>No → Yes →</td>
<td>Is the subsoil a uniform bright yellowish colour throughout (well drained)?</td>
</tr>
<tr>
<td>Does the subsoil have a loamy or clayey texture?</td>
<td>No * Yes →</td>
<td>Clayey very deep yellow soil <em>(Palehumult)</em></td>
<td>Somewhat poorly drained clayey very deep yellow soil</td>
<td>Aquic Palehumult</td>
<td>140018 - Batang Mitus <em>(Buah)</em> <em>(see page 96)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is the lower part of the subsoil a greyish colour (somewhat poorly drained)?</td>
<td>No → Yes →</td>
<td>Is the subsoil yellowish brown with red/orange mottles (spots) (moderately well drained)</td>
<td>No → Yes →</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is the subsoil a uniform yellowish or brownish colour (well drained)?</td>
<td>No * Yes →</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic features for Soil Type</td>
<td>Soil Type</td>
<td>Diagnostic features for Soil Subtype</td>
<td>Soil Subtype</td>
<td>Soil Taxonomy Class</td>
<td>Representative Profiles – Agricultural Development Area</td>
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<td>---------------------------------------------------------------------</td>
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<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Does the subsoil have a dominantly yellowish or brownish colour, AND is the soil depth less than 150 cm?</td>
<td>Yellow soil (Haplohumult) <em>(see page 103)</em></td>
<td>Is the subsoil yellowish brown with red/orange mottles (spots) (moderately well drained or somewhat poorly drained)?</td>
<td>Moderately well drained yellow soil</td>
<td>Oxyaquic Haplohumult</td>
<td>020003 - Sg Tajau 070001 - Luahan 100002 - Kupang 110006 - Maraburong, Kupang 120007 - Padrunok/Sg Burong, Kupang 140013 - Batang Mitus (Buah) 140016 - Batang Mitus (Buah) 150014 - Batang Mitus (Halaman) 170015 - Birau (Penyelidikan) <em>(see page 106)</em> 240003 - KM 26, Jalan Bukit Puan Labi</td>
</tr>
<tr>
<td>No ↓ Yes ➔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is the subsoil a uniform yellowish or brownish colour (well drained)?</td>
<td>Well drained yellow soil</td>
<td>Typic Haplohumult</td>
<td>250005 - Labu Estate 250006 - Labu Estate 250009 - Labu Estate <em>(see page 108)</em> 270005 - Bakarut</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Does the subsoil have a yellowish brown coloured layer with red/orange mottles (spots) overlying a grey layer that has its upper boundary within 50 cm of the soil surface?</td>
<td>Brown over grey soil (Aqualf) <em>(see page 111)</em></td>
<td>Does the soil have greater than 50 percent brown colour between 25 and 75 cm of the soil surface?</td>
<td>Somewhat poorly drained brown over grey soil</td>
<td>Aeric Epiaqualf</td>
<td>040001 - Si Bongkok Parit Masin 150001 - Batang Mitus (Halaman) <em>(see page 114)</em> 160005 - Birau (P. P. Muda)</td>
</tr>
<tr>
<td>No ↓ Yes ➔</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a dominantly yellowish or brownish layer with red/orange mottles (spots) overlying a grey layer that has its upper boundary within 50 cm of the soil surface?</td>
<td>Brown over grey soil (Aqualf) <em>(see page 111)</em></td>
<td>Does the soil have greater than 50 percent brown colour between 25 and 75 cm of the soil surface?</td>
<td>Poorly drained brown over grey soil</td>
<td>Typic Epiaqualf</td>
<td>020009 - Sg Tajau 070005 - Luahan 080002 - Wasan <em>(see page 116)</em> 210033 - Merangking, Bukit Sawat 260001 - Selangan 280008 - Selapon</td>
</tr>
<tr>
<td>Diagnostic features for Soil Type</td>
<td>Soil Type</td>
<td>Diagnostic features for Soil Subtype</td>
<td>Soil Subtype</td>
<td>Soil Taxonomy Class</td>
<td>Representative Profiles – Agricultural Development Area</td>
</tr>
<tr>
<td>----------------------------------</td>
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<td>---------------------------------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Does a sulfuric layer (pH&lt;3.5) occur within 150 cm of the soil surface, AND is the subsoil uniformly grey coloured (poorly drained)?</td>
<td>Sulfuric soil (Aquept) (see page 119)</td>
<td>Does the sulfuric layer occur within 50 cm of the soil surface?</td>
<td>Poorly drained sulfuric soil (Sulfaquept)</td>
<td>Soft poorly drained sulfuric soil</td>
<td>090015 - Tungku (see page 122)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the sulfuric layer occur within 100 cm of the soil surface?</td>
<td></td>
<td>No *</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the subsoil have a greyish colour and no other diagnostic features within 150 cm of the soil surface?</td>
<td>Grey soil (Aquept) (see page 137)</td>
<td>Is the topsoil a dark colour?</td>
<td>Poorly drained grey soil</td>
<td>Humaqueptic Endoaquent</td>
<td>040005 - Si Bongkok Parit Masin (see page 140)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No *</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does a buried organic layer (organic material covered by mineral soil) occur within 100 cm of the soil surface?</td>
<td>Poorly drained moderately deep sulfidic soil (Aquent)</td>
<td></td>
<td></td>
<td></td>
<td>220002 - Melayan A (see page 134)</td>
</tr>
<tr>
<td>Does the subsoil have a greyish colour and no other diagnostic features within 150 cm of the soil surface?</td>
<td></td>
<td></td>
<td>Poorly drained grey soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 3 Evaluation of Land Suitability for Cropping

3.1 Introduction

Part 3 of this report uses the Fertility Capability Classification (FCC) approach of Sanchez et al. (2003) to interpret, with respect to crop production, the soil data gathered during the field survey of 27 Agricultural Development Areas (ADAs) and subsequent laboratory analysis. These data can be found in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.1 – Laboratory Analysis of Soil Chemical and Physical Properties (Beech et al. 2006) and in Part 4 as well as in the soil database developed during the project. Part 3 provides an evaluation of the suitability of a range of soil types found in Brunei for the cultivation of a range of crops and fruit trees that are either currently grown in Brunei or have the potential to be. The suitability recommendations should not be seen as final but as a starting point to inform discussion between farmers and technical experts and which can be built upon as extra knowledge becomes available through experience and experimentation.

3.1.1 Background

Soil fertility data facilitate evidence-based assessment of intrinsic soil capability, crop suitability and management interventions required for long-term productivity. This assessment will help Negara Brunei Darussalam meet its commitment to achieve a significant degree of food security. Research and development by the Department of Agriculture and close collaboration with farmers have allowed Negara Brunei Darussalam to meet 99.9% of its table-eggs and 76% of its poultry meat requirement. We adopt a similar participatory approach to engage the Department of Agriculture and the farmers to build on this initial success in improving food security. The challenge is to increase the level of self-sufficiency in rice, fruit and vegetable production. This could be achieved through yield increases per hectare, having more crops per year, and by developing new areas for agricultural production. Negara Brunei Darussalam currently meets a modest percentage (~3%) of its annual rice needs of 29,000 tonnes. As a first step towards self-sufficiency, it launched a 400 hectares rice project at Wasan ADA to supplement production from another 600 hectares scattered across the country. A large variety of tropical fruits are produced on a small scale and meet ~10% of domestic requirements of more than 14,000 tonnes. The Department of Agriculture encourages fruit production through the agricultural stations in Batang Mitus, Tanah Jambu and Lumapas by supplying planting material. Farmers are cultivating fruit trees including rambutan, durian and oranges. Vegetables grown locally constitute about 6,700 tonnes or ~70% of the country’s needs.

3.1.2 Objectives

As part of the ultimate goal of this project to assist the sustainable use of agricultural land in Negara Brunei Darussalam by providing soil-related information, this project activity aims to interpret the field and laboratory data with respect to attributes that influence crop production. This involved several outputs:

1. An FCC classification for each Soil Subtype identified during the survey and described in Part 4. The classification involved assessing a range of attributes relevant to crop production for soil profiles of each Soil Subtype sampled during the field survey and for which there are laboratory data. This output is in Section 3.2.

2. An assessment of the limitation to production posed by each attribute for each major crop or group of crops either currently or potentially cultivated in Brunei. Each level of an attribute is rated from 1 (no limitation) to 5 (unsuitable) for each crop. This output is at the start of each subsection within Appendix A.

3. An assessment of the limitations posed by each Soil Subtype to each crop, derived by combining the FCC classification attributes (from 1. above) with the limitation
assessments for each crop (from 2. above). This output is given in tabular form in each subsection within Appendix A.

4. An overall assessment of the suitability, from 1 (no limitations) to 5 (unsuitable), of each Soil Subtype for each crop, derived using the attribute posing the maximum limitation found at 3. above. This output is given in tabular form in Section 3.3.

The crops considered in the assessment are shown in Table 2. In many cases, two or more crops were assessed together.

### 3.2 Fertility Capability Classification (FCC)

The Negara Brunei Darussalam government recognises the need to protect the environment and conserve its land and water resources when expanding and intensifying agriculture to achieve improved food security. For this reason, we adopted the internationally used Fertility Capability Classification framework to identify and manage soil constraints to crop production and potential environmental threats from nutrient leaching and land degradation by acidification, erosion and organic matter loss. This brings our soil fertility assessment into the broader natural resource management context. The FCC provides a holistic, quantitative assessment of soil attributes related to production and the environment based on the morphological, chemical and physical properties of the topsoil and subsoil (Sanchez et al. 2003). These properties consist of field observations and measurements and a range of diagnostic laboratory analyses. This is a detailed analytical approach referred to as Level 3 by Moody and Cong (2008) in the Soil Constraints and Management Package (SCAMP). The chosen properties are those that are stable at time scales from years (for example soil acidity) to centuries (for example soil texture, slope) and are therefore ideal for both crop suitability assessment and soil management. The chosen timescale provides the basis to interpret the intrinsic soil fertility and management implications of soil taxonomic work carried out as part of this project. This approach addresses a weakness of Soil Taxonomy by providing additional topsoil attributes such as surface texture and pH which are not specifically expressed in soil classifications.

The idea of using a comprehensive assessment of fertility-related soil attributes is to ensure that they are managed or can be tolerated by judicious crop selection. This allows long term productivity and effective use of inputs such as lime and fertilisers that are routinely used in Negara Brunei Darussalam. These inputs will be poorly utilised by crops if, for example, soil acidity or waterlogging impedes root growth and nutrient uptake, or if the topsoil is washed away by erosion. The most limiting factor to crop production may often not be nutrition, and failure to recognise this may undermine any quest to raise food security.

Some of the attributes considered by the FCC, such as cold climate, calcareous and alkaline soils, reflect its wide-use internationally by the Food and Agriculture Organisation (FAO), Consultative Group on International Agricultural Reseach (CGIAR) organisations, Australian Centre for International Agricultural Research (ACIAR) projects and government agencies but are not relevant to Negara Brunei Darussalam.

The effect of each attributes, for example waterlogging, on crop production can be positive or negative depending on its duration and the intended land use. The FCC designation of a given soil is therefore interpreted in relation to land use. Several taxonomic soil groups or subgroups can have the same FCC unit. Therefore the number of FCC units is usually smaller than the number of Soil Taxonomic units and this simplifies management.

### 3.2.1 Soil Attributes for Fertility Capability Classification

Attributes used in FCC occur worldwide and adoption of this classification system facilitates the transfer of agronomically important soil information and soil management options from outside Negara Brunei Darussalam. FCC is a categorical classification system. It consists of two levels: (1) soil texture at 0-20 cm depth or in the ploughed layer whichever is shallower and substrata type if textural change is encountered within 0-50 cm depth and (2) soil condition modifiers. These modifiers were called constraints in earlier versions of the FCC.
but, as indicated earlier, attributes such as waterlogging may or may not be a constraint depending on land use. The classifications used in the first categorical level and their definitions are given in Table 6. When there is no textural change within the 50 cm layer, a single symbol for the uniform profile is used (e.g. S: sand or L: loam). When a textural change occurs, the subsoil texture is given after that of the topsoil (e.g. SL: sand over loam, LC: loam over clay etc).

Table 6: First categorical level of the FCC: Soil type. (Adapted from Sanchez et al. 2003).

<table>
<thead>
<tr>
<th>Layer</th>
<th>Symbol</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture in 0-20 cm or ploughed layer, whichever is shallower</td>
<td>S</td>
<td>Sandy topsoils: sands and loamy sands</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>Loamy topsoils: sandy loam, silty loam, loam or clay loam or &lt;35% clay but not sands and loamy sands</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Clayey topsoils: fine clay or heavy clay texture or &gt;35% clay</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>Organic soils: &gt; 12% total organic carbon to a depth of 50 cm or more (histosols and histic groups)</td>
</tr>
<tr>
<td>Subsoil texture. This is only used if textural change occurs in 0-50 cm layer</td>
<td>S</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>Rock or other root restricting layer within 50 cm</td>
</tr>
<tr>
<td></td>
<td>R^-</td>
<td>As for R above but can be deep-cultivated to increase root depth</td>
</tr>
</tbody>
</table>

The soil and substrata type (if present) figure prominently in the FCC because they have important implications on water dynamics (Sanchez et al. 1982), soil conditions for root growth (Moody and Cong 2008), and agronomic interventions needed to manage these soils. Some interpretations for agriculture are given in Table 7.

Table 7: Interpretation of FCC soil type categories for agriculture. (Adapted from Moody and Cong 2008).

<table>
<thead>
<tr>
<th>Texture</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Minimal resistance to root growth. Good water holding capacity. Moderately susceptible to compaction except for sandy loam which is highly susceptible. Sandy loams and loams have moderate infiltration rates whereas silty and clay loams have moderate to low infiltration rates.</td>
</tr>
<tr>
<td>O</td>
<td>Anaerobic soils with low pH and drainage problems. Artificial drainage is needed but subsidence may occur when drained and on raised beds. Possible nitrogen and micronutrient deficiencies; high herbicide rates usually required. Very acidic. Flower sterility and empty panicles commonly occur in modern domesticated rice varieties.</td>
</tr>
<tr>
<td>SC, LC, CR, LR, SR</td>
<td>Soils prone to erosion due to sharp texture contrast (SC, LC) or shallow depth (CR, LR, SR). Prone to waterlogging in flat lands due to impeded drainage in the subsoil.</td>
</tr>
</tbody>
</table>
At its second categorical level, FCC modifies the topsoil type and substrata type (if present) according to a comprehensive list of soil conditions relevant to crop growth and productivity. Soils are classified by determining whether these conditions are present or not. The FCC lists the type and substrata type (if present) in capital letters and then the soil condition modifiers in lower case letters. For example, Sak is a sandy soil with toxic levels of aluminium toxic and low in potassium reserves (Table 8). A suffix is sometimes used to indicate the level of the modifier. For example, a– denotes 10-60% aluminium saturation which is only toxic to very sensitive crops such as soybeans. These modifiers are normally applied to the topsoil (0-20 cm depth or ploughed layer whichever is shallower) except when a soil depth is specified. The absence of modifiers after the soil type suggests no major fertility limitations, other than nitrogen deficiency. For example, L is a loamy soil with no major fertility limitations, other than nitrogen deficiency. Table 3 lists soil condition modifiers encountered in Negara Brunei Darussalam. This comprehensive list can be added to as additional soil information becomes available.

### Table 8: Identification of soil condition modifiers for Fertility Capability Classification

<table>
<thead>
<tr>
<th>Soil condition</th>
<th>Symbol</th>
<th>Identifying criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterlogging</td>
<td>g</td>
<td>Aquic moisture regime; soil is waterlogged for a significant period during the growing season; mottles with chroma &lt;2 between 0-50 cm depth and below all A horizons</td>
</tr>
<tr>
<td></td>
<td>g+</td>
<td>Prolonged waterlogging, no mottles between 0-50 cm depth; soil saturated &gt;200 days per year.</td>
</tr>
<tr>
<td>Slope</td>
<td>%</td>
<td>An estimate of the range of slopes in %.</td>
</tr>
<tr>
<td>High erosion risk</td>
<td>w</td>
<td>Soils with high erosion risk due to steepness (&gt;30% ~ 17°), or due to texture contrast (SC, LC) or shallow soils (CR, LR SR) combined with slopes &gt;20% (~ 11°).</td>
</tr>
<tr>
<td>Sulfidic</td>
<td>c</td>
<td>Field pH&lt;3.5 after drying in chip tray for more than a month; jarosite mottles with hues &gt;2.5Y and chromas&gt;6 within 60 cm depth. Sulfuquents, sulfuquepts, sulfudepts.</td>
</tr>
<tr>
<td>Aluminium toxicity for common crops</td>
<td>a a-</td>
<td>&gt;60% Al saturation within 50 cm depth.</td>
</tr>
<tr>
<td>Low potassium reserves</td>
<td>k</td>
<td>Exchangeable K &lt;0.20 cmol/kg.</td>
</tr>
<tr>
<td>High P fixation by Fe and Al oxides</td>
<td>i i+</td>
<td>Phosphorus buffer index (PBI) &gt;280 (Burkitt et al. 2002).</td>
</tr>
<tr>
<td></td>
<td>i-</td>
<td>PBI &gt;280, decreased fixation due to P fertiliser history having increased Colwell P &gt;15 mg/kg.</td>
</tr>
<tr>
<td>Cracking clays</td>
<td>v</td>
<td>&gt;35% clay and &gt;50% of 2:1 expanding clays. Vertisols and vertic groups.</td>
</tr>
<tr>
<td>High leaching potential</td>
<td>e</td>
<td>ECEC &lt;4 cmol_/kg.</td>
</tr>
</tbody>
</table>

### 3.2.2 Farmers’ Knowledge of Soil Fertility Problems

We interacted with Department of Agriculture colleagues and farmers, and visited farms in Temburong, Belait, Tutong and Brunei Muara districts to ensure that our list of FCC attributes covers Negara Brunei Darussalam comprehensively. Waterlogging, acidity and erosion risk were commonly recognised problems across these four districts. Frequent and high rates of
lime are used across Negara Brunei Darussalam to ameliorate soil acidity. Nitrogen, phosphorus and potassium were applied routinely to rice, fruit and vegetable crops and soil test values for phosphorus and potassium were often high. The conditions listed in Table 8 include all soil issues identified by farmers plus a more detailed breakdown of the type of soil acidity encountered to include sulfidic soils (c). FCC did not identify a marked dry season as being an issue in Negara Brunei Darussalam as the definition of ustic or xeric soil moisture regimes requires >60 consecutive dry days per year. The absence of a distinct dry season suggests that year-round crop production should be possible. We observed that irrigation was commonly used in all vegetable areas. This need for irrigation in a relatively wet environment (mean annual rainfall at Kilanas of 2755 mm, with a minimum mean monthly rainfall of 165 mm in May) may reflect shallow rooting depth due to subsoil constraints such as aluminium toxicity, calcium deficiency or root pruning by intermittent waterlogging. Crop diseases and lack of local drainage infrastructure were often cited as problems. These problems are outside the scope of this report.

3.2.3 Interpretation of Soil Condition Modifiers

3.2.3.1 Waterlogging (g, g+)

Poorly drained, waterlogged soils occupy a large proportion of the Agriculture Development Areas across all four districts. Many of them are used for rice cultivation. Wetland soil condition (g) is the preferred moisture regime for rice but prolonged submergence (g+) causes zinc deficiency (Buol 1986). There is no distinct dry season in Negara Brunei Darussalam and the wetlands can potentially sustain more than the current one annual rice crop per year of the local variety. In a similar climate in the Philippines, for example, up to 3 crops of short-duration cultivars can be grown.

In places where the water table is ~15 cm or less, raised beds and artificial drainage to a farm pond are used in vegetable and fruit production to avoid waterlogging. There is also a requirement for a regional drain infrastructure that can adequately remove excess water from the farms. These soils can emit the greenhouse gasses methane and nitrous oxide. Nitrous oxide loss can be minimised in paddy fields by applying ammonium or urea instead of nitrate fertilisers to the anaerobic soil.

3.2.3.2 Slope

Slope is an issue for all crops. Slope can be expressed in degrees from the horizontal or in percent. The conversion is:

\[
\text{Slope in percent} = 100 \times \tan(\text{slope in degrees})
\]
\[
\text{Slope in degrees} = \arctan \left( \frac{\text{slope in percent}}{100} \right)
\]

Steep slopes are an issue for erosion risk, water management and the difficulties of land preparation and crop management, especially for mechanised operations.

Many ADA’s had steep slopes (>30%, about 17°). The risk of erosion on such slopes is identified by the ‘w’ factor (see below) along with those with sharply contrasting soil texture. The slope modifier can be used to identify less steeply sloping lands where erosion is a risk due to the combination of intense rainfall and land management practices that leave the surface exposed at some point during the crop cycle. For example the surface may be exposed after harvesting of cassava, sweet potato, or other root crops. Vegetables crops often have exposed soils. The management required to minimize erosion is discussed in the next section.

The slope modifier can also be used to identify situations where slopes impede land preparation or crop management. For mechanical operations it is generally accepted that uninterrupted slopes of less than 15% are preferred for tree crops. Perennial fruit tree crops may be grown in areas where slopes range from flat (0%) to 55%, although with good management it may be possible to cultivate some fruit tree crops on steeper slopes. A number of pasture species can be grown on steep land.
For lowland rice, only minimal slope is acceptable due to the need for intermittent ponding. Greater slopes can be used but require substantial investment in terrace construction and terrace management. Soil fertility may be low for several years after terracing. In general, slopes steeper than 55% are best not developed.

### 3.2.3.3 High Risk of Erosion by Water (w)

A large proportion of land across the Agricultural Development Areas has slopes approaching 30% (equivalent to 17°) and is at high risk of soil erosion by water with consequent loss of nutrient-rich surface soil, organic matter, and surface applied fertilisers and manures. Soils with sharp texture contrasts and shallow topsoils increase erosion risk further but were not common across the inspected ADAs. Erosion can negatively affect both crop productivity by loss of fertile top soil and ecosystem function by increasing nutrient and sediment load in streams and rivers. Although land with such high levels of erosion risk should normally not be cropped (Moody and Cong 2008), the erosion risk appeared to be well managed in cropped areas by the farmers we visited. The main strategy used is to keep the land covered by a continuous canopy of grassy weed species throughout the year. These areas are subjected to minimal tillage and traffic. High density fruit-tree planting also decreases the impact of rainfall on the ground. Contour banks do not appear to be widely used in Negara Brunei Darussalam but continuous ground cover uninterrupted by a dry season and with minimal soil disturbance appear effective for controlling erosion in those areas cropped to fruit-trees and vegetables. Where vegetables crops require the soil surface to be exposed, the surface should be mulched.

Slopes prone to erosion require soil conservation interventions such as grass strips, graded layouts, interception drains, ground cover, grassed waterways, terraces or bench terraces. Such technology is well developed. However, in many areas throughout the tropics, such soil conservation measures have not been adopted leading to serious erosion. In uncropped areas and along farm tracks, exposed soil has led to severe channel or rill erosion that impedes normal farm traffic and farm operation. This needs engineering work to remediate.

### 3.2.3.4 Sulfidic Soils (c)

Sulfidic soils (i.e. acid sulfate soils, ASS) are soils in which sulfuric acid may be produced, is being produced, or has been produced in amounts that have a lasting effect on main soil characteristics (Pons 1973). This general definition includes potential, active (or actual), and post-active acid sulfate soils, three broad genetic kinds that continue to be recognized (e.g. Fanning et al. 2002). ASS form from the interaction of sulfates, usually from seawater, iron from sediments and abundant organic material under permanently waterlogged or water-saturated conditions to form sulfide-containing minerals, predominantly iron pyrite (FeS₂). Commonly ASS layers occur in modern tidal floodplains at less than 5 metres above sea level and may be covered by soil layers that are neither sulfidic nor acid. Sulfidic soils may also develop in sedimentary rocks (e.g. Setapi shale) where pyrite has accumulated as a result of similar processes in the geologic past.

When previously undisturbed soils or soil layers are exposed to air, for example by drainage or earth work, pyrite oxidises, with each mole of pyrite yielding 4 moles of acidity (i.e. 2 moles of sulfuric acid). This results in soil material with a pH of 3.5 or less. Soils where oxidation has already occurred usually contain stored acidity (e.g. the mineral jarosite) which must be neutralised in order to raise the soil pH.

Note that the definition of “sulfidic soil” used in the FCC classification differs from that used by Soil Taxonomy and is broadly equivalent to the more generic term “acid sulfate soil”.

Free sulfuric acid dissolves clay minerals and produces toxic concentrations of aluminium in the soil solution. Iron and manganese toxicities are also common. Phosphorus deficiency ensues because of its complexation by dissolved aluminium and iron.

The impact of the sulfidic layer on crops depends on the depth at which it occurs together with the sulfide concentration. These factors determine whether an ASS can be used for
aerobic crops. Raised beds of limed soil and high water tables are often used to avoid the acidic layer and its oxidation. This works well in mineral soils. However, in peat soils there are problems with raised beds due to loss peat by oxidation and subsidence. Flooded rice is often grown on mineral acid sulfate soils since flooding prevents oxidation of sulfides, neutralises acidity and ameliorates aluminium toxicity. Tropical peats tend to cause floral sterility and empty panicles in modern domesticated rice varieties.

3.2.3.5 Aluminium Toxicity (a, a-)

Aluminium toxicity to susceptible crops occurs as a result of mineral dissolution or desorption of organically bound aluminium in strongly acid soils (pH in CaCl₂ <5.5). Toxicity is prevalent in peat and acid sulfate soils which have pH values typically < 4.0 but occurs commonly in other soils across Negara Brunei Darussalam. Acidity in these other soils is exacerbated by acidifying practices such as application of high rates of ammonium fertilisers, poultry manures high in nitrogen, and removal of large amounts of plant residues. The amount of aluminium released into the soil solution is reflected by the exchangeable aluminium saturation of the soil. Most crop species are affected by aluminium saturation exceeding 60% (soil condition, a) but sensitive species are affected at 10-60% aluminium saturation (a-). Aluminium toxicity attributes a and a- were found in soils across all agricultural development areas (ADAs). Because solution aluminium affects root growth and the crop’s ability to take up water and nutrients, this problem must be tackled first to allow the crop to access water and nutrients. Management options include liming, addition of organic matter rich in alkalinity (Wong and Swift 2003) and use of tolerant species. Soil with marginal magnesium content will benefit from dolomitic lime.

3.2.3.6 Low Potassium Reserves (k)

Hot humid conditions accelerate mineral weathering and over a long period of time the reserves of weatherable minerals responsible for potassium release may be depleted. About a third of tropical soils have low (<10%) reserves of weatherable minerals in their sand and silt fractions. These soils can be identified by their low exchangeable potassium content (K <0.20 cmolc/kg). This constraint is easily rectified by potassium fertiliser application, so this attribute is only given a low weighting when determining a soil’s suitability for a particular crop. In the longer term, build up of soil organic matter through erosion control and improvement in crop productivity would provide a buffer against rapid potassium depletion. Crops such as banana and maize have high potassium requirements.

3.2.3.7 High P Fixation (i, i+, i-)

Soils (i) with high (>20%) iron and/or aluminium oxide contents strongly sorb large quantities of applied phosphate fertilisers into forms that are poorly available to crops. To meet crop needs, phosphate fertilisers must be applied in large amounts or in ways, such as banding, that minimise contact with the highly reactive soil.

Under prolonged waterlogging (g+ condition) these soils can dissolve toxic concentrations of iron into the soil solution and have the potential to cause toxicity in rice. This is labelled i+.

Where there has been a history of heavy fertilizer use, the phosphate reactive sites become occupied by reaction with P fertilisers so that additional P applications become increasingly less bound by the soil. Phosphate fertilisers are routinely used in Negara Brunei Darussalam leading to relatively high Colwell soil P test values in many soils across the ADAs. To accommodate the likely higher P availability following a history of P fertiliser applications to a high P fixing soil, at soil test values >15 mg Colwell P/kg, the strong phosphate sorption is downgraded to an i- condition.

Phosphorus buffer capacity provides a direct measure of fixation (Moody and Cong 2008). Phosphate buffer capacity is the slope of the plot of P sorption against equilibrium P in solution; soils with high P buffer capacity have high P fixing properties. Sorption from a single addition of solution P provides an index called the P buffer index (PBI) which is highly correlated with the more time-consuming measurement of buffer capacity. Soils with PBI
>280 are regarded as having a high P buffer capacity and are highly P fixing (Moody and Cong, 2008).

In Negara Brunei Darussalam where fertilizer is commonly applied, this attribute can be seen as a management issue rather than a land suitability issue and consequently is given a low weighting when determining suitability for a particular crop.

3.2.3.8 Cracking Clays (v)

This condition occurs in soils belonging to the Vertisol order and vertic subgroups of other soil orders. These soils swell, shrink and crack in response to changes to soil moisture content. They are very sticky when wet and very hard when dry. They are difficult to till, and the range of water contents at which they are suitable for cultivation is usually narrow. Structure degradation due to tillage at unsuitable water contents is a risk. Harvesting root crops is often difficult. They are often slow to drain, and restrict rooting depth due to poor structure. In addition, much of their water holding capacity is unavailable to plants. This combined with restricted rooting depths often leads to water stress during dry periods. They are often phosphorus deficient. They occur on flat land in Negara Brunei Darussalam.

3.2.3.9 High Leaching Potential (e)

These are sandy soils or strongly granular clayey soils with high levels of Fe and/or Al oxyhydroxides. These soils have a low number of negative charges per unit weight of soil capable of holding cations i.e. low cation exchange capacity (CEC). The CEC of these soils often varies according to the pH and ionic strength of the measuring conditions. To avoid this problem, effective CEC (ECEC) is used to estimate CEC of the soil at its field pH. ECEC is the sum of exchangeable cations and exchange acidity. Soils with ECEC <4 cmolc/kg have a high leaching potential for cations such as calcium, magnesium and potassium, and these nutrients are poorly retained against leaching. Nitrate leaching is also a problem in these soils because of higher rates of drainage compared to soils with finer texture and lack of structure. These soils can develop deficiency rapidly due to loss by leaching. Fertilisers should be applied in split applications at low rates to meet crop requirements. Areas of pale sand around KM26 Jalan Bukit Puan Labi fall into this category.

3.2.3.10 Organic matter depletion (m)

Soil organic matter is important for soil fertility in low input agriculture. Its mineralisation releases plant nutrients such as nitrogen, phosphorus and sulfur. It helps maintain soil structure and in variable charge soils is a major source of ECEC and pH buffering capacity. The threshold total soil organic carbon index (organic C divided by organic C in a nearby undisturbed/productive site with the same soil type) was arrived at using a study in Kenya (Murage et al. 2000). The problem of using this approach in Negara Brunei Darussalam is the difficulty of finding suitable undisturbed or productive soils (100% level) to establish the benchmark organic C level.

3.2.4 Fertility Capability Classification of Agriculture Development Area Soils

Field observations and laboratory analysis of representative profiles were used to determine FCC at the Soil Subtype level (Table 9). Organic soils (O, peat soils) occurred commonly in low-lying waterlogged areas. Waterlogging (g) was common and not confined to organic soils; it also occurred in low-lying sandy soils, loams and clays. Some of these clays had cracking or vertic (v) properties. Non-waterlogged soils occurred on slopes. These slopes were often steep (>30% or about 17°). This, together with texture contrast at some locations, gave rise to high risk of erosion by water. Aluminium toxicity (a) was also prevalent across the ADAs. It always occurred in sulfidic soils (c) but also occurred in other acid soils. Sandy soils typically had low potassium reserves (k) and were exposed to high leaching risk (e).
## Table 9: Fertility Capability Classification of major Soil Types and Subtypes.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope</th>
<th>Max. slope</th>
<th>Erosion risk</th>
<th>Sulfidic horizon (c, depth, cm)</th>
<th>Aluminum (a, +)</th>
<th>Low K reserves</th>
<th>High P fixation</th>
<th>High teaching</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic soils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Saprist</td>
<td>O C g+ 2%</td>
<td></td>
<td>c(30) a i+</td>
<td></td>
<td></td>
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</table>
3.3 Interpretation of Fertility Capability Classification

Inherent soil properties embodied in Fertility Capability Classifications have a determining role in land use suitability. Crops and fruit trees have different liking, sensitivity, tolerance and adaptation to the comprehensive range of soil types and attributes examined. This determines their likely success on a particular soil and the practical management interventions required.

3.3.1 Crop Suitability Rules

We used expert opinion and literature data for each grain, fruit, vegetable, and tree crop of interest to rank how well they would perform against each FCC attribute. The criteria for ranking are as follows (after FAO 1976):

1. Attribute poses no significant limitation to sustained application of the specified use.
2. Attribute poses a minor limitation to the sustained application of the specified use that will cause a minor reduction of productivity or benefits and will not raise inputs above an acceptable level.
3. Attribute poses a major limitation to the sustained application of the specified use that reduces productivity or benefits and increases required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be significantly less than from Class 1 or 2 land.
4. Attribute poses a severe limitation to the sustained application of the specified use that so reduces productivity and benefits, or increases required inputs, that this expenditure will be only marginally justified.
5. Attribute poses such a severe limitation that it precludes the sustained application of the specified use.

For each Soil Subtype, the impact of each FCC soil type category and attribute on the crop being examined was ranked on the 1 to 5 scale above. For example for leafy vegetables, the absence of waterlogging poses no limitation, so soils without the ‘g’ modifier rank 1 for this attribute. Waterlogging (g) poses a moderate limitation that can be overcome by normal agronomic practice such as the use of raised beds, so soils with the g modifier rank 2 for this attribute. Alternatively the yield loss due to waterlogging is within acceptable bounds. Prolonged waterlogging (g+) either causes severe yield loss or requires more extensive intervention, such as the construction of drains to lower the watertable. Soils with the g+ modifier rank 3 for this attribute for leafy vegetables.

The ranking of each attribute may vary considerably between different crops/fruit trees. Thus the absence of waterlogging ranks 3 for rice whereas waterlogging (g) ranks 1 and prolonged waterlogging (g+) 2.

Another consideration when ranking the attributes for each crop is the relative weighting or importance of the various attributes. Where unfavourable levels of an attribute cannot be modified or modified only with great difficulty – for example, slope, soil type – the full range of rankings from 1 to 5 are used for the various levels of the attribute. However, where unfavourable levels of an attribute can be relatively easily amended it is important that the range of rankings is restricted. For example, in the rankings for low K reserves (k) used in this study, the ranking mostly ranges from 1 to 2. This means that low K reserves, while imposing a minor limitation on cropping due to the need for greater amounts of fertilizer, cannot on its own cause a soil to be ranked as unsuitable. The relative rankings need to take into account the cultural practices commonly used in the area. In Brunei, where fertilizer is available, affordable and commonly used, low K reserves is only a minor limitation. In other socio-economic situations, where fertilizer inputs are relatively unaffordable – for example to subsistence farmers, then low K reserves might be considered a greater limitation and a wider range of rankings used, such as 1 to 3 or 1 to 4.
The rankings constitute the ‘rules’ by which soil data from the field survey are interpreted into a land suitability for each crop/fruit tree. The rankings given below are based on literature and expert opinion, but can be adjusted in the light of local experience and experimentation.

The ranking of each attribute for each crop/fruit tree is presented at the start of each subsection within Appendix A together with the literature and experience that form the basis of the rankings. A summary of the limitations posed by each attribute is given in Table 10 for short-duration crops, in Table 11 for fruit trees and crops and in Table 12 for fodder grasses and legumes.
Table 10: Comparison of suitability rules for short-duration crops.
For most attributes, the attribute level is shown on the left and the suitability ranking for each crop in the relevant column. For slope and depth to sulfidic horizon, the suitability rankings are shown on the left and the attribute levels for each crop are shown in the relevant column.

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<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
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Table 11: Comparison of suitability rules for fruit crops.
For most attributes, the attribute level is shown on the left and the suitability ranking for each crop in the relevant column. For slope and depth to sulfidic horizon, the suitability rankings are shown on the left and the attribute levels for each crop are shown in the relevant column.

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Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
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3.3.2 Ranking the Limitations of Soils on Crop Production

The next stage is to determine the limitations of each soil class for each crop/fruit tree. Using the FCC derived for a Soil Subtype in Table 9, the level of each attribute (present, absent, +, - etc.) for the soil is compared to the attribute suitability rules for each crop. A rank is then assigned to each attribute to indicate the limitations posed by the soil on a particular crop/fruit tree. This process is automatic since it simply involves using suitability rules to convert the FCC attributes in Table 9 into a suitability rank. The attribute rankings of each soil are presented in tabular form in the subsection for each crop, fruit tree or fodder crop in Appendix A.

3.3.3 Overall Land Suitability for Crops/Fruit Trees

3.3.3.1 Land Suitability Classes

Assuming negligible climate variability across Negara Brunei Darussalam and crop preselection for its wet equatorial climate, the overall suitability of a site can be determined by the FCC of the soil. The overall suitability of a soil for a crop/fruit tree is determined by the most limiting factor – i.e. the overall ranking is the maximum of all the rankings for individual attributes. The definitions of the land suitability classes are as follows:

1. **Highly suitable land** with no significant limitations to sustained application of the specified use.
2. **Suitable land** with minor limitations to the sustained application of the specified use that will cause a minor reduction of productivity or benefits and will not raise inputs above an acceptable level.
3. **Moderately suitable land** with major limitations to the sustained application of the specified use that reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be significantly less than from Class 1 or 2 land.
4. **Marginally suitable land** with severe limitations to the sustained application of the specified use that so reduce productivity and benefits, or increase required inputs, that this expenditure will be only marginally justified.
5. **Unsuitable land** with such severe limitations that they preclude the sustained application of the specified use.

These definitions broadly follow those of FAO (1976) with classes 1 and 2 equivalent to FAO suitability class S1; class 3 to FAO suitability class S2; class 4 to FAO suitability class S3 and class 5 to FAO suitability classes N1 and N2 combined.

For example, the ‘O’ attribute (occurrence of peat) is the most important limiting factor for production of modern domesticated rice varieties on some Soil Subtypes because of its link to flower sterility causing empty panicles. The marginally suitable ranking of 4 given to the ‘O’ attribute controls the overall suitability (4) of the Soil Subtype for production of these rice varieties.

It is most important to appreciate that land suitability classes cannot be used as the only factor to determine which crop is the best choice for a particular location, because the assessment involves no economic or policy information. The suitability class informs decision makers about the bio-physical limitations for a particular crop. For example, a soil may be class 1 land for fodder grass but class 3 land for vegetables. This means there are more limitations to growing vegetables than grass and that vegetables will either require greater investment to achieve optimal yield or will yield below their optimal yield for the region. However, if the potential returns from vegetables are sufficiently greater than those from grass, then it is possible that vegetables may be the more profitable crop. Alternatively, another area might be class 1 land for vegetables and class 2 land for rice, but have poor transport routes to markets, making it impossible to bring fresh vegetables to
market on a regular basis. In this case, an annual crop such as rice might be preferable because transport is only required once a year.

### 3.3.3.2 Land Suitability Subclasses

Land suitability subclasses are defined according to those attributes that cause it to be allocated its suitability class. The subclasses are shown by suffixing the suitability class with the rule or rules that caused the soil to be so classified. For example, if the suitability class of a soil for rice is 4 because it is an organic soil (O), it is designated “4 O”. Similarly, if a soil has a slope of 30% causing it to be in class 5 for rice it is designated “5 >15%”. Note that it is the rule that is given as the suffix, not the actual attribute level of the soil.

For some Soil Types a suitability subclass may be given in brackets after the main subclass. This relates to the suitability of the steepest slopes found for the Soil Type. For example “3 a [4 >65%]” means that the Soil Type is mostly suitable for the crop in question with a major limitation due to aluminium toxicity, but that sometimes it is only marginally suitable because the slope exceeds 65%.

Table 13 presents the land suitability subclasses for each Soil Subtype for short-duration crops. Similarly Table 14 presents those for fruit and tree crops and Table 15 for fodder grasses and legumes.

This approach provides a living framework for using FCC and crop data that can be improved continuously to take account, for example, of varietal difference in crops and their response to soil attributes, local knowledge and experience and new research and development. Crop variety provenance from Negara Brunei Darussalam and elsewhere is also expected to have a major influence on adaptation to the soil attributes. For each crop, we suggest the ranking to be used for each soil condition. Whilst the these rankings are based on literature and experience from a wide range of sources, they will require modification in the light of local experience and to take account of local agronomic practices. This step will improve the relevance of the suitability assessments in the Brunei context.

A decision to develop a fruit tree industry involves significant financial investment and has long-term consequence because of the long-life expectancy of trees and the lead time from planting to fruiting. Site selection therefore has to be done with upmost care as the investor will live with the consequence of that decision for a long time. FCC only deals with the soil fertility aspect of land suitability. Infrastructural (access to transport, fertilisers, drainage network, fruit processing and storage etc), social (access to labour etc) and economic (access to market, good price etc) aspects are very important considerations for land use decision. These aspects are outside the scope of our study but need to be considered separately. A system such as the Automated Land Evaluation System (ALES: http://www.css.cornell.edu/landeval/ales/alesprog.htm) provides a well-used framework for this more comprehensive analysis. Some short duration or annual tropical fruits such as papaya, banana and pineapple are included here for convenience.

The detailed derivation of the overall suitability of each Soil Subtype to each crop or group of crops with similar soil requirements is given in the tables of Appendix A. As explained earlier, we stress that these ratings do not take into account socio-economic, policy and infrastructure issues which are outside the scope of this work.
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Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
Page 45
Table 14: Suitability of major Soil Types and Subtypes for fruit crops.

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<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
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<tr>
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<td>3 a</td>
<td>3 ga</td>
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<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
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<td>5 g+</td>
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<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
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<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
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<td>3 gc(≤75)a</td>
<td>3 gc(≤75)a</td>
<td>3 Sgc(≤75)a</td>
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Table 15: Suitability of major Soil Types and Subtypes for fodder crops.

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<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Grasses for wet areas</th>
<th>Grasses for well drained areas</th>
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<td>3 Og+</td>
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<td>3 Og+</td>
<td>2 Og+c≤(20)ai+</td>
<td>4 g+</td>
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<td>3 g+v</td>
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<td>Uxrots</td>
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<td>Sulphuric soils</td>
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<td>Grey soils</td>
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<td>Poorly drained</td>
<td>Aquepts</td>
<td>2 i+</td>
<td>3 g+</td>
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</tbody>
</table>
3.3.4 Summary of Land Suitability Assessment

Table 13 and Table 14 show there are major limitations to cropping throughout the range of soils found in the Agricultural Development Areas. Table 15 shows the suitability for fodder grasses and legumes is generally better. The most common limitations are due to waterlogging or the presence of shallow sulfidic horizons in low lying areas and the steepness of many slopes in upland areas. The suitability for fruit trees is often more heavily constrained because their rooting depth is much greater that that of short-duration crops.

The suitability rules that resulted in these rankings are based on literature from a wide range of sources together with experience and observations made in Brunei and elsewhere. FCC therefore opens Negara Brunei Darussalam to this international agricultural information and facilitates agro-technology transfer. A large proportion of this information and agro-technology can be accessed on the World Wide Web and could empower Department of Agriculture staff to participate in decisions on management, research and development, and extension interventions needed to achieve a greater degree of food security.

The rules given in this report should be seen as a starting point for further discussion and modification, based on the experience of agronomists and farmers in Negara Brunei Darussalam that is more relevant to the local conditions. Local involvement and ownership of the process is critical for adoption of new crops and on-farm technologies. The matching of crop requirements with FCC offers an opportunity for this participatory approach. However, it is also important to see the suitability rankings in an international context, so that a soil seen as relatively suitable in a Brunei context, might be only moderately suitable when compared to soils elsewhere.

Some more specific observations are as follows. These relate both to the attributes on which the suitability was ranked and other laboratory and field data from the survey given in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.1 – Laboratory Analysis of Soil Chemical and Physical Properties (Beech et al. 2007) and Part 4.

3.3.4.1 Poor Drainage

Poor drainage is a widespread constraint throughout the ADAs in Brunei-Muara District, at lower elevations of ADAs in Tutong District, and in many of the ADAs surveyed in Belait and Temburong Districts. This causes many problems including high risk of denitrification, possible methane/sulphide toxicity on histic soils, and increased susceptibility of crops to root diseases. Artificial drainage and mound planting of crops are management responses to improve aeration in the root zone. Also adequate surface drainage should be developed to remove excess rainfall. Split applications of ammonium-based fertilisers in accord with crop N demand pattern, or the use of slow release N fertilisers (eg. polymer-coated urea), are strategies for reducing denitrification. Nitrification inhibitors are unlikely to be effective for reducing denitrification because of their limited efficacy at high soil temperatures.

Care must be taken when draining Histosols, because they are prone to shrinkage on drying which can negate the benefit of drainage by lowering the soil surface and bring it closer to the water table.

3.3.4.2 Compaction Risk

Compaction and structural degradation can occur when soils are tilled or trafficked when at a moisture content equal or greater than the plastic limit. The humid climate combined with poor drainage means soil water contents are frequently above plastic limit and reduces the periods when the soil can be tilled without risk of degradation. This is a particular problem with clay soils whose drained upper limit can often be close to the plastic limit. Compaction can compound the impact of poor drainage by further restricting rooting depth. This reduces the plant available water holding capacity and can cause crops to become water stressed earlier than when grown on uncompacted soils.
3.3.4.3 Surface Soil Hardsetting/Crusting

Some of the representative profiles (eg. 09 0012, 14 0018, 21 0019) have high contents of fine sand and/or silt which pre-disposes them to be surface sealing/hardsetting. Indeed the field descriptions show their consistence as extremely firm. However, the humid conditions greatly reduce the risk of surface hardsetting/crusting being actually expressed when the surface soil is dry. Nonetheless, it is wise to protect the surface of these soils by keeping them fully surface covered with mulch or crop residues/canopies to minimise raindrop impact and to keep the soil surface moist.

3.3.4.4 Aluminium Toxicity

Aluminium toxicity is a widespread constraint. Possible correction strategies are liming and/or use of plant amendments that raise soil pH and complex aluminium (eg. green manure crops such as *Peuraria* and *Mucuna*, see Wong and Swift, 2003). Effective liming management requires an accurate assessment of soil lime requirement by measuring soil pH buffer capacity and deciding on a target soil pH.

A priority area of research is investigating suitable methods for measuring pH buffering capacity in the various soils. Because of the variable nature of the organic carbon in the soils, and the sulfuric/sulfidic layer present in some, it is unlikely that any simple estimation techniques (ie. pedotransfer functions) comprising clay content, organic carbon content, etc. will be applicable across all soil types. For the non-acid sulphate soils, direct measurements of pH buffer capacity (eg. Mehlich or SMP buffers) or the lime incubation method should be evaluated. Liming management will need to take into account subsoil aluminium status as well as that of the surface soil, because it is likely that subsoil acidity will be a major constraint to rooting depth of many deeper rooted crops. For the acid sulphate soils, appropriate methods for determining lime requirement should be assessed.

A related problem is calcium deficiency, which is likely to be a major constraint for aluminium tolerant crops (e.g. sugar cane) particularly where exchangeable calcium is very low (e.g. 21 0019). In such situations, the topsoil pH and calcium deficiency should be corrected by incorporation of liming materials into the topsoil. However, none of these, including partially water soluble materials such as hydrated lime or calcium oxide, are sufficiently mobile to correct sub-soil calcium deficiency which can restrict root depth. The use of a soluble calcium source such as gypsum – in combination with topsoil liming – should be investigated for aluminium tolerant crops. By leaching into the subsoil, the gypsum would help remove the constraint to root development due to calcium deficiency. This option would require caution because in variable charged soils (all except the Vertisols) the increase in soluble salt concentrations generated by gypsum may cause the soil pH to decline further. However, this effect is likely to be transitory and outweighed by the benefits of correcting calcium deficiency.

3.3.4.5 High Organic Carbon Levels

The total organic C/total N ratio of the surface soils of some of the representative profiles is high (>20) (eg. 03 0002, 09 0015) suggesting that oxidation of soil organic matter in these soils may lead initially to immobilisation, not mineralisation, and crops growing on these soils will need planting N applications to meet their initial N demands.

3.3.4.6 Phosphorus Fixation

There is a wide range in phosphorus fixing capacity. Some of the representative profiles (eg. 21 0007, 08 0012) have extremely high PBI that requires special management of P fertilisers. In many areas already developed for agriculture, regular application of NPK fertilizer has resulted in saturation of the P fixing sites in the soil so that P fixation is no longer a problem (indicated by i-).

For areas being newly developed for agriculture and where P fixation is likely to be a problem, water soluble P fertilisers need to be spot or band placed in proximity to the seed so that the developing root system intercepts the fertilised area. Other strategies that might
be more efficient should be investigated, such as the incorporation of high rates of acid-
soluble P fertilisers such as reactive phosphate rock into the crop row prior to sowing. Whilst
cadmium contamination can be a problem with some rock phosphate sources (e.g. those
derived from guano), there are many for which this is not a problem.

Conversely, some of the Aquods (e.g. 09 0012, 24 006) have extremely low PBI indicating
leaching of soluble P into ground and surface water will occur. P fertiliser management for
these soils requires split applications of water soluble P fertiliser at rates and times in accord
with the crop's P demand pattern. P fertiliser use efficiency in these soils would be increased
by using acid-soluble P sources such as reactive phosphate rock rather than water-soluble
sources.

3.3.4.7 Copper Deficiency

Most of the representative Histosols, Spodosols, Inceptisols and Entisols have negligible
DTPA extractable Cu, suggesting that this micronutrient may be deficient for many crops.
Part 4 Description of Major Soil Types

The following pages provide descriptions of the major soil types identified during the Soil Survey conducted in the Agricultural Development Areas of Negara Brunei Darussalam. These soils probably occur in other parts of the country.

Each major soil type description is presented in a standard format:

- The Soil Type name, followed by a brief description of the characteristics of the soil, the material in which it formed, and the landscape it formed on.
- Diagnostic horizons and characteristic features are identified.
- Features that separate the Soil Type into Subtypes are described.
- A list of representative sites, in particular those that have supporting laboratory data.
- A summary list of Fertility Capability Classification (FCC) soil attributes of each Subtype, as described in Section 3.2.
- A summary of the suitability of each Soil Subtype for growing each crop or group of crops, that is determined by applying the crop requirement rules (Section 3.3.1) to the attributes for the Subtype using the process described in Sections 3.3.2 and 3.3.3.
- For each Subtype a profile description for one of the representative profiles is given (for other profiles the user can obtain the information from the project database). Photographs of the surrounding landscape, soil profile and chip tray samples are shown. (Chip trays are plastic boxes divided into a column of 20 compartments, each $5.0 \times 2.5$ cm, in which small soil samples taken by auger can be stored to allow easy viewing of the various materials encountered within a soil profile).
- Finally, the laboratory data are presented for the described representative profile.

It should be noted that the FCC attributes and land suitability ranking presented here are not for a specific sample location but are a generalised summary for the country. They were derived by examining the FCC attributes for several sample profiles of each Soil Subtype. Due to natural variation within Soil Subtypes, the attributes allocated to a Soil Subtype may differ from those observed at particular site, and thereby affect the suitability ratings of the site. Variability occurs for many reasons, in particular due to changes in slope steepness, and differences between sites in fertiliser history or number of years under cultivation (such as an uncleared site under forest compared with a developed site). The land evaluation framework described in Part 3 and the results provided here are explicit and therefore can be reviewed and compared with an actual site of interest. Modification can then be made to reflect the reality at the site.
4.1 Organic soils (Sapristis)

The Organic soils consist of a deep organic material that occurs in more than half of the upper 80 cm of soil from the soil surface. These soils are commonly known as peat soils. The organic soil material is dark grey to black colour; it is sapric, which is a highly decomposed organic soil material that contains very few plant fibres after rubbing. Organic soils are very poorly drained and the water table occurs at or near the soil surface. These soils occur on flats of alluvial valleys, and occasionally in upland basin areas where water accumulates. They are formed in organic material and alluvial sediments. In some areas, these soils contain layers of mineral matter with the organic material.

Geographically associated soils include the Brown over Grey soils, Sulfuric soils and Sulfidic soils.

Diagnostic horizons and characteristic features recognized are:

- Consist of highly decomposed organic material (peat)
- More than 40 cm depth of sapric organic material in the upper 80 cm of soil
- Dark grey to black colour
- Very poorly drained
- Watertable near to surface

Organic soils have four subtypes depending on whether a mineral soil layer occurs and the presence of a sulfuric layer (pH <3.5) or sulfidic material (pH >3.5, but decreases to <3.5 on ageing).

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
</table>
| Mineral sulfuric organic soils | Terric Sulfosaprists | • Sulfuric layer within 50 cm of surface  
                              |                     | • Mineral layer >30 cm thick in upper 100 cm                                          |
| Sulfuric organic soils     | Typic Sulfosaprists | • Sulfuric layer within 50 cm of surface                                            |
| Mineral sulfidic organic soils | Terric Sulfisaprists | • Sulfidic layer within 50 cm of surface  
                              |                     | • Mineral layer >30 cm thick in upper 100 cm                                          |
| Sulfidic organic soils     | Typic Sulfisaprists | • Sulfidic layer within 50 cm of surface                                            |

Representative profiles are:

<table>
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<tr>
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<td>Si Tukak, Limau Manis Labi Lama</td>
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<td>010015 050004 210010</td>
<td>Betumpu Lumapas Merangking, Bukit Sawat</td>
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</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Organic soils are organic topsoil texture, prolonged waterlogging, a low pH (<3.5) near the surface, aluminium toxicity, and high P fixation and Fe toxicity (Table 16).
### Table 16: Land suitability assessment for Organic soils.

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<tr>
<td>Subsoil type</td>
<td>C</td>
<td>O</td>
<td>L</td>
<td>O</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(30)</td>
<td>c(15)</td>
<td>c(30)</td>
<td>c(30)</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>-</td>
<td>-</td>
<td>k</td>
<td>-</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
<td>i+</td>
<td>i+</td>
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<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Fertility Capability Classification</td>
<td>OCG+2%c(30)ai+</td>
<td>OOG+2%c(15)ai+</td>
<td>OLg+0%c(30)ai+</td>
<td>OOG+0%c(30)ai+</td>
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</table>

### Land Suitability Subclasses

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<tr>
<th>Crops</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
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<tbody>
<tr>
<td>Rice</td>
<td>4 O</td>
<td>4 Oc(≤25)</td>
<td>4 O</td>
<td>4 O</td>
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<tr>
<td>Leafy and fruit vegetables</td>
<td>3 Og+cg(≤40)</td>
<td>4 c(≤20)</td>
<td>3 Og+cg(≤40)</td>
<td>3 Og+cg(≤40)</td>
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<tr>
<td>Root vegetables</td>
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<td>4 c(≤20)</td>
<td>3 Og+cg(≤40)</td>
<td>3 Og+cg(≤40)</td>
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<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>4 g+cg(≤20)</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+cg(≤20)</td>
<td>4 g+</td>
<td>4 g+</td>
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<tr>
<td>Ginger and turmeric</td>
<td>4 O</td>
<td>4 O(≤20)</td>
<td>4 O</td>
<td>4 O</td>
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<tr>
<td>Cassava and sweet potato</td>
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<tr>
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<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
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<td>Rambutan</td>
<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
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<tr>
<td>Langsat-duku</td>
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<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
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<td>5 c(≤20)</td>
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<td>Banana</td>
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<td>Coconut</td>
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<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
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<td>Papaya</td>
<td>5 Og+</td>
<td>5 Og+cg(≤20)</td>
<td>5 Og+</td>
<td>5 Og+</td>
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<td>Pineapple</td>
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<td>5 c(≤20)</td>
<td>4 gc+cg(≤30)</td>
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<tr>
<td>Mango and cashew nut</td>
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<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
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<td>Artocarpus</td>
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<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
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<tr>
<td>Mangosteen</td>
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<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
</tr>
<tr>
<td>Dragon fruit</td>
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<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
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<tr>
<td>Guava</td>
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<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
<td>5 Og+cg(≤30)</td>
</tr>
<tr>
<td>Star fruit</td>
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<td>5 gc(≤30)</td>
<td>5 gc(≤30)</td>
<td>5 gc(≤30)</td>
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<tr>
<td>Longan</td>
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<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
<td>5 Og+cg(≤50)</td>
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<tr>
<td>Grasses for -wet areas</td>
<td>2 i+</td>
<td>2 c(≤20)i+</td>
<td>2 i+</td>
<td>2 i+</td>
</tr>
<tr>
<td>-well drained areas</td>
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<td>3 Og+</td>
<td>3 Og+</td>
<td>3 Og+</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Og+ai+</td>
<td>2 Og+cg(≤20)ai+</td>
<td>2 Og+ai+</td>
<td>2 Og+ai+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

The main soil attribute difference between the four Soil Subtypes is the subsoil texture where there is a mineral soil layer (C or L category) or organic material (O category). The variation in sulfidic horizon depth, low K reserves and high P fixation are probably more due to the land use history rather than the Soil Subtypes identified.

### Land suitability

Before discussing cropping options for Organic soils in detail, it is important to note that, while they may be suitable in the short to medium term for a variety of crops, as shown in...
Table 16, over the longer term they will suffer from subsidence of the land surface as the organic material oxidises. This irreversible change occurs because Organic soils are severely waterlogged, and their utilization for agriculture requires the soil to be aerated either by lowering the watertable or by constructing raised beds. Tie and Kueh (1979) found subsidence of 60 cm in the first two years after reclamation of a drained, deep peat (watertable 75–100 cm below the surface) followed by a rate of 6 cm per year. On this basis, Ambak and Melling (2000) estimated subsidence of approximately 2 m in the first 25 years after reclamation.

Oxidation of organic matter and subsidence have several serious consequences. Firstly, the watertable becomes closer to the surface, whilst flooding becomes more difficult to control. Secondly, as the surface subsides, any layers with sulfidic material come closer to the surface, and it becomes increasingly difficult to find non-sulfidic material with which to replenish raised beds. Using the highly sulfidic material itself requires large applications of lime to neutralise the acid produced as it oxidises, as described in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P2-3 – Acid Sulfate Soils (Fitzpatrick et al. 2008). Thirdly, the oxidation of organic material releases large quantities of greenhouse gases into the atmosphere, which has long term impacts on global climate change. Whilst the rate of oxidation and subsidence can be slowed by careful water management to allow economic use of peatlands, these processes are nevertheless inevitable and irreversible (Melling et al. 2002) and place severe limitations on the long term sustainable use of these soils.

Organic soils are moderately suitable for a variety of vegetable crops, but require careful management to overcome limitations associated with the organic topsoil, high watertables and the presence of sulfidic material (some of which may have already oxidised to produce low pH and toxic levels of aluminium). The use of raised beds, combined with the shallow rooting depth of these crops makes production possible. If the sulfidic/ sulfuric material is too shallow, as in the Sulfuric Subtype, vegetable production may be only marginally suitable.

Organic soils are only marginally suitable for rice, because the organic topsoil can induce panicle sterility. The high and prolonged watertables make these soils marginal or unsuitable for other short duration crops.

Organic soils are unsuitable for most of the fruit crops considered because of their high watertables, organic topsoil and the presence of sulfidic material within their root zone, which is generally deeper than that of short duration crops. Possible fruit crops are citrus, banana and pineapple because they are shallower rooting. Pineapple is also more acid tolerant. The two Subtypes with mineral layers may have some advantage because these layers provide some buffering capacity against acidity produced if sulfidic material is inadvertently oxidised when used for raised mounds or when the watertable is lowered.

Grasses and fodder legumes suited to wet areas could be grown on Organic soils with only minor limitations. The wet conditions suggest that grazing is probably impractical and that fodder crops should be cut and transported to animals kept elsewhere. The peaty topsoil and prolonged waterlogging are major limitations for grasses adapted to well drained conditions. The severe waterlogging makes Organic soil only marginally suitable for fodder legumes for well drained areas.

**Occurrence**

Table 17 shows the Organic soils are widespread in surveyed ADAs in the coastal alluvial plains of Brunei-Muara District, and in the swamp area that occupies the western part of Belait District. In the Belait ADAs, the Subtypes are almost exclusively those with mineral layers.
### Table 17: Approximate proportions of ADA areas occupied by Organic soils.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Terric Sulfosapristic</td>
<td>Typic Sulfisapristic</td>
<td>Terric Sulfisapristic</td>
<td>Typic Sulfisapristic</td>
</tr>
<tr>
<td>ADA</td>
<td>ADA area (ha)</td>
<td></td>
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</tr>
<tr>
<td>Brunei-Muara</td>
<td></td>
<td></td>
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<tr>
<td>Betumpu</td>
<td>474</td>
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<td>&lt;1%</td>
</tr>
<tr>
<td>Sg Tajau</td>
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<td></td>
<td></td>
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<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
<td></td>
<td></td>
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<tr>
<td>Si Tukak, Limau Manis B</td>
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<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
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</tr>
<tr>
<td>Lumapas</td>
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<td>25%</td>
<td>18%</td>
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<tr>
<td>Limpaki</td>
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<td>9%</td>
<td>2%</td>
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<tr>
<td>Luahan</td>
<td>73</td>
<td></td>
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</tr>
<tr>
<td>Wasan</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tungku</td>
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<td>&lt;1%</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
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<td>10%</td>
</tr>
<tr>
<td>Tutong</td>
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</tr>
<tr>
<td>Kupang</td>
<td>60</td>
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<tr>
<td>Maraburong, Kupang</td>
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<td></td>
<td></td>
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<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
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<td></td>
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<td>Batang Mitus (Buah)</td>
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<tr>
<td>Batang Mitus (Halaman)</td>
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<td></td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belait</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
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<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Tungulian</td>
<td>92</td>
<td>5%</td>
<td>6%</td>
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<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
<td>&lt;1%</td>
<td>6%</td>
</tr>
<tr>
<td>Melayan A</td>
<td>13</td>
<td>30%</td>
<td>34%</td>
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<td>Labi Lama</td>
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<td>37%</td>
<td>43%</td>
</tr>
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<td>11%</td>
<td>13%</td>
</tr>
<tr>
<td>Temburong</td>
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<td>Labu Estate</td>
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<tr>
<td>Selangan</td>
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<tr>
<td>Bakarut</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selapong</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>4423</td>
<td>3%</td>
<td>2%</td>
</tr>
</tbody>
</table>
Mineral sulfuric organic soils (Terric Sulfosapristes)

**Typical pedon number:** 23 0001

**Agricultural Development Area:** Labi Lama

**Physiography**
- **Slope:** <1 degree
- **Slope position:** flat of alluvial terrace

**Location:** UTM grid reference 217900 mE 488237 mN Zone 50

**District:** Belait

**Water table depth:** 60 cm

**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ap</strong></td>
<td>0</td>
<td>5</td>
<td>7.5YR 3/2</td>
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<td>0% concentrations</td>
<td>firm</td>
<td></td>
<td></td>
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<tr>
<td><strong>Oe</strong></td>
<td>5</td>
<td>30</td>
<td>10YR 2/2</td>
<td>mucky peat</td>
<td>0% concentrations</td>
<td>friable</td>
<td></td>
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</tr>
<tr>
<td><strong>2Bg</strong></td>
<td>30</td>
<td>60</td>
<td>10YR 5/1</td>
<td>clay</td>
<td>0% concentrations</td>
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<td><strong>3Oe1</strong></td>
<td>60</td>
<td>70</td>
<td>5YR 2.5/2</td>
<td>peat</td>
<td>0% concentrations</td>
<td>soft</td>
<td>sulfuric layer</td>
<td></td>
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<tr>
<td><strong>3Oe2</strong></td>
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<td>110</td>
<td>5YR 2.5/2</td>
<td>peat</td>
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<td>soft</td>
<td>sulfuric layer</td>
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<tr>
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<td>200</td>
<td>5YR 2.5/2</td>
<td>peat</td>
<td>0% concentrations</td>
<td>soft</td>
<td>sulfuric layer</td>
<td></td>
</tr>
</tbody>
</table>

**Depth, cm**
- 0 - 5
- 5 - 30
- 30 - 60
- 60 - 70

**Depth, cm**
- 70 - 110
- 110 - 200
### Site Information

**Site no:** 23 0001  
**ADA:** Labi Lama  
**District:** Belait

### Soil Properties

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<th>Lower depth</th>
<th>EC</th>
<th>pH</th>
<th>pH&lt;sub&gt;kCl&lt;/sub&gt;</th>
<th>pH&lt;sub&gt;pH2O&lt;/sub&gt;</th>
<th>Org.C</th>
<th>N</th>
<th>ext.P</th>
<th>Bray-2</th>
<th>HCO3-</th>
<th>PBI</th>
<th>HCO3-</th>
<th>Exch.Cations NH4OAc pH 7.0</th>
<th>ECEC</th>
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<tr>
<td></td>
<td>cm</td>
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<td>cm</td>
<td>cm</td>
<td>cm</td>
<td>%</td>
<td>%</td>
<td>mg/kg</td>
<td>mg/kg</td>
<td>mg/kg</td>
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</tr>
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<td>1.06</td>
<td>1523</td>
<td>1148</td>
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<td>29.1</td>
<td>10.3</td>
<td>44.5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>30</td>
<td>* 0.31</td>
<td>* 4.8</td>
<td>* 4.0</td>
<td>* 0.8</td>
<td>23.7</td>
<td>1.13</td>
<td>721</td>
<td>710</td>
<td>801</td>
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<td>16.4</td>
<td>3.7</td>
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<td>3</td>
<td>30</td>
<td>60</td>
<td>0.30</td>
<td>3.7</td>
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<td>0.6</td>
<td>4.8</td>
<td>0.24</td>
<td>33</td>
<td>20</td>
<td>465</td>
<td>510</td>
<td>1.4</td>
<td>1.2</td>
<td>4.0</td>
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<tr>
<td>4</td>
<td>70</td>
<td>110</td>
<td>* 1.00</td>
<td>* 3.5</td>
<td>* 3.3</td>
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<td>1.01</td>
<td>27</td>
<td>165</td>
<td>843</td>
<td>535</td>
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<td>4.7</td>
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</tr>
<tr>
<td>5</td>
<td>110</td>
<td>200</td>
<td>* 2.20</td>
<td>* 3.2</td>
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<td>46.6</td>
<td>0.98</td>
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<td>57</td>
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<td>225</td>
<td>3.4</td>
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* 1:5 soil:water extract used for samples with high organic carbon

### Soluble Salts in Saturation Extract

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<th>Layer no.</th>
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<th>Lower depth</th>
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<th>EC</th>
<th>mg/L</th>
<th>SAR</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>cm</td>
<td>percent</td>
<td>cm</td>
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### Soluble Salts from Saturation Extract

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<th>EC</th>
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### Mineralogy of Bulk Sample

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<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolinite</th>
<th>Micahinite</th>
<th>Chlorite</th>
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### Mineralogy of <2µm Fraction

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### Additional Information

- **1:2.5 soil:water**
- **1M KCl ext**
- **0.01M CaCl₂ ext**
- **NH₄OAc pH 7.0**
- **Satn extract**
- **DTPA ext**
- **Wₚ**
- **WᵥL**

---

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam  
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas  
Page 59
**Sulfuric organic soils (Typic Sulfosaprists)**

**Typical pedon number:** 21 0007  
**Location:** UTM grid reference 232094 mE 502510 mN Zone 50

**Agricultural Development Area:** Merangking, Bukit Sawat  
**District:** Belait

**Physiography**  
**Slope:** <1 degree  
**Slope position:** flat of alluvial terrace

**Water table depth:** 30 cm  
**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Consistence - Type</th>
<th>Structure - Type</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<td>leaf litter</td>
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**Depth, cm**

-2 - 0  
0 - 5  
5 - 15  
15 - 30  
30 - 50  
50 - 60  
60 - 80  
80 - 120  
120 - 170  
170 - 190  
190 - 200  
200 - 250
### Site no: 21 0007
### ADA: Merangking, Bukit Sawat
### District: Belait

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<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH (\text{pH}_{\text{KCl}})</th>
<th>Total C</th>
<th>N ext.P</th>
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<th>HCO(_3^-)</th>
<th>HCO(_3^-) ext.K</th>
<th>PBI</th>
<th>Exch.Cations NH(_4)OAc pH 7.0</th>
<th>ECEC</th>
<th>1M KCl ext cmol(+)/kg</th>
<th>0.01M CaCl(_2) ext cmol(+)/kg</th>
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<td>17</td>
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* 1:5 soil:water extract used for samples with high organic carbon

### Soluble salts in saturation extract

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### Soluble salts from saturation extract

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<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
<th>Clay %&lt;2</th>
<th>Clay 2-20</th>
<th>Clay 20-50</th>
<th>Clay 50-200</th>
<th>Clay 200-5000</th>
<th>Plastic limit %</th>
<th>Liquid limit %</th>
<th>Linear shrink %</th>
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### Mineralogy of bulk sample

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolin</th>
<th>Micaillite</th>
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Mineral sulfidic organic soils (Terric Sulfisaprists)

**Typical pedon number:** 03 0002  
**Agricultural Development Area:** Si Tukak, Limau Manis A & B  
**Physiography**  
**Slope:** <1 degree  
**Slope position:** flat of alluvial terrace  
**Location:**  
**UTM grid reference:** 259490 mE 527277 mN  
**Zone:** 50  
**District:** Brunei Muara  
**Water table depth:** 20 cm  
**Drainage class:** poorly  

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth, cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Oe</td>
<td>0-30</td>
<td>5YR 3/2</td>
<td>peat</td>
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<th>EC cmol(+)/kg</th>
<th>pH</th>
<th>Org.C %</th>
<th>N ext.P mg/kg</th>
<th>HCO₃⁻ ext.P mg/kg</th>
<th>Bray-2 Ca mg/kg</th>
<th>HCO₃⁻ ext.K mg/kg</th>
<th>HCO₃⁻ mg/kg</th>
<th>PBI</th>
<th>pH H₂O</th>
<th>Total cmol(+)kg</th>
<th>Total K cmol(+)kg</th>
<th>ECEC 0.01M CaCl₂ ext cmol(+)kg</th>
<th>1M KCl ext cmol(+)kg</th>
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<tr>
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<td>18</td>
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<td>0.20</td>
<td>0.16</td>
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</tr>
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<td>1.03</td>
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<td>3.6</td>
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<td>1.5</td>
<td>0.18</td>
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</tr>
<tr>
<td>3</td>
<td>60</td>
<td>100</td>
<td>5.66</td>
<td>3.1</td>
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<td>0.0</td>
<td>12.1</td>
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<td>1116</td>
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<td>1.7</td>
<td>0.21</td>
<td>0.13</td>
<td>3.3</td>
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<table>
<thead>
<tr>
<th>Soluble salts in saturation extract</th>
<th>Ca Mg Na S Cl SAR</th>
<th>Soluble salts from saturation extract</th>
<th>Ca K Mg Na S Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>Coarse sand</td>
<td>Total sand</td>
<td>Plastic limit</td>
</tr>
<tr>
<td>Fine silt</td>
<td>Coarse sand</td>
<td>Total silt</td>
<td>Liquid limit</td>
</tr>
<tr>
<td>Fine sand</td>
<td>Coarse sand</td>
<td>Total sand</td>
<td>Linear shrink</td>
</tr>
<tr>
<td>Fine sand</td>
<td>Coarse sand</td>
<td>Total sand</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
<th>Ext.B µm</th>
<th>&lt;2-20</th>
<th>20-50</th>
<th>50-200</th>
<th>2000</th>
<th>20-60</th>
<th>50-200</th>
<th>2000</th>
<th>Plastic limit %</th>
<th>Linear shrink %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>30</td>
<td>0.1</td>
<td>474</td>
<td>3.1</td>
<td>0.9</td>
<td></td>
<td></td>
<td>28.1</td>
<td>16.5</td>
<td>4.0</td>
<td>20.5</td>
<td>41.7</td>
<td>9.7</td>
<td>51.4</td>
<td>68</td>
<td>68</td>
<td>6.7</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>60</td>
<td>&lt;0.1</td>
<td>484</td>
<td>3.3</td>
<td>0.2</td>
<td></td>
<td></td>
<td>32.8</td>
<td>25.5</td>
<td>7.5</td>
<td>33.0</td>
<td>30.7</td>
<td>3.5</td>
<td>34.2</td>
<td>44</td>
<td>59</td>
<td>7.3</td>
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<tr>
<td>3</td>
<td>60</td>
<td>100</td>
<td>&lt;0.1</td>
<td>1352</td>
<td>22.8</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mineralogy

#### Bulk Sample

- **Quartz**: 10%
- **Albite**: 30%
- **Orthoclase**: 20%
- **Pyrite**: 5%
- **Anatase**: 20%
- **Kaolin**: 5%
- **Mica/Illite**: 10%
- **Chlorite/Vermiculite**: 5%
- **Goethite**: 5%

#### <2µm Fraction

- **Kaolin**: 10%
- **Mica/Illite**: 30%
- **Chlorite/Vermiculite**: 5%
- **Smectite**: 5%
**Sulfidic organic soils (Typic Sulfisaprists)**

**Typical pedon number:** 01 0015  
**Agricultural Development Area:** Betumpu  
**Physiography**  
**Slope:** <1 degree  
**Slope position:** flat of alluvial terrace  
**Location:** UTM grid reference 262578 mE 535271 mN Zone 50  
**District:** Brunei Muara  
**Water table depth:** 25 cm  
**Drainage class:** very poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0 - 5</td>
<td>10YR 3/2</td>
<td>sandy clay loam peat</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>friable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ol1</td>
<td>5 - 20</td>
<td>5YR 3/2</td>
<td>peat</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>friable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ol2</td>
<td>20 - 30</td>
<td>5YR 3/1</td>
<td>peat</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very friable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oe1</td>
<td>30 - 50</td>
<td>5YR 3/1</td>
<td>moderately decomposed plant material</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very friable</td>
<td>Sulfidic material</td>
<td></td>
</tr>
<tr>
<td>Oe2</td>
<td>50 - 80</td>
<td>5YR 2.5/1</td>
<td>moderately decomposed plant material</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very friable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oa</td>
<td>80 - 150</td>
<td>5YR 2.5/1</td>
<td>highly decomposed plant material</td>
<td>0% concentrations</td>
<td>massive</td>
<td>firm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bh</td>
<td>150 - 200</td>
<td>7.5YR 2/0</td>
<td>sandy clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>firm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer no.</td>
<td>Upper depth cm</td>
<td>Lower depth cm</td>
<td>EC dS/m</td>
<td>pH</td>
<td>pH&lt;sub&gt;H2O&lt;/sub&gt;</td>
<td>pH&lt;sub&gt;KCl&lt;/sub&gt;</td>
<td>Org.C %</td>
<td>N ext.P mg/kg</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>----------------</td>
<td>---------</td>
<td>----</td>
<td>----------------</td>
<td>----------------</td>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
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<td>5</td>
<td>0.40</td>
<td>3.2</td>
<td>2.6</td>
<td>0.6</td>
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<td>5</td>
<td>20</td>
<td>0.40</td>
<td>3.2</td>
<td>2.6</td>
<td>0.6</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>80</td>
<td>0.40</td>
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<tr>
<td>6</td>
<td>80</td>
<td>150</td>
<td>0.40</td>
<td>3.2</td>
<td>2.6</td>
<td>0.6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>150</td>
<td>200</td>
<td>0.40</td>
<td>3.2</td>
<td>2.6</td>
<td>0.6</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>

| Layer no. | Upper depth cm | Lower depth cm | EC dS/m | pH | pH<sub>H2O</sub> | pH<sub>KCl</sub> | Satn percent | Satn extract pH dS/m | Ca | K | Mg | Na | S | Cl | SAR | 
|-----------|----------------|----------------|---------|----|----------------|----------------|---------------|---------------------|----|----|----|----|----|----|-----|---------|
| 1         | 0              | 5              | 0.40    | 3.2| 2.6            | 0.6            | 33            | 109           | 277 | 240 | 2.7 | 1.5 | 0.38 | 0.54 | 5.1 | 9.4 | 4.27 | 0.03 | 0.01 | 1.44 | <0.01 |
| 2         | 5              | 20             | 0.40    | 3.2| 2.6            | 0.6            | 15            | 22            | 142 | 109 | 0.6 | 0.8 | 0.25 | 0.37 | 2.0 | 6.7 | 4.77 | 0.01 | 1.44 | <0.01 |
| 5         | 50             | 80             | 0.40    | 3.2| 2.6            | 0.6            | 16            | 14            | 155 | 160 | 0.9 | 1.2 | 0.32 | 0.34 | 2.7 | 15.0 | 12.23 | 0.01 | 1.44 | <0.01 |
| 6         | 80             | 150            | 0.40    | 3.2| 2.6            | 0.6            | 7             | 13            | 323 | 118 | 1.0 | 0.6 | 0.28 | 0.23 | 2.1 | 41.1 | 38.91 | 0.03 | 1.44 | <0.01 |
| 7         | 150            | 200            | 0.40    | 3.2| 2.6            | 0.6            | 4              | 14            | 661 | 96  | 6.9 | 5.6 | 0.55 | 0.21 | 13.3| 55.8 | 42.43 | 0.09 | 1.44 | <0.01 |

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>DTPA ext Cu mg/kg</th>
<th>CaCl&lt;sub&gt;2&lt;/sub&gt;- ext.B As mg/kg</th>
<th>Cd mg/kg</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>&lt;0.1</td>
<td>444</td>
<td>1.0</td>
<td>1.6</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>20</td>
<td>&lt;0.1</td>
<td>444</td>
<td>1.0</td>
<td>1.6</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>80</td>
<td>&lt;0.1</td>
<td>444</td>
<td>1.0</td>
<td>1.6</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
<td>150</td>
<td>&lt;0.1</td>
<td>444</td>
<td>1.0</td>
<td>1.6</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>7</td>
<td>150</td>
<td>200</td>
<td>&lt;0.1</td>
<td>444</td>
<td>1.0</td>
<td>1.6</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
Page 65
4.2 White soils (Aquods)

The White soils consist of deep or very deep, white sand overlying a black organic layer that occurs within two meters of the soil surface. The white sand is well sorted and leached of organic and iron material (an eluvial E horizon) and the underlying organic layer is often thin (<10 cm). White soils are poorly drained and the water table occurs near the soil surface. These soils occur on old dunes that are higher in the landscape than the surrounding flats of the alluvial valleys. In some places they can occur on slopes. They are formed in sand dunes from a previous coast line. In some areas, soils have a loamy texture and they are slightly cemented.

Geographically associated soils include the Yellow soils, and the Texture Contrast Yellow soils.

Diagnostic horizons and characteristic features recognized are:

- Whitish or pale grey layer (eluvial horizon) overlying a dark brown organic layer (spodic horizon) that occurs at depth and may be quite thin (<10 cm)
- Sandy soil texture or loamy in in some areas
- Whitish sand is well sorted and leached of organic and iron material
- Usually very deep (greater than 150 cm)
- Poorly drained (aquic conditions within 50 cm of the soil surface)

White soils have two subtypes depending on soil texture and the presence of a dark organic topsoil layer (Umbric epipedon).

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy poorly drained white soils</td>
<td>Ultic Epiaquods</td>
<td>• Subsoil texture is loamy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Subsoil consistency is firm</td>
</tr>
<tr>
<td>Sandy poorly drained white soils</td>
<td>Umbric Epiaquods</td>
<td>• Subsoil texture is sandy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Darker coloured topsoil</td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy poorly drained white soils</td>
<td>Ultic Epiaquods</td>
<td>090012</td>
<td>Tungku</td>
</tr>
<tr>
<td>Sandy poorly drained white soils</td>
<td>Umbric Epiaquods</td>
<td>240004</td>
<td>KM 26, Jalan Bukit Puan Labi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240006</td>
<td>KM 26, Jalan Bukit Puan Labi</td>
</tr>
</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for White Soils are waterlogging and low K reserves (Table 18).

The main soil attribute difference between these two Soil Subtypes is texture with one being loamy and the other sandy. The sandy texture and associated high leaching potential of the Sandy poorly drained Subtype are additional limitations on crop selection as is its more prolonged waterlogging. Land suitability of Loamy poorly drained Subtype is also limited by soil acidity and aluminium toxicity.
Table 18: Land suitability assessment for White soils.

<table>
<thead>
<tr>
<th>Soil subtypes</th>
<th>Loamy poorly drained white soils</th>
<th>Sandy poorly drained white soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Utlic Epiaquods</td>
<td>Umbric Epiaquods</td>
</tr>
<tr>
<td>Soil Attribute Ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>S</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
<td>S</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>e</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>LlG0%ak</td>
<td>SSG+2%ke</td>
</tr>
<tr>
<td>Land Suitability Subclasses</td>
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<td></td>
</tr>
<tr>
<td>Rice</td>
<td>2 ak</td>
<td>5 S</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
<td>3 g+</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a</td>
<td>3 g+</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 ga</td>
<td>4 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>3 ga</td>
<td>4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a</td>
<td>3 g+</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g</td>
<td>4 g+</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
<td>5 Sg+</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
<td>5 Sg+</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 ga</td>
<td>4 g+</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gak</td>
<td>4 g+</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gak</td>
<td>5 g+</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
<td>5 g+</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 ga</td>
<td>4 g+</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 ga</td>
<td>4 g+</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
<td>4 Sg+</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Guava</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Longan</td>
<td>3 ga</td>
<td>5 g+</td>
</tr>
<tr>
<td>Grasses for -well drained areas</td>
<td>1</td>
<td>2 Sse</td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas</td>
<td>2 gk</td>
<td>3 g+</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

Land suitability

Loamy poorly drained white soils are moderately suitable for all the short duration crops assessed and most fruit crops so long as waterlogging and soil acidity/aluminium toxicity can be managed. Fruit trees such as durian, langsat-duku and papaya that are more susceptible to waterlogging are only marginally suitable.

The more severe waterlogging associated with Sandy poorly drained white soils limits crop choice. Fruit crops are generally unsuitable or only marginally suitable. Vegetables, ginger
and turmeric are moderately suitable, but other short duration crops are unsuitable or marginally suitable because of waterlogging. These soils are unsuitable for rice because of the sandy texture.

Both Subtypes of White soil are suitable for grass and fodder legumes, except those legume species better adapted to drier conditions (see Table 2).

**Occurrence**

Table 19 shows that White soils are not widespread in the surveyed ADAs and are confined to those with old coastal dunes, namely Tungku and KM26, Jalan Bukit Puan Labi.

### Table 19: Approximate proportions of ADA areas occupied by White soils.

<table>
<thead>
<tr>
<th>Soil Subtype: Loamy poorly drained white soils</th>
<th>Sandy poorly drained white soils</th>
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<td>Soil Taxonomy subgroup: Ultic Epiaquods</td>
<td>Umbric Epiaquods</td>
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<td>ADA</td>
<td>ADA area (ha)</td>
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<td>Brunei-Muara</td>
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<td>Sg Tajau</td>
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<td>Si Tukak, Limau Manis A</td>
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<td>Lumapas</td>
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<td>Limpaki</td>
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<td>Luhan</td>
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<td>Wasan</td>
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<td>Tutong</td>
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<td>Kupang</td>
<td>60</td>
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<td>Padnunok/Sg Burong, Kiudang</td>
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<tr>
<td>Batang Mitus (Buah)</td>
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<td>Batang Mitus (Halaman)</td>
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<td>Birau (P. P. Muda)</td>
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<td>Birau (Penyelidikan)</td>
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<td>Melayan A</td>
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<td>Labi Lama</td>
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<td>KM 26, Jalan Bukit Puan Labi</td>
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<td>Bakarut</td>
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<td>Selapon</td>
<td>80</td>
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<tr>
<td><strong>Overall</strong></td>
<td><strong>4423</strong></td>
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1. **2%**<br>2. **<1%**
## Loamy poorly drained white soils (Ultic Epiaquods)

### Typical pedon number: 09 0012

### Agricultural Development Area: Tungku

### Location: UTM grid reference 265482 mE 546592 mN Zone 50

### District: Brunei Muara

### Physiography Slope: <1 degree

### Slope position: summit of dune

### Water table depth: not reached

### Drainage class: moderately well

### Morphological Description:

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm Upper</th>
<th>Horizon depth cm Lower</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<td>0</td>
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<td>friable</td>
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<tr>
<td>E</td>
<td>10</td>
<td>30</td>
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<td>0% concentrations</td>
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<td>weakly cemented</td>
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<td>Bh</td>
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<td>60</td>
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<tr>
<td>BCw</td>
<td>60</td>
<td>100</td>
<td>10YR 6/4</td>
<td>clay loam</td>
<td>5% iron concentrations</td>
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<td>slightly rigid</td>
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## Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

### Volume 1 – Soils and Land Suitability of the Agricultural Development Areas

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH_KCl</th>
<th>pH_H2O</th>
<th>Org.C %</th>
<th>N ext.P mg/kg</th>
<th>Bray-2 ext.P mg/kg</th>
<th>HCO3- ext.K mg/kg</th>
<th>PBI</th>
<th>HCO3- ext.K mg/kg</th>
<th>Exch.Cations NH4OAc pH 7.0</th>
<th>ECEC</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
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<td>4.8</td>
<td>0.41</td>
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<td>39</td>
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<td>4.8</td>
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<td>71</td>
<td>181</td>
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<td>&lt;0.1</td>
<td>0.05</td>
<td>0.06</td>
<td>2.8</td>
<td>7.8</td>
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<td>60</td>
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<td>3</td>
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### Soluble salts in saturation extract

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<tr>
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<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Ca mg/kg</th>
<th>K mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>S mg/kg</th>
<th>Cl mg/kg</th>
<th>SAR</th>
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<td>5</td>
<td>0</td>
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<td>0.12</td>
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<td>1.7</td>
<td>0</td>
<td>10.0</td>
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<td>10</td>
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<td>30</td>
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<td>&lt;0.1</td>
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<td>0</td>
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<td>35</td>
<td>35</td>
<td>0.05</td>
<td>4.9</td>
<td>0.1</td>
<td>&lt;0.1</td>
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<td>0.1</td>
<td>0</td>
<td>23.8</td>
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<td>40</td>
<td>40</td>
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<td>4.8</td>
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<td>&lt;0.1</td>
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<td>&lt;0.1</td>
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<td>7</td>
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### Soluble salts from saturation extract

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<th>Fine silt</th>
<th>Coarse silt</th>
<th>Total silt</th>
<th>Fine sand</th>
<th>Coarse sand</th>
<th>Total sand</th>
<th>Plastic limit</th>
<th>Liquid limit</th>
<th>Linear shrink</th>
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<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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</tbody>
</table>

Mineralogy of bulk sample

Mineralogy of <2µm fraction

- **D**: dominant (>60%)
- **CD**: co-dominant (sum of phases >60%)
- **SD**: sub-dominant (20-60%)
- **M**: minor (5-20%)
- **T**: trace (<5%)
- **?**: possible
Sandy poorly drained white soils (Umbric Epiaquods)

**Typical pedon number:** 24 0006  
**Agricultural Development Area:** KM 26, Jalan Bukit Puan Labi  
**Physiography** Slope: 1 degree  
**Slope position:** toe slope of valley side  
**Location:** UTM grid reference 218022 mE 497303 mN Zone 50  
**District:** Belait  
**Water table depth:** 20 cm  
**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>A</td>
<td>0 - 5</td>
<td>7.5YR 2/0</td>
<td>loamy sand</td>
<td>0% concentrations</td>
<td>single grain</td>
<td>friable</td>
<td>4.5</td>
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<tr>
<td>AB</td>
<td>5 - 20</td>
<td>5YR 4/2</td>
<td>Isand</td>
<td>0% concentrations</td>
<td>single grain</td>
<td>firm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>20 - 40</td>
<td>5YR 3/2</td>
<td>sand</td>
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<td>single grain</td>
<td>firm</td>
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<tr>
<td>E</td>
<td>40 - 80</td>
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<td>firm</td>
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<tr>
<td>Bhs</td>
<td>80 - 110</td>
<td>5YR 3/2</td>
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<td>massive</td>
<td>firm</td>
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### Site Information

- **Site no:** 24 0006
- **ADA:** KM 26, Jalan Bukit Puan Labi
- **District:** Belait

### Soil Data

<table>
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<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH&lt;sub&gt;H2O&lt;/sub&gt;</th>
<th>-pH&lt;sub&gt;KCl&lt;/sub&gt;</th>
<th>Total K</th>
<th>Bray-2 K</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;-</th>
<th>PBI</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext.K Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Total Al cmol(+)/kg</th>
<th>ECEC cmol(+)/kg</th>
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<tr>
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<td>5.3</td>
<td>0.22</td>
<td>18</td>
<td>11</td>
<td>5</td>
<td>26</td>
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<td>0.01</td>
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<td>2</td>
<td>5</td>
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<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>27</td>
<td>0.5</td>
<td>0.2</td>
<td>0.05</td>
<td>&lt;0.01</td>
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<tr>
<td>3</td>
<td>20</td>
<td>40</td>
<td>0.04</td>
<td>4.8</td>
<td>4.2</td>
<td>0.8</td>
<td>1.1</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>4</td>
<td>27</td>
<td>0.5</td>
<td>0.2</td>
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<td>0.1  &lt;0.02</td>
<td>0.2</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td>4</td>
<td>11</td>
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<td>2.9</td>
<td>0.9</td>
<td>1.4  &lt;0.02</td>
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<td>0.1</td>
<td>&lt;0.1</td>
<td>3</td>
<td>22</td>
<td>0.1</td>
<td>0.18</td>
<td>0.05</td>
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### Saturation Extract

<table>
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<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Soluble salts in saturation extract Ca K Mg Na S Cl SAR</th>
<th>Soluble salts from saturation extract Ca K Mg Na S Cl mg/kg</th>
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<td>0.2 0.1</td>
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<td>1 0.2</td>
<td>&lt;0.1 0.1</td>
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### Clay Minerals

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<th>Lower depth cm</th>
<th>Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
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<th>As ext.B</th>
<th>Cd ext.B</th>
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<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>&lt;0.1</td>
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<td>17.5</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>5</td>
<td>20</td>
<td>&lt;0.1</td>
<td>2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1 &lt;0.1</td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>40</td>
<td>&lt;0.1</td>
<td>1</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td>2.4</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>80</td>
<td>&lt;0.1</td>
<td>1</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td>0.2 &lt;0.1</td>
<td></td>
<td></td>
<td>1.8</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>110</td>
<td>&lt;0.1</td>
<td>12</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mineralogy

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatas</th>
<th>Kaolinite</th>
<th>Chlorite/Vermiculite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>D</td>
<td>-</td>
<td>-</td>
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<tr>
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<td>5</td>
<td>20</td>
<td>D</td>
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<td>-</td>
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<td>20</td>
<td>40</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>80</td>
<td>D</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>110</td>
<td>D</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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</table>

### Soluble Salts

<table>
<thead>
<tr>
<th>Soluble salts from saturation extract Ca K Mg Na S Cl mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

### Mineralogy of Bulk Sample

- **Mineralogy of <2μm fraction**
  - CD: dominant (>60%)
  - CD: co-dominant (sum of phases >60%)
  - SD: sub-dominant (20-60%)
  - M: minor (5-20%)
  - T: trace (<5%)
  - ?: possible
4.3 Cracking Clay soils (Aquerts)

The Cracking Clay soils consist of deep or very deep clay, that contains cracks that periodically open and close under dry and wet conditions, and have shiny slickenside ped faces in the subsoil. These cracks occur at the surface or in a layer within 100 cm of the soil surface. The clay is often grey in colour and contains sulfidic material, a sulfuric layer or an acid (pH<4.5) layer. It is poorly drained and the water table occurs near the soil surface. These soils occur on flats of the alluvial valleys. They are formed in alluvial clay sediments.

Geographically associated soils include the Brown over Grey soils, Sulfuric soils, and Sulfidic soils.

Diagnostic horizons and characteristic features recognized are:

- Grey coloured subsoil with orange yellow spots in the upper subsoil layer
- Clay soil texture, usually heavy, sticky clay
- Crack to depth when dry and have slickensides (polished and grooved surfaces between soil aggregates)
- Usually very deep (greater than 150 cm)
- Acidic pH <4.5
- Poorly drained (aquic conditions within 50 cm of the soil surface)

Cracking clay soils have two subtypes depending on the presence of sulfidic material (pH >3.5, but decreases to <3.5 on ageing).

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfidic poorly drained cracking clay soils</td>
<td>Sulfic Sulfaquerts</td>
<td>Sulfidic material within 100 cm of the surface</td>
</tr>
<tr>
<td>Acid poorly drained cracking clay soils</td>
<td>Typic Dystraquerts</td>
<td>pH&lt;4.5 within 50 cm of the surface</td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfidic poorly drained cracking clay soils</td>
<td>Sulfic Sulfaquerts</td>
<td>080003 080004 080015</td>
<td>Wasan</td>
</tr>
<tr>
<td>Acid poorly drained cracking clay soils</td>
<td>Typic Dystraquerts</td>
<td>080012</td>
<td>Wasan</td>
</tr>
</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Cracking clay soils are their heavy clay texture, prolonged waterlogging, flat slope, moderate soil acidity and potential aluminium toxicity for sensitive crops, high P fixation and Fe toxicity (Table 20). The heavy clay texture is likely to exacerbate problems due to waterlogging, because they are prone to structural degradation if trafficked when wet which can further decrease aeration.

The main soil attribute difference between the two Soil Subtypes is the presence of sulfidic material within 1 m of the surface in the Sulfidic poorly drained Subtype.

Land suitability

Cracking clay soils are suitable for rice, which requires waterlogged conditions and can tolerate the poor aeration associated with waterlogged shrink/swell clay. The waterlogged conditions and high clay content also buffer against acidity.
Table 20: Land suitability assessment for Cracking clay soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Sulfidic poorly drained cracking clay soils</th>
<th>Acid poorly drained cracking clay soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Sulfic Sulfaquerts</td>
<td>Typic Dystraquerts</td>
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</tbody>
</table>

**Soil Attribute Ratings**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sulfidic</th>
<th>Acid</th>
</tr>
</thead>
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<tr>
<td>Topsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(40)</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>v</td>
<td>v</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>CCg+0%(c40)a-i+v</td>
<td>CCg+0%(a-i+v)</td>
</tr>
</tbody>
</table>

**Land Suitability Subclasses**

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Sulfidic</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 g+c(≤60)i+v</td>
<td>2 g+i+v</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+c(≤40)i+v</td>
<td>3 g+i+v</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>4 v</td>
<td>4 v</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>5 v</td>
<td>5 v</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 v</td>
<td>4 v</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+v</td>
<td>4 g+v</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+c(≤50)</td>
<td>5 g+</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 Cg+v</td>
<td>4 Cg+v</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+v</td>
<td>5 g+v</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+v</td>
<td>4 g+v</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+c(≤50)</td>
<td>5 g+</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+c(≤50)i+v</td>
<td>4 g+i+v</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+c(≤50)</td>
<td>4 g+</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+c(≤50)</td>
<td>5 g+</td>
</tr>
</tbody>
</table>

Grasses for -well drained areas | 3 v | 3 v |

Fodder legumes for -well drained areas | 3 g+v | 3 g+v |

1 Soil attribute codes are given in Table 6 and Table 8.

2 Land suitability classes are defined in Section 3.3.3.

Cracking clay soils are moderately suitable for vegetables, but require management to overcome the waterlogged conditions. This might be hindered by the heavy clay texture which makes it difficult to achieve aerated condition even in raised beds. Tillage of these soils is also difficult.

These soils are unsuitable or marginally suitable for other short duration crops and for fruit crops because of the severe waterlogging.
Grasses and fodder legumes adapted to wetter conditions are only moderately suited, because the heavy clay texture exacerbates the poor aeration associated with water conditions and shortens the periods when the soil might be trafficable.

**Occurrence**

Table 21 shows the Cracking Clay soils are widespread in only a few surveyed ADAs in the Brunei Muara, notably Wasan. They appear to occur on alluvial plains adjacent to hills.

**Table 21: Approximate proportions of ADA areas occupied by Craking clay soils.**

<table>
<thead>
<tr>
<th>Soil Subtype:</th>
<th>Sulfidic poorly drained cracking clay soils</th>
<th>Acid poorly drained cracking clay soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup:</td>
<td>Sulfic Sulfquerts</td>
<td>Typic Dystraquerts</td>
</tr>
<tr>
<td>ADA area (ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brunei-Muara</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
<td></td>
</tr>
<tr>
<td>Sg Tajau</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
<td>50%</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
<td>35%</td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>Lmapas</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Limpaki</td>
<td>92</td>
<td>21%</td>
</tr>
<tr>
<td>Luhan</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Wasan</td>
<td>373</td>
<td>56%</td>
</tr>
<tr>
<td>Tungku</td>
<td>262</td>
<td>44%</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Tutong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kupang</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Maraburom, Kupang</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>517</td>
<td></td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>585</td>
<td></td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
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<tr>
<td>Belait</td>
<td></td>
<td></td>
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<tr>
<td>Rampayoh</td>
<td>104</td>
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<tr>
<td>Tungulian</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
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<td></td>
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<td>Melayan A</td>
<td>13</td>
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<tr>
<td>Labi Lama</td>
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</tr>
<tr>
<td>Bakarut</td>
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<td></td>
</tr>
<tr>
<td>Selapon</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>4423</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4%</td>
</tr>
</tbody>
</table>
**Sulfidic poorly drained cracking clay soils (Sulfic Sulfaquerts)**

**Typical pedon number:** 08 0015  
**Agricultural Development Area:** Wasan  
**Location:** UTM grid reference 256988 mE 528736 mN Zone 50  
**District:** Brunei Muara  
**Physiography Slope:** <1 degree  
**Slope position:** flat of alluvial valley  
**Water table depth:** 0 cm  
**Drainage class:** very poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oi</td>
<td>-10</td>
<td>0</td>
<td>10YR 5/1</td>
<td>slightly decomposed plant material</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0</td>
<td>5</td>
<td>10YR 5/1</td>
<td>mucky clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td></td>
</tr>
<tr>
<td>Bg1</td>
<td>5</td>
<td>40</td>
<td>10YR 5/1</td>
<td>clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>firm</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>20% iron concentrations 7.5YR 5/6</td>
<td>7.5YR 5/6</td>
<td>firm</td>
<td></td>
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<tr>
<td>Bg2</td>
<td>40</td>
<td>90</td>
<td>10YR 5/1</td>
<td>clay</td>
<td>40% iron concentrations 7.5YR 5/6</td>
<td>massive</td>
<td>very firm</td>
<td></td>
</tr>
<tr>
<td>BCg</td>
<td>90</td>
<td>160</td>
<td>7.5YR 5/0</td>
<td>clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very firm</td>
<td></td>
</tr>
</tbody>
</table>

**Images:**
- Depth, cm: 10 - 0, 0 - 5, 5 - 40, 40 - 90
### Site no: 08 0015
ADA: Wasan
District: Brunei Muara

<table>
<thead>
<tr>
<th>Layer</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>EC-h2o</th>
<th>pH-hcl</th>
<th>Total Org.C %</th>
<th>N ext.P mg/kg</th>
<th>HCO3- mg/kg</th>
<th>Total PBI mg/kg</th>
<th>HCO3- ext.K mg/kg</th>
<th>Exch.Cations NH4OAc pH 7.0 ECEC cmol+/kg</th>
<th>Al mg/kg</th>
<th>Mn mg/kg</th>
<th>K mg/kg</th>
<th>Total mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0.30</td>
<td>4.4</td>
<td>3.6</td>
<td>0.8</td>
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<td>0.32</td>
<td>8</td>
<td>12</td>
<td>755</td>
<td>186</td>
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<td>0.50</td>
<td>0.43</td>
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<td>3</td>
<td>5</td>
<td>40</td>
<td>0.15</td>
<td>4.8</td>
<td>3.5</td>
<td>1.3</td>
<td>1.4</td>
<td>0.16</td>
<td>1</td>
<td>7</td>
<td>613</td>
<td>132</td>
<td>1.1</td>
<td>2.8</td>
<td>0.70</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>90</td>
<td>0.29</td>
<td>4.4</td>
<td>3.3</td>
<td>1.1</td>
<td>1.0</td>
<td>0.15</td>
<td>4</td>
<td>9</td>
<td>442</td>
<td>172</td>
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<td>4.9</td>
<td>1.16</td>
<td>0.30</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn depth cm</th>
<th>Satn depth %</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Satn extract</th>
<th>Ca mg/kg</th>
<th>K mg/L</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>S mg/kg</th>
<th>SAR</th>
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<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>Ext.B</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
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<th>Coarse sand 50-200</th>
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<td></td>
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<td>0.7</td>
<td>0.6</td>
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<td>39</td>
<td>82</td>
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### Mineralogy of bulk sample

- **Quartz**
- **Albite**
- **Orthoclase**
- **Pyrite**
- **Anatase**
- **Kaolin**
- **Mica/Illite**
- **Chlorite/Vermiculite**
- **Goethite**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>90</td>
</tr>
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### Mineralogy of <2μm fraction

- **Kaolin**
- **Mica/Illite**
- **Chlorite/Vermiculite**
- **Smtectite**

- **D: dominant (>60%)**
- **CD: co-dominant (sum of phases >60%)**
- **SD: sub-dominant (20-60%)**
- **M: minor (5-20%)**
- **T: trace (<5%)**
- **?: possible**
Acid poorly drained cracking clay soils (Typic Dystraquerts)

**Typical pedon number:** 08 0012  
**Agricultural Development Area:** Wasan  
**Physiography Slope:** <1 degree  
**Slope position:** flat of alluvial valley  
**Location:** UTM grid reference 257208 mE 529499 mN Zone 50  
**District:** Brunei Muara  
**Water table depth:** 5 cm  
**Drainage class:** very poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Oi</td>
<td>-10</td>
<td>0YR 3/2</td>
<td>Slightly decomposed plant material</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very firm</td>
<td></td>
<td></td>
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<tr>
<td>Ap1</td>
<td>0 5</td>
<td>10YR 3/1</td>
<td>mucky clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td></td>
<td></td>
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<tr>
<td>Ap2</td>
<td>5 20</td>
<td>10YR 3/1</td>
<td>mucky clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bg</td>
<td>20 60</td>
<td>7.5YR 5/0</td>
<td>clay</td>
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<td>firm</td>
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<tr>
<td>BCg</td>
<td>60 100</td>
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<td>massive</td>
<td>firm</td>
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</table>
### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

**Volume 1 – Soils and Land Suitability of the Agricultural Development Areas**

**Site no:** 08 0012  **ADA:** Wasan  **District:** Brunei Muara

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH&lt;sub&gt;KCl&lt;/sub&gt;</th>
<th>Total Org.C %</th>
<th>Total N %</th>
<th>Bray-2 ext.P mg/kg</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext.P mg/kg</th>
<th>PBI mg/kg</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext.K mg/kg</th>
<th>Exch.Cations NH4OAc pH 7.0 mg/kg</th>
<th>ECEC cmol(+)/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
<th>Ca cmol(+)/kg</th>
<th>Mg cmol(+)/kg</th>
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</thead>
<tbody>
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<thead>
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<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Satn extract Ca mg/kg</th>
<th>K mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>SAR</th>
<th>Soluble salts from saturation extract Ca mg/kg</th>
<th>K mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>Cl mg/kg</th>
<th>SAR</th>
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<tbody>
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<td>87</td>
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<td>78</td>
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<td>2.0</td>
<td>38.0</td>
<td>9.2</td>
<td>37.3</td>
<td>68.2</td>
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<td>5.4</td>
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<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>DTPA ext Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>CaCl&lt;sub&gt;2&lt;/sub&gt;- ext.B mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
<th>µm:</th>
<th>Clay</th>
<th>Coarse silt</th>
<th>Fine silt</th>
<th>Total silt</th>
<th>Coarse sand</th>
<th>Fine sand</th>
<th>Total sand</th>
<th>Plastic limit</th>
<th>Liquid limit</th>
<th>Linear shrink</th>
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<td>3.0</td>
<td>3.5</td>
<td>43</td>
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<td>70</td>
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<td>44</td>
<td>70</td>
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### Mineralogy of bulk sample

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kao.</th>
<th>Mica/illite</th>
<th>Chlorite/vermiculite</th>
<th>Goethite</th>
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<tr>
<td>2</td>
<td>0</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

### Mineralogy of <2µm fraction

- **D:** dominant (>60%)
- **CD:** co-dominant (sum of phases >60%)
- **SD:** sub-dominant (20-60%)
- **M:** minor (5-20%)
- **T:** trace (<5%)
- **?:** possible
4.4 Texture Contrast Yellow soils (Udults)

The Texture Contrast Yellow soils consist of a very deep, yellowish brown soil, with a sandy layer overlying a loamy or clayey layer. They are well drained and the water table was not encountered. These soils occur on slopes of hills. They are formed from old sand dune material.

Geographically associated soils include the Yellow soils.

Diagnostic horizons and characteristic features recognized are:

- Argillic horizon
- Udic moisture regime.
- Sandy layer overlying a loamy or clayey layer
- Yellowish brown colour
- Very deep (greater than 150 cm)
- Well drained

Texture Contrast Yellow soils have only one subtype.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
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<tbody>
<tr>
<td>Texture contrast yellow soils</td>
<td>Arenic Paleudults</td>
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Representative profiles are:

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<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
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<td>Arenic Paleudults</td>
<td>220005 220007</td>
<td>Melayan A Melayan A</td>
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</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Texture contrast yellow soils are sandy topsoil texture, moderately steep slope, potential erosion risk, soil acidity/aluminium toxicity, low K reserves and high leaching potential (Table 22). The combination of slope and texture contrast profile can increase the erosion hazard. During heavy rain, water rapidly infiltrates into the sandy topsoil, but can only move slowly into the heavier subsoil. This causes the topsoil to become saturated and generate runoff.

Land suitability

Texture contrast yellow soils are unsuitable for rice because of the sandy topsoil texture, which makes maintaining ponded conditions difficult, and the steep slope, which would require terracing.

Texture contrast yellow soils are moderately suitable for a range of short duration crops. All crops require reduction of aluminium toxicity by increasing pH. Because of the erosion hazard associated with these soils, careful maintenance of ground cover is required to prevent erosion. The slope also hinders field operations and prevents mechanized operations.

Texture contrast yellow soils are also moderately suitable for most fruit trees, although their sandy topsoil makes them marginal for mangosteen and unsuitable for durian and langsat-duku. Slope is less important for fruit trees than short-duration crops because a) ground cover can be maintained since there is minimal soil disturbance after planting; and b) there are lower requirements for mechanization. The most common limitation is the necessity of reducing aluminium toxicity by managing pH.
Table 22: Land suitability assessment for Texture contrast yellow soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Texture contrast yellow soils</th>
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<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
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**Soil Attribute Ratings**

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<th>Rating</th>
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<td>Topsoil type</td>
<td>S</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g. g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>25%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
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<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
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</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
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<tr>
<td>Fertility Capability Classification</td>
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**Land Suitability Subclasses**

<table>
<thead>
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<th>Suitability</th>
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<tr>
<td>Rice</td>
<td>5 S &gt;15%</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 &gt;20%a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Maize</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w</td>
</tr>
<tr>
<td>Durian</td>
<td>5 S</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 Sa</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 S</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 Sa</td>
</tr>
<tr>
<td>Banana</td>
<td>3 Sak</td>
</tr>
<tr>
<td>Coconut</td>
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<td>Papaya</td>
<td>3 a</td>
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<td>Pineapple</td>
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<td>Mango and cashew nut</td>
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<tr>
<td>Artocarpus</td>
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<td>Mangosteen</td>
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<td>Guava</td>
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<td>Star fruit</td>
<td>3 Sa</td>
</tr>
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<td>Longan</td>
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</table>

Grasses for wet areas  2 SNo g >20%e  
Well drained areas 2 >20%wke  
Fodder legumes for wet areas  2 >20%wake  
Well drained areas 3 wa

1 Soil attribute codes are given in Table 6 and Table 8.  
2 Land suitability classes are defined in Section 3.3.3.

These soils are suitable for grass and fodder legumes, although only moderately so for fodder legumes adapted to well drained areas. This is because of the latter’s sensitivity to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
Occurrence
Texture contrast yellow soils are mainly confined to steeply sloping parts of surveyed ADAs in Belait (Table 23) above the swamps that extend over much of western Belait.

Table 23: Approximate proportions of ADA areas occupied by Texture contrast yellow soils.

<table>
<thead>
<tr>
<th>Soil Subtype: Texture contrast yellow soils</th>
<th>Soil Taxonomy subgroup: Arenic Paleudults</th>
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<tr>
<td>Sg Tajau</td>
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<td>Si Tukak, Limau Manis A</td>
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<tr>
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<td>Batang Mitus (Halaman)</td>
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<td>Birau (P. P. Muda)</td>
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<td>Birau (Penyelidikan)</td>
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<tr>
<td>Belait</td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
<td>104</td>
</tr>
<tr>
<td>Tungulian</td>
<td>92</td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
</tr>
<tr>
<td>Melayan A</td>
<td>13</td>
</tr>
<tr>
<td>Labi Lama</td>
<td>50</td>
</tr>
<tr>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>50</td>
</tr>
<tr>
<td>Temburong</td>
<td></td>
</tr>
<tr>
<td>Labu Estate</td>
<td>97</td>
</tr>
<tr>
<td>Selangan</td>
<td>56</td>
</tr>
<tr>
<td>Bakarut</td>
<td>38</td>
</tr>
<tr>
<td>Selapon</td>
<td>80</td>
</tr>
<tr>
<td>Overall</td>
<td><strong>4423</strong></td>
</tr>
<tr>
<td></td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>
Texture contrast yellow soils (Arenic Paleudults)

**Typical pedon number:** 22 0005  
**Agricultural Development Area:** Melayan A  
**Physiography**  
**Slope:** 15 degrees  
**Slope position:** back slope of hill  
**Location:** UTM grid reference 218686 mE 496361 mN  
**Zone 50**  
**District:** Belait  
**Physiography Slope:** 15 degrees  
**Slope position:** back slope of hill  
**Water table depth:** not reached  
**Drainage class:** well

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0</td>
<td>25</td>
<td>10YR 3/2</td>
<td>loamy sand</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>very friable</td>
<td>heavy chicken manure fertiliser</td>
</tr>
<tr>
<td>Bt1</td>
<td>25</td>
<td>70</td>
<td>10YR 6/6</td>
<td>sandy loam</td>
<td>0% concentrations</td>
<td>massive</td>
<td>friable</td>
<td></td>
</tr>
<tr>
<td>Bt2</td>
<td>70</td>
<td>100</td>
<td>10YR 6/6</td>
<td>sandy loam</td>
<td>0% concentrations</td>
<td>massive</td>
<td>firm</td>
<td></td>
</tr>
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</table>
### Site no: 22 0005  
**ADA:** Melayan A  
**District:** Belait

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC cm</th>
<th>pH</th>
<th>pH&lt;sub&gt;KCl&lt;/sub&gt;</th>
<th>Total N mg/kg</th>
<th>Bray-2 ext. N mg/kg</th>
<th>PBI</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext. K mg/kg</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext. P mg/kg</th>
<th>PBI</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext. K mg/kg</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- ext. P mg/kg</th>
<th>pH&lt;sub&gt;H2O&lt;/sub&gt;</th>
<th>pH&lt;sub&gt;KCl&lt;/sub&gt;</th>
<th>Total Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
<th>Mg cmol(+)/kg</th>
<th>Ca cmol(+)/kg</th>
<th>K cmol(+)/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>25</td>
<td>0.08</td>
<td>4.7</td>
<td>3.8</td>
<td>1.0</td>
<td>2.4</td>
<td>0.13</td>
<td>25</td>
<td>16</td>
<td>136</td>
<td>275</td>
<td>1.4</td>
<td>0.4</td>
<td>0.39</td>
<td>0.15</td>
<td>2.3</td>
<td>1.91</td>
<td>0.03</td>
<td>0.39</td>
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<tr>
<td>2</td>
<td>25</td>
<td>70</td>
<td>0.03</td>
<td>4.8</td>
<td>4.1</td>
<td>0.6</td>
<td>0.5</td>
<td>0.04</td>
<td>7</td>
<td>3</td>
<td>206</td>
<td>93</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td>0.35</td>
<td>&lt;0.05</td>
<td>0.6</td>
<td>2.3</td>
<td>&lt;0.01</td>
<td>0.45</td>
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</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn depth cm</th>
<th>Satn %</th>
<th>Satn pH</th>
<th>Satn EC cm</th>
<th>Soluble salts in saturation extract</th>
<th>Ca mg/kg</th>
<th>K mg/L</th>
<th>Mg mg/L</th>
<th>Na mg/L</th>
<th>Cl mg/L</th>
<th>SAR</th>
<th>Soluble salts from saturation extract</th>
<th>Ca mg/kg</th>
<th>K mg/L</th>
<th>Mg mg/L</th>
<th>Na mg/L</th>
<th>Cl mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>DTPA ext Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>CaCl&lt;sub&gt;2&lt;/sub&gt;- ext B mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
<th>µm:</th>
<th>2-20</th>
<th>20-50</th>
<th>20-50</th>
<th>200-500</th>
<th>2000</th>
<th>Plastic limit</th>
<th>Liquid limit</th>
<th>Linear shrink</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>25</td>
<td>0.2</td>
<td>91</td>
<td>7.4</td>
<td>1.0</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>70</td>
<td>&lt;0.1</td>
<td>37</td>
<td>0.4</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

### Mineralogy of bulk sample

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kao-lin</th>
<th>Mica/Illite</th>
<th>Chlorite/Vermiculite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mineralogy of <2µm fraction

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Kao-lin</th>
<th>Mica/Illite</th>
<th>Chlorite/Vermiculite</th>
<th>Smectite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Soluble salts from saturation extract
- Soluble salts in saturation extract
- Mineralogy of bulk sample
- Mineralogy of <2µm fraction
- D: dominant (>60%)
- CD: co-dominant (sum of phases >60%)
- SD: sub-dominant (20-60%)
- M: minor (5-20%)
- T: trace (<5%)
- ?: possible
4.5 Very Deep Yellow soils (Humults)

The Very Deep Yellow soils consist of a very deep, yellowish brown soil. It is somewhat poorly drained to well drained but the water table if it occurs is deep. These soils occur on slopes of hills. They are formed in weathered sandstone and shale.

Geographically associated soils include the Yellow soils.

Diagnostic horizons and characteristic features recognized are:

- Yellowish brown colour
- Very deep (greater than 150 cm)
- Generally loamy or clayey subsoil texture (argillic horizon)
- Well drained to somewhat poorly drained
- 0.9% organic carbon in the upper 15 cm of the argillic horizon

Very Deep Yellow soils have five subtypes depending on the texture of the subsoil and drainage.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somewhat poorly drained sandy very deep yellow soils</td>
<td>Aquic Kandihumults</td>
<td>Sandy or loamy subsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Somewhat poorly drained (greyish lower subsoil)</td>
</tr>
<tr>
<td>Well drained sandy very deep yellow soils</td>
<td>Typic Kandihumults</td>
<td>Sandy or loamy subsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Well drained (uniformly bright yellowish subsoil)</td>
</tr>
<tr>
<td>Somewhat poorly drained clayey very deep yellow soils</td>
<td>Aquic Palehumults</td>
<td>Loamy or clayey subsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Somewhat poorly drained (greyish lower subsoil)</td>
</tr>
<tr>
<td>Moderately well drained clayey very deep yellow soils</td>
<td>Oxyaquic Palehumults</td>
<td>Loamy or clayey subsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderately well drained (yellowish brown subsoil with red/orange mottles)</td>
</tr>
<tr>
<td>Well drained clayey very deep yellow soils</td>
<td>Typic Palehumults</td>
<td>Loamy or clayey subsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Well drained (uniformly yellowish or brownish subsoil)</td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somewhat poorly drained sandy very deep yellow soils</td>
<td>Aquic Kandihumults</td>
<td>190001</td>
<td>Rampayoh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>190007</td>
<td>Rampayoh</td>
</tr>
<tr>
<td>Well drained sandy very deep yellow soils</td>
<td>Typic Kandihumults</td>
<td>150020</td>
<td>Batang Mitus (Halaman)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>170011</td>
<td>Birau (Penyelidikan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200003</td>
<td>Tungulian</td>
</tr>
<tr>
<td>Somewhat poorly drained clayey very deep yellow soils</td>
<td>Aquic Palehumults</td>
<td>140018</td>
<td>Batang Mitus (Buah)</td>
</tr>
<tr>
<td>Moderately well drained clayey very deep yellow soils</td>
<td>Oxyaquic Palehumults</td>
<td>210028</td>
<td>Merangking, Bukit Sawat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280003</td>
<td>Merangking, Bukit Sela pon</td>
</tr>
<tr>
<td>Well drained clayey very deep yellow soils</td>
<td>Typic Palehumults</td>
<td>210001</td>
<td>Merangking, Bukit Sawat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>210019</td>
<td>Merangking, Bukit Sawat</td>
</tr>
</tbody>
</table>
Table 24: Land suitability assessment for Very deep yellow soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Somewhat poorly drained sandy very deep yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
<th>Somewhat poorly drained clayey very deep yellow soils</th>
<th>Moderately well drained clayey very deep yellow soils</th>
<th>Well drained clayey very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Aquic Kandihumults</td>
<td>Typic Kandihumults</td>
<td>Aquic Palehumults</td>
<td>Oxyaquic Palehumults</td>
<td>Typic Palehumults</td>
</tr>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
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<tr>
<td>Subsoil type</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>-</td>
<td>g</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>25%</td>
<td>3%</td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
<td>70%</td>
<td>-</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>w</td>
<td>-</td>
<td>-</td>
<td>w</td>
</tr>
<tr>
<td>Sulphidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
<td>k</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i+, i++)</td>
<td>-</td>
<td>-</td>
<td>i</td>
<td>-</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
<td>e</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>LL2%a-ke</td>
<td>LL25-70%wake</td>
<td>LLg3%aki</td>
<td>LC0-30%ak</td>
<td>LC15-30%waki</td>
</tr>
</tbody>
</table>

Land Suitability Subclasses:

1. Rice
2. Leafy and fruit vegetables
3. Root vegetables
4. Groundnuts
5. Soya and mung beans
6. Maize
7. Ginger and turmeric
8. Cassava and sweet potato
9. Durian
10. Rambutan
11. Langsat-duku
12. Citrus
13. Banana
14. Coconut
15. Papaya
16. Pineapple
17. Mango and cashew nut
18. Artocarpus
19. Mangosteen
20. Dragon fruit
21. Guava
22. Star fruit
23. Longan
24. Grasses for -wet areas
25. -well drained areas
26. Fodder legumes for -wet areas
27. -well drained areas

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

Soil attributes

The Fertility Capability Classification attributes that influence land use for Very deep yellow soils are loamy topsoil, soil acidity/aluminium toxicity and low K reserves (Table 24).

The main soil attribute difference between the Soil Subtypes is the subsoil texture, slope and waterlogging. The Sandy very deep yellow soils (Kandihumults) have a sandy loam subsoil and high leaching potential, while the Clayey very deep yellow soils (Palehumults) have a clayey subsoil. The Somewhat poorly drained Subtypes (aquic) occur low in the landscape.
and are waterlogged. Conversely the Well drained subtypes occur higher in the landscape, often on steep slopes, with the associated erosion hazard.

**Land suitability**

The suitability of Very deep yellow soils for rice varies according to landscape position. The Somewhat poorly drained subtypes (aquic) are suitable because of their waterlogged condition. The Well drained Subtypes are unsuitable or only marginally suitable because they occur on steep slopes. The Moderately well drained Subtype (oxyaquic) is moderately suitable, because it requires irrigation water to maintain ponded conditions.

Very deep yellow soils are generally moderately suitable for the short duration crops assessed. The major limitations are soil acidity/aluminium toxicity on all Subtypes except the Somewhat poorly drained very deep yellow soil. Slope and erosion hazard are major limitations on the Well drained Subtypes, which in steeper parts of the landscape, renders these soils unsuitable. Waterlogging is a limitation on the Somewhat poorly drained Subtypes. However, a few Soil Subtype-crop combinations are rated suitable, in particular vegetables on the Somewhat poorly drained very deep yellow soil.

These soils are generally moderately suitable for fruit crops, with the pattern of limitations being similar to that for short duration crops. Waterlogging in the Somewhat poorly drained subtypes makes them only marginally suitable for susceptible species such as durian, langsat-duku and papaya. On the other hand the Somewhat poorly drained sandy Subtype is suitable for mangosteen because the soil is less acid with lower aluminium toxicity and mangosteen is tolerant to waterlogging.

These soils are suitable for grass and fodder legumes, although only moderately so for fodder legumes adapted to well drained areas. This is because of the latter’s sensitivity to soil acidity/aluminium toxicity and poorer ground cover which increases the risk of erosion.

**Occurrence**

Very deep yellow soils are common with the ADAs surveyed in Tutong, Belait and Temburong Districts (Table 25). The Well drained sandy Subtype is especially common on the upper slopes of surveyed ADAs in Tutong as well as in Rampayoh and Tungulian ADAs in Belait. The Somewhat poorly drained sandy Subtype is confined Rampayoh and Labi Lama ADAs where it is formed in similar material but at the base of the hills between the hills and the swamps covering the western part of Belait.

The Clayey Subtypes are more restricted in their occurrence. The Somewhat poorly drained clayey Subtype is located on lower slopes in the Tutong ADAs and Sg Tajau ADA. The Moderately well drained Subtype occurs on alluvial terraces associated with large rivers in three of the Temburong ADAs. Moderately well drained and Well drained clayey Subtypes are extensive in the hilly terrain of Merangking, Bukit Sawat ADA.
### Table 25: Approximate proportions of ADA areas occupied by Very deep yellow soils.

<table>
<thead>
<tr>
<th>Soil Subtype: Somewhat poorly drained sandy very deep yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
<th>Somewhat poorly drained clayey very deep yellow soils</th>
<th>Moderately well drained clayey very deep yellow soils</th>
<th>Well drained clayey very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup: Aquic Kandihumults</td>
<td>Typic Kandihumults</td>
<td>Aquic Palehumults</td>
<td>Oxyaquic Palehumults</td>
<td>Typic Palehumults</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADA</th>
<th>ADA area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei-Muara</td>
<td></td>
</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
</tr>
<tr>
<td>Sg Tajau</td>
<td>117</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127</td>
</tr>
<tr>
<td>Lumanpas</td>
<td>38</td>
</tr>
<tr>
<td>Limpaki</td>
<td>92</td>
</tr>
<tr>
<td>Luahan</td>
<td>73</td>
</tr>
<tr>
<td>Wasan</td>
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<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
</tr>
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<td>Batang Mitus (Buah)</td>
<td>517</td>
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<tr>
<td>Batang Mitus (Halaman)</td>
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<td>Birau (P. P. Muda)</td>
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<td>Birau (Penyelidikan)</td>
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<td>Rampayoh</td>
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<td>Labi Lama</td>
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</table>

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
Page 91
**Somewhat poorly drained sandy very deep yellow soils (Aquic Kandihumults)**

**Typical pedon number:** 19 0001  
**Agricultural Development Area:** Rampayoh  
**Location:** UTM grid reference 218198 mE 484358 mN Zone 50  
**District:** Belait  
**Physiography:** Slope: <1 degree  
**Slope position:** toe slope of valley side  
**Water table depth:** 60 cm  
**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
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<td>0 5</td>
<td>10YR 3/2</td>
<td>sandy loam</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>firm</td>
<td>firm</td>
<td>firm</td>
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<tr>
<td>AB</td>
<td>5 20</td>
<td>10YR 4/3</td>
<td>sandy loam</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>firm</td>
<td>extremely firm</td>
<td></td>
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<tr>
<td>Bg</td>
<td>20 22</td>
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<td>0% concentrations</td>
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<td>friable</td>
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**Depth, cm**

- 0 - 5
- 5 - 20
- 20 - 22
- 22 - 60

**Depth, cm**

- 60 - 100
<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pHKCl</th>
<th>pHH2O</th>
<th>ΔpH</th>
<th>Total HCO3- ext.P</th>
<th>PBI</th>
<th>HCO3- ext.K</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Total cmol(+)/kg</th>
<th>Al</th>
<th>Mn</th>
<th>Al</th>
<th>Mn</th>
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<table>
<thead>
<tr>
<th>Site no: 19 0001</th>
<th>ADA: Rampayoh</th>
<th>District: Belait</th>
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<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Soluble salts in saturation extract</th>
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<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Cu mg/kg</th>
<th>Fe mg/kg</th>
<th>Mn mg/kg</th>
<th>Zn mg/kg</th>
<th>As mg/kg</th>
<th>Cd mg/kg</th>
<th>CaCl2- ext.B</th>
<th>DTPA ext</th>
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<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolin</th>
<th>Mica/ilite</th>
<th>Chlorite/Vermiclite</th>
<th>Goethite</th>
<th>Kaolin</th>
<th>Mica/ilite</th>
<th>Chlorite/Vermiclite</th>
<th>Smectite</th>
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Well drained sandy very deep yellow soils (Typic Kandihumults)

**Typical pedon number:** 15 0020  
**Agricultural Development Area:** Batang Mitus (Halaman)  
**Physiography:** Slope: 35 degrees  
**Slope position:** shoulder of hill slope  
**Location:** UTM grid reference 251893 mE 527216 mN Zone 50  
**District:** Tutong  
**Water table depth:** not reached  
**Drainage class:** well

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm - Moist</th>
<th>Soil colour</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Oi</td>
<td>-2</td>
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<td>Slightly decomposed plant material</td>
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<td>loose</td>
<td></td>
<td></td>
<td>Leaves and twigs</td>
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<tr>
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<td>Bt1</td>
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<td>71</td>
<td>5YR 6/8 iron concentrations</td>
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<td>massive</td>
<td>slightly rigid</td>
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<td>Broken iron pan</td>
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<td>firm</td>
<td></td>
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Depth, cm: 0 - 5  
Depth, cm: 71 - 100
### Soluble salts in saturation extract

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth (cm)</th>
<th>Lower depth (cm)</th>
<th>EC (dS/m)</th>
<th>pH</th>
<th>Satn. percent</th>
<th>pH</th>
<th>Org.C %</th>
<th>N %</th>
<th>ext.P mg/kg</th>
<th>HCO₃⁻ mg/kg</th>
<th>PBI ext.K cmol(+)/kg</th>
<th>HCO₃⁻ ext.P mg/kg</th>
<th>ECEC 1M KCl ext. 0.01M CaCl₂ ext. cmol(+)/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
<th>Total cmol(+)/kg</th>
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</thead>
<tbody>
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<td>4.8</td>
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<td>42</td>
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<td>&lt;0.05</td>
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<tr>
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<td>71</td>
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<td>0.03</td>
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<td>0.6</td>
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<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>0.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Soluble salts from saturation extract

| Layer no. | Upper depth (cm) | Lower depth (cm) | Cu mg/kg | Fe mg/kg | Mn mg/kg | Zn mg/kg | As mg/kg | Cd mg/kg | Clay % | Coarse silt % | Fine silt % | Total silt % | Fine sand 50-2000 mg/kg | Coarse sand 200-50-200 mg/kg | Total sand 200-2000 mg/kg | Plastic limit (W_p) µm | Liquid limit (W_L) µm | Linear shrink % | SAR | SAR | SAR |
|-----------|-----------------|-----------------|----------|----------|----------|----------|----------|----------|--------|----------------|-------------|--------------|--------------------------|----------------------------|----------------------------|-------------------|-------------------|-----------------|---------|-------|
| 2         | 0               | 5               | <0.1     | 240      | 12.5     | 1.2      |          |          |        |                |             |              |                          |                            |                        |                   |                   |                 |         |       |
| 3         | 5               | 25              | <0.1     | 86       | 1.9      | 0.1      |          |          |        |                |             |              |                          |                            |                        |                   |                   |                 |         |       |
| 4         | 25              | 70              | <0.1     | 94       | 2.0      | 0.2      |          |          |        |                |             |              |                          |                            |                        |                   |                   |                 |         |       |
| 6         | 71              | 100             | <0.1     | 36       | 0.8      | 0.2      |          |          |        |                |             |              |                          |                            |                        |                   |                   |                 |         |       |

### Mineralogy of bulk sample

- D: dominant (>60%)
- CD: co-dominant (sum of phases >60%)
- SD: sub-dominant (20-60%)
- M: minor (5-20%)
- T: trace (<5%)
- ?: possible
**Somewhat poorly drained clayey very deep yellow soils (Aquic Palehumults)**

- **Typical pedon number:** 14 0018
- **Location:** UTM grid reference 252957 mE 525042 mN Zone 50
- **Agricultural Development Area:** Batang Mitus (Buah)
- **District:** Tutong
- **Physiography Slope:** 2 degrees
- **Slope position:** toe slope of valley side
- **Water table depth:** 70 cm
- **Drainage class:** somewhat poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>15</td>
<td>10YR 4/4</td>
<td>sandy clay loam</td>
<td>subangular blocky</td>
<td>firm</td>
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<td></td>
</tr>
<tr>
<td>Bt</td>
<td>15</td>
<td>70</td>
<td>10YR 5/8</td>
<td>clay loam</td>
<td>massive</td>
<td>extremely firm</td>
<td>3.7</td>
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<tr>
<td>BCgt</td>
<td>70</td>
<td>100</td>
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<td>clay loam</td>
<td>massive</td>
<td>firm</td>
<td>3.7</td>
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</tbody>
</table>

**Depth, cm**

- 0 - 15
- 15 - 70
- 70 - 100
### Site Information

- **Site no:** 14 0018
- **ADA:** Batang Mitus (Buah)
- **District:** Tutong

### Soil Analysis

#### 1st Layer
- **Upper depth:** 0 cm
- **Lower depth:** 15 cm
- **EC:** 0.18 dS/m
- **pH:** 4.6
- **pH<sub>KCl</sub>:** 3.7
- **pH<sub>H<sub>2</sub>O</sub>:** 0.9
- **EC:** 2.1 cmol(+)/kg
- **pH:** 0.17
- **Bray-2:** 30 mg/kg
- **Total:** 43 mg/kg
- **HCO<sub>3</sub>**-:** 129 mg/kg
- **Ca:** 389 mg/kg
- **Mg:** 0.5 mg/kg
- **Na:** 0.5 mg/kg
- **K:** 0.22 cmol(+)/kg
- **Total Ext.P:** 1.8 cmol(+)/kg
- **EC:** 4.1 cmol(+)/kg
- **pH:** 0.49
- **Total Ext.K:** 0.36 cmol(+)/kg
- **pH:** 0.44

#### 2nd Layer
- **Upper depth:** 15 cm
- **Lower depth:** 70 cm
- **EC:** 0.06 dS/m
- **pH:** 4.5
- **pH<sub>KCl</sub>:** 3.7
- **Bray-2:** 0.8 mg/kg
- **Total:** 0.5 mg/kg
- **HCO<sub>3</sub>**-:** 225 mg/kg
- **Ca:** 101 mg/kg
- **Mg:** 0.2 mg/kg
- **Na:** 0.2 mg/kg
- **K:** 0.19 cmol(+)/kg
- **Total Ext.P:** 0.6 cmol(+)/kg
- **EC:** 4.4 cmol(+)/kg
- **pH:** 0.94
- **Total Ext.K:** 0.94 cmol(+)/kg
- **pH:** 0.18

#### 3rd Layer
- **Upper depth:** 70 cm
- **Lower depth:** 100 cm
- **EC:** 0.06 dS/m
- **pH:** 4.9
- **pH<sub>KCl</sub>:** 3.8
- **Bray-2:** 1.1 mg/kg
- **Total:** 0.5 mg/kg
- **HCO<sub>3</sub>**-:** 316 mg/kg
- **Ca:** 103 mg/kg
- **Mg:** 0.8 mg/kg
- **Na:** 0.32 mg/kg
- **K:** 0.13 cmol(+)/kg
- **Total Ext.P:** 1.3 cmol(+)/kg
- **EC:** 5.0 cmol(+)/kg
- **pH:** 0.7
- **Total Ext.K:** 0.7 cmol(+)/kg
- **pH:** 0.16

### Soluble Salts

#### Saturation Extract

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
</tr>
</thead>
<tbody>
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#### Soluble Salts in Saturation Extract

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<th>K</th>
<th>Mg</th>
<th>Na</th>
<th>S</th>
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### Mineralogy of Bulk Sample

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<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolinite</th>
<th>Mica/Illite</th>
<th>Chlorite/ Vermiculite</th>
<th>Goethite</th>
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### Mineralogy of <2 µm fraction

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<th>Upper depth cm</th>
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<th>Keolinite</th>
<th>Mica/Illite</th>
<th>Chlorite/ Vermiculite</th>
<th>Smectite</th>
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<tbody>
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<tr>
<td>3</td>
<td>70</td>
<td>100</td>
<td></td>
<td></td>
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</table>

### Notes

- **EC:** Electrical Conductivity
- **pH:** Hydrogen Ion Concentration
- **Bray-2:** Phosphate Extracted by Bray-2 Solution
- **HCO<sub>3</sub>**-:** Bicarbonate Ion
- **CaCl<sub>2</sub>**-:** Calcium Chloride Solution
- **Al** and **Mn:** Aluminum and Manganese
- **Total Ext.P** and **Total Ext.K:** Total Exchangeable Phosphorus and Potassium
- **SAR:** Sodium Adsorption Ratio
- **D:** Dominant (>60%)
- **CD:** Co-dominant (sum of phases >60%)
- **SD:** Sub-dominant (20-60%)
- **M:** Minor (5-20%)
- **T:** Trace (<5%)
- **?:** Possible

---

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
Moderately well drained clayey very deep yellow soils (Oxyaquic Palehumults)

Typical pedon number: 28 0003
Agricultural Development Area: Selapon
Physiography Slope: <1 degree Slope position: terrace of valley
Location: UTM grid reference 298748 mE 516936 mN Zone 50
District: Temburong
Water table depth: not reached Drainage class: somewhat poorly
Agricultural Development Area: Selapon
District: Temburong

Morphological Description:

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth, cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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</thead>
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<td>0 - 5</td>
<td>10YR 3/3</td>
<td>clay loam</td>
<td>0% concentrations</td>
<td>granular</td>
<td>friable</td>
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<td>10YR 3/3</td>
<td>clay loam</td>
<td>0% concentrations</td>
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<td>very firm</td>
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<tr>
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<td>10YR 5/4</td>
<td>clay</td>
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<td>subangular blocky</td>
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<td>very firm</td>
<td></td>
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Depth, cm

0 - 5
5 - 25
25 - 60
60 - 100
## Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

Volume 1 – Soils and Land Suitability of the Agricultural Development Areas

<table>
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<th>District: Temburong</th>
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<th>( \Delta ) pH</th>
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<th>Total Bray-2 HCO(_3)-</th>
<th>HCO(_3)- ext.K</th>
<th>PBI</th>
<th>HCO(_3)- ext.K</th>
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<td>%</td>
<td>mg/kg</td>
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<th>Satn extract</th>
<th>Soluble salts in saturation extract</th>
<th>Soluble salts from saturation extract</th>
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<th>Coarse silt</th>
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<th>Fine sand</th>
<th>Coarse sand</th>
<th>Total sand</th>
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<th>Liquid limit</th>
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</table>

### Mineralogy of bulk sample

- **Quartz**
- ** albite**
- **orthoclase**
- **pyrite**
- **anatase**
- **kaolin**
- **mica/ilite**
- **chlorite/vermiculite**
- **goethite**

### Mineralogy of <2μm fraction

- **kaolin**
- **mica/ilite**
- **chlorite/vermiculite**
- **smectite**

**D**: dominant (>60%)
**CD**: co-dominant (sum of phases >60%)
**SD**: sub-dominant (20-60%)
**M**: minor (5-20%)
**T**: trace (<5%)
**?**: possible
Well drained clayey very deep yellow soils (Typic Palehumults)

**Typical pedon number:** 21 0019  
**Location:** UTM grid reference 232801 mE 502266 mN Zone 50

**Agricultural Development Area:** Merangking, Bukit Sawat  
**District:** Belait

**Physiography**  
**Slope:** 15 degrees  
**Slope position:** back slope of hill

**Water table depth:** not reached  
**Drainage class:** moderately well

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<tr>
<td>A</td>
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<td>10YR 4/4</td>
<td>clay loam</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
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<td>firm</td>
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**Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam**  
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas  

<table>
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<td>4</td>
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<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>Satn extract</th>
<th>Soluble salts in saturation extract</th>
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<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>As</th>
<th>Cd</th>
<th>CaCl₂- ext.B</th>
<th>As</th>
<th>Cd</th>
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<tr>
<td>2</td>
<td>15</td>
<td>80</td>
<td>&lt;0.1</td>
<td>95</td>
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<td>0.2</td>
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<td>3</td>
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<td>120</td>
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<td>59</td>
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<td>0.2</td>
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<td>4</td>
<td>170</td>
<td>250</td>
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<td>1.6</td>
<td>0.3</td>
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<td>251</td>
<td>300</td>
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</tr>
<tr>
<td>6</td>
<td>350</td>
<td>450</td>
<td>0.3</td>
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<td>3.2</td>
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<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolinite</th>
<th>Micaceous</th>
<th>Chlorite/Vermiculite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15</td>
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<td>-</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>80</td>
<td>120</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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</tr>
<tr>
<td>4</td>
<td>170</td>
<td>250</td>
<td>-</td>
<td>-</td>
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<tr>
<td>5</td>
<td>251</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>350</td>
<td>450</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Mineralogy of bulk sample**

**Mineralogy of <2µm fraction**

- D: dominant (>60%)
- CD: co-dominant (sum of phases >60%)
- SD: sub-dominant (20-60%)
- M: minor (5-20%)
- T: trace (<5%)
- ?: possible
4.6 Yellow soils (Haplohumults)

The Yellow soils consist of deep, yellowish brown, clayey or loamy soil, overlying weathered rock material. They are somewhat poorly drained to well drained, but the water table if it occurs is deep. These soils occur on slopes of hills. They are formed in weathered sandstone and shale.

Geographically associated soils include the Very Deep Yellow soils.

Diagnostic horizons and characteristic features recognized are:

- Yellowish brown colour
- Deep (between 100 and 150 cm)
- Generally a loamy or clayey subsoil texture (argillic horizon)
- Well drained to somewhat poorly drained
- 0.9% organic carbon in the upper 15 cm of the argillic horizon.

Yellow soils have two subtypes depending on soil drainage.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately well drained</td>
<td>Oxyaquic Haplohumults</td>
<td>• Moderately well drained or somewhat poorly drained (yellowish brown subsoil with red/orange mottles)</td>
</tr>
<tr>
<td>yellow soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well drained yellow soils</td>
<td>Typic Haplohumults</td>
<td>• Well drained (uniformly yellowish or brownish subsoil)</td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately well drained</td>
<td>Oxyaquic Haplohumults</td>
<td>020003 Sg Tajau</td>
<td></td>
</tr>
<tr>
<td>yellow soils</td>
<td></td>
<td>070001 Luahan</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100002 Kupang</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>110006 Maraburong, Kupang</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>120007 Padnunok/Sg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>140013 Batang Mitus (Buah)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>140016 Batang Mitus (Buah)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>150014 Batang Mitus (Halaman)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>170015 Birau (Penyelidikan)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>240003 KM 26, Jalan Bukit</td>
<td>Puan Labi</td>
</tr>
<tr>
<td>Well drained yellow soils</td>
<td>Typic Haplohumults</td>
<td>250005 Labu Estate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>250006 Labu Estate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>250009 Labu Estate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>270005 Bakarut</td>
<td></td>
</tr>
</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Yellow soils are steep slope, potential erosion risk, soil acidity/aluminium toxicity, low K reserves, and high P fixation (Table 26).

The main soil attribute difference between the Soil Subtypes is the topsoil texture (loamy or clayey), and the large variation in slope from flat to steep slopes with associated potential erosion risk on the steeper slopes.
<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Oxyaquic Haplohumults</td>
<td>Typic Haplohumults</td>
</tr>
<tr>
<td>Soil Attribute Ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20%</td>
<td>60%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>LC20-70%waki</td>
<td>CC60-70%waki</td>
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</table>

**Land Suitability Subclasses**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Category</th>
<th>Moderately well drained Yellow soils</th>
<th>Well drained Yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>4 &gt;55%</td>
<td>4 &gt;55%</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>4 C</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35% ak [4 &gt;65%]</td>
<td>3 &gt;35% ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35% ak [4 &gt;65%]</td>
<td>3 &gt;35% ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
<td>3 &gt;35% a [4 &gt;65%]</td>
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</table>

**Grasses for -wet areas**

<table>
<thead>
<tr>
<th>Category</th>
<th>Moderately well drained Yellow soils</th>
<th>Well drained Yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 No gi [3 &gt;55%]</td>
<td>3 &gt;55%</td>
<td></td>
</tr>
</tbody>
</table>

**Land Suitability**

Suitability for most crops on Yellow soils is controlled mainly by slope. The steep slopes make them unsuitable for rice. The Moderately well drained Subtype is moderately suitable for short duration crops, with the steep slopes hindering field operations and requiring attention to erosion control measures. Where this Subtype occurs on steeper slopes it is either marginal or unsuitable. The Well drained Subtype generally occurs on steeper slopes and is unsuitable for short duration crops.
Yellow soils are moderately suitable for most fruit trees. Slope is less important for fruit trees than short-duration crops because a) groundcover can be maintained since there is minimal soil disturbance once the trees have been planted; and b) there are fewer requirements for mechanization. The major limitation is the necessity of reducing aluminium toxicity by managing pH. Where these soils occur on slopes greater than 65% they are only marginally suitable for fruit crops because of the risk of mass soil movement (i.e. land slippage).

Yellow soils are suitable or moderately suitable for grass and fodder legumes, with slope being the controlling factor.

Occurrence

The Yellow soils are the most widespread Soil Type within the surveyed ADAs. The Moderately well drained yellow soils are common in the mid to lower slopes of all the surveyed ADAs in Tutong, as well as in Brunei Muara ADAs that contain hilly terrain – Sg Tajau, Si Tukak (Limau Manis), Luahan and Tungku (Table 27). In surveyed ADAs in Belait, Yellow soils are confined to Tungulian. In Temburong they are extensive in the hilly parts of the surveyed ADAs.

Table 27: Approximate proportions of ADA areas occupied by Yellow soils.

<table>
<thead>
<tr>
<th>Soil Subtype:</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil Taxonomy subgroup:</td>
<td>Oxyaquic</td>
</tr>
<tr>
<td>ADA</td>
<td>ADA area (ha)</td>
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</tr>
<tr>
<td>Brunei-Muara</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
<td></td>
</tr>
<tr>
<td>Sg Tajau</td>
<td>117</td>
<td>68%</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
<td>50%</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>Lomapas</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Limpaki</td>
<td>92</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Luahan</td>
<td>73</td>
<td>65%</td>
</tr>
<tr>
<td>Wasan</td>
<td>373</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Tungku</td>
<td>262</td>
<td>31%</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Tutong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kupang</td>
<td>60</td>
<td>65%</td>
</tr>
<tr>
<td>Maraburong, Kupang</td>
<td>58</td>
<td>58%</td>
</tr>
<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
<td>63%</td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>517</td>
<td>67%</td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>585</td>
<td>52%</td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>80</td>
<td>56%</td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
<td>53%</td>
</tr>
<tr>
<td>Belait</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>Tungulian</td>
<td>92</td>
<td>26%</td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
<td></td>
</tr>
<tr>
<td>Melayan A</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Labi Lama</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>50</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Temburong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labu Estate</td>
<td>97</td>
<td>4%</td>
</tr>
<tr>
<td>Selangan</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Bakarut</td>
<td>38</td>
<td>38%</td>
</tr>
<tr>
<td>Selapen</td>
<td>80</td>
<td>26%</td>
</tr>
<tr>
<td>Overall</td>
<td>4423</td>
<td>29%</td>
</tr>
</tbody>
</table>
Moderately well drained yellow soils (Oxyaquic Haplohumults)

Typical pedon number: 17 0015
Agricultural Development Area: Birau (Penyelidikan)
Physiography: Slope: 30 degrees  Slope position: back slope of hill
Location: UTM grid reference 252538 mE 528907 mN Zone 50
District: Tutong
Water table depth: not reached
Drainage class: moderately well

Morphological Description:

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 - 10</td>
<td>10YR 3/3</td>
<td>clay</td>
<td>0% concentrations</td>
<td>granular</td>
<td>friable</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>10 - 30</td>
<td>10YR 5/4</td>
<td>clay</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>firm</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Bt1</td>
<td>30 - 50</td>
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### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

**Volume 1 – Soils and Land Suitability of the Agricultural Development Areas**

Page 107

#### Site no: 17 0015

#### ADA: Birau (Penyelidikan)

#### District: Tutong

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH$_{KCl}$</th>
<th>N mg/kg</th>
<th>PBI mg/kg</th>
<th>HCO$_3^-$ mg/kg</th>
<th>Bray-2 mg/kg</th>
<th>HCO$_3^-$ ext.K mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
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<th>Soluble salts from saturation extract mg/kg</th>
<th>Ca</th>
<th>K</th>
<th>Mg</th>
<th>Na</th>
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<th>Lower depth cm</th>
<th>Satn percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Satn extract Ca</th>
<th>K</th>
<th>Mg</th>
<th>Na</th>
<th>S</th>
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<th>SAR</th>
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#### Soluble salts from saturation extract

| Layer no. | Upper depth cm | Lower depth cm | Cu mg/kg | Fe mg/kg | Mn mg/kg | Zn mg/kg | ext.B % | As % | Cd % | Total sand ext. W$_P$ % | W$_CL$ % | Total silt ext. W$_P$ % | W$_CL$ % | Total silt silt Cl % | Plastic limit % | Liquid limit % | Linear shrink % | Clay % | Fine silt | Coarse silt | Total silt | Fine sand | Coarse sand | Total sand |
|-----------|----------------|----------------|----------|----------|----------|----------|---------|------|------|-------------------------|-----------|------------------------|-----------|----------------|---------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1         | 0              | 10             | 1.5      | 357      | 40.2     | 3.7      | 39.6   | 26.1 | 10.9 | 37.0                    | 23.1      | 0.3                    | 23.4      | 36          | 47           | 6.8       |             |              |              |             |             |             |
| 2         | 10             | 30             | 2.0      | 228      | 3.5      | 1.4      | 49.7   | 24.8 | 6.0  | 30.8                    | 19.3      | <0.2                   | 19.5      | 27          | 44           | 7.7       |             |              |              |             |             |             |
| 3         | 30             | 50             | 1.0      | 139      | 1.6      | 0.9      | 51.7   | 24.3 | 6.6  | 30.8                    | 17.0      | 0.5                    | 17.5      | 29          | 44           | 9.2       |             |              |              |             |             |             |

### Mineralogy of bulk sample

#### Layer no. | Upper depth cm | Lower depth cm | Quartz | Albite | Orthoclase | Pyrite | Anatase | K-feldspar | Mica I/llite | Chlorite Vermiculite | Goethite |
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<td>D</td>
<td>T</td>
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<td>-</td>
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<td>-</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>-</td>
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### Mineralogy of <2µm fraction

#### Layer no. | Upper depth cm | Lower depth cm | Kaolin | Mica I/llite | Chlorite Vermiculite | Smectite |
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<td>CD</td>
<td>-</td>
</tr>
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<td>30</td>
<td>M</td>
<td>CD</td>
<td>CD</td>
<td>-</td>
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<td>30</td>
<td>50</td>
<td>M</td>
<td>CD</td>
<td>CD</td>
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Well drained yellow soils (Typic Haplohumults)

**Typical pedon number:** 25 0009  
**Agricultural Development Area:** Labu Estate  
**Physiography**  
Slope: 30 degrees  
Slope position: back slope of hill

**Location:** UTM grid reference 298584 mE 526428 mN Zone 50  
**District:** Temburong  
**Water table depth:** not reached  
**Drainage class:** well

**Morphological Description:**

<table>
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<tr>
<th>Horizon designation</th>
<th>Horizon depth, cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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<tr>
<td>Bw</td>
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<td>contains 15% weathered shale fragments contains 40% weathered shale fragments contains 40% weathered shale fragments</td>
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### Site no: 25 0009
ADA: Labu Estate
District: Temburong

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<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH (H₂O)</th>
<th>pH (KCl)</th>
<th>Organic C %</th>
<th>N %</th>
<th>Bray-2 mg/kg</th>
<th>HCO₃⁻ mg/kg</th>
<th>PBI mg/kg</th>
<th>HCO₃⁻ (mg/kg)</th>
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### Soluble salts in saturation extract

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<th>Coarse sand %</th>
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### Soluble salts from saturation extract

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<td>K</td>
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<tr>
<td>mgL</td>
<td>mgL</td>
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### Mineralogy of bulk sample

| D: dominant (>60%)
CD: co-dominant (sum of phases >60%)
SD: sub-dominant (20-60%)
M: minor (5-20%)
T: trace (<5%)
?: possible

### Mineralogy of <2µm fraction

<table>
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<th>Mineralogy of bulk sample</th>
<th>Mineralogy of &lt;2µm fraction</th>
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4.7 Brown over Grey soils (Aqualfs)

The Brown over Grey soils consist of a deep or very deep soil, with a yellowish brown clay or loamy layer overlying a grey clay layer. It is poorly drained and the water table occurs near the soil surface. These soils occur on flats of the alluvial valleys. They are formed in alluvial clay sediments.

Geographically associated soils include the Organic soils, Cracking Clay soils, Sulfuric soils, and Sulfidic soils.

Diagnostic horizons and characteristic features recognized are:

- Yellowish brown coloured layer with red/orange mottles overlying a grey clay layer whose upper boundary is within 50 cm of the surface
- Deep (between 100 and 150 cm) or very deep (greater than 150 cm)
- Clayey subsoil texture (argillic horizon)
- Poorly drained (aquic conditions within 50 cm of the soil surface)

Brown Over Grey soils have two subtypes depending on the water table depth.

<table>
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<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
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<tbody>
<tr>
<td>Somewhat poorly drained brown over grey soils</td>
<td>Aeric Epiaqualfs</td>
<td>• Somewhat poorly drained (subsoil has &gt;50% brown colours between 50 and 75 cm depth)</td>
</tr>
<tr>
<td>Poorly drained brown over grey soils</td>
<td>Typic Epiaqualfs</td>
<td>• Poorly drained (subsoil has &lt;50% brown colours between 50 and 75 cm depth)</td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
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</thead>
<tbody>
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<td>Aeric Epiaqualfs</td>
<td>040004</td>
<td>Si Bongkok Parit</td>
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<td>150001</td>
<td>Batang Mitus (Halaman)</td>
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<td></td>
<td>160005</td>
<td>Birau (P.P. Muda)</td>
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<td>Poorly drained brown over grey soils</td>
<td>Typic Epiaqualfs</td>
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<td>Sg Tajau</td>
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<td>Merangking, Bukit Sawat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>260001</td>
<td>Selangan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280008</td>
<td>Selapon</td>
</tr>
</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Brown over grey soils are clayey topsoil and subsoil, flat slope, and low K reserves (Table 28).

The main soil attribute difference between the Soil Subtypes is the degree of waterlogging with prolonged waterlogging for the Poorly drained Subtype (Typic); degree of aluminium toxicity with the greater toxicity in the Somewhat poorly drained Subtype (Aeric); and high P fixation in the Poorly drained Subtype.
Table 28: Land suitability assessment for Brown over grey soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Somewhat poorly drained brown over grey soils</th>
<th>Poorly drained brown over grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Aeric Epiaqualfs</td>
<td>Typic Epiaqualfs</td>
</tr>
<tr>
<td>Soil Attribute Ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>CCG2%ak</td>
<td>CCG+2%ak</td>
</tr>
</tbody>
</table>

| Land Suitability Subclasses         |                                             |                                     |
|-------------------------------------|                                             |                                     |
| Rice                                | 2 ak                                        | 2 g+ki+                             |
| Leafy and fruit vegetables          | 3 a                                         | 3 g+                                |
| Root vegetables                     | 3 a                                         | 3 g+                                |
| Groundnuts                          | 3 ga                                        | 4 g+                                |
| Soya and mung beans                 | 3 ga                                        | 5 g+                                |
| Maize                               | 3 ga                                        | 4 g+                                |
| Ginger and turmeric                 | 3 a                                         | 3 g+                                |
| Cassava and sweet potato            | 3 g                                         | 4 g+                                |
| Durian                              | 4 g                                         | 5 g+                                |
| Rambutan                           | 3 ga                                        | 5 g+                                |
| Langsat-duku                        | 4 g                                         | 5 g+                                |
| Citrus                              | 4 C                                         | 4 Cg+                               |
| Banana                              | 3 gak                                       | 4 g+                                |
| Coconut                             | 3 gak                                       | 5 g+                                |
| Papaya                              | 4 g                                         | 5 g+                                |
| Pineapple                           | 3 ga                                        | 4 g+                                |
| Mango and cashew nut                | 3 ga                                        | 5 g+                                |
| Artocarpus                          | 3 ga                                        | 4 g+                                |
| Mangosteen                          | 3 a                                         | 4 g+                                |
| Dragon fruit                        | 3 ga                                        | 5 g+                                |
| Guava                               | 3 ga                                        | 5 g+                                |
| Star fruit                          | 3 ga                                        | 5 g+                                |
| Longan                              | 3 ga                                        | 5 g+                                |
| Grasses for -wet areas              | 1                                           | 2 i+                                |
| -well drained areas                 | 2 Cgk                                       | 3 g+                                |
| Fodder legumes for -wet areas       | 2 Cak                                       | 2 Cg+ki+                            |
| -well drained areas                 | 3 Cga                                       | 4 g+                                |

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

Land suitability

The Brown over grey soils are suitable for rice. The Somewhat poorly drained Subtype is moderately suitable for other short duration crops, with limitations due to soil acidity/ aluminium toxicity and/or waterlogging. Cropping options on the Poorly drained subtype are more limited because of its prolonged waterlogging. Mung and soya beans, which are sensitive to waterlogging, are unsuitable and groundnuts, maize, cassava and sweet potato are only marginally suitable. Vegetables can be grown using raised beds.
The Somewhat poorly drained Subtype is moderately suitable for most fruit crops, with limitations due to soil acidity/aluminium toxicity and/or waterlogging. Species sensitive to waterlogging – durian, langsat-duku and payaya – are marginally suitable, as is citrus because of the clay topsoil. The Poorly drained Subtype is unsuitable or only marginally suitable for all fruit crops assessed.

The Brown over grey soils are suitable for grass and fodder legume species suited to wetter situations. Legume species more suited to well drained situations are moderately to marginally suitable depending on the severity of waterlogging.

**Occurrence**

Somewhat poorly drained brown over grey soils occur in the valley bottoms of surveyed ADAs in Tutong, as well as in Sg Tajau which has a similar landscape (Table 29). The Poorly drained Subtype is widespread in the Temburong ADAs where it occurs on alluvial flats. In Brunei Muara and Belait ADAs, Poorly drained brown over grey soils are found only in Luahan and Merangking, Bukit Sawat.

**Table 29: Approximate proportions of ADA areas occupied by Brown over grey soils.**

<table>
<thead>
<tr>
<th>Soil Subtype:</th>
<th>Somewhat poorly drained brown over grey soils</th>
<th>Poorly drained brown over grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADA</td>
<td>ADA area (ha)</td>
<td>Aeric Epiaquifs</td>
</tr>
<tr>
<td>Brunei-Muara</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Sg Tajau</td>
<td>117</td>
<td>19%</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Lumapans</td>
<td>38</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Limpakis</td>
<td>92</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Luahan</td>
<td>73</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Wasan</td>
<td>373</td>
<td></td>
</tr>
<tr>
<td>Tungku</td>
<td>262</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Tutong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kupang</td>
<td>60</td>
<td>19%</td>
</tr>
<tr>
<td>Maraburong, Kupang</td>
<td>58</td>
<td>36%</td>
</tr>
<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
<td>25%</td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>517</td>
<td>4%</td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>585</td>
<td>13%</td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>80</td>
<td>30%</td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
<td>12%</td>
</tr>
<tr>
<td>Belait</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>Tungulian</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
<td>30%</td>
</tr>
<tr>
<td>Melayan A</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Labi Lama</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Temburong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labu Estate</td>
<td>97</td>
<td>15%</td>
</tr>
<tr>
<td>Selangan</td>
<td>56</td>
<td>34%</td>
</tr>
<tr>
<td>Bakarut</td>
<td>38</td>
<td>7%</td>
</tr>
<tr>
<td>Selapon</td>
<td>80</td>
<td>23%</td>
</tr>
<tr>
<td>Overall</td>
<td>4423</td>
<td>5%</td>
</tr>
</tbody>
</table>
**Somewhat poorly drained brown over grey soils (Aeric Epiaqualfs)**

**Typical pedon number:** 15 0001  
**Agricultural Development Area:** Batang Mitus (Halaman)  
**Physiography**  
**Slope:** 1 degree  
**Slope position:** toe slope of valley side  
**Location:** UTM grid reference 251902 mE 527845 mN Zone 50  
**District:** Tutong  
**Physiography Slope:** 1 degree  
**Slope position:** toe slope of valley side  
**Water table depth:** 30 cm  
**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 3</td>
<td>10YR 4/4</td>
<td>sandy clay loam</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
<td>friable</td>
<td></td>
<td>iron layer</td>
</tr>
<tr>
<td>AB</td>
<td>3 20</td>
<td>10YR 5/2</td>
<td>clay</td>
<td>40% iron concentrations 5YR 5/8</td>
<td>massive</td>
<td>firm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bgt1</td>
<td>20 35</td>
<td>10YR 5/2</td>
<td>clay</td>
<td>50% iron concentrations 10YR 5/6</td>
<td>massive</td>
<td>firm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bgt2</td>
<td>35 90</td>
<td>10YR 7/1</td>
<td>clay</td>
<td>30% iron concentrations 10YR 5/8</td>
<td>massive</td>
<td>extremely firm</td>
<td>mottled</td>
<td></td>
</tr>
<tr>
<td>Bg</td>
<td>90 100</td>
<td>10YR 7/1</td>
<td>clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>extremely firm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Depth, cm  
0 - 3  
3 - 20  
20 - 35  
35 - 90
### Site Information

**Site no:** 15 0001  
**ADA:** Batang Mitus (Halaman)  
**District:** Tutong

### Soil Properties

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC dS/m</th>
<th>pH</th>
<th>pH&lt;sub&gt;2&lt;/sub&gt;</th>
<th>pH&lt;sub&gt;KCl&lt;/sub&gt;</th>
<th>Total N %</th>
<th>ext.P mg/kg</th>
<th>ext.P mg/kg</th>
<th>K mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
<th>Total mg/kg</th>
<th>ECEC cmol(+)/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0.15</td>
<td>4.7</td>
<td>3.9</td>
<td>0.8</td>
<td>6.0</td>
<td>0.56</td>
<td>18</td>
<td>17</td>
<td>213</td>
<td>221</td>
<td>2.4</td>
<td>1.9</td>
<td>0.07</td>
<td>0.28</td>
<td>6.6</td>
<td>1.74</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>20</td>
<td>0.06</td>
<td>4.6</td>
<td>3.7</td>
<td>0.9</td>
<td>0.8</td>
<td>0.09</td>
<td>2</td>
<td>2</td>
<td>217</td>
<td>73</td>
<td>0.7</td>
<td>1.0</td>
<td>0.08</td>
<td>0.14</td>
<td>1.9</td>
<td>6.0</td>
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<tr>
<td>3</td>
<td>20</td>
<td>35</td>
<td>0.07</td>
<td>4.7</td>
<td>3.8</td>
<td>0.9</td>
<td>0.7</td>
<td>0.10</td>
<td>2</td>
<td>4</td>
<td>254</td>
<td>68</td>
<td>0.6</td>
<td>2.2</td>
<td>0.08</td>
<td>0.16</td>
<td>3.0</td>
<td>6.5</td>
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<tr>
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<td>35</td>
<td>90</td>
<td>0.06</td>
<td>4.9</td>
<td>3.8</td>
<td>1.1</td>
<td>0.4</td>
<td>0.06</td>
<td>3</td>
<td>7</td>
<td>148</td>
<td>52</td>
<td>0.5</td>
<td>1.9</td>
<td>0.09</td>
<td>0.13</td>
<td>2.6</td>
<td>4.8</td>
</tr>
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</table>

### Soluble Salts

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn depth percent</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Ca mg/kg</th>
<th>K mg/kg</th>
<th>Na mg/kg</th>
<th>Mg mg/kg</th>
<th>S mg/kg</th>
<th>Cl mg/kg</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>4.7</td>
<td>3.9</td>
<td>0.8</td>
<td>6.0</td>
<td>0.56</td>
<td>18</td>
<td>17</td>
<td>213</td>
<td>221</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>20</td>
<td>20</td>
<td>4.6</td>
<td>3.7</td>
<td>0.9</td>
<td>0.8</td>
<td>0.09</td>
<td>2</td>
<td>2</td>
<td>217</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>35</td>
<td>35</td>
<td>4.7</td>
<td>3.8</td>
<td>0.9</td>
<td>0.7</td>
<td>0.10</td>
<td>2</td>
<td>4</td>
<td>254</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>90</td>
<td>90</td>
<td>4.9</td>
<td>3.8</td>
<td>1.1</td>
<td>0.4</td>
<td>0.06</td>
<td>3</td>
<td>7</td>
<td>148</td>
<td>52</td>
</tr>
</tbody>
</table>

### Mineralogy of Bulk Sample

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz %</th>
<th>Albite %</th>
<th>Orthoclase %</th>
<th>Pyrite %</th>
<th>Anatase %</th>
<th>Kaolin %</th>
<th>Mica/filit %</th>
<th>Chlorite/Vermiculite %</th>
<th>Goethite %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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</tr>
<tr>
<td>2</td>
<td>3</td>
<td>20</td>
<td>3</td>
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<tr>
<td>3</td>
<td>20</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>90</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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</tr>
</tbody>
</table>

### Mineralogy of <2µm Fraction

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Kaolin</th>
<th>Mica/filit</th>
<th>Chlorite/Vermiculite</th>
<th>Smectite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Soil Fertility Evaluation

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam  
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
Poorly drained brown over grey soils (Typic Epiaqualfs)

Typical pedon number: 08 0002
Agricultural Development Area: Wasan
Physiography Slope: <1 degree Slope position: flat of alluvial valley
Location: UTM grid reference 256340 mE 528772 mN Zone 50
District: Brunei Muara
Water table depth: 20 cm Drainage class: very poorly

Physiography Slope: <1 degree Slope position: flat of alluvial valley

Morphological Description:

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth, cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>Upper 0, Lower 5</td>
<td>10YR 5/4 clay loam</td>
<td>0% concentrations</td>
<td>0% concentrations</td>
<td>cloddy firm</td>
<td>4.7</td>
<td>clay coatings</td>
<td></td>
</tr>
<tr>
<td>ABt</td>
<td>5, 10</td>
<td>10YR 3/2 clay</td>
<td>0% concentrations</td>
<td>10% iron concentrations</td>
<td>cloddy firm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABgt</td>
<td>10, 20</td>
<td>10YR 6/2 clay</td>
<td>10% iron concentrations</td>
<td>10YR 5/8</td>
<td>cloddy firm</td>
<td>4.7</td>
<td>clay coatings, cracks</td>
<td></td>
</tr>
<tr>
<td>Bgt1</td>
<td>20, 35</td>
<td>10YR 6/2 clay</td>
<td>10% iron concentrations</td>
<td>10YR 5/8</td>
<td>massive firm</td>
<td></td>
<td>clay coatings</td>
<td></td>
</tr>
<tr>
<td>Bgt2</td>
<td>35, 60</td>
<td>10YR 6/1 clay</td>
<td>20% iron concentrations</td>
<td>10YR 5/8</td>
<td>massive very firm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCgt</td>
<td>60, 100</td>
<td>10YR 6/1 clay</td>
<td>20% iron concentrations</td>
<td>10YR 5/8</td>
<td>massive very firm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer no.</td>
<td>Upper depth cm</td>
<td>Lower depth cm</td>
<td>EC dS/m</td>
<td>pH</td>
<td>ORG.C %</td>
<td>N mg/kg</td>
<td>Bray-2 ext.P mg/kg</td>
<td>HCO₃⁻ ext.P mg/kg</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>----</td>
<td>---------</td>
<td>---------</td>
<td>-------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0.20</td>
<td>5.6</td>
<td>4.7</td>
<td>1.0</td>
<td>3.3</td>
<td>0.32</td>
</tr>
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<td>2</td>
<td>5</td>
<td>10</td>
<td>0.17</td>
<td>5.2</td>
<td>4.2</td>
<td>1.0</td>
<td>3.1</td>
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<td>100</td>
<td>0.10</td>
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<td>3.8</td>
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<td>0.5</td>
<td>0.09</td>
</tr>
<tr>
<td>Layer no.</td>
<td>Upper depth cm</td>
<td>Lower depth cm</td>
<td>Satn percent</td>
<td>pH</td>
<td>EC dS/m</td>
<td>Soluble salts in saturation extract</td>
<td>Ca mg/kg</td>
<td>K mg/kg</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------------</td>
<td>----</td>
<td>--------</td>
<td>-----------------------------</td>
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<td>----------</td>
</tr>
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<td>1</td>
<td>0</td>
<td>5</td>
<td>70</td>
<td>5.2</td>
<td>0.46</td>
<td>43</td>
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<td>5</td>
<td>10</td>
<td>70</td>
<td>5.2</td>
<td>0.46</td>
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<td>0.19</td>
<td>3</td>
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<td>7</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>100</td>
<td>91</td>
<td>5.0</td>
<td>0.22</td>
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<td></td>
</tr>
<tr>
<td>Layer no.</td>
<td>Upper depth cm</td>
<td>Lower depth cm</td>
<td>DTPA ext Cu mg/kg</td>
<td>Fe mg/kg</td>
<td>Mn mg/kg</td>
<td>Zn mg/kg</td>
<td>CaCl₂ ext.B As mg/kg</td>
<td>Cd mg/kg</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>----------------</td>
<td>------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>---------------------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>1.6</td>
<td>359</td>
<td>60.4</td>
<td>3.8</td>
<td>43.2</td>
<td>30.4</td>
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<td>5</td>
<td>10</td>
<td>1.7</td>
<td>481</td>
<td>38.1</td>
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</tr>
<tr>
<td>5</td>
<td>35</td>
<td>60</td>
<td>1.7</td>
<td>95</td>
<td>15.5</td>
<td>0.8</td>
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<td>6</td>
<td>60</td>
<td>100</td>
<td>1.6</td>
<td>67</td>
<td>23.3</td>
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</table>

**Mineralogy of bulk sample**

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolin</th>
<th>Mica/illite</th>
<th>Chlorite/Vermiculite</th>
<th>Goethite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>60</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>100</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mineralogy of <2µm fraction**

- D: dominant (>60%)
- CD: co-dominant (sum of phases >60%)
- SD: sub-dominant (20-60%)
- M: minor (5-20%)
- T: trace (<5%)
- ?: possible
4.8 Sulfuric soils (Aquepts)

The Sulfuric soils consist of very deep, grey, clay or loamy soil, with a sulfuric layer occurring within 150 cm of the soil surface. They are poorly drained and the water table occurs near the soil surface. These soils occur on flats of the alluvial valleys. They are formed in alluvial clay sediments.

Geographically associated soils include the Sulfidic soils and Organic soils.

- Sulfuric layer (field pH <3.5) within 150 cm of the soil surface
- Grey colour
- Very deep (greater than 150 cm)
- Clayey or loamy subsoil texture
- Poorly drained (aquic conditions within 50 cm of the soil surface)

Sulfuric soils have two subtypes depending on the depth to the sulfuric layer and the presence of a soft mineral layer.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
</table>
| Soft poorly drained sulfuric soils | Hydraquentic Sulfaquepts | • Sulfuric layer within 50 cm of the soil surface  
|                                  |                       | • Soft layer within 100 cm of the soil surface  
| Poorly drained sulfuric soils    | Typic Sulfaquepts     | • Sulfuric layer within 50 cm of the soil surface  
|                                  |                       | • No soft layer within 100 cm of the soil surface  

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft poorly drained sulfuric soils</td>
<td>Hydraquentic Sulfaquepts</td>
<td>090015</td>
<td>Tungku</td>
</tr>
</tbody>
</table>
| Poorly drained sulfuric soils    | Typic Sulfaquepts     | 010011  
|                                  |                       | 010012  
|                                  |                       | 060002                  | Betumpu  
|                                  |                       |                         | Limpaki |

Soil attributes

The Fertility Capability Classification attributes that influence land use for Sulfuric soils are waterlogging, flat slope, the presence of sulfidic/sulfuric material and soil acidity/aluminium toxicity (Table 30).

The main soil attribute difference between the Soil Subtypes is the topsoil and subsoil textures, depth to sulfuric horizon, low K reserves, high P fixation and potential for leaching. The Soft poorly drained Subtype is sandy throughout, has a sulfuric horizon near the surface, low K reserves and a high leaching potential.

Land suitability

These soils pose many challenges for cropping. The Poorly drained Subtype is moderately suitable for short duration crops, including rice, but with limitations due to shallow sulfidic/sulfuric material. Waterlogging is a limitation for sensitive species such as groundnuts, soya beans, mung beans, maize, cassava and sweet potato. Soil acidity/aluminium toxicity is a limitation for all crops except tolerant ones – rice, cassava and sweet potato. The Sandy topsoil of the Soft poorly drained Subtypes makes it unsuitable for rice, and the shallowness of its sulfuric/sulfidic material makes it only marginally suitable for other short duration crops.
Table 30: Land suitability assessment for Sulfuric soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Soft poorly drained sulfuric soils</th>
<th>Poorly drained sulfuric soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Hydroaeric Sulfaquepts</td>
<td>Typic Sulfaquepts</td>
</tr>
<tr>
<td>Soil Attribute Ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>S</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>g</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(0)</td>
<td>c(30)</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>k</td>
<td>-</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
<td>-</td>
</tr>
<tr>
<td>Fertility Capability Classification</td>
<td>SSSg3%c(0)ake</td>
<td>LCg0%c(30)ai</td>
</tr>
<tr>
<td><strong>Land Suitability Subclasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>5 S</td>
<td>3 c(≤35)</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>4 c(≤20)</td>
<td>3 c(≤40)a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>4 c(≤20)</td>
<td>3 c(≤40)a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 c(≤20)</td>
<td>3 gc(≤40)a</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>4 c(≤20)</td>
<td>3 gc(≤40)a</td>
</tr>
<tr>
<td>Maize</td>
<td>4 c(≤20)</td>
<td>3 gc(≤40)a</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 c(≤20)</td>
<td>3 c(≤40)a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 c(≤20)</td>
<td>3 gc(≤40)</td>
</tr>
<tr>
<td>Durian</td>
<td>5 Sc(≤50)</td>
<td>5 c(≤50)</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 Sc(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Citrus</td>
<td>5 c(≤20)</td>
<td>4 c(≤30)</td>
</tr>
<tr>
<td>Banana</td>
<td>5 c(≤20)</td>
<td>4 c(≤30)</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 c(≤20)</td>
<td>4 gc(≤30)</td>
</tr>
<tr>
<td>Pineapple</td>
<td>5 c(≤20)</td>
<td>4 c(≤30)</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 c(≤50)</td>
<td>5 c(≤50)</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Guava</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
</tr>
<tr>
<td>Longan</td>
<td>5 c(≤50)</td>
<td>5 c(≤50)</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 Sc(≤20)e</td>
<td>2 i</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 gc(≤20)ke</td>
<td>2 gi</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 c(≤20)ake</td>
<td>2 ai</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 gc(≤20)ja</td>
<td>3 ga</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

The deeper rooting requirement of most fruit crops makes both Subtypes unsuitable for fruit crops. Shallower rooted species – citrus, banana, papaya and pineapple – are marginally suitable on the Poorly drained Subtype.

These soils are suitable for grasses, and for fodder legumes suited to wetter areas. Fodder legumes suited to well drained areas are moderately suited.
Occurrence

The Sulfuric soils occur commonly in the alluvial plains of Brunei Muara (Table 31). The Soft poorly drained Subtype is mainly found in the Tungku ADA.

Table 31: Approximate proportions of ADA areas occupied by Sulfuric soils.

<table>
<thead>
<tr>
<th>Soil Subtype: Soft poorly drained sulfuric soils</th>
<th>Poorly drained sulfuric soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup: Hydraquentic Sulfaquepts</td>
<td>Typic Sulfaquepts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADA</th>
<th>ADA area (ha)</th>
<th>Soft poorly drained sulfuric soils</th>
<th>Poorly drained sulfuric soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei-Muara</td>
<td></td>
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</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
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<tr>
<td>Sg Tajau</td>
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<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
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<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
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<td></td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127</td>
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<tr>
<td>Lumapas</td>
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<tr>
<td>Limpaki</td>
<td>92</td>
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<td></td>
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<tr>
<td>Luahan</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wasan</td>
<td>373</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tungku</td>
<td>262</td>
<td>30%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Tutong</td>
<td></td>
<td></td>
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<tr>
<td>Kupang</td>
<td>60</td>
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<td>Maraburong, Kupang</td>
<td>58</td>
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<td></td>
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<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>517</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>585</td>
<td>&lt;1%</td>
<td></td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
<td>&lt;1%</td>
<td></td>
</tr>
<tr>
<td>Belait</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
<td>104</td>
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<td>Tungulian</td>
<td>92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
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<td></td>
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<td>Melayan A</td>
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</tr>
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<td>KM 26, Jalan Bukit Puan Labi</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Temburong</td>
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</tr>
<tr>
<td>Labu Estate</td>
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<tr>
<td>Selangan</td>
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<tr>
<td>Bakarut</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Selapon</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>4423</td>
<td>2%</td>
<td>7%</td>
</tr>
</tbody>
</table>
Soft poorly drained sulfuric soils (Hydraeutic Sulfaquepts)

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0-10</td>
<td>10YR 5/3</td>
<td>sand</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td>2.6</td>
<td>sulfuric layer</td>
</tr>
<tr>
<td>C2</td>
<td>10-30</td>
<td>10YR 5/2</td>
<td>loamy sand</td>
<td>0% concentrations</td>
<td>massive</td>
<td>firm</td>
<td>3.2</td>
<td>sulfuric layer</td>
</tr>
<tr>
<td>C3</td>
<td>30-50</td>
<td>7.5YR 5/4</td>
<td>loamy sand</td>
<td>0% concentrations</td>
<td>massive</td>
<td>soft</td>
<td>3.3</td>
<td>sulfuric layer</td>
</tr>
<tr>
<td>2Bj</td>
<td>50-60</td>
<td>10YR 4/1</td>
<td>sandy loam</td>
<td>30% iron concentrations</td>
<td>massive</td>
<td>extremely firm</td>
<td>3.3</td>
<td>jarosite?</td>
</tr>
<tr>
<td>3BC</td>
<td>60-100</td>
<td>2.5YR 4/8</td>
<td>sandy clay</td>
<td>0% concentrations</td>
<td>massive</td>
<td>slightly rigid</td>
<td>3.6</td>
<td></td>
</tr>
</tbody>
</table>
### Table: Soil Properties

<table>
<thead>
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<th>Lower depth cm</th>
<th>EC cmol(+)/kg</th>
<th>pH</th>
<th>pH\textsubscript{KCl}</th>
<th>Total Org.C mg/kg</th>
<th>Total N mg/kg</th>
<th>Bray-2 HCO\textsubscript{3} mg/kg</th>
<th>HCO\textsubscript{3} ext.P mg/kg</th>
<th>PBI</th>
<th>HCO\textsubscript{3} ext.K mg/kg</th>
<th>K mg/kg</th>
<th>Na mg/kg</th>
<th>Mg mg/kg</th>
<th>Ca mg/kg</th>
<th>ECEC 1M KCl ext mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
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### Table: Soluble Salts

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<th>Satn %</th>
<th>Satn extract pH</th>
<th>Ca mg/kg</th>
<th>K mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>S mg/kg</th>
<th>Cl mg/kg</th>
<th>SAR</th>
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### Table: Soluble Salts in Saturation Extract

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<th>Coarse silt</th>
<th>Total silt</th>
<th>Fine sand</th>
<th>Coarse sand</th>
<th>Total sand</th>
<th>Plastic limit</th>
<th>Liquid limit</th>
<th>Linear shrink</th>
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<td>200-2000</td>
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### Table: Mineralogy of Bulk Sample

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<th>Quartz %</th>
<th>Albit %</th>
<th>Orthoclase %</th>
<th>Albite %</th>
<th>Pyrite %</th>
<th>Anatas %</th>
<th>Kainite %</th>
<th>Mica/Illite %</th>
<th>Chlorite/Vermiculite %</th>
<th>Goethite %</th>
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<tbody>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>-</td>
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<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
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### Table: Mineralogy of <2µm Fraction

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<th>Lower depth cm</th>
<th>Kainite %</th>
<th>Mica/Illite %</th>
<th>Chlorite/Vermiculite %</th>
<th>Smectite %</th>
<th>D</th>
<th>CD</th>
<th>CD</th>
<th>CD</th>
</tr>
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</table>

D: dominant (>60%)
CD: co-dominant (sum of phases >60%)
SD: sub-dominant (20-60%)
M: minor (5-20%)
T: trace (<5%)
?: possible
Poorly drained sulfuric soils (Typic Sulfaquepts)

Typical pedon number: 01 0011
Agricultural Development Area: Betumpu
Physiography: Slope: <1 degree
Slope position: flat of alluvial plain
Location: UTM grid reference 262695 mE 536079 mN Zone 50
District: Brunei Muara Selapon Selapon
Water table depth: 80 cm
Drainage class: poorly

Morphological Description:

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Ap1</td>
<td>0 - 5</td>
<td>10YR 5/2</td>
<td>clay loam</td>
<td>0% concentrations</td>
<td>subangular blocky</td>
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<tr>
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<td>5 - 20</td>
<td>10YR 5/2</td>
<td>clay loam</td>
<td>5% iron concentrations</td>
<td>subangular blocky</td>
<td>firm</td>
<td></td>
<td></td>
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<tr>
<td>B</td>
<td>20 - 30</td>
<td>10YR 5/2</td>
<td>clay loam</td>
<td>7.5YR 5/8</td>
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<td>10YR 2/2</td>
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<td>5% iron concentrations</td>
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<td>very friable</td>
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<td>10YR 3/1</td>
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<td>0% concentrations</td>
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</tbody>
</table>

Depth, cm

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<th>Depth, cm</th>
<th>Depth, cm</th>
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<td>20 - 30</td>
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### Site no: 01 0011  
**ADA:** Betumpu  
**District:** Brunei Muara

<table>
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<th>1.25 soil-water EC</th>
<th>1M KCl EC</th>
<th>Δ pH</th>
<th>Total Bray-2 pH</th>
<th>HCO3- mg/kg</th>
<th>PBI</th>
<th>HCO3- ext.K mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
<th>Total cmol(+)/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
<th>Al cmol(+)/kg</th>
<th>Mn cmol(+)/kg</th>
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### Soil mineralogy

#### Layer no.

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<th>Upper depth cm</th>
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<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolinite</th>
<th>Mica-line</th>
<th>Chlorite/</th>
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### Site no: 01 0011  
**ADA:** Betumpu  
**District:** Brunei Muara

<table>
<thead>
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<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn percent</th>
<th>Satn extract pH</th>
<th>EC</th>
<th>Soluble salts in saturation extract Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>S mg/kg</th>
<th>Cl mg/kg</th>
<th>SAR</th>
<th>Soluble salts from saturation extract Ca mg/kg</th>
<th>K mg/kg</th>
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### Layer no.

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### Soil mineralogy

#### Layer no.

<table>
<thead>
<tr>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolinite</th>
<th>Mica-line</th>
<th>Chlorite/</th>
<th>Vermiculite</th>
<th>Goethite</th>
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### Site no: 01 0011  
**ADA:** Betumpu  
**District:** Brunei Muara

<table>
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<th>Lower depth cm</th>
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<th>1M KCl EC</th>
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<th>PBI</th>
<th>HCO3- ext.K mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
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<th>Mn cmol(+)/kg</th>
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4.9 Sulfidic soils (Aquents)

The Sulfidic soils consist of very deep, grey, clay or loamy soil, with sulfidic material occurring within 100 cm of the soil surface. They are poorly drained and the water table occurs near the soil surface. These soils occur on flats of the alluvial valleys. They are formed in alluvial clay sediments.

Geographically associated soils include the Sulfuric soils and Organic soils.

Diagnostic horizons and characteristic features recognized are:

- Sulfidic material (pH >3.5, but decreases to <3.5 on ageing) within 100 cm of the soil surface
- Grey colour
- Very deep (greater than 150 cm)
- Clayey or loamy subsoil texture
- Poorly drained (aquic conditions within 50 cm of the soil surface).

Sulfidic soils are divided into three subtypes depending on the depth to the sulfidic layer, and the presence of a soft mineral layer or a buried organic layer.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
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<td>Soft poorly drained sulfidic soils</td>
<td>Haplic Sulfaquents</td>
<td>Sulfidic material within 50 cm of the soil surface</td>
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<td>Soft layer between 20 and 50 cm of the soil surface</td>
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<tr>
<td>Organic poorly drained sulfidic soils</td>
<td>Thapto-Histic Sulfaquents</td>
<td>Sulfidic material within 50 cm of the soil surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buried organic layer within 100 cm of the soil surface</td>
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<tr>
<td>Organic poorly drained moderately deep sulfidic soils</td>
<td>Sulfic Fluvaquents</td>
<td>Sulfidic material deeper than 50 cm</td>
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<td></td>
<td>Buried organic layer within 125 cm of the soil surface</td>
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</table>

Representative profiles are:

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<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
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<td>Pengkalan Batu</td>
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<tr>
<td>Organic poorly drained sulfidic soils</td>
<td>Thapto-Histic Sulfaquents</td>
<td>050005</td>
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<td>Organic poorly drained moderately deep sulfidic soils</td>
<td>Sulfic Fluvaquents</td>
<td>220002</td>
<td>Melayan A</td>
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</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Sulfidic soils are flat slope, waterlogging, the presence of sulfidic material and soil acidity/aluminium toxicity (Table 32).

The main soil attribute difference between the Soil Subtypes is the topsoil and subsoil textures, severity of waterlogging, depth to sulfidic material, degree of aluminium toxicity, low K reserves, high P fixation and potential for leaching. Each of the 3 Soil Subtypes has different combinations of these properties.
Table 32: Land suitability assessment for Sulfidic soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Soft poorly drained sulfidic soils</th>
<th>Organic poorly drained sulfidic soils</th>
<th>Organic poorly drained moderately deep sulfidic soils</th>
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<tr>
<td>Subsoil type</td>
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<td>Sulfidic horizon (cm) &amp; depth</td>
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<td>c(70)</td>
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<td>Aluminium (a, a-)</td>
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<td>High P fixation (i, i-, i+)</td>
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<td>Cracking clays (v)</td>
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<td>High leaching (e)</td>
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<td>CCg+0%c(30) jaki+</td>
<td>OCg2%c(30) a-i</td>
<td>SSg3%c(70) ake</td>
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</table>

<table>
<thead>
<tr>
<th>Land Suitability Subclasses</th>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
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<td>Grasses for -well areas</td>
<td>2 i+</td>
<td>2 i</td>
<td>2 Se</td>
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<td>3 g+</td>
<td>3 O</td>
<td>2 gke</td>
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<td>2 Ol</td>
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1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.

Land suitability

Suitability for rice depends on Soil Subtype. The Soft poorly drained Subtype is moderately suitable with limitations due to shallow sulfidic material. The Organic poorly drained Subtype is marginally suitable because of its peaty topsoil which can cause panicle sterility. The Organic poorly drained moderately deep Subtype is unsuitable because of the sandy texture, making it difficult to keep water ponded.
Sulfidic soils are mostly moderately suitable for other short duration crops, with limitations depending on Subtype. For the Organic poorly drained moderately deep Subtype, the limitations are waterlogging and/or aluminium toxicity, depending on the sensitivity of the crop to these factors. For the Organic poorly drained Subtype the limitations are the shallow depth of sulfidic material, and the peaty topsoil. In the case of ginger and turmeric, the peaty topsoil makes this Subtype unsuitable. Waterlogging is also an issue for more sensitive species such as groundnuts, soya beans, mung beans, maize, cassava and sweet potato.

Two subtypes – Soft poorly drained and Organic poorly drained – are generally unsuitable for fruit crops due to the shallowness of the sulfidic material relative to the rooting depth of fruit trees. Shallower rooted species – citrus, banana and pineapple – are marginally suited. Other limitations that preclude fruit crops are prolonged waterlogging for the Soft poorly drained Subtype and the peaty topsoil for the Organic poorly drained Subtype.

The Organic poorly drained moderately deep Subtype is moderately suitable for many fruit crops because its sulfidic material is at greater depth. Other limitations are soil acidity/aluminium toxicity, waterlogging and the sandy texture. In the case of durian, langsat-duku and mangosteen the sandy texture makes this Subtype unsuitable or marginally suitable. Waterlogging makes papaya only marginally suitable.

The Sulfidic soils are suitable for grass and fodder legumes adapted to wet conditions. Grasses and fodder legumes adapted to well drained conditions are mostly moderately suitable, limited by either prolonged waterlogging or peaty topsoil or both. Prolonged waterlogging makes fodder legumes for well drained areas only marginally suitable for the Soft poorly drained Subtype.

**Occurrence**

Sulfidic soils, like Sulfuric soils, are widespread in the alluvial flats of ADAs in Brunei Muara (Table 33). The most common Subtype is Soft poorly drained sulfidic soils. The Organic poorly drained Subtype is found as a minor associated soil in the same locations. The Organic poorly drained moderately deep Subtype is confined almost entirely to the KM26, Jalan Bukit Puan Labu ADA.
Table 33: Approximate proportions of ADA areas occupied by Sulfidic soils.

<table>
<thead>
<tr>
<th>Soil Taxonomy subgroup:</th>
<th>Soft poorly drained sulfidic soils</th>
<th>Organic poorly drained sulfidic soils</th>
<th>Organic poorly drained moderately deep sulfidic soils</th>
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</tr>
<tr>
<td>Overall</td>
<td>4423</td>
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<td>&lt;1%</td>
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**Soft poorly drained sulfidic soils (Haplic Sulfaquents)**

*Typical pedon number:* 01 0016  
*Agricultural Development Area:* Betumpu  
*Physiography:* Slope: <1 degree  
*Slope position:* flat of alluvial plain  
*Location:* UTM grid reference 262665 mE 535277 mN Zone 50  
*District:* Brunei Muara  
*Water table depth:* 30 cm  
*Drainage class:* very poorly

**Morphological Description:**

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<th>Horizon designation</th>
<th>Horizon depth, cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
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### Site no.: 01 0016  
**ADA:** Betumpu  
**District:** Brunei Muara

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<th>pH&lt;sub&gt;Cl&lt;/sub&gt;</th>
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<th>N ext.P %</th>
<th>PBI ext.K mg/kg</th>
<th>Ca mg/kg</th>
<th>Mg mg/kg</th>
<th>Na mg/kg</th>
<th>K mg/kg</th>
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<th>Al cmol(+)/kg</th>
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<th>pH</th>
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<th>Mg mg/kg</th>
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### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam  
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas  
Page 131
Organic poorly drained sulfidic soils (Thapto-Histic Sulfaquents)

**Typical pedon number:** 05 0005  
**Agricultural Development Area:** Lumapas  
**Physiography Slope:** 1 degree  
**Physiography Slope position:** flat of valley  
**Location:** UTM grid reference 268610 mE 532792 mN Zone 50  
**District:** Brunei Muara  
**Water table depth:** 50 cm  
**Drainage class:** poorly

**Morphological Description:**

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<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
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Depth, cm  
0 - 10  
10 - 30  
30 - 110  
110 - 180  
Depth, cm  
180 - 200
### Site no: 05 0005
### ADA: Lumapas
### District: Brunei Muara

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<th>Anatase</th>
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<th>Mica/illite</th>
<th>Chlorite/vermiculite</th>
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### Mineralogy of <2µm fraction

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### Soluble salts from saturation extract

- **Ca**: Calcium
- **K**: Potassium
- **Mg**: Magnesium
- **Na**: Sodium
- **S**: Sulfur
- **Cl**: Chloride
- **SAR**: Sodium Adsorption Ratio

### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

Volume 1 – Soils and Land Suitability of the Agricultural Development Areas

Page 133
Organic poorly drained moderately deep sulfidic soils (Sulfic Fluvaquents)

**Typical pedon number:** 22 0002  
**Agricultural Development Area:** Melayan A  
**Physiography**  
Slope: 2 degrees  
Slope position: foot slope of valley side  
**Location:** UTM grid reference 218722 mE 496418 mN Zone 50  
**District:** Belait  
**Water table depth:** 70 cm  
**Physiography Slope:** 2 degrees  
**Slope position:** foot slope of valley side  
**Drainage class:** poorly

**Morphological Description:**

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</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth</th>
<th>Lower depth</th>
<th>Quartz</th>
<th>Albite</th>
<th>Orthoclase</th>
<th>Pyrite</th>
<th>Anatase</th>
<th>Kaolin</th>
<th>Mica/Illite</th>
<th>Chlorite/ Vermiculite</th>
<th>Goethite</th>
<th>Kaolin</th>
<th>Mica/Illite</th>
<th>Chlorite</th>
<th>Vermiculite</th>
<th>Smectite</th>
<th>D: dominant (&gt;60%)</th>
<th>CD: co-dominant (sum of phases &gt;60%)</th>
<th>SD: sub-dominant (20-60%)</th>
<th>M: minor (5-20%)</th>
<th>T: trace (&lt;5%)</th>
<th>?: possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>70</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>130</td>
<td>200</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
4.10 Grey soils (Aquents)

The Grey soils consist of very deep, grey, sandy soil, with no diagnostic horizons or characteristics. They are poorly drained and the water table occurs near the soil surface. These soils occur on flats of the alluvial valleys. They are formed in alluvial sand sediments. Geographically associated soils include the Sulfuric soils, Sulfidic soils and Organic soils.

Diagnostic horizons and characteristic features recognized are:

- Sandy to clayey texture
- Grey colour
- Very deep (greater than 150 cm)
- Poorly drained

Grey soils have only one subtype.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Diagnostic features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly drained grey soils</td>
<td>Humaqueptic Endoaquents</td>
<td></td>
</tr>
</tbody>
</table>

Representative profiles are:

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Representative Profiles</th>
<th>Agricultural Development Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly drained grey soils</td>
<td>Humaqueptic Endoaquents</td>
<td>040005</td>
<td>Si Bongkok Parit Masin</td>
</tr>
</tbody>
</table>

Soil attributes

The Fertility Capability Classification attributes that influence land use for Grey soils are clay topsoil and subsoil texture, waterlogging, flat slope, soil acidity/aluminium toxicity, low K reserves, high P fixation and potential for Fe toxicity (Table 34).

Land suitability

Grey soils are suitable for rice and moderately suitable for other short duration crops. Major limitations depend on crop sensitivity to waterlogging and soil acidity/aluminium toxicity. Waterlogging is the major issue for groundnut, soya bean, mung bean, maize, cassava and sweet potato – and aluminium toxicity is a limitation for all short duration crops except cassava and sweet potato.

Similarly, Grey soils are suitable for most fruit crops with major limitations due to water logging and soil acidity/aluminium toxicity depending on the sensitivity of the species. Waterlogging makes some species – durian, langsat-duku and papaya – only marginally suitable, whilst the clay texture makes citrus marginal.

Grey soils are suitable for grasses, and for fodder legume adapted to wetter conditions. They are moderately suitable for fodder legumes requiring well drained conditions.
Table 34: Land suitability assessment for Grey soils.

<table>
<thead>
<tr>
<th>Soil subtype</th>
<th>Poorly drained grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup</td>
<td>Humaqueptic Endoaquents</td>
</tr>
</tbody>
</table>

**Soil Attribute Ratings**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulphidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Fertility Capability Classification**

CCg0%aki

**Land Suitability Subclasses**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Subclass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 aki</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 ga</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 ga</td>
</tr>
<tr>
<td>Maize</td>
<td>3 ga</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 ga</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gak</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gak</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 ga</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 ga</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 ga</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 ga</td>
</tr>
<tr>
<td>Guava</td>
<td>3 ga</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 ga</td>
</tr>
<tr>
<td>Longan</td>
<td>3 ga</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 l</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 Cgki</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Caki</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 Cga</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.

2 Land suitability classes are defined in Section 3.3.3.
Occurrence

The Grey soils occur only as a minor associated soil on the alluvial flats of surveyed ADAs in Brunei Muara.

Table 35: Approximate proportions of ADA areas occupied by Grey soils.

<table>
<thead>
<tr>
<th>Soil Subtype: Poorly drained grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy subgroup: Humaqueptic Endoaquents</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADA</th>
<th>ADA area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei-Muara</td>
<td></td>
</tr>
<tr>
<td>Betumpu</td>
<td>474</td>
</tr>
<tr>
<td>Sg Tajau</td>
<td>117</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A</td>
<td>82</td>
</tr>
<tr>
<td>Si Tukak, Limau Manis B</td>
<td>46</td>
</tr>
<tr>
<td>Si Bongkok Parti Masin</td>
<td>127</td>
</tr>
<tr>
<td>Lumapas</td>
<td>38</td>
</tr>
<tr>
<td>Limpaksi</td>
<td>92</td>
</tr>
<tr>
<td>Luahan</td>
<td>73</td>
</tr>
<tr>
<td>Wasan</td>
<td>373</td>
</tr>
<tr>
<td>Tungku</td>
<td>262</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45</td>
</tr>
<tr>
<td><strong>Tutong</strong></td>
<td></td>
</tr>
<tr>
<td>Kupang</td>
<td>60</td>
</tr>
<tr>
<td>Maraburong, Kupang</td>
<td>58</td>
</tr>
<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>131</td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>517</td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>585</td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>80</td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>198</td>
</tr>
<tr>
<td><strong>Belait</strong></td>
<td></td>
</tr>
<tr>
<td>Rampayoh</td>
<td>104</td>
</tr>
<tr>
<td>Tungulian</td>
<td>92</td>
</tr>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>485</td>
</tr>
<tr>
<td>Melayan A</td>
<td>13</td>
</tr>
<tr>
<td>Labi Lama</td>
<td>50</td>
</tr>
<tr>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>50</td>
</tr>
<tr>
<td><strong>Temburong</strong></td>
<td></td>
</tr>
<tr>
<td>Labu Estate</td>
<td>97</td>
</tr>
<tr>
<td>Selangan</td>
<td>56</td>
</tr>
<tr>
<td>Bakarut</td>
<td>38</td>
</tr>
<tr>
<td>Selapon</td>
<td>80</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>4423</strong></td>
</tr>
</tbody>
</table>
Poorly drained grey soils (Humaqueptic Endoaquents)

**Typical pedon number:** 04 0005
**Location:** UTM grid reference 259891 mE 533521 mN Zone 50
**Agricultural Development Area:** Si Bongkok Parit Masin
**District:** Brunei Muara
**Physiography Slope:** <1 degree
**Slope position:** flat of alluvial valley
**Water table depth:** 20 cm
**Drainage class:** poorly

**Morphological Description:**

<table>
<thead>
<tr>
<th>Horizon designation</th>
<th>Horizon depth cm</th>
<th>Soil colour - Moist</th>
<th>Texture class</th>
<th>Redoximorphic features</th>
<th>Structure - Type</th>
<th>Consistence - Rupture resistance</th>
<th>Reaction (field pH)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0</td>
<td>20</td>
<td>7.5YR 2/0</td>
<td>clay loam</td>
<td>0% concentrations</td>
<td>cloddy</td>
<td>friable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>50</td>
<td>10YR 4/1</td>
<td>clay</td>
<td>40% iron concentrations 10YR 6/8</td>
<td>subangular blocky</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2Cg1</td>
<td>50</td>
<td>90</td>
<td>10YR 4/1</td>
<td>clay</td>
<td>5% iron concentrations 7.5YR 5/8</td>
<td>massive</td>
<td>firm</td>
<td></td>
</tr>
<tr>
<td>2Cg2</td>
<td>90</td>
<td>180</td>
<td>7.5YR 4/0</td>
<td>sandy clay loam</td>
<td>0% concentrations</td>
<td>massive</td>
<td>very firm</td>
<td></td>
</tr>
</tbody>
</table>

**Depth, cm**

- 0 - 5
- 5 - 20
- 20 - 50
- 50 - 90
- 90 - 180
### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

**Volume 1 – Soils and Land Suitability of the Agricultural Development Areas**

**Site no:** 04 0005  
**ADA:** Si Bongkok Parit Masin  
**District:** Brunei Muara

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>EC cm</th>
<th>pH</th>
<th>EC cm</th>
<th>pH</th>
<th>EC cm</th>
<th>pH</th>
<th>pH&lt;sub&gt;2o&lt;/sub&gt;</th>
<th>Org.C</th>
<th>N</th>
<th>ext.P</th>
<th>ext.P</th>
<th>Bray-2</th>
<th>PBI Ext.K</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;- Ext.K</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;-</th>
<th>HCO&lt;sub&gt;3&lt;/sub&gt;-</th>
<th>PBI</th>
<th>ECCEC</th>
<th>Exch.Cations NH4OAc pH 7.0</th>
<th>Al</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Total</th>
<th>1M KCl ext cmol(+)/kg</th>
<th>0.01M CaCl&lt;sub&gt;2&lt;/sub&gt; ext cmol(+)/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>20</td>
<td>0.23</td>
<td>4.8</td>
<td>3.8</td>
<td>1.0</td>
<td>10.6</td>
<td>0.71</td>
<td>424</td>
<td>505</td>
<td>744</td>
<td>829</td>
<td>15.5</td>
<td>2.8</td>
<td>0.09</td>
<td>0.54</td>
<td>19.0</td>
<td>22.3</td>
<td>3.20</td>
<td>0.12</td>
<td>0.19</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>50</td>
<td>0.22</td>
<td>3.9</td>
<td>3.3</td>
<td>0.6</td>
<td>1.7</td>
<td>0.11</td>
<td>14</td>
<td>11</td>
<td>199</td>
<td>89</td>
<td>0.6</td>
<td>0.5</td>
<td>0.07</td>
<td>0.16</td>
<td>1.3</td>
<td>8.4</td>
<td>7.02</td>
<td>&lt;0.01</td>
<td>1.24</td>
<td>&lt;0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>Satn depth cm</th>
<th>Satn extract</th>
<th>Soluble salts in saturation extract</th>
<th>Soluble salts from saturation extract</th>
<th>Satn extract</th>
<th>Soluble salts in saturation extract</th>
<th>Soluble salts from saturation extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>20</td>
<td>83</td>
<td>4.8</td>
<td>0.62</td>
<td>109</td>
<td>5</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>50</td>
<td>61</td>
<td>4.6</td>
<td>0.62</td>
<td>29</td>
<td>12</td>
<td>18</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Upper depth cm</th>
<th>Lower depth cm</th>
<th>CaCl&lt;sub&gt;2&lt;/sub&gt;- ext.B</th>
<th>DTPA ext</th>
<th>Clay</th>
<th>Fine silt</th>
<th>Coarse silt</th>
<th>Total silt</th>
<th>Fine sand</th>
<th>Coarse sand</th>
<th>Total sand</th>
<th>Plastic limit</th>
<th>Liquid limit</th>
<th>Linear shrink</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>20</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>50</td>
<td>0.9</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Mineralogy of bulk sample**

- **Quartz**
- **Albite**
- **Orthoclase**
- **Pyrite**
- **Anatase**
- **Kao Lin**
- **Mica/Illite**
- **Chlorite/Vermiculite**
- **Goethite**

**Mineralogy of <2µm fraction**

- **Kao Lin**
- **Mica/Illite**
- **Chlorite/Vermiculite**
- **Smedite**

**D:** dominant (>60%)  
**CD:** co-dominant (sum of phases >60%)  
**SD:** sub-dominant (20-60%)  
**M:** minor (5-20%)  
**T:** trace (<5%)  
**?:** possible
Part 5 Soil Distribution and Land Suitability in the ADAs

5.1 Introduction

The properties, FCC attributes and land suitability of each Soil Type were presented in Part 4. Part 5 aims to assist the sustainable and profitable use of land for agriculture within the ADAs by placing the Soil Type information in a spatial, landscape context.

The outputs of this analysis of the ADAs include:

- Presentation of the soil classification legend for the maps that allows the geographic distribution of soils to be viewed as maps.
- Application of the soil attributes and crop suitability ratings to the map units so that suitability ratings can be viewed as maps.
- Description of soil-landscape relationships (toposequences) for the ADAs, including generalised soil-landscape cross-sections.
- Identification of potentially suitable crops for the Agriculture Development Areas.

5.2 Soil Map Units and Soil Map Legend

5.2.1 Soil Classification Legend

The map units described in this report and shown on the accompanying maps (see Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.2 – Soil Maps, Grealish et al. 2007) represent the soils and landscapes found in the surveyed Agricultural Development Areas of Negara Brunei Darussalam. The map units partition the landscape into areas that have similar soils and landforms. These can then be interpreted in terms of land management.

The map unit boundary lines were obtained from previous soil surveys conducted by either ULG Consultants (1982, 1983) or Hunting Technical Services (1969). The lines were captured from their hardcopy maps by digitising and then the coordinates were projected to Universal Transverse Mercator (UTM) and WGS84 datum to produce the soil maps. The existing soil map information covered all of the Agricultural Development Areas of interest and therefore no new map unit boundary lines were created and no existing boundaries were modified or eliminated based on the results of this field survey.

The soil map unit symbology from the ULG and Hunting maps were maintained but the soils that occur within these map units are described according to Soil Taxonomy as classified during this field survey. The major soil types identified are presented in Section 4 of this report Description of Major Soil Types.

The soil classification legend is presented in Table 36 and covers all of the Agricultural Development Areas investigated in this survey. The Soil Classification Legend placed on each map sheet in the accompanying map booklet is a subset of the full legend and only identifies those units that occur in the map area of interest.

A symbol identifies the map unit on the map sheets and precedes the map unit name in the soil classification legend. The legend provides the linkage from the maps to the soil types. The map unit name is generally composed of the major soil types that occur in that map unit, with the order being from dominant to less dominant. The scale of mapping and the complexity of the soil pattern mean that there may be other minor soils, or inclusions, occurring in the map unit areas. These have not been identified in the soil classification legend but those that were observed during the field survey are listed in Table 37.
Table 36: Soil Taxonomy classification of soil map units in surveyed Agricultural Development Areas, Negara Brunei Darussalam.

<table>
<thead>
<tr>
<th>Soil Map Unit Symbol</th>
<th>Soil Taxonomy Classification</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sulfisaprists</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AN (be)</td>
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5.2.2 Interpretive Maps

The soil maps of each surveyed Agricultural Development Area presented in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.2 – Soil Maps (Grealish et al. 2007b) show the occurrence of map units, each of which is made up of one or more Soil Types. The distribution of Soil Types was described in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-2 – Soil Properties and Soil Identification Key for Major Soil Types (Grealish et al. 2007a). These maps are interpreted in this report to assist with understanding the spatial distribution of different soil attributes and crop suitability ratings.

Creating maps to represent the spatial distribution of a soil attribute or of the suitability for a specific crop requires that each map unit has a single value to display. However, soil map units commonly consist of two or more component soil types, thus necessitating decisions on how to interpret a map unit with multiple components. The components interpreted as best representing a map unit usually only occupy a portion of the total area delineated by the map unit. Similarly, the soil attribute values interpreted as best representing the map unit represent only a portion of the map unit and some parts of the map unit will have different values. The same is true for the land suitability classes chosen to represent the map unit. The probability the user will encounter the interpreted soil attribute value or land suitability class can be estimated from the percentage of the map unit area occupied by the interpretation.

For this survey the approximate proportions of Soil Subtypes in a map unit were estimated by the soil surveyor, taking into account landscape, remote sensed imagery and observations during the field survey. These proportions are not the result of a statistical analysis but result from the application of the surveyor’s experience to the soil-landscape relationships found during the field survey. The proportions of component Soil Subtypes in each map unit are shown in the Appendix.

If a map unit comprises only one component Soil Subtype then the interpretive values are the same as those of the Soil Subtype. For map units with two or more Soil Subtypes there are
six common ways a user may want to process multiple component map unit interpretations (USDA-NRCS 2005) as listed below.

1. Dominant component by percent.
2. Most limiting major component.
3. Least limiting major component.
4. Weighted average of major components.
5. All components.
6. Presence/Absence.

For this survey a map unit value was determined by the dominant component by percent. The interpretive soil attribute value of the component Soil Subtype occupying the largest proportion of the map unit is used to classify the map unit. For the component Soil Subtypes in each map unit, similar soil attribute values are grouped and their corresponding percent compositions are summed. If there is more than one group that shares the highest percent composition, a ‘tie-break rule’, based on the more limiting attribute value, indicates which value should be selected. The Appendix shows the interpretive values for each FCC attribute for each map unit together with the FCC attributes of each component soil.

The interpretive suitability class of a map unit for a specific crop is derived by applying the crop suitability rules (see Section 3.3.1) to the interpretive FCC attribute values in the same way as for individual Soil Types (see Sections 3.3.2 and 3.3.3). The interpretive suitability classes and subclasses for each map unit are shown in the Appendix. The suitability classes for each component Soil Subtype are also shown so that the variability within each map unit can be seen.

The geographic information system (GIS) developed by this project can display maps of the land suitability for each of the 27 crop groups for any of the surveyed ADAs. The map units are coloured according to the land suitability class and labelled with the suitability subclass. The large number of crop suitability-ADA combinations means it is cumbersome to print suitability maps in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.2 – Soil Maps (Grealish et al. 2007b). Instead, a land suitability legend is presented opposite the soil map of each ADA to show the soil attributes and crop suitabilities of each map unit in the ADA in a compact manner.

5.2.3 Map Unit Areas

Using the Geographical Information System, area measurements were calculated for the map units that occur in each Agricultural Development Areas, the results are presented in Table 38. The table shows that total map unit areas range from less than 0.5 to 1154 hectares. 42 map units have been used; of these 10 have total areas less than 10 hectares and 18 have total areas greater than 50 hectares.
Table 38: Area measurements for map units in surveyed Agricultural Development Areas of Negara Brunei Darussalam.

| Map Unit | Symbol | Belumpu | Sg Tajau | Sg Tukak, Limau Mans A | Sg Tukak, Limau Mans B | Sg Bongkok, Par Masin | Lumapas | Limpak | Luahan | Wasan | Tungku | Kupang | Marbunong, Kupang | Padunok/Sg Burong, Kudiang | Balang Mitus (Buah) | Balang Mitus (Haiaman) | Brau (P. Muda) | Brau (Penyelidikan) | Rampayoh | Tungillian | Merangking, Bukit Sawat | Mesyan A | Labi Lama | Labu Estate | Labu | Selangian | Belarat | Selapion |
|----------|--------|---------|----------|------------------------|------------------------|------------------------|---------|--------|--------|--------|--------|--------|----------------------|------------------------|----------------------|----------------------|----------------------|----------------------|----------|------------------|----------------------|----------------------|------------------|----------------------|----------|
|          | AN (be)| 79                  | 13        | 11                     | 40                     | 16                     |
|          | AN (bm)| 19                  | 2         | 14                     | 3                     |
|          | BDG-1  | 39                  |           |                         |                         |                         |
|          | BDG-2  | 10                  |           |                         |                         |                         |
|          | BDG-TTN-1| 7                |           |                         |                         |                         |
|          | BDG-TTN-1-2| 0         |           |                         |                         |                         |
|          | BJ (be)| 15                  |           |                         |                         |                         |
|          | BJ (bm)| 825                 | 474       | 28                     | 127                    | 24                     | 69                   | 2       | 45                   |
|          | BJ (wa)| 329                 |           |                         |                         |                         |
|          | BJ (tu)| 209                 | 57        |                         |                         |                         |
|          | BK.2 (bm)| 0                  |           |                         |                         |                         |
|          | BK.2 (tu)| 11                 |           |                         |                         |                         |
|          | BK.2/AN| 3                   |           |                         |                         |                         |
|          | BK.2/BJ| 91                  |           |                         |                         |                         |
|          | BK.3 (bm)| 102                | 60        | 41                     | 1                      |
|          | BK.3 (tu)| 205                |           |                         |                         |                         |
|          | BK/NY.2| 443                 |           |                         |                         |                         |
|          | BK/NY.3| 617                 |           |                         |                         |                         |
|          | BKT    | 79                  |           |                         |                         |                         |
|          | BKT-4  | 54                  |           |                         |                         |                         |
|          | BKT-BTN-3| 25                 |           |                         |                         |                         |
|          | BKT-BTN-4| 8                 |           |                         |                         |                         |
| Symbol         | Total Area | Betumpu | Sg Tajau | Si Tukak, Limau Mans A | Si Tukak, Limau Mans B | Si Bongkok Part Nasi | Lumapas | Limpaki | Luahran | Wesan | Tungku | Pengkeraman Batu | Kupang | Marsabusong, Kupang | Padununok/Sg Burong, Kudiang | Batang Mius (Buah) | Batang Mius (Hakaman) | Brau (P. P. Muda) | Brau (Penyelidikan) | Rampayoh | Tunggulian | Merangking Bukit Sawat | Meliay A | Labu Larn | Labu Estate | Selangian | Bakarut | Selapun |
|----------------|------------|---------|----------|-------------------------|------------------------|-----------------------|---------|---------|---------|-------|--------|------------------|--------|------------------|-------------------------|------------------------|------------------------|---------------|-----------------------|-----------|------------|-------------|-----------|---------|---------|
| BTN-3          | 201        |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| BTN-4          | 69         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| BTN-SKN-4      | 8          |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| BU/MR.1        | 35         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| JML-2          | 25         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| KKP-1          | 15         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| LU/BJ          | 191        |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| MA (be)        | 37         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| MA (bm)        | 119        | 41      | 16       | 19                      | 43                     |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| ME.1/MA        | 71         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| ME.2/BJ        | 116        | 29      | 46       | 40                      |                         |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| MR             | 5          |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| NY.3           | 83         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| NY/KP.4        | 29         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| PL             | 32         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| RMB-2          | 1          |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| SKN-4          | 19         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| SM             | 1          |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| TTN            | 18         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| TTN-1          | 23         |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| TTN-KDN-1-2    | 156        |         |          |                         |                        |                       |         |         |         |       |        |                   |        |                  |                         |                        |                        |               |           |             |           |         |         |
| **Total Area** | **4422**   | **474** | **117**  | **82**                  | **46**                 | **127**               | **38**  | **73**  | **373** | **262**| **45** | **60**          | **58** | **131**         | **517**                  | **585**                | **80**                | **198**        | **104**  | **92**       | **485**  | **13** | **50** |

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
5.3 Generalised Soil Distribution

Generalised soil landscape cross-sections were developed to assist with understanding the soil variation in the landscape and to provide some guidance as to where the major soil types might be found outside the surveyed Agricultural Development Areas. These conceptual cross-sections show the relationship of soils to each other and their approximate landscape position. They are intended to convey relationships and do not necessarily portray any actual place visited in this survey.

The four soil landscape cross sections presented below are related to each of the districts as outline in Table 39.

<table>
<thead>
<tr>
<th>District</th>
<th>Related Agricultural Development Area</th>
<th>No.</th>
<th>Relevant Cross-section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei-Muara</td>
<td>Betumpu</td>
<td>01</td>
<td>Figure 2: Brunei-Muara District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Si Tukak, Limau Manis A&amp;B</td>
<td>03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Si Bongkok Parit Masin</td>
<td>04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lumanpas</td>
<td>05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limpaki</td>
<td>06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wasan</td>
<td>08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pengkalan Batu</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Brunei-Muara</td>
<td>Sg Tajau</td>
<td>02</td>
<td>Figure 3: Tutong District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Luahan</td>
<td>07</td>
<td></td>
</tr>
<tr>
<td>Tutong</td>
<td>Kupang</td>
<td>10</td>
<td>Figure 3: Tutong District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Maraburong, Kupang</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Batang Mitus (Buah)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Batang Mitus (Halaman)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Birau (P. P. Muda)</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Birau (Penyelidikan)</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Belait</td>
<td>Tungulian</td>
<td>20</td>
<td>Figure 3: Tutong District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Merangking, Bukit Sawat</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Belait</td>
<td>Rampayoh</td>
<td>19</td>
<td>Figure 4: Belait District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Melayan A</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labi Lama</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Temburong</td>
<td>Labu Estate</td>
<td>25</td>
<td>Figure 5: Temburong District conceptual soil landscape cross-section.</td>
</tr>
<tr>
<td></td>
<td>Selangan</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bakarut</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Selapon</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>SUBSOIL TEXTURE:</td>
<td>sandy</td>
<td>loamy</td>
<td>cracking</td>
</tr>
<tr>
<td>----------------</td>
<td>-------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>&lt;150 grey loose layer</td>
<td>&lt;200 white cemented layer</td>
<td>&lt;50 pH 4.5</td>
<td>&lt;100 sulfidic material</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOIL DEPTH (cm) TO:</th>
<th>poor</th>
<th>poor</th>
<th>poor</th>
<th>poor</th>
<th>poor</th>
<th>very poor</th>
<th>very poor</th>
<th>very poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAINAGE:</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>very poor</td>
<td>very poor</td>
<td>very poor</td>
</tr>
<tr>
<td>CLASSIFICATION:</td>
<td>Humaqueptic Endoaquent</td>
<td>Ultic Epiaquod</td>
<td>Typic Dystraquent</td>
<td>Sulfic Sulfaquent</td>
<td>Haplic Sulfic</td>
<td>Typic Sulfic</td>
<td>Sulfic</td>
<td>Sulfic</td>
</tr>
<tr>
<td>LANDSCAPE:</td>
<td>Terrace</td>
<td>Drain</td>
<td>Spoil pile</td>
<td>Clay</td>
<td>Organic material</td>
<td>Approx 1000m</td>
<td>&lt;10m</td>
<td>&lt; 10m</td>
</tr>
</tbody>
</table>

Figure 2: Brunei-Muara District conceptual soil landscape cross-section.
**SUBSOIL TEXTURE:**
- clayey
- clayey or loamy
- sandy

**SOIL DEPTH (cm) TO:**
- >150 brown over grey subsoil
- <150 yellow subsoil
- <150
- >150
- <150
- >150

**DRAINAGE:**
- poor
- poor
- somewhat poor
- somewhat poor
- moderately well
- well
- well
- well

**CLASSIFICATION:**
- Typic Epiaqualf
- Aeric Epiaqualf
- Aquic Palehult
- Oxyaquic Haplohumult
- Typic Palehult
- Typic Haplohumult
- Typic Kandhumult

**LANDSCAPE:**
- Approx 100m
- Approx 500m
- Alluvial flats
- Hillslope
- Crest
- weathered sandstone and shale

Figure 3: Tutong District conceptual soil landscape cross-section.
<table>
<thead>
<tr>
<th>Subsoil Texture</th>
<th>Sandy</th>
<th>Clayey</th>
<th>Sandy</th>
<th>Sandy</th>
<th>Sandy over organic material</th>
<th>Organic material with mineral layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Depth (cm) to</td>
<td>&gt;150</td>
<td>&lt;150</td>
<td>&gt;150</td>
<td>&lt;50</td>
<td>&lt;100 sulfuric layer</td>
<td>&lt;100 sulfidic material</td>
</tr>
<tr>
<td>Drainage</td>
<td>Poor</td>
<td>Somewhat poor</td>
<td>Well</td>
<td>Somewhat poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Classification</td>
<td>Umbric Epiaquod</td>
<td>Oxyaquic Hapludult</td>
<td>Arenic Paleudult</td>
<td>Aquic Kandudult</td>
<td>Sulfic Fluvaquent</td>
<td>Terric Sulfisaprist</td>
</tr>
<tr>
<td>Landscape</td>
<td>Upper dune</td>
<td>Sandy</td>
<td>Dune</td>
<td>Sandy</td>
<td>Alluvial flat</td>
<td>Swamp</td>
</tr>
<tr>
<td>Approx 1000m</td>
<td>Approx 20m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Belait District conceptual soil landscape cross-section.
The following sections summarise the limitations to cropping and the crop suitabilities of the Agricultural Development Areas (ADAs). The ADAs are arranged in groups with similar landscapes and hence similar map units. The section is best read in conjunction with the soil maps in *Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.2 – Soil Maps* (Grealish et al. 2007b).

These summaries are designed as an overview of crop suitability in the ADAs to assist strategic planning of crop choices and provision of agronomic advice to farmers. However, because soil varies over the landscape, often over quite short distances, the actual Soil Type encountered at a particular site might vary from those considered dominant for the map unit in which the site is located. Hence the crop limitations and crop suitabilities might vary from those listed for the map unit in the Appendix. The detailed soil properties, crop limitations and suitability for different crops at a particular site can only be determined by on-site investigation.
5.4 Soil Distribution in Brunei-Muara District

5.4.1 ADAs: Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumapas, Limpaki and Pengkalan Batu

Most of the surveyed ADAs in Brunei-Muara have a similar spatial pattern of soils. All these ADAs are situated on low-lying alluvial plains dominated by Sulfuric, Sulfidic and Organic soils. In most cases, the pattern of soils is too intricate to be mapped. Most of the ADA areas are mapped as BJ (bm) which is dominated by Sulfuric and Sulfidic soils but contains large areas of Organic soils (Table 40). In the lowest parts of Si Tukak Limau Manis, Lumapas and Limpaki, which are mapped as AN (bm), Organic soils dominate. Parts of the alluvial plains in Si Tukak and Limpaki that border hills – MA (bm) – are dominated by Cracking clay soils. The only hilly terrain in this group of ADAs is in Si Tukak, Limau Manis A and is mapped as BK.3 (bm) which consists of Yellow soils.

Table 40: Areas of map units within Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumapas, Limpaki and Pengkalan Batu ADAs

<table>
<thead>
<tr>
<th>ADA</th>
<th>AN (bm)</th>
<th>BJ (bm)</th>
<th>BK.2 (bm)</th>
<th>MA (bm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betumpu</td>
<td>474 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si Tukak, Limau Manis A &amp; B</td>
<td>2 ha</td>
<td>28 ha</td>
<td>41 ha</td>
<td>57 ha</td>
</tr>
<tr>
<td>Si Bongkok Parit Masin</td>
<td>127 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumapas</td>
<td>14 ha</td>
<td>24 ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limpaki</td>
<td>3 ha</td>
<td>69 ha</td>
<td>&lt;1 ha</td>
<td>19 ha</td>
</tr>
<tr>
<td>Pengkalan Batu</td>
<td>45 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that most affect crop suitability within the BJ (bm) and AN (bm) map units of these ADAs are peaty topsoils, flat slope, prolonged waterlogging, shallow sulfidic or sulfuric material, soil acidity/aluminium toxicity, high P fixation, potential iron toxicity and in some cases low K reserves (Table 41). In the MA (bm) areas of Si Tukak and Limpaki, the limitations are similar except the topsoils are heavy clay rather than peaty and soil acidity/aluminium toxicity is less severe (a-). In the hilly part of Si Tukak, Limau Manis A (BK.3) the attributes are very different with loamy topsoil, steep slopes with an erosion hazard. However, soil acidity/aluminium toxicity, low K reserves and high P fixation remain problems.

Land Suitability

The attributes listed in Table 41 for the lowland areas cause major or severe limitations for most types of crop. About one third of the area of these ADAs comprises Organic soils (Table 17). The long term sustainability of agriculture on these soils is questionable as discussed in Section 4.1. This is particularly the case in areas mapped as AN (bm), which are mostly Organic soils. Specific crops or crop groups are discussed as follows:

Rice: The areas mapped as MA (bm) and those parts of BJ (bm) that are not Organic soils may be suitable or moderately suitable for rice, although shallow sulfidic/sulfuric material is likely to be a major limitation in many instances. In the remainder of the lowland area, the Organic topsoil makes the soil only marginally suitable for rice because of the risk of panicle sterility. However, the intricate pattern of different Soil Types in these ADAs means that it would probably be difficult to delineate large enough, contiguous areas in which to construct rice fields.

The hilly part of Si Tukak, Limau Manis A is unsuitable for rice because of the slope.
Table 41: Attributes and crop suitability of Soil Subtypes within the Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumanas, Limpaki and Pengkalan Batu ADAs.

In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>BJ (bm) 10%</th>
<th>BJ (bm) 15%</th>
<th>BJ (bm) 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN (bm) 50%</td>
<td>AN (bm) 50%</td>
<td>AN (bm) 50%</td>
<td>AN (bm) 50%</td>
</tr>
</tbody>
</table>

**Component Soil Subtypes**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(see page 54)</td>
<td>(see page 54)</td>
<td>(see page 54)</td>
<td>(see page 54)</td>
</tr>
</tbody>
</table>

**Soil Taxonomy classification of component soils**

<table>
<thead>
<tr>
<th>Terric Sulfisaprists</th>
<th>Terric Sulfosaprists</th>
<th>Typic Sulfisaprists</th>
<th>Typic Sulfosaprists</th>
</tr>
</thead>
</table>

**General landscape position**

| Swamp | Swamp | Terrace flats | Terrace flats |

---

**Soil Attribute Ratings**

1

**Topsoil type**

| OOOO | OOOO | OOOO | OOOO |

**Subsoil type**

| L | C | O | O |

**Waterlogging (g, g+)**

| g+ | g+ | g+ | g+ |

**Slope (%)**

| 0% | 2% | 0% | 2% |

**Max. slope (%)**

| 0% | 2% | 0% | 2% |

**Erosion risk (w)**

| i+ | i+ | i+ | i+ |

**Sulfidic horizon (c) & depth, cm**

| c(30) | c(30) | c(30) | c(15) |

**Aluminium (a, a-)**

| aaaa | aaaa | aaaa | aaaa |

**Low K reserves (k)**

| k | k | k | k |

**High P fixation (i, i-, i+)**

| i+ | i+ | i+ | i+ |

**Cracking clays (v)**

| 4g | 4g | 4g | 4g |

**High leaching (e)**

| 4g | 4g | 4g | 4g |

**FCC**

| OLG+6%c(30)aki+ | OCG+2%c(30)ai+ | OOG+0%c(30)ai+ | OOG+2%c(15)ai+ |

---

**Crop Suitability Ratings**

2

**Rice**

| 4O | 4O | 4O | 4O |

**Leafy and fruit vegetables**

| 5 Og+c(≤40)ai+ | 5 Og+c(≤30)ai+ | 5 Og+c(≤30)ai+ | 5 Og+c(≤20)ai+ |

**Root vegetables**

| 5 Og+c(≤40)ai+ | 5 Og+c(≤30)ai+ | 5 Og+c(≤30)ai+ | 5 Og+c(≤20)ai+ |

**Groundnuts**

| 5 g+ | 5 g+ | 5 g+ | 5 g+ |

**Soya and mung beans**

| 5 g+ | 5 g+ | 5 g+ | 5 g+ |

**Maize**

| 5 g+ | 5 g+ | 5 g+ | 5 g+ |

**Ginger and turmeric**

| 4 O | 4 O | 4 O | 4 O |

**Cassava and sweet potato**

| 5 Og+c(≤30) | 5 Og+c(≤30) | 5 Og+c(≤30) | 5 Og+c(≤30) |

**Durian**

| 5 O | 5 O | 5 O | 5 O |

**Rambutan**

| 5 O | 5 O | 5 O | 5 O |

**Langsat-duku**

| 5 O | 5 O | 5 O | 5 O |

**Citrus**

| 5 O | 5 O | 5 O | 5 O |

**Banana**

| 5 O | 5 O | 5 O | 5 O |

**Coconut**

| 5 O | 5 O | 5 O | 5 O |

**Papaya**

| 5 O | 5 O | 5 O | 5 O |

**Pineapple**

| 5 O | 5 O | 5 O | 5 O |

**Mango and cashew nut**

| 5 O | 5 O | 5 O | 5 O |

**Arbopecus**

| 5 O | 5 O | 5 O | 5 O |

**Mangosteen**

| 5 O | 5 O | 5 O | 5 O |

**Dragon fruit**

| 5 O | 5 O | 5 O | 5 O |

**Guava**

| 5 O | 5 O | 5 O | 5 O |

**Star fruit**

| 5 O | 5 O | 5 O | 5 O |

**Longan**

| 5 O | 5 O | 5 O | 5 O |

**Grasses for -well areas**

| 2 i+ | 2 i+ | 2 i+ | 2 i+ |

**-well drained areas**

| 2 O+ | 2 O+ | 2 O+ | 2 O+ |

**Fodder legumes for -well areas**

| 2 O+aki+ | 2 O+ai+ | 2 O+ai+ | 2 O+(c≤20)ai+ |

**-well drained areas**

| 4 g+ | 4 g+ | 4 g+ | 4 g+ |

---

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3
<table>
<thead>
<tr>
<th>BJ (bm) 25%</th>
<th>BJ (bm) 40%</th>
<th>MA (bm) 100%</th>
<th>BK.3 (bm) 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft poorly drained sulfidic soils</td>
<td>Poorly drained sulfuric soils</td>
<td>Sulfidic poorly drained cracking clay soils</td>
<td>Moderately well drained yellow soils</td>
</tr>
<tr>
<td>(see page 126)</td>
<td>(see page 119)</td>
<td>(see page 75)</td>
<td>(see page 103)</td>
</tr>
<tr>
<td>Haplic Sulfaquents</td>
<td>Typic Sulfaquepts</td>
<td>Sulfic Sulfaquerts</td>
<td>Oxyaquic Haplohumults</td>
</tr>
<tr>
<td>Terrace flats</td>
<td>Terrace flats</td>
<td>Terrace flats</td>
<td>Mid to lower slopes</td>
</tr>
</tbody>
</table>

| C | L | C | L |
| C | C | C | C |
| g+ | g | g+ | |
| 0% | 0% | 0% | 20% |
| 70% | 70% | 70% | 70% |
| c(30) | c(30) | c(40) | a |
| a | a | a | a |
| k | k | k | k |
| i+ | i | i+ | i |
| v | v | v | v |

<table>
<thead>
<tr>
<th>CCg+0%c(30)aki+</th>
<th>LCg0%c(30)ai</th>
<th>CCg+0%c(40)a+i+</th>
<th>LC20-70%waki</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 c(≤35)</td>
<td>3 c(≤35)</td>
<td>2 g+c(≤60)i+v</td>
<td>5 &gt;15%</td>
</tr>
<tr>
<td>3 g+c(≤40)g</td>
<td>3 c(≤40)</td>
<td>3 g+c(≤40)g</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>3 g+c(≤40)g</td>
<td>3 c(≤40)</td>
<td>4 g+v</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>4 g+</td>
<td>3 g+c(≤40)g</td>
<td>5 g+v</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>4 g+</td>
<td>3 g+c(≤40)g</td>
<td>4 g+v</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>4 g+</td>
<td>3 c(≤40)</td>
<td>3 g+c(≤40)g</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>3 g+c(≤50)g</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)g</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤50)g</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)g</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤50)g</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)g</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>4 Cg+c(≤30)</td>
<td>4 c(≤30)</td>
<td>4 Cg+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>4 g+c(≤30)</td>
<td>4 c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>4 g+c(≤30)</td>
<td>4 c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤30)</td>
<td>5 c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤30)</td>
<td>5 c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤30)</td>
<td>5 c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤30)</td>
<td>5 c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤50)</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤50)</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 g+c(≤50)</td>
<td>5 c(≤50)</td>
<td>5 g+c(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
</tbody>
</table>

| 3 g+ | 3 g+v | 2 No gi [3 >55%] |
| 3 g+ | 3 g+v | 2 wki [3 >55%] |
| 3 g+c(≤30) | 2 ai | 3 v | 2 waki [3 >55%] |
| 4 g+ | 4 g+ | 3 wa |

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Vegetables: Most of the lowland area is moderately suitable for vegetable crops, but with major limitations due to prolonged waterlogging, shallow sulfidic/sulfuric material and soil acidity/aluminium toxicity. The use of raised beds and heavy liming makes vegetable production possible. In areas with Organic soils, the peaty topsoil is also a major limitation. Where the depth to sulfidic/sulfuric material is too shallow, vegetables are marginal. In areas with Cracking clay soils, the heavy clay texture is a major limitation to vegetable crops, because the soil is difficult to cultivate. The heavy clay texture is a severe limitation to root vegetables making them only marginally suitable.

The majority of the hilly part of Si Tukak, Limau Manis A is moderately suitable for vegetables with soil acidity/aluminium toxicity and erosion hazard being major limitations. Vegetables are marginal where the slope is greater than 35% and unsuitable where it is greater than 55%.

Short duration crops: Most of the area is unsuitable or marginally suitable for the other short duration crops assessed due to prolonged waterlogging, organic topsoils or shallow sulfidic/sulfuric material. The areas of mineral soils (Poorly drained sulfuric soils and Soft poorly drained sulfidic soils, but not Cracking clay soils) may be moderately suitable for other short duration crops where waterlogging is less severe (g) or for crops that can be grown on raised beds such as ginger and tumeric. In these situations, waterlogging, soil acidity/aluminium toxicity and shallow sulfidic/sulfuric material remain major limitations.

The majority of the hilly part of Si Tukak, Limau Manis A is moderately suitable for short duration crops with soil acidity/aluminium toxicity and erosion hazard being major limitations. These crops are marginal where the slope is greater than 35% and unsuitable where it is greater than 55%.

Fruit crops: The lowland areas of these ADAs are unsuitable for commercial fruit production, although shallow rooting species, such as citrus, banana and pineapple, are marginally suitable, so long as sulfidic/sulfuric material does not occur within 20 cm of the surface. The majority of the hilly part of Si Tukak, Limau Manis A is moderately suitable for fruit crops with soil acidity/aluminium toxicity being a major limitation. Fruit crops are marginal where the slope is greater than 65% because of the risk of mass soil movement (i.e. land slippage).

Fodder crops: Fodder crops adapted to wet conditions are suitable for most of the lowland area. The wet conditions suggest that grazing is probably impractical and that fodder crops should be cut and transported to animals kept elsewhere. Areas of Cracking clay soil are only moderately suitable because the heavy clay texture combined with prolonged waterlogging is a major limitation. The peaty topsoil and/or prolonged waterlogging are major limitations for grasses adapted to well drained conditions. Prolonged waterlogging makes these areas only marginally suitable for fodder legumes adapted to well drained areas.

The hilly part of Si Tukak, Limau Manis A is suitable or moderately suitable for fodder crops.
5.4.2 ADA: Sungai Tajau

The Sungai Tajau ADA borders on the Tutong District. Its landscape is similar to those of the Tutong ADA so it is best considered collectively in Section 5.5.1.
5.4.3 ADA: Luahan

The Luahan ADA is situated in hilly terrain away from the alluvial plain that characterises most of the ADAs in Brunei-Muara. Most of the ADA is mapped as ME.1/MA (Table 42). The valley bottoms are occupied by Poorly drained brown over grey soils, and the slopes by Yellow soils. The pattern of soils is similar to that found in the Tutong ADAs (see Section 5.5.1) except that the soils in the valley bottoms have worse drainage than in Tutong.

Table 42: Areas of map units within Luahan ADA

<table>
<thead>
<tr>
<th>ADA</th>
<th>BK/NY.3</th>
<th>ME.1/MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luahan</td>
<td>2 ha</td>
<td>71 ha</td>
</tr>
</tbody>
</table>

**Soil Attributes**

In the valley bottoms the FCC attributes that influence land use are clayey topsoil and subsoil, flat slope, prolonged waterlogging and iron toxicity (Table 43). On the slopes the major attributes are loamy topsoil, steep slopes and erosion hazard. Soil acidity/aluminium toxicity (moderate in the valley bottoms), low K reserves and high P fixation are limitations throughout the ADA.

Although not a soil attribute, the narrowness of the valleys, combined with the large area of runoff generating slopes, is likely to make flooding a limitation. The flooding risk requires investigation to determine if it is manageable.

**Land Suitability**

*Rice:* The valley bottoms are suitable for rice, although the small valleys might make it difficult to delineate large enough contiguous areas in which to construct rice fields. The slopes are unsuitable for rice due to their steepness (Table 43).

*Vegetables and short duration crops:* The valley bottoms are moderately suitable for vegetables, ginger and turmeric so long as raised beds are used to overcome prolonged waterlogging. The valley bottoms are unsuitable for mung and soya beans, which are sensitive to waterlogging, and marginally suitable for groundnuts, maize, cassava and sweet potato.

The slopes are moderately suitable for short duration crops, with the steep slopes hindering field operations and requiring attention to erosion control measures. Areas with slopes greater than about 35% are only marginal suitable and those greater than about 55% are unsuitable. Soil acidity/aluminium toxicity is also a major limitation.

*Fruit crops:* Prolonged waterlogging makes the valley bottoms unsuitable for most fruit crops assessed. Some shallow rooted species, such as citrus, banana and pineapple, are marginally suitable, as are those, such as *Artocarpus* spp. and mangosteen, that are somewhat tolerant of waterlogging.

The slopes are moderately suitable for most fruit trees, with the major limitation being soil acidity/aluminium toxicity. Areas with slopes greater than 65% are only marginally suitable for fruit crops because of the risk of mass soil movement (*i.e.* land slippage).

*Fodder crops:* The valley bottoms are suitable for grass and fodder legume species suited to wetter situations. Grass species adapted to well drained conditions are moderately suitable and legume species more suited to well drained situations are only marginally suitable.

The slopes are suitable or moderately suitable for grass and fodder legumes, with slope being the controlling factor. Fodder legume species adapted to well drained areas are moderately suitable because of their sensitivity to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increase the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
Table 43: Attributes and crop suitability of Soil Subtypes within the Luahan ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>ME.1/MA 35%</th>
<th>ME.1/MA 65%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorly drained brown over grey soils</td>
<td></td>
<td>Moderately well drained yellow soils</td>
</tr>
<tr>
<td>(see page 111)</td>
<td></td>
<td>(see page 103)</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaquats</td>
<td>Oxyaquic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>Topsoil type</td>
<td>C</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td></td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>20%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td>CCg+2%a-k+</td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Crop Suitability Ratings 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3

<table>
<thead>
<tr>
<th>Crop Suitability Ratings 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 g+ki+</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 g+</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 g+</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 Cg+</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 i+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g+</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Cg+ki+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
</tr>
</tbody>
</table>
5.4.4 ADA: Wasan

Wasan is situated on an alluvial plain adjacent to hills that border the Tutong District. The ADA consists almost entirely of map units BJ (wa) and MA (bm) (Table 44) which are comprised of Cracking clay soils of both Sulfidic and Acid Subtypes.

### Table 44: Areas of map units within Wasan ADA

<table>
<thead>
<tr>
<th>ADA</th>
<th>BJ (wa)</th>
<th>BK.3 (bm)</th>
<th>MA (bm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wasan</td>
<td>329 ha</td>
<td>1 ha</td>
<td>43 ha</td>
</tr>
</tbody>
</table>

### Soil Attributes

The FCC attributes that influence land use in Wasan are the heavy clay texture, prolonged waterlogging, flat slope, potential aluminium toxicity for sensitive crops, high P fixation and Fe toxicity (Table 45). The heavy clay texture is likely to exacerbate problems due to waterlogging, because they are prone to structural degradation if trafficked when wet which can further decrease aeration. Sulfidic material occurs in some areas.

### Land Suitability

**Rice:** The Cracking clay soils that occupy most of Wasan are suitable for rice (Table 45), which requires waterlogged conditions and can tolerate the poor aeration associated with waterlogged shrink/swell clay. The waterlogged conditions and high clay content also buffer against acidity.

**Vegetables:** The area is moderately suitable for vegetables, except for root vegetables, but requires management to overcome the waterlogged conditions. This might be hindered by the heavy clay texture, which makes it difficult to achieve aerated condition even in raised beds. Tillage of these soils is also difficult.

**Short duration crops:** The area is unsuitable or marginally suitable for other short duration crops because of the severe waterlogging and heavy clay texture.

**Fruit crops:** The area is unsuitable or marginally suitable for fruit crops because of the severe waterlogging and heavy clay texture.

**Fodder crops:** Grasses and fodder legumes adapted to wetter conditions are only moderately suited, because the heavy clay texture exacerbates the poor aeration associated with water conditions and shortens the periods when the soil might be trafficable. Legumes adapted to well drained conditions are marginally suitable.
Table 45: Attributes and crop suitability of Soil Subtypes within Wasan ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest landscape positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA (bm) 100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfidic poorly drained cracking clay soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid poorly drained cracking clay soils</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(see page 75) (see page 75)

<table>
<thead>
<tr>
<th>Soil Taxonomy classification of component soils</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfic Sufaquerts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typic Dystraquerts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General landscape position</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrace flats</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsoil type C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterlogging (g, g+) g+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope (%) 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm c(40)</td>
<td>a-</td>
<td>a-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High P fixation (i, i-, i+) i+</td>
<td>i+</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v) v</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC CCg+0%c(40)a-i+v</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>BJ (wa) 50%</th>
<th>BJ (wa) 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice 2 g+c(c≤60)i+v</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables 3 g+c(c≤40)i+v</td>
<td>3 g+c(v)</td>
<td></td>
</tr>
<tr>
<td>Root vegetables 4 v</td>
<td>4 v</td>
<td></td>
</tr>
<tr>
<td>Groundnuts 5 v</td>
<td>5 v</td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Maize 4 g+</td>
<td>4 g+</td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric 4 v</td>
<td>4 v</td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato 4 g+v</td>
<td>4 g+v</td>
<td></td>
</tr>
<tr>
<td>Durian 5 g+c(c≤50)</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Rambutan 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Langsat-duku 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Citrus 4 Cg+v</td>
<td>4 Cg+v</td>
<td></td>
</tr>
<tr>
<td>Banana 4 g+</td>
<td>4 g+</td>
<td></td>
</tr>
<tr>
<td>Coconut 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Papaya 5 g+v</td>
<td>5 g+v</td>
<td></td>
</tr>
<tr>
<td>Pineapple 4 g+v</td>
<td>4 g+v</td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut 5 g+c(c≤50)</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Artocarpus 4 g+c(c≤50)</td>
<td>4 g+c(v)</td>
<td></td>
</tr>
<tr>
<td>Mangosteen 4 g+c(c≤50)</td>
<td>4 g+c(v)</td>
<td></td>
</tr>
<tr>
<td>Dragon fruit 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Guava 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Star fruit 5 g+</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Longan 5 g+c(c≤50)</td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Grasses for -well drained areas 3 v</td>
<td>3 v</td>
<td></td>
</tr>
<tr>
<td>-wet areas 3 g+v</td>
<td>3 g+v</td>
<td></td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas 3 v</td>
<td>3 v</td>
<td></td>
</tr>
<tr>
<td>-wet areas 4 g+</td>
<td>4 g+</td>
<td></td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
5.4.5 ADA: Tungku

Tungku is situated on old coastal sand dunes quite close to the current coast. The major map unit is LU/BJ (Table 46) which is made up of a toposquence of Soil Types with Loamy poorly drained white soils on the dunes, Moderately well drained yellow soils on the midslopes and Soft poorly drained sulfuric soils in the low areas between the dunes. In other areas (BK/NU.3) the crests and upper slopes are Well drained sandy very deep yellow soils.

Table 46: Areas of map units within Tungku ADA

<table>
<thead>
<tr>
<th>Map units</th>
<th>ADA</th>
<th>BJ (bm)</th>
<th>BK/NY.3</th>
<th>LU/BJ</th>
<th>MR</th>
<th>NY.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungku</td>
<td>2 ha</td>
<td>60 ha</td>
<td>191 ha</td>
<td>5 ha</td>
<td>4 ha</td>
<td></td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence land use on the dunes are loamy texture, waterlogging, soil acidity/aluminium toxicity and low K reserves (Table 47). The attributes of the Soft poorly drained sulfuric soils between the dunes are sandy texture, flat slope, waterlogging, the presence of sulfidic/sulfuric material near the surface, soil acidity/aluminium toxicity, low K reserves and high leaching potential. On the slopes the major attributes are loamy topsoil, steep slopes, erosion hazard, soil acidity/aluminium toxicity and low K reserves, with high P fixation also a limitation in some areas.

Land Suitability

**Rice:** Most of the ADA is unsuitable for rice either because of the sandy texture of the Sulfuric soils or the slope of the Yellow soils and Very deep yellow soils (Table 47). The Loamy poorly drained white soils may be suitable, but the the intricate pattern of topography means that it would probably be difficult to delineate large enough contiguous areas in which to construct rice fields.

**Vegetables and short duration crops:** The areas of Sulfuric soils between the dunes are only marginally suitable for most vegetables and short duration crops because very shallow sulfidic/sulfuric material is a severe limitation. Elsewhere short duration crops are moderately suitable. On the White soils waterlogging and/or soil acidity/aluminium toxicity are major limitations. On the Yellow soils and Very deep yellow soils on the slopes, soil acidity/aluminium toxicity, erosion hazard and hindrance to field operations by steep slopes are major limitations. Areas with slopes greater than about 35% are only marginal suitable and those greater than about 55% are unsuitable.

**Fruit crops:** The areas of Sulfuric soils between the dunes are unsuitable for fruit crops because of shallow sulfidic/sulfuric material. The White soils of the dunes are moderately suitable for most fruit crops, with soil acidity/aluminium toxicity and and waterlogging being major limitations. These soils are only marginally suitable for species susceptible to waterlogging, such as durian, langsat-duku and papaya. The Yellow soils and Very deep yellow soils are moderately suitable for fruit crops with major limitations due to soil acidity/aluminium toxicity. Slopes greater than 65% are only marginally suitable for fruit crops because of the risk of mass soil movement (i.e. land slippage).

**Fodder crops:** Most of the ADA is suitable for grasses and for those fodder legumes that are adapted to wet conditions. Fodder legumes adapted to well drained conditions are moderately suitable. Their greater susceptibility to soil acidity/aluminium toxicity makes it a major limitation. In addition, waterlogging is a major limitation for these species on the Sulfuric and White soils. On the Yellow soils and Very deep yellow soils, the poorer ground cover of some fodder legumes can increase the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
Table 47: Attributes and crop suitability of Soil Subtypes within the Tungku ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>LU/BJ 40%</th>
<th>LU/BJ 40%</th>
<th>LU/BJ 20%</th>
<th>BKN/Y.3 70%</th>
<th>BKN/Y.3 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR 40%</td>
<td>MR 60%</td>
<td>BK/NY.3</td>
<td>BK/NY.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Component Soil Subtypes
- Soft poorly drained sulfuric soils
- Loamy poorly drained white soils
- Moderately well drained yellow soils
- Well drained sandy very deep yellow soils

Soil Taxonomy classification of component soils
- Hydruaquepts
- Ultic Epiaquods
- Haplohumults
- Typic Kandihumults

General landscape position
- Terrace flats
- Dune slopes
- Mid to lower slopes
- Crests and upper slopes

Soil Attribute Ratings
1. Topsoil type
   - S
2. Subsoil type
   - S
3. Waterlogging (g, g+)
   - g
4. Slope (%)
   - 3%
5. Max. slope%
   - 20%
6. Erosion risk (w)
   - w
7. Sulfidic horizon (c) & depth, cm
   - c(0)
8. Aluminium (a, a-)
   - a
9. Low K reserves(k)
   - k
10. High P fixation (i, i-, i+)
    - i
11. Cracking clays (v)
    - v
12. High leaching (e)
    - e
13. FCC
    - SSg3%<c(0)ake
    - LLg0%<ak
    - LC20-70%waki
    - LL25-70%wake

Crop Suitability Ratings
1. Rice
   - 5 S
2. Leafy and fruit vegetables
   - 4 c(≤20)
3. Root vegetables
   - 4 c(≤20)
4. Groundnuts
   - 4 c(≤20)
5. Soya and mung beans
   - 4 c(≤20)
6. Maize
   - 4 c(≤20)
7. Ginger and turmeric
   - 4 c(≤20)
8. Cassava and sweet potato
   - 4 c(≤20)
9. Durian
   - 5 Sc(≤50)
10. Rambutan
    - 5 c(≤30)
11. Langsat-duku
    - 5 Sc(≤30)
12. Citrus
    - 5 c(≤20)
13. Banana
    - 5 c(≤20)
14. Coconut
    - 5 c(≤30)
15. Papaya
    - 5 c(≤20)
16. Pineapple
    - 5 c(≤20)
17. Mango and cashew nut
    - 5 c(≤50)
18. Artocarpus
    - 5 c(≤30)
19. Mangosteen
    - 5 c(≤30)
20. Dragon fruit
    - 5 c(≤30)
21. Guava
    - 5 c(≤30)
22. Star fruit
    - 5 c(≤30)
23. Longan
    - 5 c(≤50)
24. Grasses for -wet areas
    - 2 Sc(≤20)ke
25. Rambutan
    - 2 gc(≤20)ke
26. Fodder legumes for -wet areas
    - 2 c(≤20)ake
27. Pineapple
    - 3 gc(≤20)ja

1. Soil attribute codes are given in Table 6 and Table 8.
2. Land suitability classes are defined in Section 3.3.3.
5.5 Soil Distribution in Tutong District

5.5.1 ADAs: Kupang, Maraburong, Padnunok/Sg Burong, Batang Mitus (Buah), Batang Mitus (Halaman), Birau (P.P. Muda), Birau (Penyelidikan) and Sg Tajau (Brunei-Muara)

The ADAs in Tutong District, along with Sg Tajau in Brunei-Muara, all have similar landscapes with a consistent toposequence of Soil Types. Along the valley bottoms there are Somewhat poorly drained brown over grey soils. At the bottom of the slopes where they meet the valley bottom are Somewhat poorly drained clayey very deep yellow soils. The lower to mid slopes are occupied by Moderately well drained yellow soils and the upper slopes and crests by Well drained sandy very deep yellow soils.

The BJ (tu), BK.2/BJ and ME.2/BJ map units include the lower half of this toposequence (i.e. valley bottom to mid slope), whilst the BK.2 (tu), NK/NY.2 and BK/NY.3 units include the upper half (i.e. mid slope to crest). The BK.3 (tu) map unit includes the entire sequence. Although there is some variation in the map units occurring in the different ADAs (Table 48), all ADAs have the same sequence of Soil Types.

<table>
<thead>
<tr>
<th>ADA</th>
<th>Map units</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BJ (tu)</td>
<td></td>
</tr>
<tr>
<td>Sg Tajau, Brunei-Muara</td>
<td>57 ha</td>
<td>60 ha</td>
</tr>
<tr>
<td>Kupang</td>
<td>31 ha</td>
<td>29 ha</td>
</tr>
<tr>
<td>Maraburong, Kupang</td>
<td>46 ha</td>
<td>12 ha</td>
</tr>
<tr>
<td>Padnunok/Sg Burong, Kiudang</td>
<td>47 ha</td>
<td>83 ha</td>
</tr>
<tr>
<td>Batang Mitus (Buah)</td>
<td>40 ha</td>
<td>469 ha</td>
</tr>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>135 ha</td>
<td>346 ha</td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>2 ha</td>
<td>4 ha</td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>32 ha</td>
<td>110 ha</td>
</tr>
</tbody>
</table>

Soil Attributes

The attributes that influence land use vary along the toposequence described above (Table 49). Topsoil texture is clayey in the valley bottom but loamy elsewhere. The valley bottom and base of the slope are flat or have low slopes, and suffer from waterlogging. The gradients of the mid to upper slopes are steep, but there is no waterlogging. Soil acidity/aluminium toxicity and low K reserves occur throughout the toposequence. High P fixation occurs on mid and lower slopes.

Although not a soil attribute, the relative narrowness of the valleys, combined with the large area of slopes, is likely to make flooding a limitation.

Land Suitability

Rice: The Somewhat poorly drained brown over grey soils and Somewhat poorly drained clayey very deep yellow soils in the valley bottom are suitable for rice, but elsewhere the slopes are too steep (Table 49).

Table 49 (opposite): Attributes and crop suitability of Soil Subtypes within the ADAs surveyed in Tutong District together with those in the Sg Tajau ADA (Brunei-Muara). In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
### Component Soil Subtypes

<table>
<thead>
<tr>
<th>Soil Taxonomy classification of component soils</th>
<th>General landscape position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeric Epiaqualfs</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Aquic Palehumults</td>
<td>Lower slopes</td>
</tr>
<tr>
<td>Oxyaquic Haplohumults</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>Typic Kandihumults</td>
<td>Crests and upper slopes</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>L</td>
<td>g</td>
<td>2%</td>
<td>20%</td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td></td>
<td></td>
<td>CCG2%ak</td>
</tr>
<tr>
<td>L</td>
<td>C</td>
<td>g</td>
<td>3%</td>
<td>25%</td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td></td>
<td></td>
<td>LLg3%aki</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rating</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2</td>
<td>ak</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a</td>
<td>3 a [5 &gt;65%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 ga</td>
<td>3 wa [5 &gt;65%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 ga</td>
<td>3 wa [5 &gt;65%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 ga</td>
<td>3 wa [5 &gt;65%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a</td>
<td>3 wa [5 &gt;65%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g</td>
<td>3 w [4 &gt;65%]</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
<td>4 g</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
<td>4 g</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 C</td>
<td>3 ga</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gak</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gak</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
<td>4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Guava</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Longan</td>
<td>3 ga</td>
<td>3 ga</td>
</tr>
<tr>
<td>Grasses for - well drained areas</td>
<td>1</td>
<td>2 i</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>2 Cgk</td>
<td>2 gki</td>
</tr>
<tr>
<td>Fodder legumes for - well drained areas</td>
<td>2 Cak</td>
<td>2 aki</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>3 Cgaa</td>
<td>3 ga</td>
</tr>
</tbody>
</table>

---

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Vegetables and short duration crops: Most of the topsequence is moderately suitable for vegetables and other short duration crops. Soil acidity/aluminium toxicity is a major limitation in all situations. In the valley bottoms, waterlogging is also a limitation for crops that are not commonly grown on raised beds, such as soya and mung bean, groundnut and maize. On the slopes, erosion hazard is a major limitation, and slope itself becomes a limitation where it exceeds 20%. Where the slope exceeds 35%, cropping is marginal, and slopes in excess of 55% are unsuitable for cropping.

Fruit crops: The soils are moderately suitable for a wide variety of fruit crops. In the valley bottoms, waterlogging and soil acidity/aluminium toxicity are the major limitations. These areas are only marginally suitable for species that are sensitive to waterlogging, such as durian, langsat-duku and papaya. The Brown over grey soils are also only marginally suitable for citrus because of the clay topsoil. On the slopes, soil acidity/aluminium toxicity is a major limitation. Where slopes exceed 65%, fruit crops are only marginally suitable because of the risk of mass soil movement (i.e. land slippage).

Fodder crops: The soils are suitable for fodder crops, although only moderately so for fodder legume species adapted to well drained areas. This is because of the latter’s sensitivity to soil acidity/aluminium toxicity and waterlogging. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion on the slopes. Pinto peanut (Arachis pintoi) is one species that can give good ground cover once established.
5.6 Soil Distribution in Belait District

5.6.1 ADA: Rampayoh

The Rampayoh ADA includes alluvial plains and the lower slopes of neighbouring hills. The ADA is occupied by Very deep yellow soils. On the lower slopes, the Subtype is Well drained sandy. On the plain, the Subtype varies from Well drained sandy away from drainage lines to Somewhat poorly drained sandy nearer the drainage lines. Two groups of map units occupy the ADA (Table 50). Map units BJ (be) and MA (be) comprise the Somewhat poorly drained sandy Subtype and NK/KP.4, PL and SM are all dominated by the Well drained sandy Subtype.

Table 50: Areas of map units within Rampayoh ADA

<table>
<thead>
<tr>
<th>ADA</th>
<th>Map units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BJ (be)</td>
</tr>
<tr>
<td>Rampayoh</td>
<td>42 ha</td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence land use for Very deep yellow soils in Rampayoh are loamy topsoils, soil acidity/aluminium toxicity, low K reserves and high leaching potential (Table 51). On the flats additional attributes of the Somewhat poorly drained very deep yellow soils are flat slopes and waterlogging. However, aluminium toxicity on the flats is only moderate (a-). On the slopes there can be steep gradients and an erosion hazard.

Land Suitability

Rice: The flat areas are suitable for rice as their waterlogged condition would assist with rice cultivation (Table 51). The slopes are unsuitable for rice because of the gradient.

Vegetables and short duration crops: The flat areas are suitable for crops commonly grown on raised beds, such as vegetables, ginger and turmeric. Other short duration crops are moderately suitable with waterlogging being a major limitation.

The slopes are moderately suitable for the crops assessed. Soil acidity/aluminium toxicity is greater on the slopes and is a major limitation to all crops, except acid tolerant ones, such as cassava and sweet potato. Erosion hazard and the slope itself are major limitations where slope exceeds 20%. Where the slope exceeds 35%, cropping is marginal, and slopes in excess of 55% are unsuitable for cropping.

Fruit crops: The suitability of the flats for fruit trees depends on the species’ sensitivity to waterlogging. Tolerant species such as mangosteen are suitable, but sensitive species like durian, langsat-duku and papaya are only marginal. The other species assessed are moderately suitable.

The slopes are moderately suitable for fruit crops, with soil acidity/aluminium toxicity being the major limitation. Slopes exceeding 65% are only marginally suitable due to the risk of mass soil movement (i.e. land slippage).

Fodder crops: The soils are suitable for fodder crops, although only moderately so for fodder legumes species adapted to well drained areas. In the lower areas this is because of the latter’s sensitivity to waterlogging, and on the slopes because of their sensitivity to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (Arachis pintoi) is one species that can give good ground cover once established.
Table 51: Attributes and crop suitability of Soil Subtypes within the Rampayoh ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Map units and % of Soil Subtype in map unit</th>
<th>Soil Taxonomy classification of component soils</th>
<th>General landscape position</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJ (be)</td>
<td>100% BJ (be)</td>
<td>Aquic Kandihumults</td>
<td>Lower slopes</td>
</tr>
<tr>
<td>MA (be)</td>
<td>100% MA (be)</td>
<td>Typic Kandihumults</td>
<td>Crests and upper slopes</td>
</tr>
<tr>
<td>PL</td>
<td>100% PL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>100% SM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NY/KP.4</td>
<td>100% NY/KP.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th>Crop Suitability Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>Rice</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>Leafy and fruit vegetables</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>Root vegetables</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>Groundnuts</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>Soya and mung beans</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>Maize</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>Ginger and turmeric</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>Cassava and sweet potato</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>Durian</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>Rambutan</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>Langsat-duku</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>Citrus</td>
</tr>
<tr>
<td>FCC</td>
<td>Coconut</td>
</tr>
<tr>
<td></td>
<td>Papaya</td>
</tr>
<tr>
<td></td>
<td>Pineapple</td>
</tr>
<tr>
<td></td>
<td>Mango and cashew nut</td>
</tr>
<tr>
<td></td>
<td>Artocarpus</td>
</tr>
<tr>
<td></td>
<td>Mangosteen</td>
</tr>
<tr>
<td></td>
<td>Dragon fruit</td>
</tr>
<tr>
<td></td>
<td>Guava</td>
</tr>
<tr>
<td></td>
<td>Star fruit</td>
</tr>
<tr>
<td></td>
<td>Longan</td>
</tr>
<tr>
<td></td>
<td>Grasses for -wet areas</td>
</tr>
<tr>
<td></td>
<td>Grasses for -well drained areas</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes for -wet areas</td>
</tr>
<tr>
<td></td>
<td>Fodder legumes for -well drained areas</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
5.6.2 ADA: Tungulian

Tungulian is located in hilly country near the coast. The majority of the ADA, including the part that is currently cultivated for vegetables, is mapped as NY.3 (Table 52), which consists of a sequence of Moderately well drained yellow soils on the lower to mid slopes, Well drained sandy very deep yellow soils on the upper slopes and crests and Well drained yellow soils on the crests. This pattern is similar to that found in the Tutong ADAs (see Section 5.5.1). There may be Organic soils in the valley in the inaccessible eastern part of the ADA.

Table 52: Areas of map units within Tungulian ADA

<table>
<thead>
<tr>
<th>ADA</th>
<th>Map units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungulian</td>
<td>13 ha</td>
</tr>
<tr>
<td></td>
<td>79 ha</td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence land use in Tungulian are loamy topsoil, except on some crests where the texture is clayey, together with steep slope, potential erosion risk, soil acidity/aluminium toxicity and low K reserves (Table 53). High P fixation may be a limitation on the mid to lower slopes and crests, where the subsoil is clayey. High leaching potential is a limitation on the upper slopes and crests where the soils are Well drained sandy very deep yellow soils.

Land Suitability

Suitability for most crops is controlled mainly by slope (Table 53).

Rice: The steep slopes make the soils unsuitable for rice.

Vegetables and short duration crops: The soils are moderately suitable for vegetables and other short duration crops, with soil acidity/aluminium toxicity being a major limitation. Erosion hazard is also a major limitation, requiring attention to control measures. The difficulty of field operations is a major limitation on slopes steeper than 20%. On slopes greater than 35%, short duration crops are only marginally suitable, and on those greater than 55% they are unsuitable.

Fruit crops: Where slope is less than 65%, the soils are moderately suitable for all fruit crops assessed, with soil acidity/aluminium toxicity as the major limitation. The exception is where the topsoil texture is clayey (Well drained yellow soils), which is marginally suitable for citrus. Fruit crops are only marginally suitable where the gradient exceeds 65% due to the risk of mass soil movement (i.e. land slippage).

Fodder crops: Most of the fodder crops assessed are suitable for the area, except where slopes exceed 55% where they are moderately suitable. Fodder legumes adapted to well drained conditions are moderately suitable everywhere due to their sensitivity to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes increases the risk of erosion. Pinto peanut (Arachis pintoi) is one species that can give good ground cover once established.
Table 53: Attributes and crop suitability of Soil Subtypes within the Tungulian ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>NY.3 30%</th>
<th>NY.3 30%</th>
<th>NY.3 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately well drained yellow soils</td>
<td>Well drained sandy very deep yellow soils</td>
<td>Well drained yellow soils</td>
<td></td>
</tr>
<tr>
<td>(see page 103)</td>
<td>(see page 88)</td>
<td>(see page 103)</td>
<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic</td>
<td>Typic Kandihumults</td>
<td>Typic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
<td>Crests and upper slopes</td>
<td>Crests</td>
</tr>
<tr>
<td>Soil Attribute Ratings1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>L</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>L</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>20%</td>
<td>25%</td>
<td>60%</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>k</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>i</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop Suitability Ratings2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>5 &gt;15%</td>
<td>5 &gt;15%</td>
<td>5 &gt;15%</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 &gt;20%[a [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20%[wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20%[wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20%[wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20%[wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20%[wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>4 &gt;55%</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%[ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%[ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for - wet areas</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No g&gt;20%[e [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 &gt;20%[wke [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>Fodder legumes for - wet areas</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 &gt;20%[wake [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>3 wa</td>
<td>3 wa</td>
<td>3 C&gt;35%wa</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
5.6.3 ADA: Merangking, Bukit Sawat

Merangking is located in hilly country in the inter-riverine zone between the Belait and Tutong Rivers. The pattern of soils is similar to that in the Tutong ADAs – the difference being that the subsoil texture of the soils on the mid to upper slopes tends to be more clayey than in the Tutong ADAs. The sequence in Merangking is as follows. The valley bottoms are occupied by Poorly drained brown over grey soils. There are also areas of swamp with Mineral sulfidic organic soils. On the alluvial terraces above the valley bottom the soils are Moderate well drained clayey very deep yellow soils. The upper slopes are occupied by Well drained clayey very deep yellow soils.

The map units (Table 55) cover different parts of the toposequence. BTN-3 and BTN-4 include the whole sequence, whilst BTN-SKN-4 and TTN-KDN-1-2 also cover the whole sequence with the exception of the swamps. SKN-4 includes the upper portion of the sequence (alluvial terraces and upper slopes). BKT-BTN-3 and BKT-BTN-4 are dominated by Well drained clayey very deep yellow soils.

Table 55: Areas of map units within Meranking, Bukit Sawat ADA

<table>
<thead>
<tr>
<th>ADA BDG-TTN-1-2</th>
<th>Map units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merangking, Bukit Sawat</td>
<td>&lt;1 ha</td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence land use vary along the toposequence described above (Table 54). Topsoil texture is peaty in the swamp areas, clay on the alluvial flats and loam on the terraces and slopes. Slopes are flat in the swamp and alluvial flats, but moderate (0-30%) on the terraces and slopes. On steeper areas, the slope combined with the loam over clay texture creates an erosion hazard. Shallow sulfidic material occurs in the swamp areas. Soil acidity/aluminium toxicity and low K reserves occur throughout the ADA and high P fixation everywhere except for the soils on the terraces.

Land Suitability

Cropping options in the lower parts of the landscape – the swamps and alluvial flats – are limited, but much greater on the terraces and slopes (Table 54).

Rice: The Brown over grey soils on the alluvial flats are suitable for rice, but the swamp areas are only marginally suitable because of the risk of sterile panicles associated with growing rice on organic soils. It is likely the intricate patterns of soils would make it too difficult to find large enough contiguous areas of suitable soils to develop into rice fields. The terraces are moderately suitable, but lack of natural waterlogging is a major limitation. The slopes are unsuitable because the gradients are too steep.

Vegetables: The low areas are moderately suitable for vegetable crops, with the major limitation being prolonged waterlogging. The Organic soils of the swamps have further limitations due to their peaty topsoil, shallow sulfidic material and soil acidity/aluminium toxicity. The soils of the terraces and slopes are also moderately suitable, with soil acidity/ aluminium toxicity being the major limitation.

Table 54 (opposite): Attributes and crop suitability of Soil Subtypes within the Merangking, Bukit Sawat ADA.

In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
### Component Soil Subtypes

<table>
<thead>
<tr>
<th>Subtype Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral sulfidic organic soils</td>
</tr>
<tr>
<td>Poorly drained brown over grey soils</td>
</tr>
<tr>
<td>Moderately well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>Well drained clayey very deep yellow soils</td>
</tr>
</tbody>
</table>

### Soil Taxonomy classification of component soils

- Terric Sulfisaprists
- Typic Epiaqualfs
- Oxyaqual Palehumults
- Typic Palehumults

### General landscape position

- Swamp
- Alluvial flats
- Alluvial terrace
- Upper slopes

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>O</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(30)</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td></td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td>OLg+0%c(30)aki+</td>
<td>CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>4</td>
<td>O</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3</td>
<td>Og+c(≤40)α</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3</td>
<td>Og+c(≤40)α</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4</td>
<td>g+</td>
</tr>
<tr>
<td>Soybeans and mung beans</td>
<td>5</td>
<td>g+</td>
</tr>
<tr>
<td>Maize</td>
<td>4</td>
<td>g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4</td>
<td>O</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4</td>
<td>g+</td>
</tr>
<tr>
<td>Durian</td>
<td>5</td>
<td>Og+c(≤50)</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Langsat-daku</td>
<td>5</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Citrus</td>
<td>4</td>
<td>g+c(≤30)</td>
</tr>
<tr>
<td>Banana</td>
<td>4</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Coconut</td>
<td>5</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Papaya</td>
<td>5</td>
<td>Og+</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4</td>
<td>g+c(≤30)</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5</td>
<td>Og+c(≤50)</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5</td>
<td>c(≤30)</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5</td>
<td>Oc(≤30)</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Guava</td>
<td>5</td>
<td>Og+c(≤30)</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5</td>
<td>g+c(≤30)</td>
</tr>
<tr>
<td>Longan</td>
<td>5</td>
<td>Og+c(≤50)</td>
</tr>
<tr>
<td>Grasses for -well drained areas</td>
<td>2 i+</td>
<td>2 i+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 Og+</td>
<td>3 g+</td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas</td>
<td>2 Og+aki+</td>
<td>2 Cg+ki+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
</tbody>
</table>
Short duration crops: Low lying areas are generally only marginally suitable for the other short duration crops due to prolonged waterlogging. The exceptions are ginger and turmeric, that are moderately suited to the Brown over grey soils. Species that are very sensitive to waterlogging, such as soya and mung bean, are unsuitable.

The alluvial terraces and slopes do not suffer from prolonged waterlogging and are moderately suitable for the short duration crops assessed. Soil acidity/aluminium toxicity is the major limitation in these areas, although not for acid tolerant crops, such as cassava and sweet potato. The gradient of the Well drained clayey very deep yellow soils on the slopes may create an erosion hazard for short duration crops.

Fruit crops: Most fruit crops are unsuited to the low-lying areas because of prolonged waterlogging and, in the case of the Organic soils, shallow sulfidic material and peaty topsoils. Shallow rooted species, such as citrus, banana and pineapple, are marginally suitable. Species, such as Artocarpus spp. and mangosteen, that are somewhat tolerant of waterlogging, are also marginally suitable on the Brown over grey soils, but not on the Organic soils, where there is sulfidic material within their root depth.

The terraces and slopes are moderately suitable for fruit crops, with soil acidity/aluminium toxicity being the major limitation.

Fodder crops: Fodder grasses and legumes adapted to wet areas are suitable throughout the ADA, but on the lowest areas grazing is probably impractical due to the wet conditions and fodder crops should be cut and transported to animals kept elsewhere.

Grasses adapted to well drained conditions are suitable on the terraces and slopes, but are only moderately suitable on the lowland areas with major limitations due to waterlogging and the peaty topsoil of the Organic soils.

Severe waterlogging makes the lowland areas only marginally suitable for fodder legumes adapted to well drained areas. The terraces and slopes are moderately suitable, with soil acidity/aluminium toxicity a major limitation as well as erosion hazard on the slopes.
5.6.4 ADA: Melayan A

Melayan A is located on a steep slope above the swampy country that covers much of western Belait. It also includes some of the swampy country. The ADA includes some of the swamp area. The slopes are occupied by texture contrast yellow soils, whilst the swamps consist of Mineral sulfidic organic soils and Mineral sulfuric organic soils. Only two map units occur (Table 56), with BK.2/AN confined to the slopes and AN (be) occupying both the slopes and swamps.

Table 56: Areas of map units within Melayan A ADA

<table>
<thead>
<tr>
<th>Map units</th>
<th>ADA</th>
<th>AN (be)</th>
<th>BK.2/AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melayan A</td>
<td>11 ha</td>
<td>3 ha</td>
<td></td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence landuse in the lower, swampy parts of the ADA are peaty topsoils, prolonged waterlogging, flat slopes, shallow sulfidic/sulfuric material, soil acidity/aluminium toxicity, high P fixation and sometimes low K reserves (Table 57). On the slopes, the major attributes are the sandy over loam texture, steep gradients, erosion hazard (exacerbated by the texture contrast profile), soil acidity/aluminium toxicity, low K reserves and high leaching potential.

Land Suitability

About 40% of the area of this ADA is lowland swamp comprising mainly Organic soils (Table 17). The long term sustainability of agriculture on these soils is questionable as discussed in Section 4.1.

Rice: The Organic soils in the low parts of the ADA are marginally suitable for rice, because of the risk of sterile panicles associated with growing rice on organic soils. The slopes are unsuitable because the gradient is too steep (Table 57).

Vegetables: The ADA is moderately suitable for vegetables. On the Organic soils the major limitations are peaty topsoil, prolonged waterlogging, shallow sulfidic/sulfuric material and soil acidity/aluminium toxicity. On the slopes the major limitations are soil acidity/aluminium toxicity and the difficulty of field operations on steep slopes. Erosion hazard is also a limitation for root vegetables.

Short duration crops: The Organic soils of the low parts of the ADA are only marginally suitable for most short duration crops because of prolonged waterlogging. Sensitive species such as soya and mung bean are unsuitable. Crops more tolerant of such conditions – ginger and turmeric – are instead limited by the organic topsoil. The slopes are moderately suitable for short duration crops, with major limitations due to soil acidity/aluminium toxicity, erosion hazard and the difficulty of field operations on steep slopes.

Fruit crops: The Organic soils are unsuitable for most fruit crops due to prolonged waterlogging, shallow sulfidic/sulfuric material and organic topsoils. Shallow rooted fruit crops, such as citrus, banana and pineapple are marginally suitable. The slopes are moderately suitable for a wide variety of fruit crops, limited mainly by aluminium toxicity. The sandy topsoil is unsuitable for durian and langsat-duku, and marginally suitable for mangosteen.

Fodder crops: Fodder grasses and legumes adapted to wet areas are suitable throughout the ADA. In the low, waterlogged areas, grazing is probably impractical due to the wet conditions and fodder crops should be cut and transported to animals kept elsewhere.

On the organic soils, the peaty topsoil and prolonged waterlogging are major limitations for grasses adapted to well drained conditions. However, they are suitable on the slopes.
Table 57: Attributes and crop suitability of Soil Subtypes within the Melayan ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>AN (be) 40%</th>
<th>AN (be) 35%</th>
<th>AN (be) 25%</th>
<th>BK.2/AN 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Mineral sulfidic organic soils</td>
<td>Mineral sulfuric organic soils</td>
<td>Texture contrast yellow soils</td>
<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Terric Sulfsaprist</td>
<td>Terric Sulfosaprist</td>
<td>Arenic Paleudults</td>
<td></td>
</tr>
<tr>
<td>General landscape position</td>
<td>Swamp</td>
<td>Swamp</td>
<td>Upper slopes</td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>O</td>
<td>O</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
<td>C</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>2%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(30)</td>
<td>c(30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop Suitability Ratings²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>4 O</td>
<td>4 O</td>
<td>5 S&gt;15%</td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 O</td>
<td>4 O</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 w</td>
<td></td>
</tr>
<tr>
<td>Durian</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>5 S</td>
<td></td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>5 S</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>4 Og+c(≤30)</td>
<td>4 Og+c(≤30)</td>
<td>3 Sak</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 ak</td>
<td></td>
</tr>
<tr>
<td>Papaya</td>
<td>5 Og+</td>
<td>5 Og+</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
<td>4 S</td>
<td></td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Guava</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Longan</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 i+</td>
<td>2 i+</td>
<td>2 SNo ≥20%e</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 Og+</td>
<td>3 Og+</td>
<td>2 &gt;20%wke</td>
<td></td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Oga+aki+</td>
<td>2 Oga+ai+</td>
<td>2 &gt;20%wke</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 wa</td>
<td></td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
The severe waterlogging makes the Organic soils areas marginally suitable for fodder legumes adapted to well drained areas. On the slopes, these species are moderately suitable because of their sensitivity to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (Arachis pintoi) is one species that can give good ground cover once established.
5.6.5 ADA: Labi Lama

Labi Lama is situated on the edge of the swammy country that covers much of western Belait. Unlike Melayan A, there is a more gradual transition between the hills to the east of the ADA and the swamps. The swamps are mapped as AN (be) and consist of Mineral sulfidic organic soils and Mineral sulfuric organic soils. The transition between hills and swamp – mapped as BJ (be) and MA (be) – is composed of Somewhat poorly drained sandy very deep yellow soils, similar to those found at Rampayoh. Table 58 shows the map unit areas in Labi Lama.

<table>
<thead>
<tr>
<th>Map units</th>
<th>ADA AN (be)</th>
<th>BJ (be) MA (be)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labi Lama</td>
<td>40 ha</td>
<td>10 ha</td>
</tr>
</tbody>
</table>

**Soil Attributes**

The FCC attributes that influence landuse in the swammy parts of the ADA are peaty topsoils, prolonged waterlogging, flat slopes, shallow sulfidic/sulfuric material, soil acidity/aluminium toxicity, high P fixation and sometimes low K reserves (Table 59). On Very deep yellow soils between the swamps and the slopes, the major attributes are the sandy loam texture (in the FCC ‘loamy’ category in Table 6), waterlogging, moderate soil acidity/aluminium toxicity, low K reserves and high leaching potential.

**Land Suitability**

Over 80% of the area of this ADAs comprises Organic soils (Table 17). The long term sustainability of agriculture on these soils is questionable as discussed in Section 4.1. This is particularly the case in areas mapped as AN (be), which are mostly Organic soils. The clearing of the eastern part of this ADA for agriculture in 2006/7 provides an ideal opportunity for long term monitoring the soil after clearing. This would provide an invaluable dataset on the sequence of changes as the soil changes from its natural state.

*Rice:* The Organic soils occupying most of the ADA are marginally suitable for rice, because of the risk of sterile panicles associated with growing rice on organic soils. The areas of Very deep yellow soils are suitable for rice because of their waterlogged condition (Table 59).

*Vegetables:* The Organic soils are moderately suitable for vegetables. The major limitations are peaty topsoil, prolonged waterlogging, shallow sulfidic/sulfuric material and soil acidity/aluminium toxicity. The Very deep yellow soils are suitable for vegetables.

*Short duration crops:* The Organic soils are only marginally suitable for most short duration crops because of prolonged waterlogging. Sensitive species such as soya and mung bean are unsuitable. Crops more tolerant of such conditions – ginger and turmeric – are instead limited by the organic topsoil.

The Very deep yellow soils are suitable for crops, such as ginger and turmeric, that can be grown on raised beds. Other crops are moderately suitable with waterlogging being the major limitation.

*Fruit crops:* The Organic soils are unsuitable for most fruit crops due to prolonged waterlogging, shallow sulfidic/sulfuric material and organic topsoils. Shallow rooted fruit crops, such as citrus, banana and pineapple are marginally suitable.

The suitability of the areas of very deep yellow soils for fruit trees depends on the species’ sensitivity to waterlogging. Tolerant species such as mongosteen are suitable, but sensitive species like durian, langsat-duku and papaya are only marginal. The remainder are moderately suitable.
Table 59: Attributes and crop suitability of Soil Subtypes within the Labi Lama ADA.

In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right. The proportion of soil components in AN (be) have been adjusted to allow for the non-occurrence of Texture contrast yellow soils – normally a component of AN (be) – within this ADA.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>AN (be)</th>
<th>AN (be)</th>
<th>BJ (be)</th>
<th>MA (be)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral sulfidic organic soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see page 54)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terric Sulfisaprist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terric Sulvosaprist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquic Kandihumults</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General landscape position</td>
<td>Swamp</td>
<td>Swamp</td>
<td>Lower slopes</td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>O</td>
<td>O</td>
<td>L</td>
<td></td>
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<tr>
<td>Subsoil type</td>
<td>L</td>
<td>C</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
<td>g</td>
<td></td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>2%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(30)</td>
<td>c(30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
<td>a-</td>
<td></td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td>OLg+0%c(30)aki+</td>
<td>OCg+2%c(30)ai+</td>
<td>LLg2%a-ke</td>
<td></td>
</tr>
<tr>
<td>Crop Suitability Ratings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>4 O</td>
<td>4 O</td>
<td>2 ke</td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>2 ga-ke</td>
<td></td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>2 ga-ke</td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 O</td>
<td>4 O</td>
<td>2 ga-ke</td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Durian</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>4 g</td>
<td></td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>4 g</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>4 Og+c(≤30)</td>
<td>4 Og+c(≤30)</td>
<td>3 gk</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 gk</td>
<td></td>
</tr>
<tr>
<td>Papaya</td>
<td>5 Og+</td>
<td>5 Og+</td>
<td>4 g</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
<td>2 ga-ke</td>
<td></td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Guava</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Longan</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Grasses for -well areas</td>
<td>2 i+</td>
<td>2 i+</td>
<td>2 e</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 Og+</td>
<td>3 Og+</td>
<td>2 ke</td>
<td></td>
</tr>
<tr>
<td>Fodder legumes for -well areas</td>
<td>2 Og+aki+</td>
<td>2 Og+ai+</td>
<td>2 ke</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 g</td>
<td></td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
Fodder crops: Fodder grasses and legumes adapted to wet areas are suitable throughout the ADA. However, grazing is probably impractical due to the wet conditions and fodder crops should be cut and transported to animals kept elsewhere.

On the organic soils, the peaty topsoil and prolonged waterlogging are major limitations for grasses adapted to well drained conditions. However, they are suitable on the very deep yellow soils.

Prolonged waterlogging makes the areas of Organic soils marginally suitable for fodder legumes adapted to well drained areas. These species are moderately suitable on the very deep yellow soils with waterlogging as the major limitation.
5.6.6 ADA: KM26, Jalan Bukit Puan Labi

KM26, Jalan Bukit Puan Labi is located on an old coastal sand dune above the swampy country that covers much of western Belait. It includes both sand dunes and swamp as well as some other sloping land and alluvial flats between the slopes and the swamp. Most of the ADA is BU/MR.1 with the swampy part being AN (be) (Table 60). In BU/MR.1 the soils on the old dunes are Sandy poorly drained white soils, whilst those on other slopes are Texture contrast yellow soils. The alluvial flats between the slopes and the swamp have Organic poorly drained moderately deep sulfidic soils. The swamps have Mineral sulfuric and Mineral sulfidic organic soils, similar to those found at Melayan A and Labi Lama.

Table 60: Areas of map units within KM26, Jalan Bukit Puan Labi ADA

<table>
<thead>
<tr>
<th>Map units</th>
<th>ADA</th>
<th>AN (be)</th>
<th>BU/MR.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM 26, Jalan Bukit Puan Labi</td>
<td>16 ha</td>
<td>35 ha</td>
<td></td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence landuse on the Organic soils in the lower, swampy parts of the ADA are peaty topsoils, prolonged waterlogging, flat slopes, shallow sulfidic/sulfuric material, soil acidity/aluminium toxicity, high P fixation and sometimes low K reserves (Table 61). The Organic poorly drained moderately deep sulfidic soils on alluvial flats have similar attributes except for the sandy texture, less severe waterlogging and deeper sulfidic material. In addition, they do not suffer from high P fixation, but do have high leaching potential.

On the slopes, the major attributes are the sandy over loam texture, steep gradients, erosion hazard (exacerbated by the texture contrast profile), soil acidity/aluminium toxicity, low K reserves and high leaching potential. The White soils of the dunes have sandy texture, prolonged waterlogging, low K reserves and high leaching potential.

Land Suitability

About a quarter of the area of this ADAs comprises Organic soils (Table 17). The long term sustainability of agriculture on these soils is questionable as discussed in Section 4.1. This is particularly the case in areas mapped as AN (be), which are mostly Organic soils.

Rice: The Organic soils in the low parts of the ADA are marginally suitable for rice, because of the risk of sterile panicles associated with growing rice on organic soils. Elsewhere rice is unsuitable because of the sandy textures and/or the slope (Table 61).

Vegetables: The ADA is moderately suitable for vegetables. On the Organic soils the major limitations are peaty topsoil, prolonged waterlogging, shallow sulfidic/sulfuric material and soil acidity/aluminium toxicity. The major limitation on the Organic poorly drained sulfidic soils is soil acidity/aluminium toxicity.

On the slopes the major limitations for vegetables are soil acidity/aluminium toxicity and the difficulty of field operations on steep slopes. Erosion hazard is also a limitation for root vegetables. Prolonged waterlogging is the major limitation on the White soils of the dunes.

Short duration crops: The Organic soils of the low parts of the ADA are only marginally suitable for most short duration crops because of prolonged waterlogging. Sensitive species such as soya and mung bean are unsuitable. Crops more tolerant of such conditions – ginger and turmeric – are instead limited by the organic topsoil. The Sulfidic soils on the alluvial flats have less severe waterlogging and greater depth to sulfidic material. Hence they are moderately suitable for short duration crops with major limitations due to soil acidity/aluminium toxicity and/or waterlogging.

The slopes are moderately suitable for short duration crops, with major limitations due to soil acidity/aluminium toxicity, erosion hazard and the difficulty of field operations on steep
Table 61: Attributes and crop suitability of Soil Subtypes within the KM26, Jalan Bukit Puan Labi ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>AN (be) 40%</th>
<th>AN (be) 35%</th>
<th>AN (be) 25%</th>
<th>BU/MR.1 30%</th>
<th>BU/MR.1 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral sulfidic organic soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see page 54)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terric Sulfisaprists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terric Sulfosaprists</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic poorly drained moderately deep sulfidic soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see page 126)</td>
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</tr>
<tr>
<td>Texture contrast yellow soils</td>
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<td></td>
</tr>
<tr>
<td>(see page 83)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
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<td>Terric Sulfisaprists</td>
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<td>Sulfic Fluvaquents</td>
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<td>Arenic Paleudults</td>
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<td>Alluvial flats</td>
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<td>S</td>
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<tr>
<td>Subsoil type</td>
<td>L</td>
<td>C</td>
<td>S</td>
<td>L</td>
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</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
<td>g</td>
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<tr>
<td>Slope (%)</td>
<td>0%</td>
<td>2%</td>
<td>3%</td>
<td>25%</td>
<td></td>
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<tr>
<td>Max. slope (%)</td>
<td></td>
<td></td>
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<tr>
<td>Erosion risk (w)</td>
<td></td>
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<tr>
<td>Sulfidic horizon (cm) &amp; depth</td>
<td>c(30)</td>
<td>c(30)</td>
<td>c(70)</td>
<td></td>
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<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
<td>a</td>
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<td>Low K reserves (k)</td>
<td>k</td>
<td>k</td>
<td>k</td>
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<td></td>
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<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
<td></td>
<td></td>
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<tr>
<td>Cracking clays (v)</td>
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<td>High leaching (e)</td>
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<tr>
<td>FCC</td>
<td>OLG+6%c(30)aki+</td>
<td>OCg+2%c(30)ai+</td>
<td>SSg3%c(70)ake</td>
<td>e</td>
<td>e</td>
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<td>Crop Suitability Ratings2</td>
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<tr>
<td>Rice</td>
<td>4 O</td>
<td>4 O</td>
<td>5 S</td>
<td>5 S&gt;15%</td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>3 a</td>
<td>3 &gt;20%a</td>
<td></td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 Og+c(≤40)a</td>
<td>3 Og+c(≤40)a</td>
<td>3 a</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 ga</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 ga</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 ga</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 O</td>
<td>4 O</td>
<td>3 a</td>
<td>3 &gt;20%wa</td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 g</td>
<td>3 w</td>
<td></td>
</tr>
<tr>
<td>Durian</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>5 S</td>
<td>5 S</td>
<td></td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 Sgc(≤75)a</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>5 S</td>
<td>5 S</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 Sga</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>4 Og+c(≤30)</td>
<td>4 Og+c(≤30)</td>
<td>3 Sgak</td>
<td>3 Sak</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 gc(≤75)ak</td>
<td>3 ak</td>
<td></td>
</tr>
<tr>
<td>Papaya</td>
<td>5 Og+</td>
<td>5 Og+</td>
<td>4 g</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
<td>3 ga</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 gc(≤75)ja</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5 c(≤30)</td>
<td>5 c(≤30)</td>
<td>3 Sgc(≤75)ja</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5 Oc(≤30)</td>
<td>5 Oc(≤30)</td>
<td>4 S</td>
<td>4 S</td>
<td></td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 gc(≤75)ja</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Guava</td>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
<td>3 gc(≤75)ja</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+c(≤30)</td>
<td>5 g+c(≤30)</td>
<td>3 Sgc(≤75)ja</td>
<td>3 Sa</td>
<td></td>
</tr>
<tr>
<td>Longan</td>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
<td>3 gc(≤75)ja</td>
<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 i+</td>
<td>2 i+</td>
<td>2 Se</td>
<td>2 SNo g&gt;20%e</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 Og+</td>
<td>3 Og+</td>
<td>2 gke</td>
<td>2 &gt;20%wke</td>
<td></td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Og+aki+</td>
<td>2 Og+aki+</td>
<td>2 ake</td>
<td>2 &gt;20%wake</td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 ga</td>
<td>3 wa</td>
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</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
<table>
<thead>
<tr>
<th>5 S</th>
<th>5 Sg+</th>
<th>5 Sg+</th>
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</tr>
<tr>
<td>2 g+</td>
<td>3 g+</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
<td>2 g+ke</td>
</tr>
</tbody>
</table>

Sandy poorly drained white soils (see page 67)

Umbric Epiaquods

Dune slopes

$S$

$S$

$g^+$

2%
slopes. The White soils are unsuitable or marginally suitable for most short duration crops due to prolonged waterlogging. Crops suited to raised beds – ginger and turmeric – are moderately suitable.

**Fruit crops:** The Organic soils are unsuitable for most fruit crops due to prolonged waterlogging, shallow sulfidic/sulfuric material and organic topsoils. Shallow rooted fruit crops, such as citrus, banana and pineapple are marginally suitable.

The Sulfidic soils are moderately suitable for most fruit crops, with major limitations due to waterlogging and soil acidity/aluminium toxicity. The presence of sulfidic material, whilst too deep to be a severe limitation, is still within the root depth of many species, and is thus a major limitation. The sandy topsoil renders durian and langsat-duku unsuitable, and mangosteen marginally suitable. Papaya is also marginal because of waterlogging.

The slopes are moderately suitable for a wide variety of fruit crops, limited mainly by soil acidity/aluminium toxicity. The sandy topsoil is unsuitable for durian and langsat-duku, and marginally suitable for mangosteen.

Prolonged waterlogging makes the White soils of the dunes unsuitable for most fruit crops. Shallow rooted species, such as citrus, banana and pineapple are marginally suitable as are those showing a degree of tolerance to waterlogging – *Artocarpus* spp. and mangosteen.

**Fodder crops:** Fodder crops adapted to wet areas are suitable throughout the ADA. However, grazing is probably impractical, except on the slopes, due to the wet conditions, and fodder crops should be cut and transported to animals kept elsewhere.

Grasses adapted to well drained conditions are suitable on the Sulfidic soils and Texture contrast yellow soils of the alluvial flats and slopes. The Organic soils and White soils are moderately suitable due to prolonged waterlogging.

The Organic soils and the White soils are only marginally suitable for fodder legumes adapted to well drained conditions. These species are moderately suitable on the Sulfidic soils due to waterlogging and soil acidity/aluminium toxicity. On the Texture contrast yellow soils of the slopes, these species are also moderately suitable and limited by soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
5.7 Soil Distribution in Temburong District

5.7.1 ADA: Labu Estate

The landscape of Labu Estate is hilly with two map units (Table 62). TTN covers the valley floor and lower slopes while BKT covers the upper slopes and crests. There is a well defined toposequence of soils from Poorly drained brown over grey soils in the valley bottoms, Moderately well drained yellow soils on the lower to mid slopes and Well drained yellow soils on the upper slopes and crests. The toposequence is similar to that in the other ADAs surveyed in Temburong District, but unlike the others the valley in Labu Estate is not associated with a large river. Thus the river terraces found in the other Temburong ADAs, and their associated soils, are not found in Labu Estate.

Table 62: Areas of map units within Labu Estate ADA

<table>
<thead>
<tr>
<th></th>
<th>Map units</th>
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<tbody>
<tr>
<td>ADA</td>
<td>BKT</td>
</tr>
<tr>
<td>Labu Estate</td>
<td>79 ha</td>
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</tbody>
</table>

Soil Attributes

The FCC attributes that influence landuse on the Brown over grey soils on the alluvial flats are clay topsoils, prolonged waterlogging, flat slopes, moderate soil acidity/aluminium toxicity (a-), low K reserves and high P fixation (Table 63). On the Yellow soils on the slopes, the major attributes are loam or clay topsoils, steep slopes, erosion hazard, soil acidity/aluminium toxicity, low K reserves and P fixation.

Land Suitability

Rice: The alluvial flats are suitable for rice, but the the surrounding slopes are too steep and are unsuitable (Table 63).

Vegetables: Much of the ADA is moderately suitable for vegetables. On the alluvial flats the major limitation is prolonged waterlogging, whereas on the slopes it is soil acidity/aluminium toxicity and, in the case of root vegetables, erosion hazard. The difficulty of field operations is a major limitation on slopes steeper than 20%. On slopes greater than 35%, vegetable crops are only marginally suitable, and on those greater than 55% they are unsuitable.

Short duration crops: The alluvial flats are marginally suitable for most other short duration crops due to prolonged waterlogging. Species sensitive to waterlogging, such as soya and mung bean, are unsuitable, but those that can be grown on raised beds, such as ginger and turmeric, are moderately suitable. The Yellow soils of the slopes are generally moderately suitable for short duration crops, with major limitations due to soil acidity/aluminium toxicity and erosion hazard. However, the difficulty of field operations is a major limitation on slopes steeper than 20%. On slopes greater than 35%, short duration crops are only marginally suitable, and on those greater than 55% they are unsuitable.

Fruit crops: Prolonged waterlogging of the alluvial flats makes them unsuitable for most fruit crops. Shallow rooted species, such as citrus, banana and pineapple, are marginally suitable, as are species, such as Artocarpus spp. and mangosteen, that are somewhat tolerant of waterlogging.

The slopes are generally moderately suitable for all fruit crops assessed, with soil acidity/aluminium toxicity as the major limitation, except where the topsoil texture is clayey (Well drained yellow soils) which is only marginally suitable for citrus. Fruit crops are only marginally suitable where the gradient exceeds 65%, due to the risk of mass soil movement (i.e. land slippage).

Fodder crops: Most of the ADA is suitable for grass and fodder legume species that are adapted to wet conditions, except where the slope exceeds 55% which is only moderately
Table 63: Attributes and crop suitability of Soil Subtypes within the Labu Estate ADA.
In the table, soils are generally arranged with those in the lowest landscape positions on the left and those in the highest positions on the right.

<table>
<thead>
<tr>
<th>Map units and % of Soil Subtype in map unit</th>
<th>TTN 80%</th>
<th>TTN 20%</th>
<th>BKT 100%</th>
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<tr>
<td>Component Soil Subtypes</td>
<td>Poorly drained brown over grey soils</td>
<td>Moderately well drained yellow soils</td>
<td>Well drained yellow soils</td>
</tr>
<tr>
<td>(see page 111)</td>
<td>(see page 103)</td>
<td>(see page 103)</td>
<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaqualfs</td>
<td>Oxyaquic Haplohumults</td>
<td>Typic Haplohumults</td>
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<td>General landscape position</td>
<td>Alluvial flats</td>
<td>Mid to lower slopes</td>
<td>Crests</td>
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<td>Soil Attribute Ratings</td>
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<tr>
<td>Topsoil type</td>
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<td>L</td>
<td>C</td>
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<tr>
<td>Subsoil type</td>
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<td>C</td>
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<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>20%</td>
<td>60%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
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<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
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<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a</td>
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<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
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<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i</td>
<td></td>
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<tr>
<td>Cracking clays (v)</td>
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<tr>
<td>High leaching (e)</td>
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<td></td>
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</tr>
<tr>
<td>FCC</td>
<td>CCg+2%a-ki+</td>
<td>LC20-70%waki</td>
<td>CC60-70%waki</td>
</tr>
<tr>
<td>Crop Suitability Ratings</td>
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<td></td>
</tr>
<tr>
<td>Rice</td>
<td>2 g+ki+</td>
<td>5 &gt;15%</td>
<td>5 &gt;15%</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+</td>
<td>3 a [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 g+</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 g+</td>
<td>3 wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>3 w [4 &gt;55%]</td>
<td>4 &gt;55%</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 Cg+</td>
<td>3 a [4 &gt;65%]</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 i+</td>
<td>2 No gi [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g+</td>
<td>2 wki [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Cg+ki+</td>
<td>2 waki [3 &gt;55%]</td>
<td>3 &gt;55%</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>3 wa</td>
<td>3 C&gt;35%wa</td>
</tr>
</tbody>
</table>

1 Soil attribute codes are given in Table 6 and Table 8.
2 Land suitability classes are defined in Section 3.3.3.
suitable. Grasses adapted to well drained conditions are moderately suitable on the alluvial flats due to waterlogging, but are suitable on the slopes.

Fodder legumes adapted to well drained conditions are only marginally suitable on the alluvial flats due to prolonged waterlogging. Elsewhere they are moderately suitable with major limitations due to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
5.7.2 ADAs: Selangan, Bakarut and Selapon

These three ADAs all have similar landscapes that include alluvial flats, alluvial terraces and the surrounding hills, although they differ in the proportions that these different landscape elements occupy. The soils on the alluvial flats along the rivers are Poorly drained brown over grey soils. The alluvial terraces above the flats consist of Moderately well drained clayey very deep yellow soils. The lower to mid slopes of the surrounding hills are Moderately well drained yellow soils, and the upper slopes and crests are Well drained yellow soils.

Selapon includes all of the above landscape components. Bakarut is dominated by the hilly components with only a small area of alluvial terraces, whilst Selangan includes mainly alluvial flats and terraces without any hilly component. There are a variety of map units that cover different parts of these landscapes (Table 64). TTN-1, BDG-1, BDG-TNN-1 and JML-2 cover the alluvial flats and terraces. BDG-2 covers only alluvial terraces. KKP-1 covers alluvial terraces and the lower to mid slopes of the surrounding hills. RMB-2 includes the lower to mid slopes, and BKT-4 the lower slopes to the hill crests.

Table 64: Areas of map units within Selangan, Bakarut and Selapon ADAs

<table>
<thead>
<tr>
<th>ADA</th>
<th>BDG-1</th>
<th>BDG-TTN-1</th>
<th>BDG-2</th>
<th>BKT-4</th>
<th>KKP-1</th>
<th>RMB-2</th>
<th>TTN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selangan</td>
<td>46 ha</td>
<td>10 ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakarut</td>
<td>9 ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29 ha</td>
<td></td>
</tr>
<tr>
<td>Selapon</td>
<td>16 ha</td>
<td></td>
<td>25 ha</td>
<td>15 ha</td>
<td>1 ha</td>
<td>23 ha</td>
<td></td>
</tr>
</tbody>
</table>

Soil Attributes

The FCC attributes that influence landuse on the Brown over grey soils on the alluvial flats are clay topsoils, prolonged waterlogging, flat slopes, moderate soil acidity/aluminium toxicity (a-), low K reserves and high P fixation (Table 65). The attributes on the terraces are loam topsoils, soil acidity/aluminium toxicity and low K reserves. On the Yellow soils on the slopes, the major attributes are loam or clay topsoils, steep slopes, erosion hazard, soil acidity/aluminium toxicity, low K reserves and P fixation.

Land Suitability

Rice: The alluvial flats are suitable for rice. The alluvial terraces are moderately suitable for rice, but lack natural waterlogging. The surrounding slopes are too steep and are unsuitable (Table 65).

Vegetables: Much of the area of ADAs is suitable for vegetables. On the alluvial flats the major limitation is prolonged waterlogging, whereas on the terraces and slopes it is soil acidity/aluminium toxicity and, in the case of root vegetables, erosion hazard. The difficulty of field operations is a major limitation on slopes steeper than 20%. On slopes greater than 35%, vegetable crops are only marginally suitable, and on those greater than 55% they are unsuitable.

Short duration crops: The alluvial flats are marginally suitable for most other short duration crops due to prolonged waterlogging. Species sensitive to waterlogging, such as soya and mung bean, are unsuitable, but those that can be grown on raised beds, such as ginger and turmeric, are moderately suitable. The terraces are moderately suitable, with soil acidity/
<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Poorly drained brown over grey soils</th>
<th>Moderately well drained clayey very deep yellow soils</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaqualfs</td>
<td>Oxyaquic Paleu mults</td>
<td>Oxyaquic Haplu mults</td>
<td>Typic Haplu mults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
<td>Alluvial terrace</td>
<td>Mid to lower slopes</td>
<td>Crests</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

1. **Topsoil type**
   - BDG-1: C
   - BDG-TTN-1: L
   - JML-2: L
   - BKT-4: C
2. **Subsoil type**
   - BDG-1: C
   - BDG-TTN-1: C
   - JML-2: C
   - BKT-4: C
3. **Waterlogging (g, g+)**
   - BDG-1: g+
   - BDG-TTN-1: g+
   - JML-2: g+
   - BKT-4: g+
4. **Slope (%)**
   - BDG-1: 2%
   - BDG-TTN-1: 0%
   - JML-2: 20%
   - BKT-4: 60%
5. **Max. slope (%)**
   - BDG-1: 30%
   - BDG-TTN-1: 70%
   - JML-2: 70%
   - BKT-4: 70%
6. **Erosion risk (w)**
   - BDG-1: w
   - BDG-TTN-1: w
   - JML-2: w
   - BKT-4: w
7. **Sulphidic horizon (c) & depth, cm**
   - BDG-1: a
   - BDG-TTN-1: a
   - JML-2: a
   - BKT-4: a
8. **Aluminium (a, a-)**
   - BDG-1: a
   - BDG-TTN-1: a
   - JML-2: a
   - BKT-4: a
9. **Low K reserves (k)**
   - BDG-1: k
   - BDG-TTN-1: k
   - JML-2: k
   - BKT-4: k
10. **High P fixation (i, i-, i+)**
    - BDG-1: i+
    - BDG-TTN-1: i+
    - JML-2: i+
    - BKT-4: i+
11. **Cracking clays (v)**
    - BDG-1: v
    - BDG-TTN-1: v
    - JML-2: v
    - BKT-4: v
12. **High leaching (e)**
    - BDG-1: e
    - BDG-TTN-1: e
    - JML-2: e
    - BKT-4: e

### Crop Suitability Ratings

1. **Rice**
   - BDG-1: g+k+i+
   - BDG-TTN-1: g+k+i+
   - JML-2: g+k+i+
   - BKT-4: g+k+i+
2. **Leafy and fruit vegetables**
   - BDG-1: 3 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
3. **Root vegetables**
   - BDG-1: 3 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
4. **Groundnuts**
   - BDG-1: 4 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
5. **Soya and mung beans**
   - BDG-1: 5 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
6. **Maize**
   - BDG-1: 4 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
7. **Ginger and turmeric**
   - BDG-1: 3 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
8. **Cassava and sweet potato**
   - BDG-1: 4 g+
   - BDG-TTN-1: 2 ak
   - JML-2: 3 w
   - BKT-4: 3 w
9. **Durian**
   - BDG-1: 5 g+
   - BDG-TTN-1: 3 a
   - JML-2: 3 a
   - BKT-4: 3 a
10. **Rambutan**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
11. **Langsat-duku**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
12. **Citrus**
    - BDG-1: 4 Cg+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 4 C
13. **Banana**
    - BDG-1: 4 g+
    - BDG-TTN-1: 3 ak
    - JML-2: 3 ak
    - BKT-4: 3 ak
14. **Coconut**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 ak
    - JML-2: 3 ak
    - BKT-4: 3 ak
15. **Papaya**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
16. **Pineapple**
    - BDG-1: 4 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
17. **Mango and cashew nut**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
18. **Artocarpus**
    - BDG-1: 4 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
19. **Mangosteen**
    - BDG-1: 4 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
20. **Dragon fruit**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
21. **Guava**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
22. **Star fruit**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
23. **Longan**
    - BDG-1: 5 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 a
    - BKT-4: 3 a
24. **Grasses for -wet areas**
    - BDG-1: 2 i+
    - BDG-TTN-1: 2 No g
    - JML-2: 2 No g [3 >55%]
    - BKT-4: 3 >55%
25. **-well drained areas**
    - BDG-1: 3 g+
    - BDG-TTN-1: 2 k
    - JML-2: 2 wki [3 >55%]
    - BKT-4: 3 >55%
26. **Fodder legumes for -wet areas**
    - BDG-1: 2 Cg+ki+
    - BDG-TTN-1: 2 ak
    - JML-2: 2 waki [3 >55%]
    - BKT-4: 3 >55%
27. **-well drained areas**
    - BDG-1: 4 g+
    - BDG-TTN-1: 3 a
    - JML-2: 3 wa
    - BKT-4: 3 C >35%wa

---

1. Soil attribute codes are given in Table 6 and Table 8.
2. Land suitability classes are defined in Section 3.3.3.
aluminium toxicity as the major limitation. The terraces are suitable for more acid tolerant species such as cassava and sweet potato. The Yellow soils of the slopes are generally moderately suitable for short duration crops, with major limitations due to soil acidity/aluminium toxicity and erosion hazard. However, the difficulty of field operations is a major limitation on slopes steeper than 20%. On slopes greater than 35%, short duration crops are only marginally suitable, and on those greater than 55% they are unsuitable.

**Fruit crops:** Prolonged waterlogging of the alluvial flats makes them unsuitable for most fruit crops. Shallow rooted species, such as citrus, banana and pineapple, are marginally suitable, as are species, such as *Artocarpus* spp. and mangosteen, that are somewhat tolerant of waterlogging.

The terraces and slopes are generally moderately suitable for all fruit crops assessed, with soil acidity/aluminium toxicity as the major limitation, except where the topsoil texture is clayey (Well drained yellow soils) which is only marginally suitable for citrus. Fruit crops are only marginally suitable where the gradient exceeds 65% due to the risk of mass soil movement (i.e. land slippage).

**Fodder crops:** Most of the ADA is suitable for grasses and for fodder legume species that are adapted to wet conditions. The exceptions are that suitability is moderate where the slope exceeds 55%, and that the suitability of grass species adapted to well drained conditions is moderate on the alluvial flats, due to waterlogging.

Fodder legumes adapted to well drained conditions are only marginally suitable on the alluvial flats due to prolonged waterlogging. Elsewhere they are moderately suitable with major limitations due to soil acidity/aluminium toxicity. In addition, the poorer ground cover of some fodder legumes can increases the risk of erosion. Pinto peanut (*Arachis pintoi*) is one species that can give good ground cover once established.
### 5.8 Summary of Land Suitability in the ADAs

In Part 4, the soil attributes of the Soil Types and Subtypes are described, together with their suitability for a variety of crops. In Part 5, the ADAs in each district were grouped into similar landscapes and the spatial variation of Soil Types, soil attributes and suitability classifications were discussed, usually in the context of toposequences within the landscape. Here this information is summarised by listing the crops that are suitable for different parts of each ADA.

#### 5.8.1 Brunei-Muara District

Note that Sungai Tajau ADA is included in Section on the Tutong District.

**Low Lying, Alluvial Plains (Organic Soils)**

<table>
<thead>
<tr>
<th>ADAs:</th>
<th>Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumapas, Limpaki, Pengkalan Batu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Types:</td>
<td>Organic soils</td>
</tr>
<tr>
<td>Suitable crops:</td>
<td>Grass species adapted to wet areas</td>
</tr>
<tr>
<td></td>
<td>Fodder legume species adapted to wet areas</td>
</tr>
<tr>
<td>Moderately suitable crops:</td>
<td>Leafy, fruit and root vegetables (except where sulfidic material occurs within 20 cm of the surface)</td>
</tr>
<tr>
<td></td>
<td>Grass species adapted to well drained conditions</td>
</tr>
</tbody>
</table>

**Low Lying, Alluvial Plains (Sulfuric and Sulfidic Soils)**

<table>
<thead>
<tr>
<th>ADAs:</th>
<th>Betumpu, Si Tukak Limau Manis, Si Bongkok Parit Masin, Lumapas, Limpaki, Pengkalan Batu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Types:</td>
<td>Sulfuric and Sulfidic soils</td>
</tr>
<tr>
<td>Suitable crops:</td>
<td>Grass species adapted to wet areas</td>
</tr>
<tr>
<td></td>
<td>Fodder legume species adapted to wet areas</td>
</tr>
<tr>
<td>Where waterlogging is less severe:</td>
<td>Grass species adapted to well drained conditions</td>
</tr>
<tr>
<td>Moderately suitable crops:</td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Leafy, fruit and root vegetables</td>
</tr>
<tr>
<td></td>
<td>Ginger and turmeric</td>
</tr>
<tr>
<td>Where waterlogging is less severe:</td>
<td>Groundnuts</td>
</tr>
<tr>
<td></td>
<td>Soya and mung bean</td>
</tr>
<tr>
<td></td>
<td>Maize</td>
</tr>
<tr>
<td></td>
<td>Cassava and sweet potato</td>
</tr>
<tr>
<td></td>
<td>Fodder legume species adapted to well drained conditions</td>
</tr>
<tr>
<td>Where waterlogging is prolonged:</td>
<td>Grass species adapted to well drained conditions</td>
</tr>
</tbody>
</table>

**Low Lying, Alluvial Plains (Cracking Clay Soils)**

<table>
<thead>
<tr>
<th>ADAs:</th>
<th>Wasan, Si Tukak Limau Manis, Limpaki</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Types:</td>
<td>Cracking clay soils</td>
</tr>
<tr>
<td>Suitable crops:</td>
<td>Rice</td>
</tr>
<tr>
<td>Moderately suitable crops:</td>
<td>Leafy and fruit vegetables</td>
</tr>
<tr>
<td></td>
<td>Grass species adapted to wet areas</td>
</tr>
<tr>
<td></td>
<td>Grass species adapted to well drained conditions</td>
</tr>
<tr>
<td></td>
<td>Fodder legume species adapted to wet areas</td>
</tr>
</tbody>
</table>
Valley Bottoms

ADAs: Luahan
Soil Types: Brown over grey soils
Suitable crops: Rice
Grass species adapted to wet areas
Fodder legume species adapted to wet areas
Moderately suitable crops: Leafy, fruit and root vegetables
Ginger and turmeric
Grass species adapted to well drained conditions

Hill Slopes

ADAs: Si Tukak Limau Manis, Luahan, Tungku
Soil Types: Yellow soils, Very deep yellow soils
Suitable crops: Where slope <55%:
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas
Moderately suitable crops: Fodder legume species adapted to well drained conditions
Where slope <65%:
All fruit crops assessed (see Table 2)
Where slope <55%:
Cassava and sweet potato
Where slope <35%:
Leafy, fruit and root vegetables
Groundnuts
Soya and mung bean
Maize
Ginger and turmeric

Dunes

ADAs: Tungku
Soil Types: White soils
Suitable crops: Rice
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas
Moderately suitable crops: Leafy, fruit and root vegetables
Groundnuts
Soya and mung bean
Maize
Ginger and turmeric
Cassava and sweet potato
All fruit crops assessed (see Table 2) except:
   Durian
   Langsat-duku
   Papaya
Fodder legume species adapted to well drained conditions
Flats Between Dunes

ADAs: Tungku
Soil Types: Sulfuric soils
Suitable crops: Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas
Moderately suitable crops: Fodder legume species adapted to well drained conditions

5.8.2 Tutong District

Alluvial Valley Flats and Lower Slopes

ADAs: Kupang, Maraburong, Padnunok/Sg Burong, Batang Mitus (Buah), Batang Mitus (Halaman), Birau (P.P. Muda), Birau (Penyelidikan) and Sg Tajau (Brunei-Muara)
Soil Types: Brown over grey soils and Very deep yellow soils
Suitable crops: Rice
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas
Moderately suitable crops: Leafy, fruit and root vegetables
Groundnuts
Soya and mung bean
Maize
Ginger and turmeric
Cassava and sweet potato
All fruit crops assessed (see Table 2) except:
  Durian
  Langsat-duku
  Papaya
  Citrus (moderately suitable only on lower slopes)
Fodder legume species adapted to well drained conditions

Mid Slopes, Upper Slopes and Crests

ADAs: Kupang, Maraburong, Padnunok/Sg Burong, Batang Mitus (Buah), Batang Mitus (Halaman), Birau (P.P. Muda), Birau (Penyelidikan) and Sg Tajau (Brunei-Muara)
Soil Types: Yellow soils and Very deep yellow soils
Suitable crops: Where slope <55%:
  Grass species adapted to wet areas
  Grass species adapted to well drained conditions
  Fodder legume species adapted to wet areas
Moderately suitable crops: Fodder legume species adapted to well drained conditions
Where slope >55%:
  Grass species adapted to wet areas
  Grass species adapted to well drained conditions
  Fodder legume species adapted to wet areas
Where slope <65%:
  All fruit crops assessed (see Table 2)
Where slope <55%:
  Cassava and sweet potato
Where slope <35%:
5.8.3 Belait District

Low Lying, Alluvial Plains and Swamps (Organic Soils)

ADAs: Merangking Bukit Sawat, Melayan A, Labi Lama, KM26 Jalan Bukit Puan Labi
Soil Types: Organic soils
Suitable crops: Grass species adapted to wet areas
Fodder legume species adapted to wet areas
Moderately suitable crops: Leafy, fruit and root vegetables
Grass species adapted to well drained conditions

Alluvial Plains

ADAs: Rampayoh, Labi Lama
Soil Types: Very deep yellow soils
Suitable crops: Rice
Leafy, fruit and root vegetables
Ginger and turmeric
Mangosteen
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to well drained conditions
Moderately suitable crops: Groundnuts
Soya and mung bean
Maize
Cassava and sweet potato
All fruit crops assessed (see Table 2) except:
Durian
Langsat-duku
Papaya
Mangosteen
Fodder legume species adapted to well drained conditions

Hill Slopes

ADAs: Rampayoh, Tungulian, Merangking Bukit Sawat, Melayan A, KM26 Jalan Bukit Puan Labi
Soil Types: Texture contrast yellow soils, Very deep yellow soils, Yellow soils
Suitable crops: Where slope <55%:
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas

Moderately suitable crops: Fodder legume species adapted to well drained conditions
Where slope >55%:
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas

Where slope <65% and soil is not Texture contrast yellow soil:
All fruit crops assessed (see Table 2)

Where slope < 65% and soil is Texture contrast yellow soil:
All fruit crops assessed (see Table 2) except:
- Durian
- Langsat-duku
- Mangosteen

Where slope <55%:
- Cassava and sweet potato

Where slope <35%:
- Leafy, fruit and root vegetables
- Groundnuts
- Soya and mung bean
- Maize
- Ginger and turmeric

**Valley Bottoms**

ADAs: Merangking Bukit Sawat

Soil Types: Brown over grey soils

Suitable crops:
- Rice
- Grass species adapted to wet areas
- Fodder legume species adapted to wet areas

Moderately suitable crops:
- Leafy, fruit and root vegetables
- Ginger and turmeric
- Grass species adapted to well drained conditions

**Alluvial Terraces**

ADAs: Merangking Bukit Sawat

Soil Types: Very deep yellow soils

Suitable crops:
- Cassava and sweet potato
- Grass species adapted to wet areas
- Grass species adapted to well drained conditions
- Fodder legume species adapted to wet areas

Moderately suitable crops:
- Rice
- Leafy, fruit and root vegetables
- Groundnuts
- Soya and mung bean
- Maize
- Ginger and turmeric

All fruit crops assessed (see Table 2)

Fodder legume species adapted to well drained conditions

**Dunes**

ADAs: KM26 Jalan Bukit Puan Labi

Soil Types: White soils

Suitable crops:
- Grass species adapted to wet areas
- Fodder legume species adapted to well drained conditions

Moderately suitable crops:
- Leafy, fruit and root vegetables
- Ginger and turmeric
- Grass species adapted to well drained conditions
**Flats Between Dunes**

ADAs: KM26 Jalan Bukit Puan Labi

Soil Types: Sulfidic soils

Suitable crops: Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas

Moderately suitable crops: Leafy, fruit and root vegetables
Groundnuts
Soya and mung bean
Maize
Ginger and turmeric
Cassava and sweet potato

All fruit crops assessed (see Table 2) except:
- Durian
- Langsat-duku
- Papaya
- Mangosteen

Fodder legume species adapted to well drained conditions

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**5.8.4 Temburong District**

**Alluvial Valley Flats**

ADAs: Labu Estate, Selangan, Bakarut, Selapon

Soil Types: Brown over grey soils

Suitable crops: Rice
Grass species adapted to wet areas
Fodder legume species adapted to wet areas

Moderately suitable crops: Leafy, fruit and root vegetables
Ginger and turmeric
Grass species adapted to well drained conditions

---

**Alluvial Terraces**

ADAs: Selangan, Bakarut, Selapon

Soil Types: Very deep yellow soils

Suitable crops: Cassava and sweet potato
Grass species adapted to wet areas
Grass species adapted to well drained conditions
Fodder legume species adapted to wet areas

Moderately suitable crops: Rice
Leafy, fruit and root vegetables
Groundnuts
Soya and mung bean
Maize
Ginger and turmeric
All fruit crops assessed (see Table 2)
Fodder legume species adapted to well drained conditions

---

**Hill Slopes**

ADAs: Labu Estate, Selangan, Bakarut, Selapon

Soil Types: Yellow soils
Suitable crops:  
*Where slope <55%:*  
Grass species adapted to wet areas  
Grass species adapted to well drained conditions  
Fodder legume species adapted to wet areas

Moderately suitable crops:  
Fodder legume species adapted to well drained conditions

*Where slope >55%:*  
Grass species adapted to wet areas  
Grass species adapted to well drained conditions  
Fodder legume species adapted to wet areas

*Where slope <65%:*  
All fruit crops assessed (see Table 2)

*Where slope <55%:*  
Cassava and sweet potato

*Where slope <35%:*  
Leafy, fruit and root vegetables  
Groundnuts  
Soya and mung bean  
Maize  
Ginger and turmeric
Appendix A  Interpretation of Fertility Capability Classification for Crops

A.1 Short Duration Crops

A.1.1 Modern Domesticated Rice (Oryza sativa)

FCC was interpreted for rice using the following information:

- Sanchez and Buol (1985) and White et al. (2000) provide interpretations of FCC conditions for rice.
- Rice needs heavy, relatively impervious waterlogged soils. Acidity and aluminium toxicity are generally not important as flooding tends to neutralise acidity (Skerman and Riveros, 1990).
- Moderately acid soil is not harmful to rice but is usually associated with low nutrient availability (Williams 1975c).
- An impermeable layer is required just below the worked horizon (25 cm) to impede downward movement of water. (Williams 1975c).
- Some degree of drainage or some lateral movement of water is desirable to prevent excessive reduction of the soil. (Williams 1975c).
- Sulfidic soils can have toxic levels of H₂S. (Williams 1975c).
- Peat swamps (‘O’ attribute) are not suitable for rice due to the need for control of the watertable, and common occurrence of floral sterility and empty panicles in modern domesticated rice varieties. Rice can be grown but need high management (Andriesse 1988).

Soil type

\[
\begin{array}{c|c}
S & 5 \\
L & 1 \\
C & 1 \\
O & 4
\end{array}
\]

Does not hold water or nutrients.

Problems with toxicity, low nutrients, floral sterility in rice.

Waterlogging (g)

\[
\begin{array}{c|c}
No g & 3 \\
g & 1 \\
g+ & 2
\end{array}
\]

Or greater.

Possible zinc deficiency.

Slope

\[
\begin{array}{c|c}
0-2\% & 1 \\
3-5\% & 2 \\
6-10\% & 3 \\
11-15\% & 4 \\
>15\% & 5
\end{array}
\]

Would need terracing.

Would need major landscaping works.

Erosion (w)

\[
\begin{array}{c|c}
No w & 1 \\
w & 3
\end{array}
\]

Sulfidic (c)

\[
\begin{array}{c|c}
No c or >60 cm & 1 \\
c at 36-60 cm & 2 \\
c at 26-35 cm & 3 \\
c \leq 25 cm & 4
\end{array}
\]

Likely Fe and S toxicity in anaerobic conditions and Al toxicity when aerobic.

Needs constant flooding to reduce toxicity problem. Need to flush soil at land preparation.
Aluminium (a)
- No a 1
- a- 1
- a 2

Low potassium reserves (k)
- No k 1
- k 2

High P fixation (i)
- No rating 1
- i- 2
- i 2
- i+ 2 Needs varieties tolerant to iron and Al toxicity.

Cracking clays (v)
- No v 1

High leaching (e)
- No e 1
- e 2

Based on these initial criteria, suitable Soil Subtypes for rice are shown in Table 66.
## Table 66: Rice - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfur horizon (c and depth)</th>
<th>Aluminum (a, a-)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>Cracking height (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
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<tbody>
<tr>
<td><strong>Organic soils</strong></td>
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<td>Mineral sulfuric</td>
<td>Saprists</td>
<td>OCG+2%c(30)a+i</td>
<td>4</td>
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<td>5 &gt;15%</td>
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<td>5 &gt;15%</td>
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<td>5 &gt;15%</td>
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<td>2 g+ki+</td>
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<td>3 c(≤35)</td>
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<td><strong>Grey soils</strong></td>
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</table>
A.1.2 Leafy and Fruit Vegetables

This assessment covers the following crops:

**Leafy vegetables**
- Kobis (Cabbage) \( Brassica oleracea \) var. \( capitata \)
- Kailan (Italian) \( Brassica alboglabra \)
- Daun Bawang (Shallot shoot) \( Allium cepa L. \)
- Kangkung (Water spinach) \( Ipomoea aquatica \)
- Sawi \( Brassica spp. \)
- Bayam (Spanish spinach) \( Amaranthus spp. \)

**Fruit vegetables**
- Tomato (Tomato) \( Lycopersicum esculentum \)
- Lada (Chilli) \( Capsicum annum \)
- Kacang panjang (Long bean) \( Vigna sinensis \) var. \( sesquipedalis \)
- Jagung niuda (Baby corn) \( Zea mays \)
- Terong (Brinjal) \( Solanum melongena \)
- Labu kuning (Pumpkin) \( Cucurbita spp. \)
- Timun (Cucumber) \( Cucumis sativus \)
- Kacang buncis (French bean) \( Phaseolus vulgaris \)
- Bendir (Lady's Finger) \( Hibiscus esculentus \)
- Petola (Angled loofah) \( Luffa acutangula \)
- Peria (Bitter gourd) \( Momordica spp. \)
- Labu Air (Bottle gourd) \( Lagenaria siceraria (Mol) Standl \)

FCC was interpreted for leaf and fruit vegetables using composite of information from AVRDC (1990); Hastie (1994); Knott (1962); Tindal (1983) and Yamaguchi (1983).

**Soil type**
- S 2
- L 1
- C 1
- O 3

**Waterlogging (g)**
- No g 1
- g 2
- g+ 3

 Need good drainage.

**Slope**
- 0-10% 1
- 11-20% 2
- 21-35% 3
- 36-55% 4
- >55% 5

 May need revision according to specific vegetable and local knowledge.

**Erosion (w)**
- No w 1
- w 2

**Sulfidic (c)**
- No c or >60 cm 1
- c at 41-60 cm 2
- c at 21-40 cm 3
- c at ≤20 cm 4

**Aluminium (a)**
- No a 1
- a- 2
- a 3
Low potassium reserves (k)
   No k 1
   k 2

High P fixation (i)
   No rating 1
   i- 2
   i 2
   i+ 2

Cracking clays (v)
   No v 1
   v 3 Less suited to heavy soil.

High leaching (e)
   No e 1
   e 2

Based on these initial criteria, suitable Soil Subtypes for leafy and fruit vegetables are shown in Table 67.
Table 67: Leafy and fruit vegetables - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphate horizon (c) and depth (m)</th>
<th>Aluminium (a)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High Leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
<th>Modified suitability rating for max. slope</th>
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<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosapric</td>
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<td>Very deep yellow soils</td>
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<td>LLG2%-a-ke</td>
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<td>LC15-30%waki</td>
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<td>Aeriq Epiqualt</td>
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<td>Hydraulentic Sulfuquaetes</td>
<td>SSG3%-G(0)</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>c(≤20)</td>
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<td>1</td>
<td>3</td>
<td>c(≤40)a</td>
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<td>1</td>
<td>3</td>
<td>g+c(≤40)a</td>
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<td>Humraqueptic</td>
<td>CCG0%-aki</td>
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<td>1</td>
<td>3</td>
<td>a</td>
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</table>
A.1.3 Root Vegetables

This assessment covers the following crops:

Lobak Putih (Radish)  
*Raphanus sativus*

Onion  
*Allium cepa*

Composite of information from AVRDC (1990); Hastie (1994); Knott (1962); Tindal (1983) and Yamaguchi (1983).

**Soil type**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Value</th>
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<td>S</td>
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<tr>
<td>L</td>
<td>1</td>
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<tr>
<td>C</td>
<td>2</td>
</tr>
<tr>
<td>O</td>
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**Waterlogging (g)**

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<td>g</td>
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<td>g+</td>
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Needs good drainage.

**Slope**

<table>
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<tbody>
<tr>
<td>0-10%</td>
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<tr>
<td>11-20%</td>
<td>2</td>
</tr>
<tr>
<td>21-35%</td>
<td>3</td>
</tr>
<tr>
<td>36-55%</td>
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<tr>
<td>&gt;55%</td>
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**Erosion (w)**

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<tr>
<td>w</td>
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</tbody>
</table>

Measures needed to prevent erosion after harvest.

**Sulfidic (c)**

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<th>Value</th>
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<tr>
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</tr>
<tr>
<td>c at 41-60 cm</td>
<td>2</td>
</tr>
<tr>
<td>c at 21-40 cm</td>
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<tr>
<td>c ≤20 cm</td>
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**Aluminium (a)**

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<th>Value</th>
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<tr>
<td>a-</td>
<td>2</td>
</tr>
<tr>
<td>a</td>
<td>3</td>
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</table>

**Low potassium reserves (k)**

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**High P fixation (i)**

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<tr>
<td>i</td>
<td>2</td>
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<tr>
<td>i+</td>
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**Cracking clays (v)**

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</thead>
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<td>v</td>
<td>4</td>
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</table>

Less suited to heavy soil.

**High leaching (e)**

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<th>Value</th>
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<td>e</td>
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Based on these initial criteria, suitable Soil Subtypes for root vegetables are shown in Table 68.
Table 68: Root vegetables - Soil Subtype suitability.

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<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphuric horizon (c) and depth (a, a-)</th>
<th>Aluminium (K)</th>
<th>Low K reserves (L, L+)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High Leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
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<tr>
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<td>Terric Sulfasapristis</td>
<td>OCg+2%c(30)ai+</td>
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<td>3 Og+c(540)a</td>
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<td>Typic Sulfasapristis</td>
<td>OOG+2%c(15)ai+</td>
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<td>3 Og+c(540)a</td>
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A.1.4 Groundnut (Arachis hypogea)

FCC was interpreted for groundnut using the following information:

- Groundnut will grow and produce in most soils but the ability to harvest the crop with minimal losses determines the soil's suitability. Black cracking clays are not suitable (Crosthwaite 1994).
- Well drained friable soils include sand sandy loams, silt loams, friable clay loam and duplex (sand over clay) are suitable. Heavy clays should be avoided (Hatfield et al. 1993).
- Groundnut prefers well drained soil with medium textures, and slightly acidic (pH 5.5-6.5) (Jogloy et al. 1992).
- Aluminium is toxic at low pH. Optimum pH is 5.5-7.0 (Crosthwaite 1994).
- Low pH, flooding and low fertility are limiting factors for groundnut in SE Asia (Jogley et al. 1992).
- 0-40% aluminium saturation is best; 40-70% is suitable; >70% is not suitable (Moody and Cong 2008).

**Soil type**

| S | 2 | Needs fertilizer and good water. |
| L | 1 |
| C | 1 |
| O | 3 | Needs drainage and raised beds. |

**Waterlogging (g)**

- No g | 1 |
- g | 3 |
- g+ | 4 |

**Slope**

- 0-10% | 1 |
- 11-20% | 2 |
- 21-35% | 3 |
- 36-55% | 4 |
- >55% | 5 |

**Erosion (w)**

- No w | 1 |
- w | 3 | Measures needed to prevent erosion after harvest. |

**Sulfidic (c)**

- No c or c at >60 cm | 1 |
- c at 41-60 cm | 2 |
- c at 21-40 cm | 3 |
- c ≤20 cm | 4 |

**Aluminium (a)**

- No a | 1 |
- a- | 2 | Requires a Ca source such as lime or dolomite in the podding zone. |
- a | 3 | Requires a Ca source such as lime or dolomite in the podding zone. |

**Low potassium reserves (k)**

- No k | 1 |
- k | 2 |
**High P fixation (i)**

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Potential toxic metal contamination issues.

**Cracking clays (v)**

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Less suited to heavy soil – harvest problems.

**High leaching (e)**

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**Comments**

- Groundnut will suffer from Cercospora and other diseases especially in the Brunei climate.
- It is normally grown in drier climates, or with heavy use of foliar fungicidal sprays if grown in the wet season.

Based on these initial criteria, suitable Soil Subtypes for groundnut plantation are shown in Table 69.
Table 69: Groundnut plantation - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphuric horizon (c) and depth (a)</th>
<th>Aluminum (a, a-)</th>
<th>LOW K reserves (K)</th>
<th>High P fixation (i, i+, i++)</th>
<th>Cracking clays (V)</th>
<th>High Leaching (e)</th>
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</table>
A.1.5 Soya beans (*Glycine max*) and Mung Beans (*Vigna radiata*)

FCC was interpreted for soy and mung beans using the following information:

**Soybean**

- Soybean can grow on a range of soil types but heavy clays should be avoided. It grows best on deep fertile clay loams with pH 6.0-7.5 (Anon. 1971).
- Well drained fertile loams with pH 6.0-7.5 are most suitable. Waterlogging is injurious (Anon. 2007b).
- Almost any soil with pH 6.0-7.0 is suitable. Excessive moisture is not acceptable but it will tolerate a degree of poor drainage. Well drained paddy fields can be used (Anon. ?a).
- In Brunei, the yield is related to the degree of drainage in paddy soils (Williams 1978).
- It can be grown in shallow drained peat soils (Andriesse 1988).
- It can only tolerate up to 40% aluminium saturation in the soil (Moody and Cong 2008).
- It will not tolerate flooding.
- Varietal selection is important.

**Mung Bean**

- Mung bean will grow on most soils with a preference for loams with pH 5.5-7.5. Root growth is restricted on heavy clays (Imrie 1997a).
- Black gram, a close relative, is more tolerant of waterlogging than mung bean (Imrie 1997b).
- Mung bean can only tolerate up to 40% aluminium saturation in the soil (Moody and Cong 2008).
- It could grow on peat if there is shallow drainage as for soybean.

**Soil type**

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<thead>
<tr>
<th>Soil</th>
<th>Code</th>
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<td>L</td>
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<td>Need drainage and raised beds.</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>Need good fertiliser and water supply.</td>
</tr>
<tr>
<td>O</td>
<td>3</td>
<td>Need drainage and raised beds.</td>
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**Waterlogging (g)**

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**Slope**

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<tr>
<td>11-20%</td>
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</tr>
<tr>
<td>36-55%</td>
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<tr>
<td>&gt;55%</td>
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**Erosion (w)**

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</table>
Sulfidic (c)

Likely Fe and S toxicity when anaerobic and Al toxicity when dry.

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<td>c at 21-40 cm</td>
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<tr>
<td>c ≤20 cm</td>
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</tbody>
</table>

Aluminium (a)

No a | 1
a-   | 2
a    | 3

Low potassium reserves (k)

No k | 1
k    | 2

High P fixation (i)

No i | 1
i-   | 2
i    | 2
i+   | 2

Cracking clays (v)

No v | 1
v    | 4 Less suited to heavy soil.

High leaching (e)

No e | 1
e    | 2

Based on these initial criteria, suitable Soil Subtypes for soya and mung beans are shown in Table 70.
<table>
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<th>Waterlogging (6, g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth</th>
<th>Aluminum (a, a-)</th>
<th>Low K reserves (k)</th>
<th>High P fixation (i+, i-, i+)</th>
<th>Cracking clays (V)</th>
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<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Epiaquafns</td>
<td>CCG2%a-ki+</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Sulfuric soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Aquets</td>
<td>Hydraulentic Sulfaquets SSG3%c(0)iake</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 c(≤20)</td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Sulfaquets</td>
<td>LCg3%c(30)i+</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 gc(≤50)</td>
<td></td>
</tr>
<tr>
<td>Sulfidic soils</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Aquets</td>
<td>Haplic Sulfaquents CCG0%c(30)i+</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 g+</td>
<td></td>
</tr>
<tr>
<td>Organic poorly drained</td>
<td>Thapto-Histic Sulfaquents</td>
<td>OCG2%c(30)i</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 Ogc(≤50)</td>
<td></td>
</tr>
<tr>
<td>Organic poorly drained moderately deep</td>
<td>Sulfac Fluvaquents</td>
<td>SSG3%c(70)iak</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 ga</td>
<td></td>
</tr>
<tr>
<td>Grey soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Humaquetic</td>
<td>CCG0%aki</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 ga</td>
<td></td>
</tr>
</tbody>
</table>
A.1.6 Maize (Zea mays L.)

FCC was interpreted for maize using the following information:

- Well drained, fertile, alluvial loams, deep latosols, or clay loams are preferred. Maize has no tolerance to flooding (Skerman and Riveros 1990).
- Maize grows on a wide range of soils but medium loams which are well drained, with high organic matter and pH 5.5-6.8 are preferable. (Tindall 1983)
- Acid soils reduce yield (Tindall 1983).
- Maize prefers well drained, aerated, deep warm loams and silt loams with organic matter and nutrients. Good management can make many other soils suitable for maize (Berger 1962).
- Maize can tolerate up to 70% aluminium saturation (Moody and Cong 2008).
- The soil requirements for maize and soybean are similar but they differ in their adaptation to depth of water table.

### Soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
<td>Needs extra fertilizer and good water.</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>3</td>
<td>Needs drainage and beds.</td>
</tr>
</tbody>
</table>

### Waterlogging (g)

<table>
<thead>
<tr>
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<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No g</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>g+</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

### Slope

<table>
<thead>
<tr>
<th>Slope</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10%</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>11-20%</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>21-35%</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>36-55%</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>&gt;55%</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### Erosion (w)

<table>
<thead>
<tr>
<th>Erosion</th>
<th>Code</th>
<th>Requirement</th>
</tr>
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<tbody>
<tr>
<td>No w</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### Sulfidic (c)

<table>
<thead>
<tr>
<th>Sulfidic</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No c or &gt;60 cm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>c at 41-60 cm</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>c at 21-40 cm</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>c ≤20 cm</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

### Aluminium (a)

<table>
<thead>
<tr>
<th>Aluminium</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No a</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>a-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### Low potassium reserves (k)

<table>
<thead>
<tr>
<th>Low potassium reserves</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No k</td>
<td>1</td>
<td>Has heavy K requirement.</td>
</tr>
<tr>
<td>k</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### High P fixation (i)

<table>
<thead>
<tr>
<th>High P fixation</th>
<th>Code</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No i</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>i-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>i+</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
**Cracking clays (v)**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Code</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>v</td>
<td>v</td>
<td>1</td>
</tr>
<tr>
<td>v</td>
<td>v</td>
<td>3</td>
</tr>
</tbody>
</table>

**High leaching (e)**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Code</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>e</td>
<td>1</td>
</tr>
<tr>
<td>e</td>
<td>e</td>
<td>2</td>
</tr>
</tbody>
</table>

**Comments**

- Maize can grow in most places but yields are low on acid soil. It needs good drainage.

Based on these initial criteria, suitable Soil Subtypes for maize plantation are shown in Table 71.
### Table 71: Maize plantation - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Erosion risk</th>
<th>Sulphur horizon</th>
<th>Aluminium</th>
<th>Low K reserves</th>
<th>High P fixation</th>
<th>Cracking clays</th>
<th>High leaching</th>
<th>Modified suitability rating</th>
<th>Modified rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic soils</strong></td>
<td>Sapristst</td>
<td>OCG+2%(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfusapristst</td>
<td>OCG+2%(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td>Sulfuric</td>
<td>Typic Sulphosapristst</td>
<td>OOG+2%(15)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+(≤20)</td>
</tr>
<tr>
<td>Mineral sulfidic</td>
<td>Terric Sulphisapristst</td>
<td>OLG+0%(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td>Sulfidic</td>
<td>Typic Sulphisapristst</td>
<td>OOG+0%(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td><strong>White soils</strong></td>
<td>Aquods</td>
<td>LLg0%ak</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
</tr>
<tr>
<td>Loamy poorly drained</td>
<td>Ultic Epiaquods</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4 g+</td>
</tr>
<tr>
<td>Sandy poorly drained</td>
<td>Umbric Epiaquods</td>
<td>SSg+2%ke</td>
<td>2</td>
<td>4</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Cracking clay soils</strong></td>
<td>Aquerts</td>
<td>CCG+0%(40)a-i+v</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td>Sulfidic poorly drained</td>
<td>Sulfic Sulfaquerts</td>
<td>CCG+0%(40)a-i+v</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td>Acid poorly drained</td>
<td>Typic Dysraquerts</td>
<td>CCG+0%(a-i+v)</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td><strong>Texture contrast yellow soils</strong></td>
<td>Udults</td>
<td>SL25%wake</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td><strong>Very deep yellow soils</strong></td>
<td>Humults</td>
<td>LLg2%a-ke</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3 g</td>
<td></td>
</tr>
<tr>
<td>Somewhat poorly drained sandy</td>
<td>Aquic Kandihumults</td>
<td>LL25-70%wake</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3 g</td>
</tr>
<tr>
<td>Well drained sandy</td>
<td>Typic Kandihumults</td>
<td>LL25-70%wake</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3 &gt;20%wa</td>
</tr>
<tr>
<td>Somewhat poorly drained clayey</td>
<td>Aquic Palehumults</td>
<td>LLg3%aki</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
<td></td>
</tr>
<tr>
<td>Moderately well drained clayey</td>
<td>Oxyaquic Palehumults</td>
<td>LC0-30%aki</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
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<td>3 a</td>
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<td>LC15-30%waki</td>
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<tr>
<td><strong>Yellow soils</strong></td>
<td>Haplohumults</td>
<td>LCC0-30%waki</td>
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<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
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<td>3</td>
<td>2</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Modestly well drained</td>
<td>Oxyaquic Haplohumults</td>
<td>LCC0-30%waki</td>
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<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
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<td>3</td>
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<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Well drained</td>
<td>Typic Haplohumults</td>
<td>CCG+0%aki</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
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<td>3</td>
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<td>1</td>
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<tr>
<td><strong>Brown over grey soils</strong></td>
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<td>CCG2%a-ki</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
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</tr>
<tr>
<td>Somewhat poorly drained</td>
<td>Aeric Epiqualfs</td>
<td>CCG+2%a-ki</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
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</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Epiqualfs</td>
<td>CCG+2%a-ki+</td>
<td>1</td>
<td>4</td>
<td>1</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td><strong>Sulfuric soils</strong></td>
<td>Aquepts</td>
<td>SSs3%(0)ake</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4 c(≤20)</td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Hydraulentic Sulfuaquepts</td>
<td>SSs3%(0)ake</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4 c(≤20)</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Sulfuaquepts</td>
<td>LG0%(30)ake</td>
<td>1</td>
<td>3</td>
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<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
<tr>
<td><strong>Sulfidic soils</strong></td>
<td>Aquents</td>
<td>CCG2%(30)aki+</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
</tr>
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A.1.7  Ginger (*Zingiber officinale*) and Turmeric (*Curcuma longa*)

FCC was interpreted for ginger and turmeric using the following information:

- There is little information on Turmeric culture. It is assumed to be similar to ginger.
- Ginger needs rich, well drained soils, high in organic matter and with pH 5.5-6.5 (Yamaguichi 1983).
- Ginger prefers well drained soil with pH 5.0-6.0. In soils with high manganese it needs pH 6.5-7.0 (Broadley 2005).
- Well drained sandy loams are preferred with 20-25 cm of loose and friable topsoil (McMahon 2004).

### Soil type

- S 2
- L 1
- C 2
- O 4

### Waterlogging

- No g 1
- g 2
- g+ 3

### Slope

- 0-10% 1
- 11-20% 2
- 21-35% 3
- 36-55% 4
- >55% 5

### Erosion (w)

- No w 1
- w 3

### Sulfidic (c)

- No c or c >60 cm 1
- c at 41-60 cm 2
- c at 21-40 3
- c ≤20 cm 4

### Aluminium (a)

- No a 1
- a- 2
- a 3

### Low potassium reserves (k)

- No k 1
- k 2

### High P fixation (i)

- No i 1
- i- 2
- i 2
- i+ 2

### Cracking clays (v)

- No v 1
- v 4  Less suited to heavy soil.
Based on these initial criteria, suitable Soil Subtypes for ginger and turmeric cultivation are shown in Table 72.

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Table 72
Table 72: Ginger and turmeric - Soil Subtype suitability.

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<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth (a)</th>
<th>Aluminum (a, a-)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>Cracking depth (e)</th>
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A.1.8 Cassava (*Manihot esculenta* Crantz) and Sweet Potato (*Ipomoea batatas* L.)

FCC was interpreted for cassava and sweet potato using the following information:

**Cassava**
- Cassava needs loose textured soil not only for root penetration but for tuber filling. It is known for tolerance to low fertility (Leihner 2002).
- Cassava tolerates a wide range of soil pH from 4.0-8.0 (O’Hair 1995).
- Cassava grows best on friable soils. Sandy soils are acceptable with irrigation and fertilizer (Williams 1975d).
- Lowland oligotrophic peat is acceptable for cassava with drainage and fertilization. The loose nature of these soils greatly facilitates harvesting (Williams 1975d).
- It grows well on peat that is well drained (>60 cm) (Andriesse 1988).
- Cassava does not tolerate flooding (O’Hair 1995).
- Cassava can tolerate 70% aluminium saturation (Moody and Cong 2008).
- Often grown on steep hillsides in SE Asia.

**Sweet potato**
- Sweet potato needs moist but well drained soil. Many tropical types can tolerate short periods (a few days) of flooding (Martin 1988).
- It is tolerant to wide range of soils but a well drained sandy loam with a moderately clay subsoil is preferable. Sweet potato is sensitive to waterlogging – ridges should be used in areas likely to flood (Tindall 1983).
- pH 5.6-6.6 is optimum (Tindall 1983)
- It can be grown in poor soils with little fertiliser (Anon. 2007a).

**Soil type**

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Need fertilizer and good water.

**Waterlogging (g)**

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**Slope**

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<tr>
<td>0-10%</td>
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</tr>
<tr>
<td>11-35%</td>
<td>2</td>
</tr>
<tr>
<td>36-55%</td>
<td>3</td>
</tr>
<tr>
<td>56-85%</td>
<td>4</td>
</tr>
<tr>
<td>&gt;85%</td>
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</tbody>
</table>

**Erosion (w)**

<table>
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<th>Erosion</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No w</td>
<td>1</td>
</tr>
<tr>
<td>w</td>
<td>3</td>
</tr>
</tbody>
</table>
Sulfidic (c)
   No c or c >60 cm 1
   c at 41-60 cm 2
   c at 21-40 cm 3
   c ≤20 cm 4

Aluminium (a)
   No a 1
   a- 1
   a 2

Low potassium reserves (k)
   No k 1
   k 2

High P fixation (i)
   No i 1
   i- 2
   i 2
   i+ 2

Cracking clays (v)
   No v 1
   v 4 Less suited to heavy soil – problems with harvesting and tuber formation.

High leaching (e)
   No e 1
   e 2

Based on these initial criteria, suitable Soil Subtypes for cassava and sweet potato are shown in Table 73.
Table 73: Cassava and sweet potato - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfate horizon (c, d, c)</th>
<th>Aluminum (a, a-), Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>High leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic soils</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosapristis</td>
<td>OCG+2%c(30)ai+</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
<td>4 g+(c≤20)</td>
</tr>
<tr>
<td>Sulfuric</td>
<td>Typic Sulfosapristis</td>
<td>OCG+2%c(15)ai+</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
<td>4 g+(c≤20)</td>
</tr>
<tr>
<td>Mineral sulfidic</td>
<td>Terric Sulfsapristis</td>
<td>OLg+0%c(30)ai+</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4 g+</td>
<td>4 g+(c≤20)</td>
</tr>
<tr>
<td>Sulfidic</td>
<td>Typic Sulfsapristis</td>
<td>OCG+0%c(30)ai+</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
<td>4 g+(c≤20)</td>
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<td><strong>White soils</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loamy poorly drained</td>
<td>Ulitic Epiaquods</td>
<td>LLg0%ak</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 g</td>
<td></td>
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<td>Umbria Epiaquods</td>
<td>SSg+2%ke</td>
<td>2</td>
<td>4</td>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
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<td><strong>Cracking clay soils</strong></td>
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<td></td>
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<td>Sulfic Sulfaquepts</td>
<td>CCG+0%c(40)ai-v</td>
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<td>4</td>
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<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4 g+v</td>
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<td>Typic Dystraquerts</td>
<td>CCG+0%ai-v</td>
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<td>4</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4 g+v</td>
<td></td>
</tr>
<tr>
<td><strong>Texture contrast yellow soils</strong></td>
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<td></td>
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</tr>
<tr>
<td>Loamy poorly drained</td>
<td>Uditic Paleudults</td>
<td>SL25%wake</td>
<td>2</td>
<td>1</td>
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<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 w</td>
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</tr>
<tr>
<td><strong>Very deep yellow soils</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
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<td>Aquic Kandihumults</td>
<td>LLg2%ai-ke</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 g</td>
<td>4 &gt;55%</td>
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<tr>
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<td>Typic Kandihumults</td>
<td>LL25-70%wake</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3 w</td>
<td>4 &gt;55%</td>
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<td>LLg3%aki</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3 g</td>
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<td>LC0-30%aki</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 ak</td>
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<tr>
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<td>LC15-30%waki</td>
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<td>1</td>
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<td>2</td>
<td>3</td>
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<td>2</td>
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<td>1</td>
<td>3 w</td>
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<td>LC20-70%waki</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3 w</td>
<td>4 &gt;55%</td>
</tr>
<tr>
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<td>Typic Haplohumults</td>
<td>CC60-70%waki</td>
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<td>1</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4 &gt;55%</td>
<td>4 &gt;55%</td>
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<td><strong>Brown over grey soils</strong></td>
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<tr>
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<td>Aerici Epiaquiffs</td>
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<td>3</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 g</td>
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<tr>
<td>Poorly drained</td>
<td>Typic Epiaquiffs</td>
<td>CCG+2%a-ki+</td>
<td>2</td>
<td>4</td>
<td>1</td>
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<td>4 g+</td>
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<td><strong>Sulfuric soils</strong></td>
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</tr>
<tr>
<td>Soft poorly drained</td>
<td>Hydraquentic Sulfaquepts</td>
<td>SSg3%c(0)ake</td>
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<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 c≤20</td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Sulfaquepts</td>
<td>LG0%c(30)ai</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 c≤20</td>
<td></td>
</tr>
<tr>
<td><strong>Sulfidic soils</strong></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Haplic Sulfaquepts</td>
<td>CCG+0%c(30)ai+</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+</td>
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<td>Thapto-Histic Sulfaquepts</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3 gc≤40</td>
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<td>Sulfic Fluvaquepts</td>
<td>SSg3%c(70)ai</td>
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<td>3 g</td>
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<tr>
<td><strong>Grey soils</strong></td>
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</tr>
<tr>
<td>Poorly drained</td>
<td>Humaqueptic</td>
<td>CCG0%ai</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3 g</td>
<td></td>
</tr>
</tbody>
</table>
A.2 Fruit Crops

A decision to develop a fruit tree industry involves significant financial investment and has long-term consequence because of the long-life expectancy of trees and the lead time from planting to fruiting. Site selection therefore has to be done with upmost care as the investor will live with the consequence of that decision for a long time. FCC only deals with the soil fertility aspect of land suitability. Infrastructure (access to transport, fertilisers, drainage network, fruit processing and storage etc), social (access to labour etc) and economic (access to market, good price etc) aspects are very important considerations for land use decision. These aspects are outside the scope of our study but need to be considered separately. A system such as the Automated Land Evaluation System (ALES: http://www.css.cornell.edu/landeval/ales/alesprog.htm) provides a well-used framework for this more comprehensive analysis. Some smaller and faster maturing tropical fruits such as papaya, banana and pineapple are included here for convenience.

A.2.1 Durian (*Durio* spp.)

This assessment covers the following durian species:

- Durian kuning
- Durian putih
- Durian sukang
- Durian pulu
- Durian suluk
- Durian *spp.* (Probably hybrid of *D. zibethinus* and *D. graveolens*)

FCC was interpreted for durian using the following information:

- The optimum soils for durian are deep, well drained sandy loams or clay loams. Most common soils for durian are alluvium from basaltic rocks. Durian is not found in swamps or peat swamps (Subhadrabandhu and Ketsa 2001).
- Durian roots to about 1 m (Subhadrabandhu and Ketsa 2001).
- Clay soils with poor drainage should be avoided (Subhadrabandhu and Ketsa 2001).
- Sandy soils should be avoided due to excessive drainage (Subhadrabandhu and Ketsa 2001).
- Ground water should ideally be below 2 m (Subhadrabandhu and Ketsa 2001).
- Slope should be less than 35% (Subhadrabandhu and Ketsa 2001).
- The range of suitable pHs are 4.5 – 6.5 (Subhadrabandhu and Ketsa 2001); 4.5 – 5.5 (Watson 1983).
- Durian prefers deep sandy to clay loams developed from basalt or granite, with excellent drainage. It is very intolerant of poor aeration and soils conducive to Phytophthora (Watson 1983).
- Durian *suluk* performs best in Brunei on well drained, alluvial soil of riverine areas (Serudin Tinggal 1994).
- In Belait durian is found in the Labi area, but none in the coastal region due to sandy soils (Jumat Hj. Alim 1994).
- Durian prefers well drained, deep (1 m) loamy or clay loam soil. Peaty and sandy soils should be avoided along with areas susceptible to water logging. It needs flat land or gentle slope (<25 degree) (Anon. 1999).
- Deep well drained sands to clay loams are optimum (Diczbalis 2004).
In Vietnam it is grown on water inundated delta soils with extensive mounding protected with plastic sheets to shed excess rainfall.

**Soil type**

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Score</th>
</tr>
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<td>S</td>
<td>5</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>5</td>
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</table>

*Does not grow.*

**Waterlogging (g)**

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<tbody>
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</tr>
<tr>
<td>g</td>
</tr>
<tr>
<td>g+</td>
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</tbody>
</table>

*Needs very good drainage due to Phytophthora palmivora fungus.*

**Slope**

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<th>Score</th>
</tr>
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<tbody>
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<tr>
<td>16-35%</td>
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<tr>
<td>36-65%</td>
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</tr>
<tr>
<td>66-85%</td>
<td>4</td>
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<td>&gt;85%</td>
<td>5</td>
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**Erosion (w)**

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<th>Score</th>
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</thead>
<tbody>
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</tr>
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<td>w</td>
<td>2</td>
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**Sulfidic (c)**

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<th>Score</th>
</tr>
</thead>
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<tr>
<td>c at 76-100 cm</td>
<td>2</td>
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<tr>
<td>c at 51-75 cm</td>
<td>3</td>
</tr>
<tr>
<td>c ≤50 cm</td>
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**Aluminium (a)**

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<th>Score</th>
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<td>a-</td>
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<td>a</td>
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**Low potassium reserves (k)**

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**High P fixation (i)**

<table>
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<th>Score</th>
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<tr>
<td>i</td>
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<td>i+</td>
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**Cracking clays (v)**

<table>
<thead>
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<th>Score</th>
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<td>v</td>
<td>4</td>
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</tbody>
</table>

*Less suited to heavy soil, root rot.*

**High leaching (e)**

<table>
<thead>
<tr>
<th>Leaching</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No e</td>
<td>1</td>
</tr>
<tr>
<td>e</td>
<td>2</td>
</tr>
</tbody>
</table>

**Comment**

- There is limited cultivation of local species although some have potential. Imported lines have suffered from root rot problems especially due to adverse site selection. Local lines may be more tolerant of Phytophthora but this needs confirmation.

Based on these initial criteria, suitable Soil Subtypes for durian are given in Table 74.
Table 74: Durian - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphur horizon (c) and depth (a)</th>
<th>Aluminium (a)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i+, i-)</th>
<th>Cracking clay (V)</th>
<th>High leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic soils</td>
<td>Saprists</td>
<td></td>
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</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosapristis</td>
<td>OCG+2%c(30)ai+</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>5 Og+c(550)</td>
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<tr>
<td>Sulfuric</td>
<td>Typic Sulfosapristis</td>
<td>OCG+2%c(15)ai+</td>
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<td>3</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>5 Og+c(550)</td>
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<td>OLG+0%c(30)ai</td>
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<td>4</td>
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<td>1</td>
<td>1</td>
<td>3</td>
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<td>1</td>
<td>1</td>
<td>4 g</td>
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<td>Umbric Epiaquods</td>
<td>SSg+2%ke</td>
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<td>5 Sg+</td>
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<td>Aquerts</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 g</td>
</tr>
<tr>
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<td>Typic Epiaqualfs</td>
<td>CCG+2%a-ki+</td>
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<td>5</td>
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<td>5 g+c(550)</td>
</tr>
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<td>Aquepts</td>
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<td>Soft poorly drained</td>
<td>Hydraulentic Sulfaquepts</td>
<td>SSG3%c(0)ake</td>
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<td>1</td>
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<td>5 Sc(550)</td>
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<td>1</td>
<td>2</td>
<td>5 c(550)</td>
</tr>
<tr>
<td>Sulfidic soils</td>
<td>Aqueunts</td>
<td></td>
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</tr>
<tr>
<td>Soft poorly drained</td>
<td>Haplic Sulfaquepts</td>
<td>CCG0%c(30)ak+</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5 g+c(550)</td>
</tr>
<tr>
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<td>Thaipo-Histic Sulfaquepts</td>
<td>OCG2%c(30)ai+</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5 Oc(550)</td>
</tr>
<tr>
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<td>Sulfic Fluvaquents</td>
<td>SSG3%c(70)ake</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5 S</td>
</tr>
<tr>
<td>Grey soils</td>
<td>Aqueunts</td>
<td></td>
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</tr>
<tr>
<td>Poorly drained</td>
<td>Humaqueptic</td>
<td>CC0%aki</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g</td>
</tr>
</tbody>
</table>

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A.2.2 Rambutan (*Nephelium lappaceum* L.)

FCC was interpreted for rambutan using the following information:

- Deep, well drained sandy loams or clay loams with high organic matter are best for rambutan. Optimum pH is 4.5-6.5 (Watson 1984a).

- Rambutan is tolerant of poor drainage but will not tolerate waterlogging. It prefers pH 4.5-6.5 (Marshall 1988; Tindal *et al.* 1994).

- It is suitable for most soil types, except for waterlogged soils and peat. It does not do well in sandy areas. Deep alluvial soil and those which contain high organic matter are ideal. It needs to be well drained. Soils with high water table are not favourable (Mohamad Idris bin Zainal Abidin 1990).

- Rambutan tolerates a wide range of soil types but the optimum is rich, well drained sandy loams or clay loams high in organic matter. Good drainage is essential. It does not like high watertables. The watertable should be 3-4 m from the surface (Tindal *et al.* 1994).

- As a result of differences in variety and provenance, very good eating rambutan from prolific trees grown next to a paddy field have been observed in Temburong. Therefore, these classes will need to be adjusted according to local knowledge.

- Deep well drained soils in loam to clay loam range are suitable. Shallow soils and poor drainage will reduce yield. Soil less than 50 cm deep should be avoided (Watson *et al.* 1988).

**Soil type**

| S | 3 | Needs more fertilizer and irrigation. |
| L | 1 |
| C | 1 |
| O | 5 | Too wet. |

**Waterlogging (g)**

| No g | 1 |
| g   | 3 |
| g+  | 5 |

**Slope**

| 0-15% | 1 |
| 16-35% | 2 |
| 36-65 | 3 |
| 66-85 | 4 |
| >85%  | 5 |

**Erosion (w)**

| No w | 1 |
| w    | 2 |

**Sulfidic (c)**

| No c or c >100 cm | 1 |
| c at 76-100 cm    | 2 |
| c at 51-75 cm     | 3 |
| c at 31-50        | 4 |
| c ≤30 cm          | 5 |

**Aluminium (a)**

| No a | 1 |
| a-   | 2 |
| a    | 3 |
**Low potassium reserves (k)**
- No k  
  - k

**High P fixation (i)**
- No i  
  - i-  
  - i  
  - i+

**Cracking clays (v)**
- No v  
  - v

**High leaching (e)**
- No e  
  - e

**Comments**
- There are root rot and disease issues if water logged. Soil drainage is very important.

Based on these initial criteria, suitable Soil Subtypes for rambutan are given in Table 75.
### Table 75: Rambutan - Soil Subtype suitability.

**Suitability for: Rambutan**

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth</th>
<th>Aluminium (a)</th>
<th>Low K reserves (K)</th>
<th>High P Fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>High Leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Sapristic</td>
<td>OCC+2%c(30)a+i</td>
<td>5 5 1</td>
<td>1 5</td>
<td>3</td>
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<td>1 1</td>
<td>5 Og+c(≤30)</td>
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<td>Sulfuric</td>
<td>Sapristic</td>
<td>OCC+2%c(15)a+i</td>
<td>5 5 1</td>
<td>1 5</td>
<td>3</td>
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<td>5 Og+c(≤30)</td>
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<td>5 5 1</td>
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<td>1 1</td>
<td>5 Og+c(≤30)</td>
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<td>3</td>
<td>2</td>
<td>2 1</td>
<td>1 1</td>
<td>5 Og+c(≤30)</td>
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<tr>
<td>Loamy poorly drained</td>
<td>Aquods</td>
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<td>1 3 1</td>
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<td>3</td>
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<td>1 1</td>
<td>2 1</td>
<td>5 G+</td>
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<td>Aquerts</td>
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<td>2 4</td>
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</table>
A.2.3 Langsat - Duku (*Lansium domesticum* Jack.)

FCC was interpreted for langsat - duku using the following information:

- Langsat and duku are classified as a single species but there are differences in tree form, fruit arrangement and the fruit itself (Watson 1984b).
- Langsat - duku does best on deep, rich, well drained, sandy loam or other soils that are slightly acid to neutral and high in organic matter. It does poorly on clay that dries and cracks during rainless periods. It is not at all adapted to alkaline soils. Langsat – duku will not endure even a few days of waterlogging (Morton 1987).
- Langsat will not tolerate alkaline soils (Whitman 1984).
- It has a clear preference for soils with good drainage and water retention, e.g. river banks, in Malaysia. It dislikes sandy coastal and alkaline soils. Medium textured soils rich in organic matter and slightly acid are preferred (Yaacob and Bamroongrugsa 1991).
- Duku grows best in well drained loams (Mohamad Idris bin Zainal Abidin 1990).
- There is a lack of specific information on soil requirements. Some information for Sapodilla and Santol, which are closely related, is used in this assessment.
  - Sapodilla is tolerant of a wide range of soil types from heavy clay to sand but prefers a deep medium textured loam with pH 6.0-8.0 (Marshall and Marshall 1983b).
  - Santol prefers well drained soils (Watson 1984b).

### Soil type

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<th>Soil Type</th>
<th>Value</th>
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### Waterlogging (g)

- Needs very good drainage.
  - No g: 1
  - g: 4
  - g+: 5

### Slope

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### Erosion (w)

- No w: 1
- w: 2

### Sulfidic (c)

- No c or c >100 cm: 1
  - c at 76-100 cm: 2
  - c at 51-75 cm: 3
  - c at 31-50 cm: 4
  - ≤30 cm: 5

### Aluminium (a)

- No a: 1
  - a-: 2
  - a: 3
Low potassium reserves (k)
- No k 1
- k 2

High P fixation (i)
- No i 1
- i- 2
- i 2
- i+ 2

Cracking clays (v)
- No v 1
- v 4 Soil remains too wet after heavy rain. Water stress during dry periods.

High leaching (e)
- No e 1
- e 2

Based on these initial criteria, suitable Soil Subtypes for langsat duku are given in Table 76.
### Table 76: Langsat - duku - Soil Subtype suitability.

#### Rating for soil attributes:

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<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk</th>
<th>Sulfuric horizon (c) and depth</th>
<th>Aluminum</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays</th>
<th>High Leaching (e)</th>
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</tr>
<tr>
<td>Poorly drained</td>
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</tbody>
</table>

Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam
Volume 1 – Soils and Land Suitability of the Agricultural Development Areas Page 235
A.2.4 Citrus (*Citrus spp.*)

This assessment covers the following citrus species:

- Sweet mandarin (Limau manis) *Citrus reticulata* Blanco
- Musk lime (Limau kasturi) *X Citrofortunella mitis* or *C. macrocarpa*
- Common lime (Limau Itapas) *Citrus aurantifolia*
- Pomelo *Citrus grandis* Osbeck

FCC was interpreted for citrus using the following information:

- Citrus trees need light, friable soils with good drainage (Williams 1975f). Heavy clays are not suitable.
- Loams and sands are preferred (Citrus Information Kit 1999; Owen-Turner 1994).
- Tree deaths due to root rot occur more often on wet clayey soils (Owen-Turner 1994).
- Musk lime does well on a wide range of soil types (Morton 1987).
- Soil for sweet mandarins should be either organic or sandy. More problems are encountered on clay soils – with mounds being required. Tangerines should not be grown in wet soils (Anon. 2005).
- Pomelo grows best on sandy loams to loams with a minimum soil depth of 1 m and pH 5.5-6.5 (Diczbalis and McMahon 2004).
- Pomelo needs well drained sandy loams. Poorly drained soils are more likely to have root rot (Jorgensen 1984).
- Pomelo tolerates a wide range of soils from coarse sand to heavy clay. However, the tree prefers deep, fertile soils of medium texture and free from salts (Niyomdham 1991).
- Air-layered mandarins with a shallow root system are preferred for areas with a high fluctuating water table where deep rooted seedling stocks would suffocate (Ashari 1991).
- Soil types were rated by Chuong and Boehme (2005) as follows: loam or loamy sand = S1; sand loam, silt loam = S2; silt, clay loam = S3; sand, clay = N.
- Erosion hazard (slopes) were rated by Chuong and Boehme (2005) as: 0-5% = S1; 5-15% = S2; 15-30% = S3; >30% = N.
- Citrus is not well adapted to very acid soils. The optimum pHs quoted are 6.5 (Williams 1975f), 6.0-6.5 (Citrus Information Kit 1999; Owen-Turner 1994), 5.7-6.9 (Anon. 2005).

### Soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>3</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>O</td>
<td>3</td>
</tr>
</tbody>
</table>

Needs fertilizer and irrigation.

### Waterlogging (*g*)

<table>
<thead>
<tr>
<th>Waterlogging (<em>g</em>)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No g</td>
<td>1</td>
</tr>
<tr>
<td>g</td>
<td>3</td>
</tr>
<tr>
<td>g+</td>
<td>4</td>
</tr>
</tbody>
</table>

Needs very good drainage.

### Slope

<table>
<thead>
<tr>
<th>Slope</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15%</td>
<td>1</td>
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<tr>
<td>16-35%</td>
<td>2</td>
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<tr>
<td>36-65%</td>
<td>3</td>
</tr>
<tr>
<td>66-85%</td>
<td>4</td>
</tr>
<tr>
<td>&gt;85%</td>
<td>5</td>
</tr>
</tbody>
</table>
Erosion (w)
- No w 1
- w 2

Sulfidic (c)
- No c or c > 60 cm 1
- c at 46-60 2
- c at 31-45 3
- c at 21-30 4
- c ≤20 cm 5

Aluminium (a)
- No a 1
- a- 2
- a 3

Low potassium reserves (k)
- No k 1
- k 2

High P fixation (i)
- No i 1
- i- 2
- i 2
- i+ 2

Cracking clays (v)
- No v 1
- v 4  Soil remains too wet after heavy rain, maybe problem with root rots. Water stress during dry periods.

High leaching (e)
- No e 1
- e 2

Comments
- Raised beds are required if the watertable is high. Beds should be a decent size, >1 m above water table and about 3 m wide. The area needs to be drained.
- The main problem with mandarins is greening. Pomelo is much more tolerant of greening.

Based on these initial criteria, suitable Soil Subtypes for citrus trees are given in Table 77.
Table 77: Citrus - Soil Subtype suitability. 

<table>
<thead>
<tr>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth</th>
<th>Aluminum (a)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>High leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic soils</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Saprist</td>
<td>Terric Sulfosaprist</td>
<td>OCG+2%c(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+c(S30)</td>
</tr>
<tr>
<td>Sulfuric</td>
<td>Typical Saprist</td>
<td>OCG+2%c(15)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5 c(S20)</td>
<td></td>
</tr>
<tr>
<td>Mineral sulfidic</td>
<td>Saprist</td>
<td>Terric Sulfisaprist</td>
<td>OLg+0%c(30)ai+</td>
<td>3</td>
<td>4</td>
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<td>1</td>
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<td>4 g+c(S30)</td>
</tr>
<tr>
<td>Sulfidic</td>
<td>Typical Saprist</td>
<td>OCG+0%c(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+c(S30)</td>
<td></td>
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<td>Aquods</td>
<td>Ullic Epiaquods</td>
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<td>3</td>
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<td>1</td>
<td>3</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
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<tr>
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<td>Ulmic Epiaquods</td>
<td>SSg2%ke</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>4 g+</td>
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<td>Aquerts</td>
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<td>CCG+0%c(40)ai+v</td>
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<td>4 Gc+v</td>
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<td>Udults</td>
<td>Arenic Paleudults</td>
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<td>1</td>
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<td>2</td>
<td>3 Sa</td>
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<td>1</td>
<td>2</td>
<td>3 g</td>
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<td>1</td>
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<td>2</td>
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<td>3</td>
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<td>1</td>
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<td>3 ga</td>
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<td>4 C</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>4 C</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Epiaquils</td>
<td>CCG2%a-ki+</td>
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<td>4</td>
<td>1</td>
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<td>1</td>
<td>4 Cg+</td>
<td></td>
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<td>Aquepts</td>
<td>Hydraquentic Sulfaquepts</td>
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<td>2</td>
<td>5 c(S20)</td>
</tr>
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<td>1</td>
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<td>1</td>
<td>5 c(S20)</td>
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<tr>
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<td>Typic Sulfaquepts</td>
<td>LGc2%c(30)ake</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5 c(S20)</td>
<td></td>
</tr>
<tr>
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<td>Aquents</td>
<td>Haplic Sulfaquepts</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>4 Gc+c(S30)</td>
</tr>
<tr>
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<td>Haplic Sulfaquepts</td>
<td>CCG2%c(30)ai+</td>
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<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 Gc+c(S30)</td>
<td></td>
</tr>
<tr>
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<td>Thapto-Histic Sulfaquepts</td>
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<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 Gc(S30)</td>
<td></td>
</tr>
<tr>
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<td>Sulfic Fluvaquents</td>
<td>SSg3%c(70)ake</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3 Sga</td>
<td></td>
</tr>
<tr>
<td>Grey soils</td>
<td>Aquents</td>
<td>Humaqueptic</td>
<td>CCG0%aki</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 C</td>
</tr>
</tbody>
</table>
A.2.5 Banana (*Musa spp.*)

FCC was interpreted for banana using the following information:

- Banana grows well in wide range of soils, but best are deep, well drained, water retentive loams with high humus content. Low lying, waterlogged areas should be avoided (Tropical Banana Information Kit 1998; CRC Handbook 1984).

- Bananas are grown on a great variety of soils ranging from alluvial flood plains to inland latosols in the tropics; from organic peat soils to volcanic loams and grumusols or 'black cotton soils' and sandy soils in the Canary Islands. The most important features of a soil for banana cultivation is its depth and moisture holding capacity in relation to rainfall, unless extra irrigation applied. (Williams 1975a).

- Most tropical and monsoonal inland soils are adequately drained but do not possess great water holding capacity. The banana root system is largely superficial so that the plant is unable to draw on water in the lower profile even if the soil is deeply structured. For this reason irrigation is often practiced in modern plantations even in humid tropical zones. (Williams 1975a).

- It is sometimes stated that a high soil pH is best for bananas but some very successful crops are grown on rather acid soils. However Panama disease is more prevalent on acid soils so that susceptible varieties are better confined to non-acid soils (Williams 1975a).

- Well drained, sandy clay loam with good moisture holding capacity are preferred. Peat and sandy soils should be avoided. Bananas prefer pH 6.0-7.5, but can survive pH 4.5-8.0 (Anon. 2001).

- Banana will not survive flooding or prolonged waterlogging.

- Fusarium wilt can be an issue where there is flooding or poor drainage for part of year (Boonyanuphap *et al.* 2004).

- Banana will grow and fruit under very poor conditions but will not flourish and be economically productive without deep, well drained soil which holds water – loam, rocky sand, marl, laterite, volcanic ash, sandy clay, even heavy clay but not fine sand. Alluvial soils are ideal. Low, perennially wet soils require draining (Morton 1987).

### Soil

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>3</td>
<td>Lack of water and nutrient.</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>4</td>
<td>Drainage and subsidence issues.</td>
</tr>
</tbody>
</table>

### Waterlogging (g)

- No g 1
- g 3
- g+ 4

### Slope

- 0-15% 1
- 16-35% 2
- 36-65% 3
- 66-85% 4
- >85% 5

### Erosion (w)

- No w 1
- w 2
### Sulfidic (c)
- No c or c >60 cm: 1
- c at 46-60 cm: 2
- c at 31-45 cm: 3
- c at 21-30 cm: 4
- c ≤20 cm: 5

### Aluminium (a)
- No a: 1
- a-: 2
- a: 3

### Low potassium reserves (k)
- No k: 1
- k: 3

### High P fixation (i)
- No i: 1
- i-: 2
- i: 2
- i+: 2

### Cracking clays (v)
- No v: 1
- v: 3

### High leaching (e)
- No e: 1
- e: 2

### Comment
- Many areas which could be used will need raised mounds to avoid waterlogging.
- Bananas have a heavy potassium requirement.

Based on these initial criteria, suitable Soil Subtypes for bananas are given in Table 78.
Table 78: Bananas - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth (a, a-)</th>
<th>Aluminum (a, a-)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>High Cracking clays (V)</th>
<th>High Leaching (e)</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic soils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Saprist</td>
<td>OCGg+2%c(30)ai+</td>
<td>4</td>
<td>4</td>
<td>1</td>
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A.2.6 Coconut (Cocos nucifera)

FCC was interpreted for coconut using the following information:

- Coconut is very adaptable and grows on soils right across the textural range from coarse coralline and volcanic gravels to clay loams over coral and heavy marine clays with artificial drainage (Foale 1984).
- Coconut soils range from pH 3.4-9.0 (Foale 1984) but pH of 5.0-8.0 is best (Williams 1975e).
- Banana needs good, constant moisture supply but is not adapted to waterlogging (Foale 1984).
- Potassium is the most important element for coconut growing (Williams 1975e).
- Alluvial river and estuarine soils, when rich in nutrient and freely drained, are stated to be the best coconut soils (Williams 1975e).
- If heavy clay soils used, extensive drainage is needed (Williams 1975e).
- Acid sulfate and peat soils are generally not suitable (Williams 1975e).

### Soil type

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<th>Soil Type</th>
<th>Value</th>
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**Waterlogging (g)**

- No g: 1
- g: 3
- g+: 5

**Slope**

- <15%: 1
- 16-35%: 2
- 36-65%: 3
- 56-85%: 4
- >85%: 5

**Erosion (w)**

- No w: 1
- w: 2

**Sulfidic (c)**

- No c or c > 100 cm: 1
- c at 76-100 cm: 2
- c at 51-75 cm: 3
- c at 31-50 cm: 4
- c ≤30 cm: 5

**Aluminium (a)**

- No a: 1
- a-: 2
- a: 3

**Low potassium reserves (k)**

- No k: 1
- k: 3
**High P fixation** (i)

No i 1
i- 2
i 2
i+ 2

**Cracking clays** (v)

No v 1
v 3  Soil remains too wet after heavy rain, drainage issues.

**High leaching** (e)

No e 1
e 2

Based on these initial criteria, suitable Soil Subtypes for coconuts are given in Table 79.
**Table 79: Coconut - Soil Subtype suitability.**

**Suitability for: Coconut**

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<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)(%)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c, and depth)</th>
<th>Aluminum (a, a-, a+)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>Cracking height (e)</th>
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</table>
A.2.7 Papaya (*Carica papaya* L.)

FCC was interpreted for papaya using the following information:

- Papaya prefers well drained, fertile soil with pH 6.0-6.5 (Batten 1985).
- Deep well, drained soils are most suitable, ideally with soil depth of 1 m. The minimum soil depth is 0.5 m. Waterlogging and heavy clays should be avoided (O’Hare 1993).
- All soil types are suitable, but clays only if drainage is good (Anon. 1989).
- Good drainage essential (Anon. 1989).
- Waterlogging is unsuitable for papaya due to Phytophthora issues.
- Sand loams are used extensively in North Queensland with irrigation.
- Watertables should be at more than 300 mm depth (Anon. 1989).
- Deep, well drained soil with high organic matter are the most suitable, but heavy clays should be avoided. The preferred top soil depth is 1 m, with the minimum depth being 50 cm. Mounding should be to 75 cm (Papaw Information Kit 2000).

**Soil type**

- **S** 1 Need fertilisers frequently and irrigation.
- **L** 1
- **C** 1
- **O** 5 Too wet.

**Waterlogging (g)**

- **No g** 1
- **g** 4 Needs very good drainage for root rot control.
- **g+** 5

**Slope**

- **< 15%** 1
- 16-35% 2
- 36-65% 3
- 66-85% 4
- >85% 5

**Erosion (w)**

- **No w** 1
- **w** 2

**Sulfidic (c)**

- **No c or c >60 cm** 1
- **c at 46-60 cm** 2
- **c at 31-45 cm** 3
- **c at 21-30 cm** 4
- **c ≤20 cm** 5

**Aluminium (a)**

- **No a** 1
- **a-** 2
- **a** 3

**Low potassium reserves (k)**

- **No k** 1
- **k** 2
### High P fixation (i)

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### Cracking clays (v)

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*Soil remains too wet after heavy rain. Water stress during dry periods.*

### High leaching (e)

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### Comments

- In far north Queensland, the papaya industry used to be located on the wet tropical coast. Now the bulk of production is inland on granitic, sandy loam with relatively low rainfall. There were too many problems with disease and windy conditions along the coast.

Based on these initial criteria, suitable Soil Subtypes for papaya are given in Table 80.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphur horizon (c and depth)</th>
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<th>Low K reserves (K)</th>
<th>High P fixation (i, i+, i–)</th>
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</tr>
<tr>
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<td>CCG0%c(30)a+</td>
<td>1</td>
<td>5</td>
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<td>4</td>
<td>3</td>
<td>2</td>
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<td>Thapto-Histic Sulfaquettss</td>
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<td>4</td>
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<td>1</td>
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<td>2</td>
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<td>1</td>
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<td>5 O</td>
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<tr>
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<td>Sulfic Fluvaquettss</td>
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<td>4</td>
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<td>1</td>
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<td>3</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>4 g</td>
<td>4 g</td>
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<tr>
<td><strong>Grey soils</strong></td>
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<tr>
<td>Poorly drained</td>
<td>Humaqueptic</td>
<td>CCG0%ak</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4 g</td>
<td>4 g</td>
<td></td>
</tr>
</tbody>
</table>
A.2.8 Pineapple (*Ananas comosus* Merr.)

FCC was interpreted for pineapple using the following information:

- Pineapple needs well drained soil with pH 4.5-5.5 (CRC Handbook 1984).
- Pineapples are grown on acid sulfate soils in Mekong delta of Vietnam.
- The best soil is friable, well drained, sandy loam with high organic content and pH 4.5-6.5. It cannot withstand waterlogging (Anon. 1996c).
- A wide range of soil types are suitable, mostly on latosols of varying parent material (Williams 1975b).
- In Hawaii they are grown on dark red volcanic soil. In Malaysia they can be grown on almost pure organic peat soils (Williams 1975b).
- It is most essential to have good drainage. Heavy soils are unsuitable unless well drained (Williams 1975b).
- Pineapple grows high quality fruit on granitic, sandy loams in North Queensland with irrigation and good management.
- It prefers well drained loams. Heavy clay soils with poor internal drainage should be avoided. The suitable pH range is 4.0-5.0 (Grattidge and Wait 1989).
- Pineapple is well suited to peat soils if well drained to more than 60 cm depth (Andriesse 1988).
- The best soil is well drained sandy loam with high content of organic matter and friable for a depth of at least 60 cm and pH 4.5-6.5. The plant cannot withstand waterlogging and if there is impervious subsoil, drainage must be improved (Morton 1987).

**Soil type**

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Factor</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Needs fertilizer, irrigation, and organic matter.</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

**Waterlogging (g)**

- No g 1
- g 3
- g+ 4

**Slope**

<table>
<thead>
<tr>
<th>Slope</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15%</td>
<td>1</td>
</tr>
<tr>
<td>15-35%</td>
<td>2</td>
</tr>
<tr>
<td>36-65%</td>
<td>3</td>
</tr>
<tr>
<td>66-85%</td>
<td>4</td>
</tr>
<tr>
<td>&gt;85%</td>
<td>5</td>
</tr>
</tbody>
</table>

**Erosion (w)**

- No w 1
- w 2

**Sulfidic (c)**

- No c or c >60 cm 1
- c at 46-60 cm 2
- c at 31-45 cm 3
- c at 21-30 cm 4
- c ≤20 cm 5
### Aluminium (a)
- No a 1
- a- 2
- a 3

### Low potassium reserves (k)
- No k 1
- k 2

### High P fixation (i)
- No i 1
- i- 2
- i 2
- i+ 2

### Cracking clays (v)
- No v 1
- v 4  Soil remains too wet after heavy rain. Water stress during dry periods.

### High leaching (e)
- No e 1
- e 2

### Comments
- Pineapple is suitable for both steep land and peat areas (if there is good drainage). It should be able to grow in many locations in Brunei.

Based on these initial criteria, suitable Soil Subtypes for pineapple are given in Table 81.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Erosion risk</th>
<th>Sulphate horizon</th>
<th>Aluminium</th>
<th>Low K reserves</th>
<th>High P fixation</th>
<th>Cracking clays</th>
<th>High Leaching</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
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</thead>
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<tr>
<td><strong>Organic soils</strong></td>
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<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosapristos</td>
<td>OCG+2%c(30)ai+</td>
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<td>4</td>
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<td>4</td>
<td>3</td>
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<td>4 g+c(≤30)</td>
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<td>LLg0%ak</td>
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<td>3 ga</td>
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<td>Umbric Epiaquods</td>
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<td>1</td>
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<td>1</td>
<td>4 g+</td>
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<tr>
<td><strong>Cracking clay soils</strong></td>
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<tr>
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<td>Sulfic Sulfuraquerts</td>
<td>CG+0%c(40)ai+v</td>
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<td>4</td>
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<td>3</td>
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<td>4 g+v</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4 g+v</td>
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<td><strong>Texture contrast yellow soils</strong></td>
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<td>3</td>
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<td>1</td>
<td>1</td>
<td>3 ga</td>
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<td>Typic Epiaqualfs</td>
<td>CG+2%a-ki+</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>4 g+</td>
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<tr>
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<td>Hydraulentic Sulfuaquets</td>
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</tr>
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<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
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</tr>
<tr>
<td>Soft poorly drained</td>
<td>Haplic Sulfuaquents</td>
<td>CG+0%c(30)ai+</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
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<td>2</td>
<td>1</td>
<td>4 g+c(≤30)</td>
<td>4 g+c(≤30)</td>
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<td>Organic poorly drained</td>
<td>Thapto-Histic Sulfuaquents</td>
<td>CG+2%c(30)ai-</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
<td>2</td>
<td>1</td>
<td>4 c(≤30)</td>
<td>4 c(≤30)</td>
</tr>
<tr>
<td>Organic poorly drained moderately deep</td>
<td>Sulfic Fluvaquents</td>
<td>SSg3%(70)ake</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
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</tr>
<tr>
<td><strong>Grey soils</strong></td>
<td></td>
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</tr>
<tr>
<td>Poorly drained</td>
<td>Humaquitectic</td>
<td>CG0%aki</td>
<td>1</td>
<td>3</td>
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<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3 ga</td>
<td></td>
</tr>
</tbody>
</table>
A.2.9 Mango (*Mangifera* spp.) and Cashew Nut (*Anarcardium occidentale* L.)

This assessment covers the following species:

- **Mango**: *Mangifera indica* L.
- **Belunu**: *Mangifera caesia*
- **Membangan**: *Mangifera panjang* Kost.
- **Cashew nut**: *Anarcardium occidentale* L.

Manago and cashew trees are members of the same family. They need a distinct dry season for flowering and fruit development. Although some soils may be suitable, the climatic conditions in Negara Brunei Darussalam may not be suited for plantations of commercial varieties. However, local mango species may do well. FCC was interpreted for mango and cashew nut using the following information:

**Mango**

- **Membangan** (*Mangifera panjang*) prefers well drained alluvial soils, but will also grow on upland soils. Will not grow in peat or leached coastal sands (Anon. 2004).
- **Mango membangan** prefers well drained alluvium. Adapted to lowlands where there is abundant and well distributed rainfall (Bompard 1991b).
- **Mango belunu** (*Mangifera caesia*) is restricted to wet tropical lowlands. It requires rainfall evenly distributed over the year. It withstands inundation well, and is commonly cultivated on periodically inundated riverbanks in east Kalimantan (Bompard 1991a).
- **Mango** prefers deep, well drained sands to loams with water table below 2.5 m depth. Mango can withstand occasional flooding (Whiley 1984).
- It does not grow well in soils with pH <5.0 (Whiley 1984). *Mangifera indica* grows well on a wide range of soil types. It prefers well drained, loamy soil. Low fertility is acceptable with suitable fertiliser application. Highly organic and fertile soils tend to give excessive growth and less fruit. Fruit quality is also much poorer. Rich soils should not be used.
- mango needs more than 1 m soil depth, and has a high calcium requirement.

**Cashew**

- **Cashew** needs a wet/dry tropical climate (O’Farrell *et al.* 1998). It requires free draining soils, and does not tolerate waterlogging. Low fertility soils are suitable (O’Farrell *et al.* 1998).
- **Cashew** prefers sandy soils of medium fertility, but also grows on well drained clays and shallow, stony, and lateritic soils. Waterlogged soils are unsuitable (Sturtz 1984).
- In drier areas (annual rainfall of 800-1000 mm), a deep, well drained soil without an impervious layer is essential (Van Eijnatten 1991).

**Soil type**

<table>
<thead>
<tr>
<th>Soil type</th>
<th>1</th>
<th>2</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
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<tr>
<td>L</td>
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<td>C</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>O</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Waterlogging (g)**

- **No g**: Will tolerate some flooding but with yield losses.
- **g**: Should be 4 for cashew as they are less tolerant.
- **g+**:
### Slope

- 0-15%  1
- 16-35%  2
- 36-65%  3
- 66-85%  4
- >85%  5

### Erosion (w)

- No w  1
- w  2

### Sulfidic (c)

- No c or c > 100 cm  1
- c at 76-100 cm  2
- c at 51-75 cm  3
- c ≤50 cm  5

### Aluminium (a)

- No a  1
- a-  2
- a  3

### Low potassium reserves (k)

- No k  1
- k  2

### High P fixation (i)

- No i  1
- i-  2
- i  2
- i+  2

### Cracking clays (v)

- No v  1
- v  3 Not suited to heavy soil. Soil remains too wet after heavy rain.

### High leaching (e)

- No e  1
- e  2

### Comments

- Local mangifera are not commercially cultivated so there is little agronomic information available and no research has been done. Both are very large trees and limited to local market.

- *Mangifera indica* is not well suited climatically. It and cashew require a pronounced dry season to help induce flowering and good fruit development. Both more suited for a wet/dry climate.

- Wet weather during fruit development causes fruit rots in both mango and cashew.

- Wet weather at flowering can lead to 100% crop loss due to disease in both mango and cashew.

- *Mangifera indica* flowers best with cold induction (can use Paclobutrazol to induce flowering).

- With a rainfall regime like that of Brunei, mango trees will grow very well, but growth will be at expense of fruiting. Brunei is more suited for growing mangos for timber than for fruit.

- Mango could be grown in Brunei but will involve heavy use of chemicals to induce flowering and to control fruit rots.
• Neither mango nor cashew can really be recommend as commercial ventures.

Based on these initial criteria, and ignoring climatic requirements, suitable Soil Subtypes for commercial mango and cashew nut plantation are given in Table 82.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphur horizon (c) and depth (mm)</th>
<th>Aluminium (a)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i)</th>
<th>Cracking clays (v)</th>
<th>Cracking depthing (e)</th>
<th>Modified suitability rating for max. slope</th>
<th>Modified suitability rating for max. slope</th>
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</thead>
<tbody>
<tr>
<td>Organic soils</td>
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<td>1</td>
<td>1</td>
<td>3 ga</td>
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</table>
A.2.10 *Artocarpus spp.*

This assessment covers the following *Artocarpus* species:

- **Cempedak** *(Artocarpus integer Merr.)*  
  (also called *A. champeden* (Lour.) Stokes)
- **Jack fruit** *(Artocarpus heterophyllus Lam.)*
- **Tarap** *(Artocarpus odoratissimus Blanco)*

FCC was interpreted for *Artocarpus spp.* using the following information:

- Jack fruit needs fertile well drained soils with high water table (Subhadrabandu 2001).
- Jack fruit has poor tolerance to continuous flooding. It requires well drained soil in lowland areas (Diczbalis and McMahon 2004).
- Jack fruit and chempadek grow best on deep, alluvial soils of open texture and pH 6.0-7.5 (Sedgley 1984a).
- Jack fruit flourishes on rich deep soil of medium or coarser texture, sometimes on deep gravelly or laterite soil. It cannot tolerate waterlogging (Morton 1987).
- Jack fruit needs good drainage and cannot tolerate waterlogging. It prefers deep soil of medium or coarser texture (Anon. 1996b).
- Chempadek thrives on fertile, well drained soils, but prefers a fairly high water table (0.5-2.0 m). It can survive periodic flooding even with acid swamp water (Jansen 1991).
- Tarap prefers rich, loamy, well drained soils (Subhadrabandu 2001).
- Tarap in Sarawak is grown on sandy clay soils. In the Philippines it grows best in regions with abundant and well distributed rainfall on rich loamy well drained soils (dela Cruz Jr. 1991).
- It apppears that *Artocarpus* types survive better than mango or longan on acid soils in Brunei.

### Soil type

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<td>O</td>
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### Waterlogging (g)

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### Slope

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### Erosion (w)

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</table>
Sulfidic (c)
- No c or c >100 cm: 1
- c at 76-100 cm: 2
- c at 51-75 cm: 3
- c at 31-50 cm: 4
- c ≤30 cm: 5

Aluminium (a)
- No a: 1
- a-: 2
- a: 3

Low potassium reserves (k)
- No k: 1
- k: 2

High P fixation (i)
- No i: 1
- i-: 2
- i: 2
- i+: 2

Cracking clays (v)
- No v: 1
- v: 4 Not suited to heavy soil. Soil remains too wet after heavy rain.

High leaching (e)
- No e: 1
- e: 2

Based on these initial criteria, suitable Soil Subtypes for artocarpus are given in Table 83.
Table 83: Artocarpus - Soil Subtype suitability.

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<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (w)</th>
<th>Sulfuric horizon (c) and depth (a)</th>
<th>Aluminum (a, a-)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (V)</th>
<th>High leaching (e)</th>
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</tr>
<tr>
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<td>LLg0%ak</td>
<td>3</td>
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<td>1</td>
<td>3</td>
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<td><strong>Cracking clay soils</strong></td>
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<td>4 g+c(≤55)</td>
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<td>4 &gt;65%</td>
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<td>3 ga</td>
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<td>1</td>
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<td>3</td>
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<td>1</td>
<td>1</td>
<td>5 c(≤30)</td>
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<td><strong>Sulfidic soils</strong></td>
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<td>1</td>
<td>1</td>
<td>5 c(≤30)</td>
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<td>Thauphoto-Histic Sulfuaqets</td>
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<td>3</td>
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<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5 c(≤30)</td>
<td></td>
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<td>Sulfic Fluvaqets</td>
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<td>3 Sgc(≤75)</td>
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<td>1</td>
<td>3 ga</td>
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</tbody>
</table>
A.2.11 Black Mangosteen (*Garcinia mangostana* L.) and Asam Aur-Aur (*G. parvifolia*)

FCC was interpreted for *Garcinia* spp. using the following information:

- It prefers deep, permeable soils with high moisture holding capacity and organic matter. Sandy soils are unsuitable. In India the best soils are coarse clays containing some sand and silt. In general, deep, clay loams or silt loams with good drainage are best (Yaacob *et al.* 1995).
- Mangosteen will grow on a wide range of soils provided the water regime is satisfactory. It prefers slightly acidic, clayey soil, high in organic matter with a fluctuating water table at about 2 m depth (Alexander 1984).
- The water table should be less than 2 m from soil surface (Yaacob *et al.* 1995).
- Asam aur-aur (*Garcinia parvifolia*) probably has similar requirements to mangosteen, but this still needs to be investigated.

### Soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Value</th>
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<td>S</td>
<td>4</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
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<tr>
<td>O</td>
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### Waterlogging

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<th>Tolerates poor drainage.</th>
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</tr>
<tr>
<td>g</td>
<td>3</td>
</tr>
<tr>
<td>g+</td>
<td>4</td>
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### Slope

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<tr>
<td>16-35%</td>
<td>2</td>
</tr>
<tr>
<td>36-65%</td>
<td>3</td>
</tr>
<tr>
<td>66-85%</td>
<td>4</td>
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<tr>
<td>&gt;85%</td>
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### Erosion (w)

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<td>w</td>
<td>2</td>
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### Sulfdic (c)

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</tr>
<tr>
<td>c at 76-100 cm</td>
<td>2</td>
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<tr>
<td>c at 51-75</td>
<td>3</td>
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<tr>
<td>c at 31-50</td>
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<tr>
<td>c ≤30 cm</td>
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### Aluminium (a)

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<td>a-</td>
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<td>a</td>
<td>3</td>
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### Low potassium reserves (k)

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<td>High P fixation (i)</td>
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<td>i</td>
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<td>i+</td>
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<table>
<thead>
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<th>Cracking clays (v)</th>
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<tr>
<td>v</td>
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</table>

Soil remains too wet after heavy rain. Water stress during dry periods.

<table>
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<th>High leaching (e)</th>
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<tbody>
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<tr>
<td>e</td>
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</tr>
</tbody>
</table>

Comment

- Mangosteen can grow in wetter areas than most crops. Information above is based on *Garcinia mangostana* as there is no information on local *Garcinia parvifolia*, assuming its requirements are similar.

Based on these initial criteria, suitable Soil Subtypes for mangosteen are given in Table 84.
Table 84: Mangosteen - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk</th>
<th>Sulfuric horizon</th>
<th>Aluminium</th>
<th>Low K reserves</th>
<th>High P fixation</th>
<th>Cracking clays</th>
<th>High leaching</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
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<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosaprist</td>
<td>OCg+2%c(30)ai±</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>5 Oc(30)</td>
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<tr>
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<td>Typic Sulfosaprist</td>
<td>OOG+2%c(15)ai±</td>
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<td>4</td>
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<td>1</td>
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<td>3</td>
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<td></td>
<td>5 Oc(30)</td>
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<td>LLg0%ak</td>
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<tr>
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<td>Umbric Epiaquods</td>
<td>SSg+2%ke</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4 Sg+</td>
<td></td>
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<tr>
<td><strong>Cracking clay soils</strong></td>
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<td></td>
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</tr>
<tr>
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<td>Sulfic Sulfuaquerts</td>
<td>CCG+0%c(40)a-i+v</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td>4 g+c(550)</td>
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</tr>
<tr>
<td>Acid poorly drained</td>
<td>Typic Dystruquerts</td>
<td>CCG+0%a-i+v</td>
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<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td>4 g±</td>
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</tr>
<tr>
<td><strong>Texture contrast yellow soils</strong></td>
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<td></td>
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<td>Haplohuults</td>
<td>LC20-70%waki</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
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<td>3 &gt;35%±</td>
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</tr>
<tr>
<td><strong>Brown over grey soils</strong></td>
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<td></td>
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<tr>
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<td>Aerig Epiaqualfs</td>
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<td>2</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<td>3 a</td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Epiaqualfs</td>
<td>CCG+2%a-k±</td>
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<td>4</td>
<td>1</td>
<td>1</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Hydraulentic Sulfuaquents</td>
<td>SSg3%c(0)a±</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td>5 c(30)</td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Sulfuaquents</td>
<td>LGg0%c(30)a±</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>5 c(30)</td>
<td></td>
</tr>
<tr>
<td><strong>Sulfidic soils</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Haplic Sulfuaquents</td>
<td>CCG+0%c(30)a±</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>5 c(30)</td>
<td></td>
</tr>
<tr>
<td>Organic poorly drained</td>
<td>Thapto-Histic Sulfuaquents</td>
<td>OCG+2%c(30)a±</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>5 Oc(30)</td>
<td></td>
</tr>
<tr>
<td>Organic poorly drained</td>
<td>Sulficfluuaquents</td>
<td>SSg3%c(70)a±</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4 S</td>
<td></td>
</tr>
<tr>
<td><strong>Grey soils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Humaqu Seattle</td>
<td>CCG+0%a±</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3 a</td>
<td></td>
</tr>
</tbody>
</table>
A.2.12 Dragon Fruit (*Hylocereus undatus* and *H. polyrhizus*)

*Hylocereus undatus* is white fleshed and *H. polyrhizus* red fleshed. FCC was interpreted for dragon fruit using the following information:

- Dragon fruit is a cactus that prefers a dry tropical climate (Diczbalis and McMahon 2004).
- Based on climate, dragon fruit may not be a commercial proposition in Negara Brunei Darussalam.
- Excessive rain leads to flower drop and rotting of immature fruit. Needs alternating wet/dry seasons (Barbeau 1993).
- It grows in Thailand and Vietnam where there is a pronounced dry season. However, it is seen growing in the wet tropics of North Queensland.
- It is epiphytic with strong aerial roots (Morton 1987).
- Dragon fruit tolerates poor soil and has low fertiliser and water needs (Luders 1989).
- Limited soil information is available for dragon fruit so this FCC interpretation is tentative.

### Soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>5</td>
</tr>
</tbody>
</table>

### Waterlogging (g)

- Needs good drainage.
- No g: 1
- g: 3
- g+: 5

### Slope

- 0-15%: 1
- 16-35%: 2
- 36-65%: 3
- 66-85%: 4
- >85%: 5

### Erosion (w)

- No w: 1
- w: 2

### Sulfidic (c)

- No c or c > 100 cm: 1
- c at 76-100 cm: 2
- c at 51-75 cm: 3
- c at 31-50 cm: 4
- c ≤30 cm: 5

### Aluminium (a)

- No a: 1
- a-: 2
- a: 3

### Low potassium reserves (k)

- No k: 1
- k: 2
High P fixation (i)

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>i</td>
<td>1</td>
</tr>
<tr>
<td>-</td>
<td>i-</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>i</td>
<td>2</td>
</tr>
<tr>
<td>+</td>
<td>i+</td>
<td>2</td>
</tr>
</tbody>
</table>

Cracking clays (v)

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>v</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>v</td>
<td>4</td>
</tr>
</tbody>
</table>

Soil remains too wet after heavy rain, drainage issues.

High leaching (e)

<table>
<thead>
<tr>
<th>Level</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>e</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>e</td>
<td>2</td>
</tr>
</tbody>
</table>

Based on soil limited information and ignoring climatic constraints, soils that could be used for dragon fruit are given in Table 85.
### Table 85: Dragon fruit - Soil Subtype suitability.

**Suitability for: Dragon fruit**

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>Rating for soil attributes:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Topsoil type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FCC</td>
</tr>
<tr>
<td><strong>Organic soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosaprists</td>
<td>OCG+2%c(30)a-i+</td>
</tr>
<tr>
<td>Sulfuric</td>
<td>Typic Sulfosaprists</td>
<td>OCG+2%c(15)a-i+</td>
</tr>
<tr>
<td>Mineral sulfidic</td>
<td>Terric Sulfisaprists</td>
<td>OLG+0%c(30)a-+</td>
</tr>
<tr>
<td>Sulfidic</td>
<td>Typic Sulfisaprists</td>
<td>OCG+0%c(30)a-+</td>
</tr>
<tr>
<td><strong>White soils</strong></td>
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<td></td>
</tr>
<tr>
<td>Loamy poorly drained</td>
<td>Ultic Epiuquods</td>
<td>LLG0%ak</td>
</tr>
<tr>
<td>Sandy poorly drained</td>
<td>Ummbric Epiuquods</td>
<td>SSg+2%ke</td>
</tr>
<tr>
<td><strong>Cracking clay soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfidic poorly drained</td>
<td>Sulfic Sulfuquerts</td>
<td>CCG+0%c(40)a-+</td>
</tr>
<tr>
<td>Acid poorly drained</td>
<td>Typic Dystraquerts</td>
<td>CCG+0%a-+v</td>
</tr>
<tr>
<td><strong>Texture contrast yellow soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>ardaclaceae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>sodic</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>arenic</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Very deep yellow soils</strong></td>
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<td></td>
</tr>
<tr>
<td>Somewhat poorly drained</td>
<td>Aquic Kandihumults</td>
<td>LLG2%a-ke</td>
</tr>
<tr>
<td>Well drained</td>
<td>Typic Kandihumults</td>
<td>LL25-70%wake</td>
</tr>
<tr>
<td>Somewhat poorly drained</td>
<td>Aquic Palehumults</td>
<td>LLL3%ak</td>
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<tr>
<td>Moderately well drained</td>
<td>Oxyaquic Palehumults</td>
<td>LC0-30%ak</td>
</tr>
<tr>
<td>Well drained clayey</td>
<td>Typic Palehumults</td>
<td>LC15-30%waki</td>
</tr>
<tr>
<td><strong>Yellow soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately well drained</td>
<td>Oxyaquic Haplohumults</td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Well drained</td>
<td>Typic Haplohumults</td>
<td>CC60-70%waki</td>
</tr>
<tr>
<td><strong>Brown over grey soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somewhat poorly drained</td>
<td>Aerlic Epiuquads</td>
<td>CCG2%ak</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>Typic Epiuquads</td>
<td>CCG+2%a-ki+</td>
</tr>
<tr>
<td><strong>Sulfuric soils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Hydroaquentic Sulfuquepts</td>
<td>SSg3%c(0)a-ke</td>
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<tr>
<td>Poorly drained</td>
<td>Typic Sulfuquepts</td>
<td>LCg3%c(30)a-ke</td>
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<td>Haplic Sulfuquepts</td>
<td>CCG+0%c(30)a-+</td>
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<td>Organic poorly drained</td>
<td>Thalpo-Histic Sulfuquepts</td>
<td>OCG2%c(30)a+i</td>
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<td>Sulfic Fluvaquets</td>
<td>SSG3%c(70)a-ke</td>
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</tr>
<tr>
<td>Poorly drained</td>
<td>Humaqueptic</td>
<td>CCG0%ak</td>
</tr>
</tbody>
</table>
A.2.13 Guava (Psidium guajava L.)

FCC was interpreted for guava using the following information:

- Guava is adapted to a wide range of soil types from coarse sand to rather heavy clay. It will tolerate waterlogging. pH should be 5.0-8.0 (Batten 1984, 1985).
- Loam and alluvial soils are preferred (Mohamad Idris bin Zainal Abidin 1990).
- Guava grows well in many soil types including very poor ones. The poorest growth is in heavy clay. It is tolerant of flooding (CRC Handbook 1984).
- Phytophthora species can kill trees in Thailand (Soetopo 1991).
- Good drainage is recommended but guava is seen growing spontaneously on land with a high water table – too wet for most other fruit trees (Morton 1987).
- Guava in Labi has been seen to succumb to either Phytophthora or water logging.

**Soil type**

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>5</td>
</tr>
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</table>

**Waterlogging (g)**

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<th>Grade</th>
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<tbody>
<tr>
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<tr>
<td>g</td>
<td>3</td>
</tr>
<tr>
<td>g+</td>
<td>5</td>
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**Slope**

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<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15%</td>
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<tr>
<td>16-35%</td>
<td>2</td>
</tr>
<tr>
<td>36-65%</td>
<td>3</td>
</tr>
<tr>
<td>66-85%</td>
<td>4</td>
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<tr>
<td>&gt;85%</td>
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**Erosion (w)**

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<tbody>
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<td>w</td>
<td>2</td>
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</tbody>
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**Sulfidic (c)**

<table>
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<tr>
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<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>No c or c &gt; 100 cm</td>
<td>1</td>
</tr>
<tr>
<td>c at 75-100 cm</td>
<td>2</td>
</tr>
<tr>
<td>c at 51-75 cm</td>
<td>3</td>
</tr>
<tr>
<td>c at 31-50 cm</td>
<td>4</td>
</tr>
<tr>
<td>c ≤30 cm</td>
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</tr>
</tbody>
</table>

**Aluminium (a)**

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</thead>
<tbody>
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<td>No a</td>
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</tr>
<tr>
<td>a-</td>
<td>2</td>
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<tr>
<td>a</td>
<td>3</td>
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</table>

**Low potassium reserves (k)**

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<td>k</td>
<td>2</td>
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</table>

**High P fixation (i)**

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<th>Grade</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>i-</td>
<td>2</td>
</tr>
<tr>
<td>i</td>
<td>2</td>
</tr>
<tr>
<td>i+</td>
<td>2</td>
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</table>
Cracking clays (v)

<table>
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</thead>
<tbody>
<tr>
<td>v</td>
<td>4</td>
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</tbody>
</table>

Soil remains too wet after heavy rain.

High leaching (e)

<table>
<thead>
<tr>
<th>No e</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
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</tr>
</tbody>
</table>

Based on these initial criteria, suitable Soil Subtypes for guava are given in Table 86.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (%)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuri horizon (c) and depth</th>
<th>Aluminum (a, -)</th>
<th>Low K reserves (K)</th>
<th>High Fe fixation (I+, +)</th>
<th>Cracking clays (V)</th>
<th>High Leaching (e)</th>
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<td>5 c(≤30)</td>
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<td>Aqueunts</td>
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A.2.14 Star Fruit (*Averrhoa carambola* L.)

FCC was interpreted for star fruit using the following information:

- Star fruit is adapted to poor, sandy soils if organic mulch is applied (Diczbalis and McMahon 2004).
- Any soil type is suitable as long as it is well drained. It does best on moderately acid soil of pH 5.5-6.5 (Sedgley 1984b).
- Star fruit is not too particular about soil, but grows best in rich loam with pH 5.5-6.5. Star fruit is sensitive to waterlogging (Anon. 1996a).
- It is tolerant to a wide range of soil types from sands to heavy clay loams, but grows best on deep clay loams (Parker 1984).
- Deep rich fertile soils of a loamy or clayey loam texture with high organic matter are preferable. Guava needs good drainage and pH 5.5-6.5. It does not require a particularly fertile soil (Galan Sauco *et al.* 1993).
- It prefers a climate with a dry season, thriving in similar locations to teak but also does well in wetter climates. It has a high water requirement. It needs well drained soils with pH 5.5-6.5 and grows well on peat. It does not tolerate drought, flooding or salinity (Sampson 1991).

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<tr>
<td>L</td>
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<td>C</td>
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<tr>
<td>O</td>
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<td>36-65%</td>
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<tr>
<td>c at 76-100 cm</td>
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<tr>
<td>c at 51-75 cm</td>
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</tr>
<tr>
<td>c at 31-50 cm</td>
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<td>c ≤30 cm</td>
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<td>k</td>
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</table>
**High P fixation (i)**
- No i  
  - i- 2
  - i 2
  - i+ 2

**Cracking clays (v)**
- No v 1
  - v 4 Soil remains too wet after heavy rain. Water stress during dry periods.

**High leaching (e)**
- No e 1
  - e 2

Based on these initial criteria, suitable Soil Subtypes for star fruit are given in Table 87.
### Table 87: Star fruit - Soil Subtype suitability.

#### Suitability for: Star fruit

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulfuric horizon (c) and depth (a)</th>
<th>Aluminium (a)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays</th>
<th>High Leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
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<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosaprist</td>
<td>OCG+2%c(30)ai+</td>
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<td>3 ga</td>
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</table>
A.2.15 Longan (*Dimocarpus longan* Lour.)

FCC was interpreted for longan using the following information:

- Traditional longan cultivars are unsuitable for Brunei as they are subtropical trees and have a high chilling requirement (Crane *et al.* 2005; E Winston).

- Newer cultivars such as Phetsakon (Diamond River), Ping Pong, Longnhan and Tieuhue from Thailand and Vietnam require little chilling and are suitable for tropical areas (E Winston, Choo 2000).

- Phetsakon has already been tried in Brunei. Some were planted on acid sulfate soil, and thrived for a few years on small mounds with lime and chicken manure but deteriorated once they outgrew their mounds.

- Warm and wet winters can lead to vegetative rather than floral development. Wet weather at flowering causes flower drop and reduced pollination and fruit set (Crane *et al.* 2005).

- Young trees can die with as little as 5 - 10 days of flooding or constantly wet soil (Crane *et al.* 2005; Bastas 2002/03).

- Longan grows best on rich sandy loam. It prefers deep, well drained soils with pH 5.5-6.0. In Thailand the best production is on heavy alluvial soils with root access to the water table (Bastas 2002/03).

- Longan will grow on various soil types if well drained (Bastas 2002/03).

- Longan thrives on wide variety of soil types as long as drainage is good enough to prevent waterlogging. It grows best on deep, clay loam soils with pH 5.0-6.5. Soil types that support lush growth can be counter-productive because they encourage vegetative rather than floral growth (Diczbalis and Campbell 2004).

- The requirements of longan are also given by Menzel and Waite (2005).

### Soil Type

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<thead>
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<th>Value</th>
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<tr>
<td>S</td>
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<tr>
<td>L</td>
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<tr>
<td>C</td>
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<td>O</td>
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### Waterlogging (g)

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<tr>
<td>g</td>
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### Slope

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<td>16-35%</td>
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<td>36-65%</td>
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<td>&gt;85%</td>
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### Erosion (w)

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### Sulfidic (c)

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<td>c at 76-100 cm</td>
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<tr>
<td>c at 51-75 cm</td>
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<tr>
<td>c ≤50 cm</td>
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</table>
### Aluminium (a)
- No a 1
- a- 2
- a 3

### Low potassium reserves (k)
- No k 1
- k 2

### High P fixation (i)
- No i 1
- i- 2
- i 2
- i+ 2

### Cracking clays (v)
- No v 1
- v 4  
  Soil remains too wet after heavy rain. Water stress during dry periods.

### High leaching (e)
- No e 1
- e 2

Based on these initial criteria, suitable Soil Subtypes for longan are given in Table 88.
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<th>Waterlogging</th>
<th>Erosion risk</th>
<th>Sulfuric horizon (c) and depth</th>
<th>Aluminum</th>
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<th>Suitability rating</th>
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<td>SSg3%c(70)ake</td>
<td>2 3 1 1 3 3 2 1 1 2</td>
<td>3 gc(≤75)a</td>
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<td>Grey soils</td>
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<td>Humaqueptic</td>
<td>CC60%0%cak</td>
<td>1 3 1 1 1 3 2 2 1 1</td>
<td>3 ga</td>
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</table>
A.3 Fodder Crops

A.3.1 Fodder Grasses for Wet Areas

This assessment covers the following grass species that are more suited to wet areas:

- Para grass
- Brachiaria humicola
- Brachiaria mutica
- Humidicola
- Brachiaria humidicola

FCC was interpreted for *Brachiara* spp. using the following information:

- *Brachiaria humicola* and *B. mutita* can tolerate waterlogging (Horne and Stur 1999). Although *B. humicola* is less tolerant of flooding than *B. mutica*, it has good tolerance (Skerman and Riveros 1990).
- *Brachiaria* has excellent tolerance to aluminium (Skerman and Riveros 1990, Moody and Cong 2008).
- *B. humicola* grows in wide range of soils including those that are very infertile, acid or high pH (Horne and Stur 1999).
- *B. mutica* is semi-aquatic and can persist in standing and running water (Skerman and Riveros 1990).

**Soil type**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
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</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
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**Waterlogging (g)**

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</tr>
<tr>
<td>g</td>
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<td>g+</td>
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**Slope**

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<td>1</td>
</tr>
<tr>
<td>21-55%</td>
<td>2</td>
</tr>
<tr>
<td>&gt;55%</td>
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**Erosion (w)**

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<td>w</td>
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**Sulfidic (c)**

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<tr>
<td>c at ≤20 cm</td>
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**Aluminium (a)**

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<td>a</td>
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**Low potassium reserves (k)**

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<td>k</td>
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**High P fixation (i)**

<table>
<thead>
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</tr>
<tr>
<td>i-</td>
<td>2</td>
</tr>
<tr>
<td>i</td>
<td>2</td>
</tr>
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<td>i+</td>
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**Cracking clays (v)**

<table>
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<tr>
<td>v</td>
<td>3</td>
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</tbody>
</table>

**High leaching (e)**

<table>
<thead>
<tr>
<th>e</th>
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</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>2</td>
</tr>
</tbody>
</table>

**Comments**

- These grasses need N fertiliser, but have a low P requirement.
- They can withstand short periods of flooding.

Based on these initial criteria, suitable Soil Subtypes for fodder grasses suitable for wet areas are shown in Table 89.
### Table 89: Fodder grasses suitable for wet areas - Soil Subtype suitability.

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Erosion risk</th>
<th>Sulphur horizon (c) and depth</th>
<th>Aluminium</th>
<th>Low K reserves</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking days</th>
<th>Cracking severity (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
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<tr>
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<td>Erosion risk</td>
<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
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<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosaprist</td>
<td>OCG+2%c(30)ai+</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
</tr>
<tr>
<td>Sulfuric</td>
<td>Typic Sulfosaprist</td>
<td>OOG+2%c(15)ai+</td>
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<td>1</td>
<td>1</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
</tr>
<tr>
<td>Mineral sulfidic</td>
<td>Terric Sulfisaprist</td>
<td>OLG+0%c(30)aki+</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
<td></td>
</tr>
<tr>
<td>Sulfidic</td>
<td>Typic Sulfisaprist</td>
<td>OOG+0%c(30)ai+</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
<td></td>
</tr>
<tr>
<td><strong>White soils</strong></td>
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<td></td>
<td>Topsoil type</td>
<td>Waterlogging</td>
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<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
</tr>
<tr>
<td>Loamy poorly drained</td>
<td>Ultic EpiAquods</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>Sandy poorly drained</td>
<td>Umbric EpiAquods</td>
<td>SSG+2%ke</td>
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<td>1</td>
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<td>1</td>
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<td><strong>Cracking clay soils</strong></td>
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<td>Topsoil type</td>
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<td>Erosion risk</td>
<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
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<tr>
<td>Sulfidic poorly drained</td>
<td>Sulfic Sulfaquerts</td>
<td>CCG+0%c(40)ai+v</td>
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<td>1</td>
<td>1</td>
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<td>3 v</td>
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<td>Typic Dysbraquerts</td>
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<td>1</td>
<td>3 v</td>
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<tr>
<td><strong>Texture contrast yellow soils</strong></td>
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<td>Erosion risk</td>
<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
</tr>
<tr>
<td>Arenic Paleudults</td>
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<td>Waterlogging</td>
<td>Erosion risk</td>
<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
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<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
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<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
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<td>2</td>
<td>2 e</td>
<td>2 e</td>
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<td>LLG3%akl</td>
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<td>2 i</td>
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<td>Oxyaquic Palehumults</td>
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<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
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<td>CCG2%ai+</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
</tr>
<tr>
<td><strong>Sulfuric soils</strong></td>
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<td></td>
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<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
</tr>
<tr>
<td>Soft poorly drained</td>
<td>Hydraquentic Sulfaquents</td>
<td>SSG3%ci(0)ake</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2 Sc(S20)e</td>
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<td>Typic Sulfaquents</td>
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<td>1</td>
<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
</tr>
<tr>
<td><strong>Sulfidic soils</strong></td>
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<td>Sulphur horizon (c) and depth</td>
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<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
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<td>Haplic Sulfaquents</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
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<td>Thapto-Histic Sulfaquents</td>
<td>OG2%ci(30)ai-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 i+</td>
<td>2 i+</td>
</tr>
<tr>
<td>Organic poorly drained moderately deep</td>
<td>Sulfic Fluvaquents</td>
<td>SGG3%ci(70)ake</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2 Se</td>
<td></td>
</tr>
<tr>
<td><strong>Grey soils</strong></td>
<td></td>
<td></td>
<td>Topsoil type</td>
<td>Waterlogging</td>
<td>Erosion risk</td>
<td>Sulphur horizon (c) and depth</td>
<td>Aluminium</td>
<td>Low K reserves</td>
<td>High P fixation (i, i-, i+)</td>
<td>Cracking days</td>
<td>Cracking severity (e)</td>
<td>Suitability rating</td>
<td>Modified suitability rating for max. slope</td>
</tr>
</tbody>
</table>
A.3.2 Fodder Grasses for Well Drained Areas

This assessment covers the following grass species that are more suited to well drained areas:

- Signal grass
- Napier grass
- Guinea grass
- Guatemala grass
- Molasses grass
- Brachiaria decumbens
- Pennisetum purpureum
- Panicum maximum
- Tripsacium laxum
- Melinis minutiflora

FCC was interpreted for these fodder grasses using the following information:

- *Brachiaria decumbens* and *Panicum maximum* have an excellent tolerance to aluminium (Skerman and Riveros 1990).
- *B. decumbens* will persist on infertile, acid soils (Horne and Stur 1999, Skerman and Riveros 1990).
- *B. decumbens* is tolerant of a wide range of soils and little affected by high aluminium or shallow soil. It needs good drainage (Skerman and Riveros 1990).
- *Panicum maximum* will grow on large range of soils but does poorly on infertile soils. Well adapted to sloping land. It will tolerate acid soil if drained (Skerman and Riveros 1990).
- *P. maximum* will not do well in areas subject to prolonged waterlogging or flooding (Duke 1983a).
- *Pennisetum purpureum* needs high fertility (Horne and Stur 1999). Research has indicated the species is productive in Brunei with high fertilizer inputs (Williams 1980).
- *P. purpureum* is deep rooting and drought tolerant for short dry seasons. It has a heavy nutrient requirement (Skerman and Riveros 1990).
- *Melinis minutiflora* is good for sloping lands (Duke 1983b).
- *M. minutiflora* grows on a variety of well drained soils, with surface textures ranging from sands to medium clays. It tends to be vigorous on hillsides and road cuttings. It is tolerant of low fertility, a wide range of pH and high aluminium (Anon. ?b).
- *M. minutiflora* is tolerant of up to 4 - 5 months dry season and of soils of low fertility, high aluminium and light texture. It responds to fertiliser, but needs good drainage.
- *Tripsacum laxum* has poor drought tolerance, poor flooding tolerance, needs rich soil but will tolerate aluminium. It needs a heavy fertiliser programme. It is less productive than *Pennisetum purpureum* (Skerman and Riveros 1990).

Soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>1</th>
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<tr>
<td>L</td>
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Waterlogging (g)

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Slope

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<tr>
<td>&gt;55%</td>
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Depends on which grass, some more suited.
**Erosion (w)**
- No w 1
- w 2

**Sulfidic (c)**
- No c or >20 cm 1
- c at ≤20 cm 2

**Aluminium (a)**
- No a 1
- a- 1
- a 1

**Low potassium reserves (k)**
- No k 1
- k 2

**High P fixation (i)**
- No rating 1
- i- 2
- i 2
- i+ 2

**Cracking clays (v)**
- No v 1
- v 3

**High leaching (e)**
- No e 1
- e 2

**Comments**
- There are large differences in environmental needs between species.
- They generally need high nutrition.
- There are differences in productivity and palatability.

Based on these initial criteria, suitable Soil Subtypes for fodder grasses for well drained areas are shown in Table 90.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
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<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphuric horizon (c) and depth (a, ±)</th>
<th>Aluminium</th>
<th>Low K reserves</th>
<th>High P fixation (i, ±)</th>
<th>Cracking clays</th>
<th>High Leaching</th>
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<th>Modified suitability rating for max. slope</th>
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</table>
A.3.3 Fodder Legumes for Wet Areas

This assessment covers the following legume species that are more suited to wet areas:

- Centro
- Calapo
- Stylo
- Pinto Peanut
- Indian jointed vetch
- Arachis pintoi
- Clapogonium mucnoides
- Styloanthes guianensis
- Aeschynomene indica L.

FCC was interpreted for these fodder legumes using the following information:

- **Centrosema pubescens** does not tolerate water logging. (Horne and Stur 1999). However, Skerman et al. (1988) stated that it has good flood tolerance.

- **C. pubescens** grows in wide range of soils from sandy loams to clays. In Sri Lanka it prefers heavier clay loams to clay (Skerman et al. 1988). Horne and Stur (1999) reported that it needs moderately fertile, well drained soils.

- **Calapogonium mucnoides** has good flooding tolerance. It is adaptable to wide range of soil textures and pH, doing well at pH 4.5-5.0 (Skerman et al. 1988).

- **C. mucnoides** is relatively unpalatable (Skerman et al. 1988, Anon. ?c).

- **Styloanthes guianensis** will tolerate temporary waterlogging, but will not grow in swamps. It does well on coarse textured soils but not as well on heavy clays. It grows well on latosols, gleys, loams and sandy podzolic soils. It needs well drained, open textured soils. It is tolerant of acid soils (Horne and Stur 1999).

- **Arachis pintoi** grows well in Negara Brunei Darussalam as an ornamental. This species is widely used elsewhere as an orchard cover crop and as a pasture legume. It could well have a role to play as a pasture species in Negara Brunei Darussalam.

- **Aeschynomene indica L.**, also known as Budda Pea, curly indigo, and sensitive vetch, is a freely nodulating nitrogen-fixing species. *A. indica* can be used as a green manure crop and may also have application as a fodder crop in rotation with rice (Cook et al. 2005).

- **A. indica** is found on soils with texture ranging from sandy loam to clay with its distribution more determined by moisture availability and drainage than by soil texture. It occurs mostly on soils that are subject to flooding and waterlogging (Cook et al. 2005).

### Soil type

- **S**
- **L**
- **C**
- **O**

### Waterlogging (g)

- **No g**
- **g**
- **g+**

### Slope

- **0-20%**
- **21-55%**
- **>55%**

### Erosion (w)

- **No w**
- **w**
**Sulfidic (c)**

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<td>c at ≤20 cm</td>
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**Aluminium (a)**

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**Low potassium reserves (k)**

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**High P fixation (i)**

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<td>i+</td>
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</table>

**Cracking clays (v)**

<table>
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</thead>
<tbody>
<tr>
<td>No v</td>
<td>1</td>
</tr>
<tr>
<td>v</td>
<td>3</td>
</tr>
</tbody>
</table>

Less suited to heavy soil.

**High leaching (e)**

<table>
<thead>
<tr>
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<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>No e</td>
<td>1</td>
</tr>
<tr>
<td>e</td>
<td>2</td>
</tr>
</tbody>
</table>

**Comments**

- The requirements vary slightly between species.
- The palatability of Calopo could be an issue

Based on these initial criteria, suitable Soil Subtypes for fodder legumes suitable for wet areas are shown in Table 91.
Table 91: Fodder legumes suitable for wet areas - Soil Subtype suitability.

**Suitability for: Fodder legumes for wet areas**

**Ratings for soil attributes:**

<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (w)</th>
<th>Sulfuric horizon (c) and depth (a, i, k)</th>
<th>Aluminium</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i- i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic soils</strong></td>
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<td></td>
</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfosaprist</td>
<td>OCg+2%c(30)ai+</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 Og+ai+</td>
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<td></td>
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</tr>
<tr>
<td>Sulfuric</td>
<td>Typic Sulfosaprist</td>
<td>OCg+2%c(15)ai+</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 Og+c(s20)ai+</td>
<td></td>
<td></td>
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<tr>
<td>Mineral sulfidic</td>
<td>Terric Sulfasaprist</td>
<td>OLg+0%c(30)aki+</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 Og+aki+</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sulfidic</td>
<td>Typic Sulfasaprist</td>
<td>OOG+0%c(30)aki+</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2 Og+ai+</td>
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<td><strong>White soils</strong></td>
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</tr>
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<td>Ultic Epiaquods</td>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2 ak</td>
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</tr>
<tr>
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<td>Umbric Epiaquods</td>
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<td>2</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2 g+ke</td>
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<tr>
<td><strong>Cracking clay soils</strong></td>
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<td>Sulfic Sufquaquets</td>
<td>CCg+0%c(40)ai+v</td>
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<td>3 v</td>
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<td>3 v</td>
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<tr>
<td>Yellow soils</td>
<td>Haplotufts</td>
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<td>1</td>
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<td>2 &gt;20%wak e</td>
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<td></td>
<td>3 &gt;55%</td>
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<tr>
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<td>Aquic Palehumults</td>
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<td>1</td>
<td>2 Cak</td>
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<td>Typic Epiaquots</td>
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<td>1</td>
<td>2 Cg+ki+</td>
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<tr>
<td><strong>Sulfuric soils</strong></td>
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<td>Soft poorly drained</td>
<td>Hydraulentic Sulfquaquets</td>
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<td>1</td>
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<td>1</td>
<td>2 c(s20)aake</td>
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<td>1</td>
<td>2</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2 ake</td>
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<tr>
<td><strong>Sulfidic soils</strong></td>
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<tr>
<td>Soft poorly drained</td>
<td>Haplic Sulfquaquets</td>
<td>CCg0%c(30)aki+</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 Cg+aki+</td>
<td></td>
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<td>Thapto-Histic Sulfquaquets</td>
<td>OCG2%c(30)a-i</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 Oi</td>
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<tr>
<td>Organic poorly drained moderately deep</td>
<td>Sulfic Fluvaquequets</td>
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<td>2 ake</td>
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<tr>
<td><strong>Grey soils</strong></td>
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<td>Poorly drained</td>
<td>Humaqueptic</td>
<td>CCg0%aki</td>
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<td>1</td>
<td>1</td>
<td>2 Caki</td>
<td></td>
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</tbody>
</table>
A.3.4 Fodder Legumes for Well Drained Areas

This assessment covers the following legume species that is more suited to well drained areas:

- Apil-Apil
- *Leucaena leucocephala*

FCC was interpreted for this fodder legume using the following information:

- *Leucaena leucocephala* is a long lived tree/shrub. It has deep roots and is good for areas with long dry periods (and is often used in tropical Australia as a drought crop). It does not tolerate infertile, acid soils nor soils prone to waterlogging (Horne and Stur 1999).
- *L. leucocephala* is not aluminium tolerant (Moody and Cong 2008).
- *L. leucocephala* will not tolerate flooding. It requires good drainage where roots can reach the watertable. It does not do well in acid soils (Skerman et al. 1988).
- *L. leucocephala* is not a ground cover crop.
- *Arachis pintoi* (see section A.3.3) could be used as a pasture species in well drained areas as well as wetter areas.

Suitability rankings below are based mainly on *Leucaena*.

### Soil type

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
</tr>
<tr>
<td>O</td>
<td>3</td>
</tr>
</tbody>
</table>

### Waterlogging (g)

<table>
<thead>
<tr>
<th>Waterlogging (g)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
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<tr>
<td>g</td>
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</tr>
<tr>
<td>g+</td>
<td>4</td>
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### Slope

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<th>Rating</th>
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</thead>
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<td>0-20%</td>
<td>1</td>
</tr>
<tr>
<td>21-35%</td>
<td>2</td>
</tr>
<tr>
<td>&gt;35%</td>
<td>3</td>
</tr>
</tbody>
</table>

### Erosion (w)

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<th>Rating</th>
</tr>
</thead>
<tbody>
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<td>w</td>
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### Sulfidic (c)

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<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>No c or &gt;30 cm</td>
<td>1</td>
</tr>
<tr>
<td>c at 21-30 cm</td>
<td>2</td>
</tr>
<tr>
<td>c at ≤20 cm</td>
<td>3</td>
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</tbody>
</table>

### Aluminium (a)

<table>
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<tr>
<th>Aluminium (a)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>No a</td>
<td>1</td>
</tr>
<tr>
<td>a-</td>
<td>2</td>
</tr>
<tr>
<td>a</td>
<td>3</td>
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</tbody>
</table>

### Low potassium reserves (k)

<table>
<thead>
<tr>
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<th>Rating</th>
</tr>
</thead>
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<td>1</td>
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<tr>
<td>k</td>
<td>2</td>
</tr>
</tbody>
</table>
**High P fixation (i)**
- No rating: 1
- i-: 2
- i: 2
- i+: 2

**Cracking clays (v)**
- No v: 1
- v: 3 Less suited to heavy soil.

**High leaching (e)**
- No e: 1
- e: 2

**Comments**
- The requirements vary slightly between species.
- Apil Apil is a tree or large shrub, not a ground cover crop.
- Pintoi peanut may be a better option.

Based on these initial criteria, suitable Soil Subtypes for fodder legumes suitable for well drained areas are shown in Table 92.
<table>
<thead>
<tr>
<th>Soil Subtype</th>
<th>Soil Taxonomy Class</th>
<th>FCC</th>
<th>Topsoil type</th>
<th>Waterlogging</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (W)</th>
<th>Sulphur horizon (c and depth)</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves (K)</th>
<th>High P fixation (i, i+, i++)</th>
<th>Cracking clay (V)</th>
<th>High Leaching (e)</th>
<th>Suitability rating</th>
<th>Modified suitability rating for max. slope</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Mineral sulfuric</td>
<td>Terric Sulfsaprist</td>
<td>OCg+2%c(30)ai+</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>2</td>
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<td>1</td>
<td>4 g+</td>
<td></td>
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<tr>
<td>Sulfuric</td>
<td>Typic Sulfsaprist</td>
<td>OOG+2%c(15)ai+</td>
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<td>4</td>
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<td>4 g+</td>
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<td>OLg+0%c(30)ai+</td>
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<td>1</td>
<td>4 g+</td>
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<td>Typic Sulfsaprist</td>
<td>OOG+0%c(30)ai+</td>
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Appendix B  Map units – Soil Attributes and Crop Suitability

Forty three map units are identified within the 27 surveyed Agricultural Development Areas (ADAs). The component Soil Types that occur within these maps units are listed in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-2 – Soil Properties and Soil Identification Key for Major Soil Types (Grealish et al. 2007a). The map units are presented in this section in alphabetical order. The top row of the table for each map unit has the map unit symbol and the colour used to represent the map unit in Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam Report P1-1.2 – Soil Maps (Grealish et al. 2007b). The second row shows the component Soil Types for the map unit followed by the approximate proportion of the map unit that they occupy. The next block of rows under each Soil Type presents its Fertility Capability Classification (FCC) soil attributes (as determined in Part 4 above). Soil attribute codes are given in Table 6 and Table 8. The lowest block of rows show the suitability of each Soil Type for the range of 27 crops or groups of crops listed in Table 2.

In the table for each map unit, the second column from the left (i.e. under the map unit symbol) shows the interpretive FCC soil attributes and crop suitabilities determined as described in Section 5.2.2. Land suitability classes are defined in Section 3.3.3.

Under each table, the areas of the map unit within any ADA in which it occurs are listed. Finally any other map units that have an identical composition of Soil Types are given.
### Map unit AN (be)

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<th>Component Soil Subtypes</th>
<th>Mineral sulfidic organic soils</th>
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<td>Terric Sulfosaprists</td>
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#### Soil Attribute Ratings

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<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
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<td>O</td>
<td>L</td>
<td>g+</td>
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<td>25%</td>
<td>-</td>
<td>c(30)</td>
<td>a</td>
<td>k</td>
<td>i+</td>
<td>-</td>
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#### Crop Suitability Ratings

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<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soy and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Arctocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -wet areas</th>
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<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>3≤20%w</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>4 g+c≤(30)</td>
<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>3≤20%w</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>4 g+</td>
<td>4 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 g+</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>4 g+c≤(30)</td>
<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>4 g+c≤(30)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>5 Og+c≤(50)</td>
<td>3≤20%w</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Map unit AN (be) occurs in the following surveyed Agricultural Development Areas:

**Belait**
- Tungulian: 13 ha
- Melayan A: 11 ha
- Labi Lama: 40 ha
- KM 26, Jalan Bukit Puan Labi: 16 ha
## Map unit AN (bm)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Mineral sulfidic organic soils</th>
<th>Mineral sulfuric organic soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Terric Sulfisaprists</td>
<td>Terric Sulfosaprists</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Swamp</td>
<td>Swamp</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>L</td>
<td>g+</td>
<td>0%</td>
<td>2%</td>
<td>-</td>
<td>c(30)</td>
<td>a</td>
<td>k</td>
<td>i+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

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Map unit AN (bm) occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**
- Si Tukak, Limau Manis B: 2 ha
- Lumapas: 14 ha
- Limpaki: 3 ha
### Map unit BDG-1

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>BDG-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Moderately well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Poorly drained brown over grey soils</td>
</tr>
<tr>
<td>Soils</td>
<td>Oxyaquic Palehumults</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>70%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>-</td>
<td>0%</td>
<td>30%</td>
<td>-</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>i+</td>
<td>-</td>
<td>-</td>
<td>LC0-30%ak</td>
</tr>
<tr>
<td>L</td>
<td>C</td>
<td>g+</td>
<td>0%</td>
<td>30%</td>
<td>-</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>i+</td>
<td>-</td>
<td>-</td>
<td>LC0-30%ak</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>-</td>
<td>2%</td>
<td>30%</td>
<td>-</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>i+</td>
<td>-</td>
<td>-</td>
<td>CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconuts</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -well drained areas</th>
<th>Fodder legumes for -well drained areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 No g [5 &gt;15%]</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 ak</td>
<td>2 ak</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
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<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 No g</td>
<td>2 No g</td>
</tr>
<tr>
<td>3 No g [5 &gt;15%]</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 ak</td>
<td>2 ak</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 No g</td>
<td>2 No g</td>
</tr>
<tr>
<td>3 No g [5 &gt;15%]</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 ak</td>
<td>2 ak</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 No g</td>
<td>3 a</td>
</tr>
<tr>
<td>3 No g [5 &gt;15%]</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 ak</td>
<td>2 ak</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>2 No g</td>
<td>3 a</td>
</tr>
</tbody>
</table>

Map unit BDG-1 occurs in the following surveyed Agricultural Development Areas:

- **Temburong**
  - Selangan: 21 ha
  - Bakarut: 9 ha
  - Selapon: 9 ha

Map unit BDG-1 has the same soil components as map units BDG-TTN-1 and JML-2.
# Map unit BDG-2

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BDG-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Moderately well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Palehumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial terrace</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

## Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Soil Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC0-30%ak TLC0-30%ak</td>
</tr>
</tbody>
</table>

## Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>3 No g [5 &gt;15%] 3 No g [5 &gt;15%]</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 a</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 a</td>
</tr>
<tr>
<td>Maize</td>
<td>3 a</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>2 ak</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No g</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 k</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 ak</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 a</td>
</tr>
</tbody>
</table>

Map unit BDG-2 occurs in the following surveyed Agricultural Development Areas:

- **Temburong** 10 ha
- **Selangan**
Map unit BDG-TTN-1

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BDG-TTN-1</th>
</tr>
</thead>
</table>
| Component Soil Subtypes | Moderately well drained clayey very deep yellow soils
| Soil Taxonomy classification of component soils | Oxyaquic Palehumults Tyfic Eapiaqualfs
| General landscape position | Alluvial terrace Alluvial flats
| Proportion of map unit | 70% 30% |
| Soil Attribute Ratings |                      |
| Topsoil type | L C L C |
| Subsoil type | C C C C |
| Waterlogging (g, g+) | - g+ |
| Slope (%) | 0% 0% 2% |
| Max. slope (%) | 30% 30% |
| Erosion risk (w) | - |
| Sulfidic horizon (c) & depth, cm | - |
| Aluminium (a, a-) | a a a- |
| Low K reserves (k) | k k k |
| High P fixation (i, i, i+) | - i+ |
| Cracking clays (v) | - |
| High leaching (e) | - |
| FCC | LC0-30%ak LC0-30%ak CCg+2%a-ki+ |
| Crop Suitability Ratings |                      |
| Rice | 3 No g [5 >15%] 3 No g [5 >15%] 2 g+k+i+ |
| Leafy and fruit vegetables | 3 a 3 a 3 g+ |
| Root vegetables | 3 a 3 a 3 g+ |
| Groundnuts | 3 a 3 a 4 g+ |
| Soya and mung beans | 3 a 3 a 5 g+ |
| Maize | 3 a 3 a 4 g+ |
| Ginger and turmeric | 3 a 3 a 3 g+ |
| Cassava and sweet potato | 2 ak 2 ak 4 g+ |
| Durian | 3 a 3 a 5 g+ |
| Rambutan | 3 a 3 a 5 g+ |
| Langsat-duku | 3 a 3 a 5 g+ |
| Citrus | 3 a 3 a 4 Cg+ |
| Banana | 3 ak 3 ak 4 g+ |
| Coconut | 3 ak 3 ak 5 g+ |
| Papaya | 3 a 3 a 5 g+ |
| Pineapple | 3 a 3 a 4 g+ |
| Mango and cashew nut | 3 a 3 a 5 g+ |
| Artocarpus | 3 a 3 a 5 g+ |
| Mangosteen | 3 a 3 a 4 g+ |
| Dragon fruit | 3 a 3 a 5 g+ |
| Guava | 3 a 3 a 5 g+ |
| Star fruit | 3 a 3 a 5 g+ |
| Longan | 3 a 3 a 5 g+ |
| Grasses for -well drained areas | 2 No g 2 No g 2 i+ |
| -well drained areas | 2 k 2 k 3 g+ |
| Fodder legumes for -well drained areas | 2 ak 2 ak 2 Cg+k+i+ |
| -well drained areas | 3 a 3 a 4 g+ |

Map unit BDG-TTN-1 occurs in the following surveyed Agricultural Development Areas:

- **Temburong**: 7 ha
- **Selapon**: 7 ha

Map unit BDG-TTN-1 has the same soil components as map units BDG-1 and JML-2.
## Map unit BDG-TTN-1-2

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained clayey very deep yellow soils</th>
<th>Poorly drained brown over grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Palehumults</td>
<td>Typic Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial terrace</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th></th>
<th>BDG-TTN-1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC0-30%ak</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>BDG-TTN-1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>3 No g [5 &gt;15%] 3 No g [5 &gt;15%] 2 g+ki+</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a 3 a 3 g+</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a 3 a 3 g+</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 a 3 a 5 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 a 3 a 5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>3 a 3 a 4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a 3 a 3 g+</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>2 ak 2 ak 4 g+</td>
</tr>
</tbody>
</table>

Map unit BDG-TTN-1-2 occurs in the following surveyed Agricultural Development Areas:

**Belait**
Merangking, Bukit Sawat
<1 ha
Map unit BJ (be)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Somewhat poorly drained sandy very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Aquic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Lower slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Soil Attribute Ratings**

- **Topsoil type**: L
- **Subsoil type**: L
- **Waterlogging (g, g*)**: g, g
- **Slope (%)**: 2
- **Max. slope(%)**: -
- **Erosion risk (w)**: -
- **Sulphidic horizon (c) & depth, cm**: -
- **Aluminium (a, a-)**: a, a-
- **Low K reserves (k)**: k, k
- **High P fixation (i, i-, i+)**: -
- **Cracking clays (v)**: -
- **High leaching (e)**: e, e
- **FCC**: LLg2%a-ke, LLg2%a-ke

**Crop Suitability Ratings**

- **Rice**: 2 ke
- **Leafy and fruit vegetables**: 2 ga-ke
- **Root vegetables**: 2 ga-ke
- **Groundnuts**: 3 g
- **Soya and mung beans**: 3 g
- **Maize**: 3 g
- **Ginger and turmeric**: 2 ga-ke
- **Cassava and sweet potato**: 3 g
- **Durian**: 4 g
- **Rambutan**: 3 g
- **Langsat-duku**: 4 g
- **Citrus**: 3 g
- **Banana**: 3 g
- **Coconut**: 3 g
- **Papaya**: 4 g
- **Pineapple**: 3 g
- **Mango and cashew nut**: 3 g
- **Artocarpus**: 3 g
- **Mangosteen**: 2 ga-ke
- **Dragon fruit**: 3 g
- **Guava**: 3 g
- **Star fruit**: 3 g
- **Longan**: 3 g
- **Grasses for -wet areas**: 2 e
- **-well drained areas**: 2 gke
- **Fodder legumes for -wet areas**: 2 ke
- **-well drained areas**: 3 g

Map unit BJ (be) occurs in the following surveyed Agricultural Development Areas:

- **Belait**: Rampayoh - 7 ha, Labi Lama - 8 ha

Map unit BJ (be) has the same soil components as map unit MA (be).
### Map unit BJ (bm)

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BJ (bm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component Soil Subtypes</strong></td>
<td>Poorly drained sulfuric soils</td>
</tr>
<tr>
<td><strong>Soil Taxonomy classification of component soils</strong></td>
<td>Typic Sulfaquepts</td>
</tr>
<tr>
<td><strong>General landscape position</strong></td>
<td>Terrace flats</td>
</tr>
<tr>
<td><strong>Proportion of map unit</strong></td>
<td>40%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Soil Attribute</th>
<th>Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>O</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>2%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(30)</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>- k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>OCg+0-2%c(30)ai+</td>
</tr>
<tr>
<td>LCg0%c(30)ai</td>
<td>CCg+0%c(30)aki+</td>
</tr>
<tr>
<td>OOG+0%c(30)ai+</td>
<td></td>
</tr>
</tbody>
</table>

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Suitability</th>
<th>Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>4 O 3 c(≤35) 3 c(≤35) 3 c(≤35) 4 O</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 Og+c(≤35) 3 c(≤35) 3 g+c(≤35) 3 Og+c(≤35)</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 Og+c(≤35) 3 c(≤35) 3 g+c(≤35) 3 Og+c(≤35)</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+ 3 gc(≤35) 4 g+ 4 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+ 3 gc(≤35) 5 g+ 5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+ 3 gc(≤35) 4 g+ 4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 O 3 c(≤35) 3 g+c(≤35) 4 O</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+ 3 gc(≤35) 4 g+ 4 g+</td>
</tr>
<tr>
<td>Durian</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+c(≤35) 4 c(≤35) 4 g+c(≤35) 4 g+c(≤35)</td>
</tr>
<tr>
<td>Banana</td>
<td>4 Og+c(≤35) 4 c(≤35) 4 g+c(≤35) 4 Og+c(≤35)</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 Og+ 4 gc(≤35) 5 g+ 5 Og+</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+c(≤35) 4 c(≤35) 4 g+c(≤35) 4 g+c(≤35)</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>5 c(≤35) 5 c(≤35) 5 c(≤35) 5 c(≤35)</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>5 Oc(≤35) 5 c(≤35) 5 c(≤35) 5 Oc(≤35)</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Guava</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 g+c(≤35)</td>
</tr>
<tr>
<td>Longan</td>
<td>5 Og+c(≤35) 5 c(≤35) 5 g+c(≤35) 5 Og+c(≤35)</td>
</tr>
</tbody>
</table>

#### Grasses for -wet areas

Grasses for -wet areas: 2 i+ 2 i+ 2 i+ 2 i+

Grasses for -well drained areas: 3 Og+ 3 gi+ 3 g+ 3 Og+

#### Fodder legumes for -wet areas

Fodder legumes for -wet areas: 2 Og+ai+ 2 ai 2 Cg+ai+ 2 Og+ai+

Fodder legumes for -well drained areas: 4 g+ 3 ga 4 g+ 4 g+

---

Map unit BJ (bm) occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**

- Betumpu: 474 ha
- Si Tukak, Limau Manis B: 28 ha
- Si Bongkok Parit Masin: 127 ha
- Lumapas: 24 ha
- Limpaki: 69 ha
- Tungku: 2 ha
- Pengkalan Batu: 45 ha

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Soil Fertility Evaluation/Advisory Service in Negara Brunei Darussalam

Volume 1 – Soils and Land Suitability of the Agricultural Development Areas
### Map unit BJ (bm) continued

<table>
<thead>
<tr>
<th>Mineral sulfuric organic soils</th>
<th>Sulfuric organic soils</th>
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<tbody>
<tr>
<td>Terric Sulfosaprists</td>
<td>Typic Sulfosaprists</td>
</tr>
<tr>
<td>Swamp</td>
<td>Terrace flats</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>C</td>
<td>O</td>
</tr>
<tr>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>c(30)</td>
<td>c(15)</td>
</tr>
<tr>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>i+</td>
<td>i+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OCg+2%c(30)ai+</th>
<th>OOG+2%c(15)ai+</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 O</td>
<td>4 Oc(≤25)</td>
</tr>
<tr>
<td>3 Og+c(≤40)a</td>
<td>4 c(≤20)</td>
</tr>
<tr>
<td>3 Og+c(≤40)a</td>
<td>4 c(≤20)</td>
</tr>
<tr>
<td>4 g+</td>
<td>4 g+c(≤20)</td>
</tr>
<tr>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>4 g+</td>
<td>4 g+c(≤20)</td>
</tr>
<tr>
<td>4 O</td>
<td>4 Oc(≤20)</td>
</tr>
<tr>
<td>4 g+</td>
<td>4 g+c(≤20)</td>
</tr>
<tr>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
</tr>
<tr>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
</tr>
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<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
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<tr>
<td>4 g+c(≤30)</td>
<td>4 c(≤20)</td>
</tr>
<tr>
<td>4 Og+c(≤30)</td>
<td>5 c(≤20)</td>
</tr>
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<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
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<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
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<tr>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
</tr>
<tr>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
</tr>
<tr>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
</tr>
<tr>
<td>5 g+c(≤30)</td>
<td>5 g+c(≤30)</td>
</tr>
<tr>
<td>5 Og+c(≤50)</td>
<td>5 Og+c(≤50)</td>
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<tr>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
</tr>
<tr>
<td>5 Og+c(≤30)</td>
<td>5 Og+c(≤30)</td>
</tr>
<tr>
<td>2 i+</td>
<td>2 c(≤20)i+</td>
</tr>
<tr>
<td>3 Og+</td>
<td>3 Og+</td>
</tr>
<tr>
<td>2 Og+ai+</td>
<td>2 Og+c(≤20)ai+</td>
</tr>
<tr>
<td>4 g+</td>
<td>4 g+</td>
</tr>
</tbody>
</table>
### Map unit BJ (tu)

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BJ (tu)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Somewhat poorly drained brown over grey soils</td>
</tr>
<tr>
<td>Component Soil Subtypes</td>
<td>Aeric Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
</tr>
</tbody>
</table>

#### Proportion of map unit
- 40%
- 35%
- 25%

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>CLL</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>CCL</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>gg</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LCg2-70%aki</td>
<td>CCg2%ak</td>
</tr>
</tbody>
</table>

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 aki [5 &gt;15%]</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 ga [5 &gt;55%]</td>
</tr>
<tr>
<td>Soybean and mung beans</td>
<td>3 ga [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 ga [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and Turmeric</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 ga [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for - wet areas</td>
<td>2 i [3 &gt;55%]</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>2 gki [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for - wet areas</td>
<td>2 aki [3 &gt;55%]</td>
</tr>
<tr>
<td>- well drained areas</td>
<td>3 ga</td>
</tr>
</tbody>
</table>

Map unit BJ (tu) occurs in the following surveyed Agricultural Development Areas:

<table>
<thead>
<tr>
<th>Area</th>
<th>Percentage (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei-Muara</td>
<td>Sg Tajau</td>
</tr>
<tr>
<td></td>
<td>Batang Mitus (Buah)</td>
</tr>
<tr>
<td></td>
<td>Batang Mitus (Halaman)</td>
</tr>
<tr>
<td></td>
<td>Birau (P. P. Muda)</td>
</tr>
<tr>
<td></td>
<td>Birau (Penyelidikan)</td>
</tr>
</tbody>
</table>
### Map unit BJ (wa)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Sulfidic poorly drained cracking clay soils</th>
<th>Acid poorly drained cracking clay soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Sulfic Sulfaquerts</td>
<td>Typic Dystraquerts</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Terrace flats</td>
<td>Terrace flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

| Topsoil type | C | C | C |
| Subsoil type | C | C | C |
| Waterlogging (g, g+) | g+ | g+ | g+ |
| Slope (%) | 0% | 0% | 0% |
| Max. slope(%) | - | - | - |
| Erosion risk (w) | - | - | - |
| Sulfidic horizon (c) & depth, cm | c(40) | c(40) | |
| Aluminium (a, a-) | a- | a- | a- |
| Low K reserves(k) | - | - | - |
| High P fixation (i, i-, i+) | i+ | i+ | i+ |
| Cracking clays (v) | v | v | v |
| High leaching (e) | - | - | - |
| FCC | CCg+0%(40)a-i+v | CCg+0%(40)a-i+v | CCg+0%(40)a-i+v |

#### Crop Suitability Ratings

| Rice | 2 g+c(≤50)i+v | 2 g+c(≤50)i+v | 2 g+i+v |
| Leafy and fruit vegetables | 3 g+c(≤40)v | 3 g+c(≤40)v | 3 g+v |
| Root vegetables | 4 v | 4 v | 4 v |
| Groundnuts | 5 v | 5 v | 5 v |
| Soya and mung beans | 5 g+ | 5 g+ | 5 g+ |
| Maize | 4 g+ | 4 g+ | 4 g+ |
| Ginger and turmeric | 4 v | 4 v | 4 v |
| Cassava and sweet potato | 4 g+v | 4 g+v | 4 g+v |
| Durian | 5 g+c(≤50) | 5 g+c(≤50) | 5 g+ |
| Rambutan | 5 g+ | 5 g+ | 5 g+ |
| Langsat-duku | 5 g+ | 5 g+ | 5 g+ |
| Citrus | 4 Cg+v | 4 Cg+v | 4 Cg+v |
| Banana | 4 g+ | 4 g+ | 4 g+ |
| Coconut | 5 g+ | 5 g+ | 5 g+ |
| Papaya | 5 g+v | 5 g+v | 5 g+v |
| Pineapple | 4 g+v | 4 g+v | 4 g+v |
| Mango and cashew nut | 5 g+c(≤50) | 5 g+c(≤50) | 5 g+ |
| Artocarpus | 4 g+c(≤50)v | 4 g+c(≤50)v | 4 g+v |
| Mangosteen | 4 g+c(≤50) | 4 g+c(≤50) | 4 g+ |
| Dragon fruit | 5 g+ | 5 g+ | 5 g+ |
| Guava | 5 g+ | 5 g+ | 5 g+ |
| Star fruit | 5 g+ | 5 g+ | 5 g+ |
| Longan | 5 g+c(≤50) | 5 g+c(≤50) | 5 g+ |
| Grasses for -wet areas | 3 v | 3 v | 3 v |
| -well drained areas | 3 g+v | 3 g+v | 3 g+v |
| Fodder legumes for -wet areas | 3 v | 3 v | 3 v |
| -well drained areas | 4 g+ | 4 g+ | 4 g+ |

Map unit BJ (wa) occurs in the following surveyed Agricultural Development Areas:

- **Brunei-Muara**
- **Wasan**

329 ha
Map unit BK.2 (bm)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
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<tr>
<td>Proportion of map unit</td>
<td>100%</td>
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</table>

Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>C</td>
<td>-</td>
<td>20%</td>
<td>70%</td>
<td>w</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td>-</td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>L</td>
<td>C</td>
<td>-</td>
<td>20%</td>
<td>70%</td>
<td>w</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td>-</td>
<td>LC20-70%waki</td>
</tr>
</tbody>
</table>

Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -wet areas</th>
<th>Fodder legumes for -wet areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 &gt;15%</td>
<td>3 a [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td></td>
<td>5 &gt;15%</td>
<td>5 a [5 &gt;55%]</td>
<td>5 a [5 &gt;55%]</td>
<td>5 a [5 &gt;55%]</td>
<td>5 a [5 &gt;55%]</td>
<td>5 a [5 &gt;55%]</td>
<td>5 a [5 &gt;55%]</td>
<td>5 w [4 &gt;55%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 ak [4 &gt;65%]</td>
<td>5 ak [4 &gt;65%]</td>
<td>5 ak [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
<td>5 a [4 &gt;65%]</td>
</tr>
</tbody>
</table>

Map unit BK.2 (bm) occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**
Limpaki <1 ha

Map unit BK.2 (bm) has the same soil components as map units BK.3 (bm) and RMB-2.
### Map unit BK.2 (tu)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults</td>
<td>Typic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
<td>Crests and upper slopes</td>
</tr>
</tbody>
</table>

| Proportion of map unit          | 60%                                  | 40%                                      |

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i, i+)</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td></td>
<td>e</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Crop Suitability Ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root vegetables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rambutan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Langsat-duku</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papaya</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artocarpus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangosteen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dragon fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guava</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-well drained areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Map unit BK.2 (tu) occurs in the following surveyed Agricultural Development Areas:
- **Tutong**: Batang Mitus (Halaman) 11 ha

Map unit BK.2 (tu) has the same soil components as map unit BK/NY.2.
Map unit BK.2/AN

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BK.2/AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Texture contrast yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Arenic Paleudults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>L</td>
<td>-</td>
<td>25%</td>
<td>25%</td>
<td>w</td>
<td>-</td>
<td>a</td>
<td>k</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>SL25%wake</td>
</tr>
<tr>
<td>SL25%wake</td>
<td>SL25%wake</td>
<td>SL25%wake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -wet areas</th>
<th>Grassee for -well drained areas</th>
<th>Fodder legumes for -wet areas</th>
<th>Fodder legumes for -well drained areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 S&gt;15%</td>
<td>3 &gt;20%a</td>
<td>3 &gt;20%wa</td>
<td>3 &gt;20%wa</td>
<td>3 &gt;20%wa</td>
<td>3 &gt;20%wa</td>
<td>3 &gt;20%wa</td>
<td>3 &gt;20%wa</td>
<td>5 S</td>
<td>3 Sa</td>
<td>5 S</td>
<td>3 Sa</td>
<td>3 Sa</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>3 a</td>
<td>4 S</td>
<td>3 a</td>
<td>3 a</td>
<td>3 Sa</td>
<td>3 a</td>
<td>3 a</td>
<td>2 SNo g&gt;20%e</td>
<td>2 &gt;20%wake</td>
<td>2 &gt;20%wake</td>
<td>3 wa</td>
</tr>
</tbody>
</table>

Map unit BK.2/AN occurs in the following surveyed Agricultural Development Areas:

- Belait: Melayan A 3 ha
Map unit BK.2/BJ

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BK.2/BJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Moderately well</td>
</tr>
<tr>
<td></td>
<td>drained yellow soils</td>
</tr>
<tr>
<td></td>
<td>Somewhat poorly</td>
</tr>
<tr>
<td></td>
<td>drained brown over</td>
</tr>
<tr>
<td></td>
<td>grey soils</td>
</tr>
<tr>
<td>Soil Taxonomy</td>
<td>Oxyaquic</td>
</tr>
<tr>
<td>classification of</td>
<td>Haplohumults</td>
</tr>
<tr>
<td>component soils</td>
<td></td>
</tr>
<tr>
<td>General landscape</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>position</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>60% 40%</td>
</tr>
</tbody>
</table>

| Soil Attribute Ratings  |                         |
| Topsoil type            | L                        |
| Subsoil type            | C                        |
| Waterlogging (g, g+)    | -                        |
| Slope (%)               | 20% 20%                  |
| Max. slope(%)           | 70% 70%                  |
| Erosion risk (w)        | w                        |
| Sulfidic horizon (c) & depth, cm | - |
| Aluminium (a, a-)       | a                        |
| Low K reserves(k)       | k                        |
| High P fixation (i, i-, i+) | i  |
| Cracking clays (v)      | -                        |
| High leaching (e)       | -                        |
| FCC                     | LC20-70%waki  LC20-70%waki  CCg2%ak |

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>2 ak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3 a [5 &gt;55%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 wa [5 &gt;55%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 w [4 &gt;55%]</td>
<td>3 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 w [4 &gt;55%]</td>
<td>3 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 a [4 &gt;65%]</td>
<td>3 ga</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grasses for -wet areas</td>
<td>2 No gi [3 &gt;55%] 2 No gi [3 &gt;55%] 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-well drained areas</td>
<td>2 wki [3 &gt;55%] 2 wki [3 &gt;55%] 2 Cgk</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fodder legumes for -wet areas</td>
<td>2 wak [3 &gt;55%] 2 wak [3 &gt;55%] 2 Cak</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-well drained areas</td>
<td>3 wa 3 wa 3 Cga</td>
<td></td>
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</tr>
</tbody>
</table>

Map unit BK.2/BJ occurs in the following surveyed Agricultural Development Areas:

Tutong Padnunok/Sg Burong, Kiudang 83 ha
Batang Mitus (Buah) 8 ha

Map unit BK.2/BJ has the same soil components as map unit ME.2/BJ.
Map unit BK.3 (bm)

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BK.3 (bm)</th>
</tr>
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<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Moderately well</td>
</tr>
<tr>
<td></td>
<td>drained yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of</td>
<td>Oxyaquic</td>
</tr>
<tr>
<td>component soils</td>
<td>Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Soil Attribute Ratings**

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>L</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
</tr>
</tbody>
</table>

**Crop Suitability Ratings**

<table>
<thead>
<tr>
<th>Crop</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
</tbody>
</table>

Grasses for -wet areas 2 No gi [3 >55%] 2 No gi [3 >55%]
Grasses for -well drained areas 2 wki [3 >55%] 2 wki [3 >55%]

Fodder legumes for -wet areas 2 waki [3 >55%] 2 waki [3 >55%]
Fodder legumes for -well drained areas 3 wa 3 wa

Map unit BK.3 (bm) occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**
- Sg Tajau 60 ha
- Si Tukak, Limau Manis A 41 ha
- Wasan 1 ha

Map unit BK.3 (bm) has the same soil components as map units BK.2 (bm) and RMB-2.
Map unit BK.3 (tu)

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
<th>Somewhat poorly drained brown over grey soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplustolls</td>
<td>Typic Kandihumults</td>
<td>Aeric Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
<td>Crests and upper slopes</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
<td>30%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Soil Attribute Ratings

| Topsoil type | L | L | L | C |
| Subsoil type | C | C | L | C |
| Waterlogging (g, g+) | - | - | g |
| Slope (%) | 20% | 20% | 25% | 2% |
| Max. slope (%) | 70% | 70% | 70% | 2% |
| Erosion risk (w) | w | w | w |
| Sulfidic horizon (c) & depth, cm | - |
| Aluminium (a, a-) | a | a | a |
| Low K reserves(k) | k | k | k |
| High P fixation (i, i-, i+) | i | i | i |
| Cracking clays (v) | - |
| High leaching (e) | - | e |
| FCC | LC20-70%waki | LC20-70%waki | LL25-70%wake | CCg2%ak |

Crop Suitability Ratings

<table>
<thead>
<tr>
<th>rice</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>2 ak</th>
</tr>
</thead>
<tbody>
<tr>
<td>leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a [5 &gt;55%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 a</td>
</tr>
<tr>
<td>root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 a</td>
</tr>
<tr>
<td>groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 a</td>
</tr>
<tr>
<td>cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
<td>3 a</td>
</tr>
<tr>
<td>durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>4 g</td>
</tr>
<tr>
<td>rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>4 g</td>
</tr>
<tr>
<td>pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 a</td>
</tr>
<tr>
<td>dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
<td>3 ga</td>
</tr>
<tr>
<td>grasses for -well drained areas</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No g&gt;20%e [3 &gt;55%]</td>
<td>1</td>
</tr>
<tr>
<td>grasses for -well drained areas</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 &gt;20%wke [3 &gt;55%]</td>
<td>2 Cgk</td>
</tr>
<tr>
<td>fodder legumes for -well drained areas</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 &gt;20%wak [3 &gt;55%]</td>
<td>2 Cak</td>
</tr>
<tr>
<td>fodder legumes for -well drained areas</td>
<td>3 wa</td>
<td>3 wa</td>
<td>3 wa</td>
<td>3 Cga</td>
</tr>
</tbody>
</table>

Map unit BK.3 (tu) occurs in the following surveyed Agricultural Development Areas:

<table>
<thead>
<tr>
<th>Tutong</th>
<th>Maraburong, Kupang</th>
<th>12 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batang Mitus (Halaman)</td>
<td>104 ha</td>
<td></td>
</tr>
<tr>
<td>Birau (P. P. Muda)</td>
<td>35 ha</td>
<td></td>
</tr>
<tr>
<td>Birau (Penyelidikan)</td>
<td>55 ha</td>
<td></td>
</tr>
</tbody>
</table>

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Map unit BK/NY.2

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults</td>
<td>Typic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
<td>Crests and upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>60%</td>
<td>40%</td>
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**Soil Attribute Ratings**

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>L</th>
<th>L</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High teaching (e)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
<td>LL25-70%wake</td>
</tr>
</tbody>
</table>

**Crop Suitability Ratings**

<table>
<thead>
<tr>
<th>Rice</th>
<th>5 &gt;15%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a [5 &gt;55%]</td>
<td>3 &gt;20% a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 &gt;20% wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
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<td>3 a [4 &gt;65%]</td>
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<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
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<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No g&gt;20% e [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 &gt;20% wke [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 &gt;20% wake [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 wa</td>
<td>3 wa</td>
<td>3 wa</td>
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</table>

Map unit BK/NY.2 occurs in the following surveyed Agricultural Development Areas:

- **Tutong**: Batang Mitus (Halaman) 335 ha
- **Birau (Penyelidikan)** 107 ha

Map unit BK/NY.2 has the same soil components as map unit BK.2 (tu).
Map unit BK/NY.3

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults</td>
<td>Typic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
<td>Crests and upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Soil Attribute Ratings</strong></td>
<td></td>
<td></td>
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<tr>
<td>Topsoil type</td>
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<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g*)</td>
<td>-</td>
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</tr>
<tr>
<td>Slope (%)</td>
<td>20%</td>
<td>20%</td>
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<tr>
<td>Max. slope(%)</td>
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<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i, i+)</td>
<td>i</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
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<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>e</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki</td>
<td>LC20-70%waki</td>
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<tr>
<td></td>
<td>LL25-70%wake</td>
<td>LL25-70%wake</td>
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<tr>
<td><strong>Crop Suitability Ratings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>5 &gt;15%</td>
<td>5 &gt;15%</td>
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<tr>
<td></td>
<td>5 &gt;15%</td>
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<tr>
<td>Leafy and fruit vegetables</td>
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<td>3 a [5 &gt;55%]</td>
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<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
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<tr>
<td>Soya and mung beans</td>
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<td>3 wa [5 &gt;55%]</td>
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<td>3 wa [5 &gt;55%]</td>
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<td>3 w [4 &gt;55%]</td>
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<td>3 a [4 &gt;65%]</td>
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<td>3 a [4 &gt;65%]</td>
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<tr>
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<td>3 a [4 &gt;65%]</td>
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<td>2 No gi [3 &gt;55%]</td>
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<td>2 wki [3 &gt;55%]</td>
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<tr>
<td></td>
<td>2 wki [3 &gt;55%]</td>
<td>2 wki [3 &gt;55%]</td>
</tr>
</tbody>
</table>

Map unit BK/NY.3 occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**
- Luahan: 2 ha
- Tungku: 60 ha

**Tutong**
- Kupang: 31 ha
- Padunok/Sg Burong, Kiudang: 47 ha
- Batang Mitus (Buah): 469 ha
- Birau (P. P. Muda): 4 ha
- Birau (Penyelidikan): 3 ha
**Map unit BKT**

<table>
<thead>
<tr>
<th>Map unit</th>
<th>BKT</th>
</tr>
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<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Well drained yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Crests</td>
</tr>
<tr>
<td>Proportion of map unit</td>
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**Soil Attribute Ratings**

<table>
<thead>
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<th>Soil Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
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</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>60%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>CC60-70%waki</td>
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**Crop Suitability Ratings**

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<tr>
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<tr>
<td>Leafy and fruit vegetables</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Maize</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 &gt;55%</td>
</tr>
<tr>
<td>Durian</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
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<td>Mangosteen</td>
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<tr>
<td>Dragon fruit</td>
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</tr>
<tr>
<td>Guava</td>
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<tr>
<td>Star fruit</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
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<tr>
<td>Longan</td>
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<tr>
<td>Grasses for -wet areas</td>
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</tr>
<tr>
<td>-well drained areas</td>
<td>3 &gt;55%</td>
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<tr>
<td>Fodder legumes for -wet areas</td>
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<tr>
<td>-well drained areas</td>
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Map unit BKT occurs in the following surveyed Agricultural Development Areas: Temburong Labu Estate 79 ha
### Map unit BKT-4

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>BKT-4</th>
<th>Moderately well drained yellow soils</th>
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<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Haplohumults</td>
<td>Oxyaquic Haplohumults</td>
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<td>General landscape position</td>
<td>Crests</td>
<td>Mid to lower slopes</td>
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<tr>
<td>Proportion of map unit</td>
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#### Soil Attribute Ratings

<table>
<thead>
<tr>
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<th>Rating</th>
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<tbody>
<tr>
<td>Topsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>60%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>70%</td>
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<tr>
<td>Erosion risk (w)</td>
<td>w</td>
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<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
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<tr>
<td>Aluminiun (a, a-)</td>
<td>a</td>
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<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i, i+)</td>
<td>i</td>
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<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>CC60-70%waki</td>
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#### Crop Suitability Ratings

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<tbody>
<tr>
<td>Rice</td>
<td>5 &gt;15%</td>
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<tr>
<td>Leafy and fruit vegetables</td>
<td>5 &gt;55%</td>
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<tr>
<td>Root vegetables</td>
<td>5 &gt;55%</td>
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<tr>
<td>Groundnuts</td>
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<tr>
<td>Soya and mung beans</td>
<td>5 &gt;55%</td>
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<tr>
<td>Maize</td>
<td>5 &gt;55%</td>
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<tr>
<td>Ginger and turmeric</td>
<td>5 &gt;55%</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 &gt;55%</td>
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<table>
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<tr>
<td>Langsat-duku</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 C</td>
</tr>
<tr>
<td>Banana</td>
<td>3 &gt;35%[ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 &gt;35%[ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
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<td>Pineapple</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
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<tr>
<td>Artocarpus</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
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<tr>
<td>Mangosteen</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
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</tr>
<tr>
<td>Guava</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 &gt;35%[a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
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<table>
<thead>
<tr>
<th>Crop</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Grasses for -wet areas</td>
<td>3 &gt;55%</td>
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<td>-well drained areas</td>
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<td>Fodder legumes for -wet areas</td>
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<td>-well drained areas</td>
<td>3 C &gt;35%wa</td>
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Map unit BKT-4 occurs in the following surveyed Agricultural Development Areas:

**Temburong**
- Bakarut
  - 29 ha
- Selapong
  - 25 ha
### Map units BKT-BTN-3 and BKT-BTN-4

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<th>BKT-BTN-3</th>
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<td>Well drained clayey very deep yellow soils</td>
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<td>Soil Taxonomy classification of component soils</td>
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<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
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<td>C</td>
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<tr>
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<tr>
<td>Slope (%)</td>
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<tr>
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<td>LC15-30%waki</td>
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<td>4 &gt;10% [5 &gt;15%]</td>
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<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
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<td>3 wa</td>
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<tr>
<td>Groundnuts</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa</td>
<td>3 wa</td>
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<tr>
<td>Cassava and sweet potato</td>
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<td>3 w</td>
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<tr>
<td>Durian</td>
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<td>Pineapple</td>
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<td>Mango and cashew nut</td>
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<td>Guava</td>
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<td>3 a</td>
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<td>Fodder legumes for -wet areas</td>
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Map unit BKT-BTN-3 occurs in the following surveyed Agricultural Development Areas:

**Belait**

Merangking, Bukit Sawat 25 ha

Map unit BKT-BTN-4 occurs in the following surveyed Agricultural Development Areas:

**Belait**

Merangking, Bukit Sawat 8 ha
## Map units BTN-3 and BTN-4

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<tr>
<th>Map unit</th>
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<td>Oxyaquic Palehumults</td>
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<td>Alluvial terrace</td>
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<td>Soil Attribute Ratings</td>
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<tr>
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<tr>
<td>Aluminium (a, a-)</td>
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<td>a</td>
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<tr>
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<td>i</td>
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<td>Cracking clays (v)</td>
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<td>High leaching (e)</td>
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<td>LC15-30%waki</td>
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<td>4 &gt;10% [5 &gt;15%]</td>
<td>4 &gt;10% [5 &gt;15%]</td>
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<tr>
<td>Leafy and fruit vegetables</td>
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<td>3 a</td>
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<tr>
<td>Root vegetables</td>
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<td>3 wa</td>
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<tr>
<td>Groundnuts</td>
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<td>3 wa</td>
</tr>
<tr>
<td>Soya and mung beans</td>
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<td>3 wa</td>
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<tr>
<td>Maize</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
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<td>3 w</td>
</tr>
<tr>
<td>Durian</td>
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<td>3 a</td>
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<tr>
<td>Rambutan</td>
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<td>3 a</td>
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<tr>
<td>Langsat-duku</td>
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<td>Citrus</td>
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<td>Pineapple</td>
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<td>Fodder legumes for -wet areas</td>
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Map unit BTN-3 occurs in the following surveyed Agricultural Development Areas:

**Belait**

Merangking, Bukit Sawat

201 ha

Map unit BTN-4 occurs in the following surveyed Agricultural Development Areas:

**Belait**

Merangking, Bukit Sawat

69 ha
Map units BTN-3 and BTN-4 continued

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<td>3 Og+c(≤40)a</td>
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<td>4 O</td>
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<table>
<thead>
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<th>5 Og+c(≤50)</th>
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<td>4 g+c(≤30)</td>
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<td>4 Og+c(≤30)</td>
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<tr>
<td>2 Og+aki+</td>
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<tr>
<td>4 g+</td>
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## Map unit BTN-SK-N-4

### Component Soil Subtypes
- Well drained clayey very deep yellow soils
- Moderately well drained clayey very deep yellow soils
- Poorly drained brown over grey soils

### Soil Taxonomy classification of component soils
- Typic Palehumults
- Oxyaquic Palehumults
- Typic Epiaqualfs

### General landscape position
- Upper slopes
- Alluvial terrace
- Alluvial flats

### Proportion of map unit
- 35%
- 35%
- 30%

### Soil Attribute Ratings

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<tr>
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<tr>
<td>Subsoil type</td>
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<td></td>
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<tr>
<td>Waterlogging (g, g+)</td>
<td>w</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>15%</td>
<td>15%</td>
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<tr>
<td>Max. slope(%)</td>
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<td>30%</td>
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<tr>
<td>Erosion risk (w)</td>
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<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>i</td>
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<td>Aluminium (a, a-)</td>
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<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
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<tr>
<td>High P fixation (i, i-, i+)</td>
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<td>i+</td>
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<tr>
<td>Cracking clays (v)</td>
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<td>High leaching (e)</td>
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### Crop Suitability Ratings

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<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
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<tr>
<td>Root vegetables</td>
<td>3 wa</td>
</tr>
<tr>
<td>Groundnuts</td>
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<tr>
<td>Soya and mung beans</td>
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<tr>
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<td>3 wa</td>
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<tr>
<td>Ginger and turmeric</td>
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<tr>
<td>Cassava and sweet potato</td>
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<tr>
<td>Durian</td>
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<tr>
<td>Rambutan</td>
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Map unit BTN-SK-N-4 occurs in the following surveyed Agricultural Development Areas:

**Belait**
- Merangking, Bukit Sawat
- 8 ha
### Map unit BU/MR.1

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<tr>
<td>Component Soil Subtypes</td>
<td>Sandy poorly drained white soils, Texture contrast yellow soils, Organic poorly drained moderately deep sulfidic soils</td>
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<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Umbric Epiaquods, Arenic Paleudults, Sulfic Fluvaiquents</td>
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<td>General landscape position</td>
<td>Dune slopes, Upper slopes, Alluvial flats</td>
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<tr>
<td>Proportion of map unit</td>
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<tr>
<td><strong>Soil Attribute Ratings</strong></td>
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<tr>
<td>Subsoil type</td>
<td>S S L</td>
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<td>Waterlogging (g, g+)</td>
<td>g+ g+ g</td>
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<tr>
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<tr>
<td>Cracking clays (v)</td>
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<td>High leaching (e)</td>
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<tr>
<td>Rice</td>
<td>5 S 5 S 5 S &gt;15% 5 S</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+a 3 g+ 3 &gt;20% 3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 g+a 3 g+ 3 &gt;20%wa 3 a</td>
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<tr>
<td>Groundnuts</td>
<td>4 g+ 4 g+ 3 &gt;20%wa 3 ga</td>
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<tr>
<td>Soya and mung beans</td>
<td>5 g+ 5 g+ 3 &gt;20%wa 3 ga</td>
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<td>Cassava and sweet potato</td>
<td>4 g+ 4 g+ 3 w 3 g</td>
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<td>Rambutan</td>
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<tr>
<td>Langsat-duku</td>
<td>5 Sg+ 5 Sg+ 5 S 5 S</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+ 4 g+ 3 Sa 3 Sga</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+ 4 g+ 3 Sak 3 Sgak</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+ 5 g+ 3 ak 3 gc(75)ak</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+ 5 g+ 3 a 4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+ 4 g+ 3 a 3 g</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+ 5 g+ 3 a 3 gc(75)a</td>
</tr>
<tr>
<td>Artoctapus</td>
<td>4 g+ 4 g+ 3 Sa 3 Sc(75)a</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 Sg+ 4 Sg+ 4 S 4 S</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+ 5 g+ 3 a 3 gc(75)a</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+ 5 g+ 3 a 3 gc(75)a</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+ 5 g+ 3 a 3 Sc(75)a</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+ 5 g+ 3 a 3 gc(75)a</td>
</tr>
<tr>
<td>Grasses for -well drained areas</td>
<td>2 Se 2 Se 2 Sc 2 Sa &gt;20%e 2 Se</td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas</td>
<td>2 g+a ke 2 g+ 2 &gt;20%ake 2 gke</td>
</tr>
<tr>
<td>Map unit BU/MR.1 occurs in the following surveyed Agricultural Development Areas: Belait</td>
<td>KM 26, Jalan Bukit Puan Labi 35 ha</td>
</tr>
</tbody>
</table>
## Map unit JML-2

<table>
<thead>
<tr>
<th></th>
<th>JML-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Moderately well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Palehumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial terrace</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC0-30%ak LC0-30%ak CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 a</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 a</td>
</tr>
<tr>
<td>Maize</td>
<td>3 a</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>2 a k</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a</td>
</tr>
<tr>
<td>Banana</td>
<td>3 a</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 a</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No g</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 k</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 ak</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 a</td>
</tr>
</tbody>
</table>

Map unit JML-2 occurs in the following surveyed Agricultural Development Areas:

- **Temburong**: 25 ha
- **Selangan**: 25 ha

Map unit JML has the same soil components as map units BDG-1 and BDG-TTN-1.
Map unit KKP-1

<table>
<thead>
<tr>
<th>Map unit</th>
<th>KKP-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Moderately well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Palehumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial terrace</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
</tr>
</tbody>
</table>

Soil Attribute Ratings

- Topsoil type: L, L, L
- Subsoil type: C, C, C
- Waterlogging (g, g+): -
- Slope (%): 0%, 0%, 20%
- Max. slope (%): 70%, 30%, 70%
- Erosion risk (w): -
- Sulfidic horizon (c) & depth, cm: -
- Aluminium (a, a-): a, a, a
- Low K reserves (k): k, k, k
- High P fixation (i, i-, i+): -
- Cracking clays (v): -
- High leaching (e): -
- FCC: LC0-70%ak, LC0-30%ak, LC20-70%waki

Crop Suitability Ratings

- Rice: 3 No g [5 >15%], 3 No g [5 >15%], 5 >15%
- Leafy and fruit vegetables: 3 a [5 >55%], 3 a, 3 a [5 >55%]
- Root vegetables: 3 a [5 >55%], 3 a, 3 wa [5 >55%]
- Groundnuts: 3 a [5 >55%], 3 a, 3 wa [5 >55%]
- Soya and mung beans: 3 a [5 >55%], 3 a, 3 wa [5 >55%]
- Maize: 3 a [5 >55%], 3 a, 3 wa [5 >55%]
- Ginger and turmeric: 3 a [5 >55%], 3 a, 3 wa [5 >55%]
- Cassava and sweet potato: 2 ak [4 >55%], 2 ak, 3 w [4 >55%]
- Durian: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Rambutan: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Mangosteen: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Dragon fruit: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Star fruit: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Longan: 3 a [4 >65%], 3 a, 3 a [4 >65%]
- Grasses for -wet areas: 2 No g [3 >55%], 2 No g, 2 No gi [3 >55%]
- -well drained areas: 2 k [3 >55%], 2 k, 2 wki [3 >55%]
- Fodder legumes for -wet areas: 2 ak [3 >55%], 2 ak, 2 waki [3 >55%]
- -well drained areas: 3 a, 3 a, 3 wa

Map unit KKP-1 occurs in the following surveyed Agricultural Development Areas:

- Temburong: 15 ha
- Selapon: 15 ha
### Map unit LU/BJ

<table>
<thead>
<tr>
<th>Map unit</th>
<th>LU/BJ</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Loamy poorly drained white soils</th>
<th>Soft poorly drained sulfuric soils</th>
<th>Moderately well drained yellow soils</th>
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</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Ultic Epiaquods</td>
<td>Hydraquentic Sulfaquents</td>
<td>Oxyaquic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Dune slopes</td>
<td>Terrace flats</td>
<td>Mid to lower slopes</td>
</tr>
</tbody>
</table>

| Proportion of map unit | 40% | 40% | 20% |

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope(%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td>0%</td>
<td>3%</td>
<td>70%</td>
<td>0%</td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td>e</td>
<td>LLg0-70%ak</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>LLg0%ak</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>SSg3%c(0)ake</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
<td></td>
<td></td>
<td>3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>0%</td>
<td></td>
<td></td>
<td>3%</td>
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<td></td>
<td></td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>LC20-70%waki</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
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<td>LC20-70%waki</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
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<td>a</td>
<td>a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>LLg0-70%ak</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>LLg0%ak</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>SSg3%c(0)ake</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td>LC20-70%waki</td>
</tr>
<tr>
<td>FCC</td>
<td>LLg0-70%ak</td>
<td>LLg0%ak</td>
<td>SSg3%c(0)ake</td>
<td>LC20-70%waki</td>
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<td></td>
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<td></td>
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</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>2 ak [5 &gt;15%]</th>
<th>2 ak</th>
<th>5 S</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a</td>
<td>4 c(≤20)</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a</td>
<td>4 c(≤20)</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 ga [5 &gt;55%]</td>
<td>3 ga</td>
<td>4 c(≤20)</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 ga [5 &gt;55%]</td>
<td>3 ga</td>
<td>4 c(≤20)</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 ga [5 &gt;55%]</td>
<td>3 ga</td>
<td>4 c(≤20)</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a</td>
<td>4 c(≤20)</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g [4 &gt;55%]</td>
<td>3 g</td>
<td>4 c(≤20)</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
<td>4 g</td>
<td>5 Sc(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
<td>4 g</td>
<td>5 Sc(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤20)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gak [4 &gt;65%]</td>
<td>3 gak</td>
<td>5 c(≤20)</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gak [4 &gt;65%]</td>
<td>3 gak</td>
<td>5 c(≤30)</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
<td>4 g</td>
<td>5 c(≤20)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤20)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤30)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 ga [4 &gt;65%]</td>
<td>3 ga</td>
<td>5 c(≤50)</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for -well drained areas</td>
<td>1 [3 &gt;55%]</td>
<td>1</td>
<td>2 Sc(≤20)e</td>
<td>2 No gi [3 &gt;55%]</td>
</tr>
<tr>
<td>-wet areas</td>
<td>2 gk [3 &gt;55%]</td>
<td>2 gk</td>
<td>2 gc(≤20)ke</td>
<td>2 wki [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas</td>
<td>2 ak [3 &gt;55%]</td>
<td>2 ak</td>
<td>2 c(≤20)ake</td>
<td>2 waki [3 &gt;55%]</td>
</tr>
</tbody>
</table>

Map unit LU/BJ occurs in the following surveyed Agricultural Development Areas:

- **Brunei-Muara** 191 ha
- **Tungku** 191 ha
### Map unit MA (be)

<table>
<thead>
<tr>
<th>Map unit</th>
<th>MA (be)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Somewhat poorly drained sandy very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Aquic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Lower slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
</tr>
</tbody>
</table>

FCC: LLg2%a-ke LLg2%a-ke

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Suitability Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 ke</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>2 ga-ke</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>2 ga-ke</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 g</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 g</td>
</tr>
<tr>
<td>Maize</td>
<td>3 g</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>2 ga-ke</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 g</td>
</tr>
<tr>
<td>Durian</td>
<td>4 g</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 g</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>4 g</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 g</td>
</tr>
<tr>
<td>Banana</td>
<td>3 gk</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 gk</td>
</tr>
<tr>
<td>Papaya</td>
<td>4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 g</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 g</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 g</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>2 ga-ke</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 g</td>
</tr>
<tr>
<td>Guava</td>
<td>3 g</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 g</td>
</tr>
<tr>
<td>Longan</td>
<td>3 g</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 e</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 gke</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 ke</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g</td>
</tr>
</tbody>
</table>

Map unit MA (be) occurs in the following surveyed Agricultural Development Areas:

- **Belait**: Rampayoh 35 ha, Labi Lama 2 ha

Map unit MA (be) has the same soil components as map unit BJ (be).
### Map unit MA (bm)

<table>
<thead>
<tr>
<th>Map unit</th>
<th>MA (bm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Sulfidic poorly drained cracking clay soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Sulfic Sulfaquerts</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Terrace flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>-</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>c(40)</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>-</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>v</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>CCg+0%c(40)a-i+v</td>
</tr>
</tbody>
</table>

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>2 g+c(≤60)i+v</th>
<th>2 g+c(≤60)i+v</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>3 g+c(≤40)v</td>
<td>3 g+c(≤40)v</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>4 v</td>
<td>4 v</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+c(≤50)</td>
<td>5 g+c(≤50)</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+c+i+v</td>
<td>4 g+c+i+v</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+i</td>
<td>4 g+i</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+i</td>
<td>5 g+i</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+i</td>
<td>5 g+i</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+i</td>
<td>4 g+i</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+c(≤50)</td>
<td>5 g+c(≤50)</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+c(≤50)v</td>
<td>4 g+c(≤50)v</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+c(≤50)</td>
<td>4 g+c(≤50)</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
<td>5 g+</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+c(≤50)</td>
<td>5 g+c(≤50)</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>3 v</td>
<td>3 v</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g+v</td>
<td>3 g+v</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>3 v</td>
<td>3 v</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
</tr>
</tbody>
</table>

Map unit MA (bm) occurs in the following surveyed Agricultural Development Areas:

- **Brunei-Muara**
  - Si Tukak, Limau Manis A: 41 ha
  - Si Tukak, Limau Manis B: 16 ha
  - Limpaki: 19 ha
  - Wasan: 43 ha
### Map unit MA.1/MA

<table>
<thead>
<tr>
<th>Map unit</th>
<th>ME.1/MA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component Soil Subtypes</strong></td>
<td>Moderately well drained yellow soils Poorly drained brown over grey soils</td>
</tr>
<tr>
<td><strong>Soil Taxonomy classification of component soils</strong></td>
<td>Oxyaquic Haplohumults Typic Epiaqualfs</td>
</tr>
<tr>
<td><strong>General landscape position</strong></td>
<td>Mid to lower slopes Alluvial flats</td>
</tr>
<tr>
<td><strong>Proportion of map unit</strong></td>
<td>65% 35%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L L C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C C C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>- g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20% 20% 2%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>70% 70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>- a-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a a a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k k k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i i i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki LC20-70%waki CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rice</strong></td>
<td>5 &gt;15% 5 &gt;15% 2 g+ki+</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%] 3 a [5 &gt;55%] 3 g+</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 g+</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 4 g+</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 5 g+</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 4 g+</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 g+</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%] 3 w [4 &gt;55%] 4 g+</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 Gg+</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%] 3 ak [4 &gt;65%] 4 g+</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%] 3 ak [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 g+</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 g+</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 g+</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 5 g+</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No gi [3 &gt;55%] 2 No gi [3 &gt;55%] 2 i+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 wki [3 &gt;55%] 2 wki [3 &gt;55%] 3 g+</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 wki [3 &gt;55%] 2 wki [3 &gt;55%] 2 Cg+ki+</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 wa 3 wa 4 g+</td>
</tr>
</tbody>
</table>

Map unit MA.1/MA occurs in the following surveyed Agricultural Development Areas:

**Brunei-Muara**

Luahan 71 ha
# Map unit ME.2/BJ

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>ME.2/BJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately well drained yellow soils</td>
<td>Somewhat poorly drained brown over grey soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults Aeric Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>60% 40%</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th>ME.2/BJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L L C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C C C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>- g</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>20% 20% 2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70% 70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w w</td>
</tr>
<tr>
<td>Sulphidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a a a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k k k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i i i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>ME.2/BJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>5 &gt;15% 5 &gt;15% 2 ak</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%] 3 a [5 &gt;55%] 3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 ga</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 ga</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 ga</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%] 3 wa [5 &gt;55%] 3 a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%] 3 w [4 &gt;55%] 3 g</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 g</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 C</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 gak</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%] 3 ak [4 &gt;65%] 3 gak</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%] 3 ak [4 &gt;65%] 3 gak</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 4 g</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%] 3 a [4 &gt;65%] 3 ga</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No gi [3 &gt;55%] 2 No gi [3 &gt;55%] 1</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 wki [3 &gt;55%] 2 wki [3 &gt;55%] 2 Cgk</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 waki [3 &gt;55%] 2 waki [3 &gt;55%] 2 Cak</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 wa 3 wa 3 Cga</td>
</tr>
</tbody>
</table>

Map unit ME.2/BJ occurs in the following surveyed Agricultural Development Areas:

- **Tutong**
  - Kupang: 29 ha
  - Maraburong, Kupang: 46 ha
  - Birau (P. P. Muda): 40 ha

Map unit ME.2/BJ has the same soil components as map unit BK.2/BJ.
### Map unit MR

<table>
<thead>
<tr>
<th>Map unit</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Loamy poorly drained white soils</td>
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<tr>
<td>Soil Taxonomy classification of component soils</td>
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</tr>
<tr>
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<tr>
<td>Proportion of map unit</td>
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#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
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<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>3%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LLg0-3%a</td>
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#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -wet areas</th>
<th>Grasses for -well drained areas</th>
<th>Fodder legumes for -wet areas</th>
<th>Fodder legumes for -well drained areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
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Map unit MR occurs in the following surveyed Agricultural Development Areas:

- **Brunei-Muara**
- **Tungku**

5 ha
## Map unit NY.3

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Well drained yellow soils</th>
<th>Well drained sandy very deep yellow soils</th>
<th>Moderately well drained yellow soils</th>
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</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Haplohumults</td>
<td>Typic Kandihumults</td>
<td>Oxyaquic Haplohumults</td>
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<tr>
<td>General landscape position</td>
<td>Crests</td>
<td>Crests and upper slopes</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>40%</td>
<td>30%</td>
<td>30%</td>
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### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Soil Attribute</th>
<th>Topsoil type</th>
<th>Subsoil type</th>
<th>Waterlogging (g, g+)</th>
<th>Slope (%)</th>
<th>Max. slope (%)</th>
<th>Erosion risk (w)</th>
<th>Sulfidic horizon (c) &amp; depth, cm</th>
<th>Aluminium (a, a-)</th>
<th>Low K reserves(k)</th>
<th>High P fixation (i, i-, i+)</th>
<th>Cracking clays (v)</th>
<th>High leaching (e)</th>
<th>FCC</th>
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<tbody>
<tr>
<td></td>
<td>L</td>
<td>C</td>
<td>L</td>
<td></td>
<td></td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>C</td>
<td></td>
<td>25%</td>
<td></td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>60%</td>
<td></td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
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<td>w</td>
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<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
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<td></td>
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<td></td>
<td>70%</td>
<td></td>
<td>w</td>
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<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
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<td></td>
<td>w</td>
<td></td>
<td>a</td>
<td>k</td>
<td>i</td>
<td>-</td>
<td></td>
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### Crop Suitability Ratings

#### Rice

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soyabeans</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>5 &gt;55%</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>4 &gt;55%</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
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</table>

#### Leafy and fruit vegetables

<table>
<thead>
<tr>
<th>Leafy and fruit vegetables</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-dukul</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>4 C</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 &gt;35%ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 &gt;35%a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
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</tbody>
</table>

#### Grasses for -wet areas

<table>
<thead>
<tr>
<th>Grasses for -wet areas</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>-wet drained areas</td>
<td>2 No g&gt;20% [3 &gt;55%]</td>
<td>3 &gt;55%</td>
<td>2 No g&gt;20% [3 &gt;55%]</td>
<td>2 No g [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 &gt;20%wa [3 &gt;55%]</td>
<td>3 &gt;55%</td>
<td>2 &gt;20%wa [3 &gt;55%]</td>
<td>2 wa [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 w [3 &gt;55%]</td>
<td>3 &gt;55%</td>
<td>2 w [3 &gt;55%]</td>
<td>3 wa [3 &gt;55%]</td>
</tr>
</tbody>
</table>

Map unit NY.3 occurs in the following surveyed Agricultural Development Areas:

- **Brunei-Muara**
  - Tungku: 4 ha
- **Belait**
  - Tungulian: 79 ha
## Map units NY/KP.4 and PL

<table>
<thead>
<tr>
<th>Map unit</th>
<th>NY/KP.4</th>
<th>PL</th>
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<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Well drained sandy very deep yellow soils</td>
<td></td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Kandihumults</td>
<td></td>
</tr>
<tr>
<td>General landscape position</td>
<td>Crests and upper slopes</td>
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<td>Proportion of map unit</td>
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### Soil Attribute Ratings

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<th>NY/KP.4</th>
<th>PL</th>
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<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Slope (%)</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
<td>e</td>
</tr>
<tr>
<td>FCC</td>
<td>LL25-70%wake</td>
<td>LL25-70%wake</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rice</th>
<th>5 &gt;15%</th>
<th>5 &gt;15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 wa [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td></td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td></td>
</tr>
</tbody>
</table>

Grasses for -wet areas: 2 No g>20%e [3 >55%] 2 No g>20%e [3 >55%]
Grasses for -well drained areas: 2 >20%wake [3 >55%] 2 >20%wake [3 >55%]
Fodder legumes for -wet areas: 2 >20%wa [3 >55%] 2 >20%wa [3 >55%]
Fodder legumes for -well drained areas: 3 wa | 3 wa

Map unit NY/KP.4 occurs in the following surveyed Agricultural Development Areas:
- **Belait** Rampayoh 29 ha

Map unit PL occurs in the following surveyed Agricultural Development Areas:
- **Belait** Rampayoh 32 ha

Map units NY/KP.4 and PL have the same soil components as map unit SM.
### Map unit RMB-2

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Moderately well drained yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Oxyaquic Haplohumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Mid to lower slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Soil Attribute Ratings</th>
<th>RMB-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC20-70%waki</td>
</tr>
</tbody>
</table>

#### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Suitability Ratings</th>
<th>RMB-2</th>
<th>RMB-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>5 &gt;15%</td>
<td>5 &gt;15%</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a [5 &gt;55%]</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa [5 &gt;55%]</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w [4 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutian</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No gi [3 &gt;55%]</td>
<td>2 No gi [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 wki [3 &gt;55%]</td>
<td>2 wki [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 waki [3 &gt;55%]</td>
<td>2 waki [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 wa</td>
<td>3 wa</td>
</tr>
</tbody>
</table>

Map unit RMB-2 occurs in the following surveyed Agricultural Development Areas:

- **Temburong**: Selapen 1 ha

Map unit RMB-2 has the same soil components as map units BK.2 (bm) and BK.3 (bm).
### Map unit SKN-4

<table>
<thead>
<tr>
<th>Map unit</th>
<th>SKN-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Well drained clayey very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Palehumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>50%</td>
</tr>
<tr>
<td>Soil Attribute Ratings</td>
<td></td>
</tr>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>15%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i+, i+)</td>
<td>i</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LC15-30%waki</td>
</tr>
<tr>
<td>Crop Suitability Ratings</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>4 &gt;10% [5 &gt;15%]</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 wa</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>3 wa</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>3 wa</td>
</tr>
<tr>
<td>Maize</td>
<td>3 wa</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 wa</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>3 w</td>
</tr>
<tr>
<td>Durian</td>
<td>3 a</td>
</tr>
<tr>
<td>Rambutan</td>
<td>3 a</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>3 a</td>
</tr>
<tr>
<td>Citrus</td>
<td>3 a</td>
</tr>
<tr>
<td>Banana</td>
<td>3 ak</td>
</tr>
<tr>
<td>Coconut</td>
<td>3 ak</td>
</tr>
<tr>
<td>Papaya</td>
<td>3 a</td>
</tr>
<tr>
<td>Pineapple</td>
<td>3 a</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>3 a</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>3 a</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Guava</td>
<td>3 a</td>
</tr>
<tr>
<td>Star fruit</td>
<td>3 a</td>
</tr>
<tr>
<td>Longan</td>
<td>3 a</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 No gi</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>2 wki</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 waki</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 wa</td>
</tr>
</tbody>
</table>

Map unit SKN-4 occurs in the following surveyed Agricultural Development Areas:

**Belait**
Merangking, Bukit Sawat

19 ha
## Map unit SM

<table>
<thead>
<tr>
<th>Map unit</th>
<th>SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Well drained sandy very deep yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Kandihumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Crests and upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>L</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>-</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>25%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>70%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>w</td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves (k)</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>-</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>e</td>
</tr>
<tr>
<td>FCC</td>
<td>LL25-70%wake LL25-70%wake</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop Suitability</th>
<th>Rice</th>
<th>Leafy and fruit vegetables</th>
<th>Root vegetables</th>
<th>Groundnuts</th>
<th>Soya and mung beans</th>
<th>Maize</th>
<th>Ginger and turmeric</th>
<th>Cassava and sweet potato</th>
<th>Durian</th>
<th>Rambutan</th>
<th>Langsat-duku</th>
<th>Citrus</th>
<th>Banana</th>
<th>Coconut</th>
<th>Papaya</th>
<th>Pineapple</th>
<th>Mango and cashew nut</th>
<th>Artocarpus</th>
<th>Mangosteen</th>
<th>Dragon fruit</th>
<th>Guava</th>
<th>Star fruit</th>
<th>Longan</th>
<th>Grasses for -wet areas</th>
<th>Fodder legumes for -wet areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 &gt;15%</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>5 &gt;15%</td>
<td>3 &gt;20%a [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 &gt;20%wa [5 &gt;55%]</td>
<td>3 w [4 &gt;55%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 ak [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
<td>3 a [4 &gt;65%]</td>
</tr>
</tbody>
</table>

Map unit SM occurs in the following surveyed Agricultural Development Areas:
- **Belait** Rampayoh 1 ha

Map unit SM has the same soil components as map units NY/KP.4 and PL.
## Map unit TTN

<table>
<thead>
<tr>
<th>Map unit</th>
<th>TTN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Poorly drained brown over grey soils</td>
</tr>
<tr>
<td></td>
<td>Moderately well drained yellow soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>C</td>
<td>C</td>
<td>L</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
<td>20%</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
<td>20%</td>
</tr>
<tr>
<td>Max. slope (%)</td>
<td>70%</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>w</td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a-</td>
<td>a</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-</td>
<td>i+</td>
<td>i+</td>
<td></td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td>CCg+2-70%a-ki+</td>
<td>CCg+2%a-ki+</td>
<td>LC20-70%waki</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>crop</th>
<th>rating</th>
<th>rating</th>
<th>rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 g+ki+ [5 &gt;15%]</td>
<td>2 g+ki+</td>
<td>5 &gt;15%</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+ [5 &gt;55%]</td>
<td>3 g+</td>
<td>3 a [5 &gt;55%]</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 g+ [5 &gt;55%]</td>
<td>3 g+</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+ [5 &gt;55%]</td>
<td>4 g+</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+ [5 &gt;55%]</td>
<td>4 g+</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 g+ [5 &gt;55%]</td>
<td>3 g+</td>
<td>3 wa [5 &gt;55%]</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 w [4 &gt;55%]</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 ak [4 &gt;65%]</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a [4 &gt;65%]</td>
</tr>
<tr>
<td>Grasses for -wet areas</td>
<td>2 i+ [3 &gt;55%]</td>
<td>2 i+</td>
<td>2 No gi [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g+</td>
<td>3 g+</td>
<td>2 wki [3 &gt;55%]</td>
</tr>
<tr>
<td>Fodder legumes for -wet areas</td>
<td>2 Cg+ki+[3 &gt;55%]</td>
<td>2 Cg+ki+</td>
<td>2 waki [3 &gt;55%]</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 wa</td>
</tr>
</tbody>
</table>

Map unit TTN occurs in the following surveyed Agricultural Development Areas:

**Temburong**  Labu Estate  18 ha
Map unit TTN-1

<table>
<thead>
<tr>
<th>Map unit</th>
<th>TTN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Soil Subtypes</td>
<td>Poorly drained brown over grey soils</td>
</tr>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaqualfs</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>60%</td>
</tr>
</tbody>
</table>

### Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Sulfidic horizon (c) &amp; depth, cm</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Aluminium (a, a-)</td>
<td>a-</td>
<td>a-</td>
</tr>
<tr>
<td>Low K reserves(k)</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i+</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>FCC</td>
<td>CCg+2-30%a-ki+</td>
<td>CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

### Crop Suitability Ratings

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rating</th>
<th>Rating</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>2 g+ki+ [5 &gt;15%]</td>
<td>2 g+ki+</td>
<td>3 No g [5 &gt;15%]</td>
</tr>
<tr>
<td>Leafy and fruit vegetables</td>
<td>3 g+</td>
<td>3 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>3 g+</td>
<td>3 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Soya and mung beans</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Maize</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Ginger and turmeric</td>
<td>3 g+</td>
<td>3 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Cassava and sweet potato</td>
<td>4 g+</td>
<td>4 g+</td>
<td>2 ak</td>
</tr>
<tr>
<td>Durian</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Rambutan</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Langsat-duku</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Citrus</td>
<td>4 Cg+</td>
<td>4 Cg+</td>
<td>3 a</td>
</tr>
<tr>
<td>Banana</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 ak</td>
</tr>
<tr>
<td>Coconut</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 ak</td>
</tr>
<tr>
<td>Papaya</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Pineapple</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Mango and cashew nut</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Artocarpus</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Mangosteen</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Dragon fruit</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Guava</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Star fruit</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Longan</td>
<td>5 g+</td>
<td>5 g+</td>
<td>3 a</td>
</tr>
<tr>
<td>Grasses for -well drained areas</td>
<td>2 i+</td>
<td>2 i+</td>
<td>2 No g</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>3 g+</td>
<td>3 g+</td>
<td>2 k</td>
</tr>
<tr>
<td>Fodder legumes for -well drained areas</td>
<td>2 Cg+ki+</td>
<td>2 Cg+ki+</td>
<td>2 ak</td>
</tr>
<tr>
<td>-well drained areas</td>
<td>4 g+</td>
<td>4 g+</td>
<td>3 a</td>
</tr>
</tbody>
</table>

Map unit TTN-1 occurs in the following surveyed Agricultural Development Areas:

- **Temburong** 23 ha
- **Selapon** 23 ha
# Map unit TTN-KDN-1-2

<table>
<thead>
<tr>
<th>Component Soil Subtypes</th>
<th>Poorly drained brown over grey soils</th>
<th>Moderately well drained clayey very deep yellow soils</th>
<th>Well drained clayey very deep yellow soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Taxonomy classification of component soils</td>
<td>Typic Epiaqualfs</td>
<td>Oxyaquic Palehumults</td>
<td>Typic Palehumults</td>
</tr>
<tr>
<td>General landscape position</td>
<td>Alluvial flats</td>
<td>Alluvial terrace</td>
<td>Upper slopes</td>
</tr>
<tr>
<td>Proportion of map unit</td>
<td>40%</td>
<td>30%</td>
<td>30%</td>
</tr>
</tbody>
</table>

## Soil Attribute Ratings

<table>
<thead>
<tr>
<th>Topsoil type</th>
<th>L</th>
<th>CLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsoil type</td>
<td>C</td>
<td>CCC</td>
</tr>
<tr>
<td>Waterlogging (g, g+)</td>
<td>g+</td>
<td>g+</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Max. slope(%)</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Erosion risk (w)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfodic horizon (c) &amp; depth, cm</td>
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<td>Aluminium (a, a-)</td>
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</tr>
<tr>
<td>Low K reserves(k)</td>
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<td>k</td>
</tr>
<tr>
<td>High P fixation (i, i-, i+)</td>
<td>i</td>
<td>i+</td>
</tr>
<tr>
<td>Cracking clays (v)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High leaching (e)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FCC</td>
<td>LCg+2-30%aki</td>
<td>CCg+2%a-ki+</td>
</tr>
</tbody>
</table>

## Crop Suitability Ratings

### Rice
- 2 g+aki [5 >15%] 2 g+ki+ [5 >15%] 3 No g [5 >15%] 4 >10% [5 >15%]
- Leafy and fruit vegetables
  - 3 g+a 3 g+ a 3 a
- Root vegetables
  - 3 g+a 3 g+ a 3 a
- Groundnuts
  - 4 g+ 4 g+ a 3 a
- Soy and mung beans
  - 5 g+ 5 g+ a 3 a
- Maize
  - 4 g+ 4 g+ a 3 a
- Ginger and turmeric
  - 3 g+a 3 g+ a 3 a
- Cassava and sweet potato
  - 4 g+ 4 g+ a 2 ak

### Durian
- 5 g+ 5 g+ a 3 a
### Rambutan
- 5 g+ 5 g+ a 3 a
### Langsat-duku
- 5 g+ 5 g+ a 3 a
### Citrus
- 4 g+ 4 Cg+ 3 a
### Banana
- 4 g+ 4 g+ a 3 ak
### Coconut
- 5 g+ 5 g+ a 3 ak
### Papaya
- 5 g+ 5 g+ a 3 a
### Pineapple
- 4 g+ 4 g+ a 3 a
### Mango and cashew nut
- 5 g+ 5 g+ a 3 a
### Artocarpus
- 4 g+ 4 g+ a 3 a
### Mangosteen
- 4 g+ 4 g+ a 3 a
### Dragon fruit
- 5 g+ 5 g+ a 3 a
### Guava
- 5 g+ 5 g+ a 3 a
### Star fruit
- 5 g+ 5 g+ a 3 a
### Longan
- 5 g+ 5 g+ a 3 a

### Grasses for -wet areas
- 2 i 2 i+ 2 No g 2 No gi
- for well drained areas
  - 3 g+ 3 g+ 2 k
### Fodder legumes for -wet areas
- 2 g+aki 2 Cg+ki+ 2 ak
- for well drained areas
  - 4 g+ 4 g+ 3 a

Map unit TTN-KDN-1-2 occurs in the following surveyed Agricultural Development Areas:

- **Belait**
  - Merangking, Bukit Sawat
  - 156 ha
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