Soil Fertility Evaluation in Negara Brunei Darussalam

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Abstract
A goal of Negara Brunei Darussalam Department of Agriculture is to increase agricultural production and reduce dependence on imported food products by increasing the area of land used for agriculture and by increasing productivity on existing agricultural land. This consultancy project provided supporting information by assessing the soil characteristics and their suitability for a variety of crops and provided recommendations for profitable and sustainable land management. This project generated a number of soil evaluation products that assisted with providing consolidated information and transfer of knowledge to assist with improved land use decision making for policy makers, advisory officers, and farmers. The products included: soil data for 24 soil types, maps, soil identification key, field manual for soil type identification (in English and Malay), toposequence cross-sections, database and land information system, land evaluation calculator, suitability assessment for 69 crops, acid sulfate soil identification, fertilizer and lime calculator, and identification of management options. This paper presents key features for some of these products that were successfully used to communicate and deliver soil evaluation information targeted to the different levels of users in Brunei.

Key Words
Soil identification key, suitability, limitation, toposequence cross-section.

Introduction
Negara Brunei Darussalam is a small country of 5765 square kilometres, located on the north of Borneo Island next to the South China Sea and land borders with Malaysia. Rainforest covers about 80 percent of Brunei's land and its capital city, Bandar Seri Begawan is next to the Brunei River. Historical soil survey information was of limited use to address the current soil evaluation and fertility guidance required because not all soils of interest were investigated and the soils that were described and analysed did not provide sufficient data for evaluation of the current issues. Most current knowledge about the soils and their behaviour resided with some farmers and agricultural advisors obtained through experience and this information has not easily been captured to allow transfer of information elsewhere.

To achieve the goal of increasing agricultural production and reduce dependence on imported food products, soil suitability and limitations needed to be identified to determine appropriate management. Specific questions that this project provided data for included:
Evaluation of new areas for agricultural development

- Can the soil be sustainably developed for agriculture?
- Is the soil suitable for the intended crop?

Evaluation of existing areas of agricultural land

- Is the soil suitable for the crops being grown?
- What are the alternative crop options that the soil is suitable for?
- What are the major soil constraints limiting cropping and can these be managed?

To assist the Bruneian users with obtaining answers to the above land evaluation questions, this project presented information and assessments in a format that could readily be used to guide decision making. This poster paper provides a summary description of the products used to communicate and deliver soil information.

Methods
The soil fertility evaluation project consisted of a number of inter-related steps that included:

- Data collection – extraction of relevant historical soil data and maps, conducting field soil surveys and sampling of soils, laboratory analysis to provide data on soil chemical and physical characteristics,

- Compilation of soil information – identifying key soil types, generating soil maps, developing relationships between the soil and key features including landscape.
- Evaluation of the soil - using the Fertility Capability Classification (Sanchez *et al.* 2003).
- Evaluation of the crops for each soil type – using literature data to provide guidance with regard to crop behaviour for different soil properties, a number of the tropical fruits and crops had limited information to draw on and therefore expert and local experience was used.
- Linking soil types with crops – evaluation to determine suitability and limitations of the soils for each crop.
- Acid sulfate soil investigations – soils of concern sampled and analysed to evaluate the magnitude and extent of this soil hazard.
- Reporting – generation of detailed technical reports, soil information system, fertility calculator, field manual and training of advisory staff in the use of the project soil outputs.

The field survey described 295 soil profiles in 29 different areas and across a variety of landscapes, soil layers from 60 profiles underwent laboratory analysis to determine selected chemical and physical properties. The assessment identified 24 soil types that were then evaluated for their suitability to grow 69 crop types ranging from vegetables, grasses, rice, and fruit trees. Significant soil limitations identified included: water logged soils, hill-slope soil erosion, acid sulfate soils, excessive or insufficient fertilising of soils. The project generated a significant volume of information that required compiling into products that people who are not experts in soil identification and evaluation could use to assist them with land evaluation.

Results

The results presented in this poster paper are examples of project products generated as part of the soil fertility evaluation in Negara Brunei Darussalam. The products were used to provide soil information to people who are not specialist in identifying and interpreting soil data and therefore the products were in a simple and easily understood form that would assist them with evaluating land use suitability and limitations, and to provide guidance for management.

Soil Identification Key

The classification, morphology and extent of the soils are described in Grealish *et al.* (2007a, 2007b). Soils were initially classified according to Soil Taxonomy (Soil Survey Staff 2003), which allowed valuable information on soil and crop behaviour to be transferred to the Brunei soils to support the soil and crop evaluation. To assist people who are not soil experts to identify soils, a simplified soil identification key was developed and tested with agricultural advisory staff and farmers. The identification key uses plain language terms and simple soil descriptive questions to guide the user systematically through the key until a soil type is arrived at; the upper level of the key is shown in Figure 1. Further questions at lower levels in the key are used to separate out the soil subtypes.

The plain language soil type and subtype names, corresponds to the major Soil Taxonomy Suborder and Subgroup classes found in the survey. These names provide assistance in understanding the intent and general nature of the soils classified using Soil Taxonomy. For example, the four acid sulfate soil types in the Key are: (i) Organic Soils, (ii) Cracking Clay Soils, (iii) Sulfuric Soils and (iv) Sulfidic Soils (Grealish *et al.* 2008). These are further sub-divided into eleven subtypes at a lower level in the identification key based on depth to sulfuric/sulfidic horizon; firmness; and drainage (waterlogging).

Soil Property Interpretation

An evaluation of the soil property data held in the soil information system was conducted using an adapted Fertility Capability Classification (Sanchez *et al.* 2003). The data and evaluation was summarised to allow users to quickly identify important soil features, the main limitations and determine what crops were suitable as shown in Figure 2.

Toposequence Cross-Sections

The project recognised that farmers and agriculture advisors identified and understood soil distribution on their farms by relating the soil type to positions in the landscape, and that they were more familiar with this relationship than interpreting a soil map. To assist with conveying the soil distribution and linking that to crop suitability, simplified soil-landscape cross-sections with tabulated crop suitability information was used (Figure 3).

Major Soils
Descriptive classification - Soil identification key

Diagnostic features for Soil Type	Soil Type
Does more than half of the upper 80 cm of soil consist of organic material? No ↓ Yes →	Organic soil (Saprist)
Does a white soil layer occur overlying an organic layer within 2 m of the soil surface, AND is the soil poorly or somewhat poorly drained? No ↓ Yes →	White soil (Aquod)
Does the soil develop cracks at the surface or in a layer within 100 cm of the soil surface, AND is the soil poorly or very poorly drained? No ↓ Yes →	Cracking clay soil (Aquert)
Does the subsoil have a dominantly yellow colour AND texture contrast? No ↓ Yes →	Texture contrast yellow soil (Udult)
Does the subsoil have a dominantly yellow colour AND, is the soil depth greater than 150 cm? No ↓ Yes →	Very deep yellow soil (Humult)
Does the subsoil have a dominantly yellow colour, AND is the soil depth less than 150 cm? No ↓ Yes →	Yellow soil (Haplohumult)
Does the subsoil have a yellowish brown layer overlying a grey layer that has its upper boundary within 50 cm of the soil surface? No ↓ Yes →	Brown over grey soil (Aqualf)
Does a sulfuric (pH<3.5) layer occur within 150 cm of the soil surface AND is the soil poorly drained? No ↓ Yes →	Sulfuric soil (Aquept)
Does sulfidic material occur within 100 cm of the soil surface AND is the soil poorly drained? No ↓ Yes →	Sulfidic soil (Aquent)
Does the soil have no other diagnostic features within 150 cm of the soil surface? No * Yes →	Grey soil (Aquent)

Figure 1. The upper level of the Soil Identification Key, showing linkage between Soil Taxonomy and local common name classification.

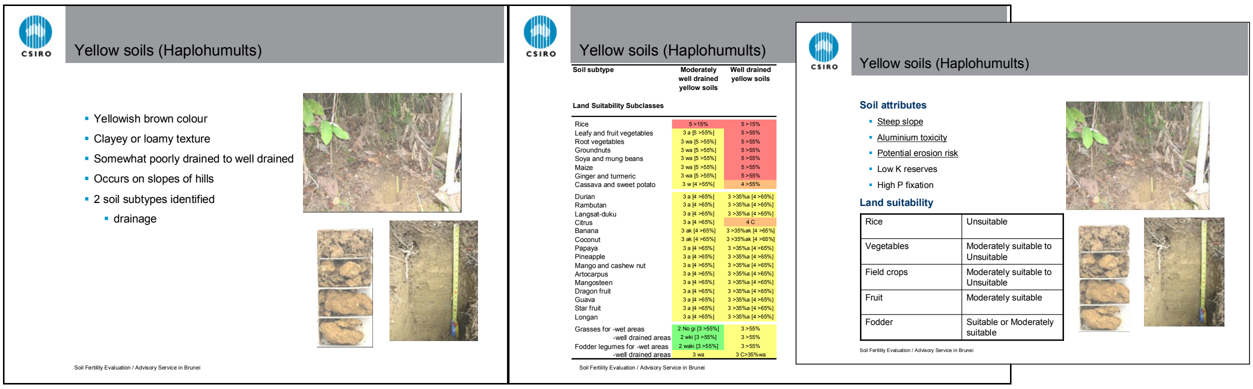

Figure 2. Example of soil type description, capability classification for crops and key soil attributes.

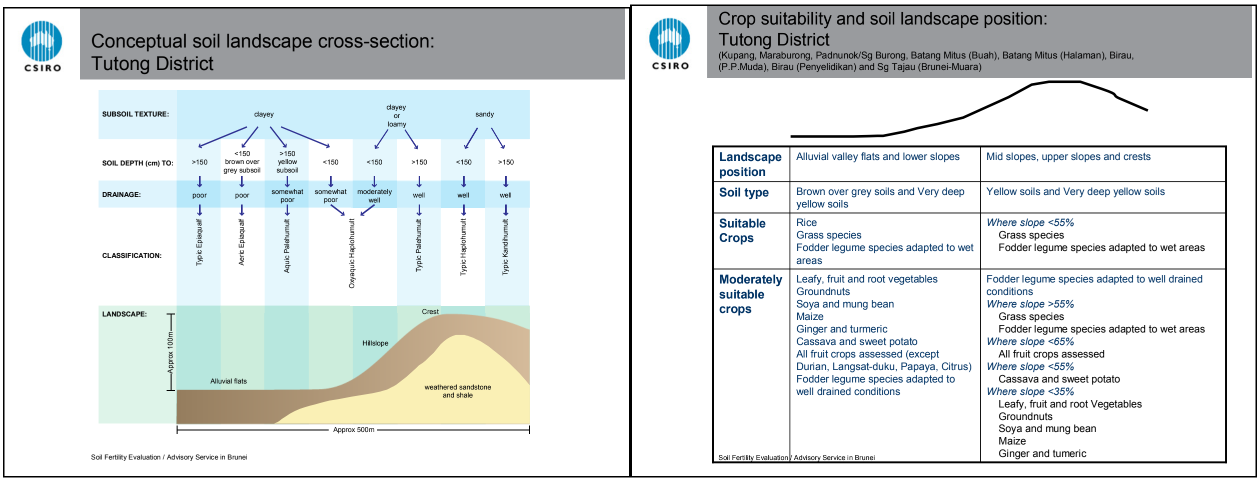

Figure 3. Example of use of landscape cross-section, identifying soils in different landscape position and the related crop suitability

Soil Fertiliser and Lime Calculator

Soil analyses showed excessive fertilizer use in some areas and in other areas it was found that insufficient fertilizer was being applied. To improve the application of nutrients to the soil for a specific crop, a calculator was developed for Brunei conditions. The calculator was targeted for use by agricultural advisors who make recommendations to farmers. The soil fertiliser calculator allows different fertiliser scenarios to be modelled as well as determination of the most suitable fertiliser approach for the soil and crop conditions (Wong *et al.* 2007).

Reports and Field Manual

The project generated a number of Technical Reports (e.g. Fitzpatrick *et al.* 2008; Grealish *et al.* 2007a,b, Ringrose-Voase *et al.* 2008; Wong *et al.* 2007), but for use by farmers a field manual was prepared in English and Malay. The manual provides simplified descriptions of soil types, pictures, and evaluation for crop suitability and management.

Conclusion

Key features for the successful delivery of soil evaluation information included:

- A soil identification key specific to the soils of the region and written in plain language for people who are not experts in soil identification could work through to determine the soil type.
- Simplified landscape cross-sections that showed the expected positions of the soils and their distribution as people working on the land were familiar with topographic positions
- An identification key to recognise acid sulfate soils occurrence and evaluated soil data to provide suggested management options.
- Soil fertilizer and lime calculator established for the Brunei soil conditions, with an easy to use input interface and outputs of recommended nutrient requirements
- A soil land information system and detailed technical reports with soil property data, maps and a comprehensive assessment of 69 crops, including the clear rationale behind the assessments should users want more detailed information.

Acknowledgements

This work was commissioned and funded by the Department of Agriculture, Negara Brunei Darussalam. We would like to acknowledge the input of staff from the Soil Science and Plant Nutrition Unit in particular Hajah Suria binti Zanuddin and Dr H.M. Thippeswamy. URS South Australian office for project management and agronomy experts. Comments provided by CSIRO reviewers to improve this poster paper.

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