PNG Oil Palm Research Association Inc.
AIGF Project No. 1106

Site specific fertiliser recommendations to increase income of smallholder oil palm producers in West New Britain Province, Papua New Guinea

Australian Government
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Summary

Oil palm is an important cash crop for farmers in Papua New Guinea, especially in West New Britain Province (WNBP). Nutritional constraints are a major limitation to productivity. Fertiliser recommendations for company plantations are based on fertiliser trials and annual leaf sampling and symptom assessment, which is not possible for individual smallholder growers due to their large number (>9,000 in WNBP) and the small size of their blocks (1-6 ha each). Fertiliser recommendations for smallholder growers have traditionally been given at one rate for the whole province. However, it is clear from plantation data that optimum fertiliser rates vary throughout the province, due to environmental factors.

This project produced site-specific mature palm fertiliser recommendations for smallholders by extrapolating from the company plantations. The extrapolation was achieved using eight regional soil maps and a geographical information system (GIS). The soil maps were scanned, digitised, geographically registered and incorporated into a MapInfo GIS. A Landsat image was used as the base map and various other layers, including plantation management units (MUs), smallholder blocks, topographic maps, geological maps, and roads were included. Soil map unit descriptions were incorporated into the GIS. For each of the soil map units underlying company plantations, a fertiliser recommendation was calculated by combining the recommendations for each of the MUs overlying that unit, weighting for areas. That recommendation was then applied to smallholder blocks on that soil map unit. In cases where several soil map units underlay one smallholder block, an area-weighted average was calculated. For smallholder blocks underlain by a soil map unit that did not occur in company plantations, broader soil type units were used. Where there was no match between the plantation soil types and smallholder soil types even at the broad group level the recommendations were taken from the nearest blocks with values.

The new fertiliser recommendations were reported as maps and in tables and distributed on a CD, which is the main output of this project. The CD also contains the digital regional soil map that was produced and other relevant data. The fertiliser recommendations are intended a) as a guide to the optimum rate rather than an absolutely correct value, b) to be used together with information on grower productivity, cash flow etc, and c) to be modified as more information becomes available.




Acknowledgments

This project was funded by AusAID through the PNG Agricultural Innovations Grant Facility (AIGF), and supported by PNGOPRA and JCU.

We are very grateful to the following people for helping us carry out the project. Ian Orrell (PNGOPRA) and Frank Lewis (OPIC) helped design and implement the project. Steven Kamis, Ben Darius, John Kama, Reuben Sigi Taureka (OPIC), Peter Tarramurry, Richard Tiamu (HOPL) helped with checking the soil maps in the field. Elizabeth Kibikibi typed out soil map unit descriptions from the soil survey reports. Angela Pollet gave GIS advice. Simon Lord and Severina Betitis (NBPOL) made NBPOL data available to us. Mika Andrew (DALLUS) and Thomas Betitis (NBPOL) helped compile the original soil maps and Daniel Barth and Heiko Seitz did much of the digitising.

The data used in the project came from the following sources:

- Soil maps and reports: DALLUS
- Plantation MUs: NBPOL and HOPL
- Smallholder blocks: OPIC and HOPL
- Plantation fertiliser recommendations: PNGOPRA
- Roads: OPIC
- Coast, villages: PNGRIS
- Rivers, catchments: KGIDP
- Satellite: NASA (public domain)
- DEM: NASA SRTM, processed by CGIAR-CSI (public domain)
- Topographic maps: NMB
- Volcanic ash isopachs: Machida et al. (1996).

List of abbreviations

AC	Ammonium chloride
AIGF	Agricultural Innovations Grant Facility (funding program of AusAID)
AN	Ammonium nitrate
CGIAR-CSI	Consultative Group on Internat. Agric. Research- Consortium for Spatial Information
DAL	Department of Agriculture and Livestock
DALLUS	Department of Agriculture and Livestock, Land Use Section
DAP	Diammonium phosphate
DEM	Digital elevation model
GIS	Geographical information system
HOPL	Hargy Oil Palms Limited
JCU	James Cook University
KGIDP	Kandrian-Gloucester Integrated Development Project
KIE	Kieserite
LSU	Plantation leaf sampling unit (term used by HOPL at time of project; same as MU)
MOP	Muriate of potash (potassium chloride)
MU	Plantation management unit (term used by NBPOL at time of project; same as LSU)
NASA	National Aeronautics and Space Administration
NBPOL	New Britain Palm Oil Limited
NMB	National Mapping Bureau
OPIC	Oil Palm Industry Corporation
PNGOPRA	Papua New Guinea Oil Palm Research Association
PNGRIS	Papua New Guinea Resource Information System
SH	Smallholder
SPF	Soil profile form
UMA	Unique mapping area
WNBP	West New Britain Province

Introduction

Oil palm is an important cash crop for farmers in Papua New Guinea, especially in West New Britain Province (WNBP), and nutritional constraints are a major limitation to productivity. Fertiliser recommendations for company plantations are based on fertiliser trial results and annual leaf sampling, but that is not possible for individual smallholder growers due to their large number (>9,000 in WNBP) and the small size of their blocks (1-6 ha each). Therefore, fertiliser recommendations for smallholder growers have until recently been given at one rate for the whole province. However, it is clear from plantation data that optimum fertiliser rates vary throughout the province, due to environmental factors.

The Oil Palm Industry Corporation (OPIC) recently introduced a graduated fertiliser recommendation scale based on the productivity of the grower. N fertiliser is the only fertiliser recommended, as N supply is the most limiting for productivity. However, if N is applied and becomes non-limiting, some areas may also require K and Mg applications. We recognise that there are many factors influencing nutrient management by growers, and that appropriate fertiliser recommendations are only one part of encouraging growers to maximize yield and income. However, it would be an advance to have fertiliser recommendations that are appropriate for different areas.

The main purpose of this project was to produce site-specific mature palm fertiliser recommendations for smallholders to be integrated with cash management schemes in order to increase income generation. Another purpose was to capture the soil maps of the area and enhance their utility by incorporating them in a GIS.

This report is intended as a technical record of the project procedures and outputs. A separate report was submitted to the funding body AusAID-AIGF in June 2006.

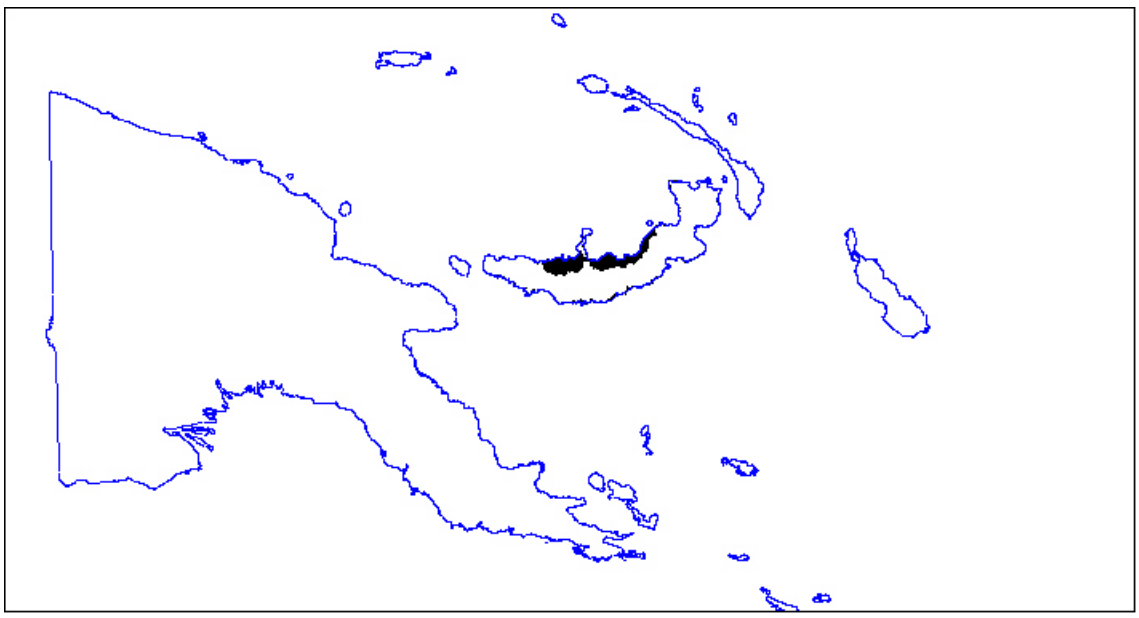

Figure 1. Location of study area (black shading), in West New Britain Province, Papua New Guinea.

GIS framework

Data was collated from a wide variety of sources and integrated into a MapInfo GIS. The data was projected to UTM zone 56, WGS84 datum. Where data existed outside zone 56 it was provided using Cartesian Coordinates (Latitude, Longitude). MapInfo performs re-projection on the fly to allow various data projections to be viewed correctly.

Compilation of information

Soil maps

The soil survey reports and maps in Table 1. were compiled and maps 164, 176, 440, 441, 192, 505, 166 and 167 were incorporated into the GIS (Figure 2).

Table 1. Soil surveys, soil maps and soil profile descriptions for oil palm growing areas of West New Britain

Map No.	Report title	Report author	Report date	Digi-tised	Scale 1:x
National scale map					
	Explanatory notes to the soils map of Papua New Guinea. CSIRO Natural Resources Series no. 10	Bleeker P	1988		1,000,000
Maps used in project and included on CD					
164	Soil survey of West New Britain. The Tiaru-Ala area[1]	Aland FB & Searle PGE	1966	Y	50,000
176	Soil survey of West New Britain. The Balima-Tiauru area. Department of Agriculture, Stock and Fisheries. Soil Survey Report No. 1	Hartley AC, Aland FB & Searle PGE	1967	Y	50,000
440	Soil survey and land use potential of the Ala-Kapiura area, West New Britain, PNG. Department of Agriculture, Stock and Fisheries. Research Bulletin No. 17	Zijsvelt MFW & Torlach DA	1975	Y	50,000
441	Soil survey and land use potential of the Kapiura-Dagi area, West New Britain. DPI Research Bulletin No. 19	Zijsvelt MFW	1977	Y	50,000
505	No report. Map title: Kapuluk (Gaho-Kulu).	Tyrie GR	1986	Y	100,000
192	No report. Map title: Dagi-Kulu Soils	Hartley AC		Y	50,000
167	Soi land soil survey report	Alland FB & Torlach DA	1971	Y	31,522
166	Navo land soil survey report	Murty	1967	Y	31,522
No map	Ulamona Survey (minute additional to 166)	Murty			
Other maps and reports for WNB					
No map	Multi-layered ash soils of New Britain	Hartley AC			
No map	Interim report on the Mosa Block				
30	Land inspection of Ilau-Loso, Ugauge-Loso and Masisege-Veli lands at Silanga, New Britain	Unwin			
34	(Airport area)			Y	7,920
42	Soil Survey of Dami land	Aland FB		Y	15,840
43	Gigo land, Talasea subdistrict	Williams	1963/9?		15,840
44	Kalo-Kwalakesi land inspection	Aland FB		Y	7,920
48	Land inspection of Mimeri clan lands at Uasilau, New Britain	Unwin		Y	15,840
53	Wangu-wangu land, Talasea subdistrict	Williams	1960		7,920
54	Agriculture assessment, West New Britain district oil palm lands, Sarakolok-Nahavio-Tamba	Aland FB	1960		
55	Report on the north-west Pota Galai and Galai block	Searle PGE	1967		31,680
56	North-west Pota Galai-Galai and Galai block			Y	31,680
58	Rikau land, Talasea subdistrict	Williams	1960	Y	15,840
60	Kavugara	Strong		Y	15,840
61	Pangalu Land	Hartley		Y	7,920

Table continued on next page

Map No.	Report title	Report author	Report date	Digi-tised	Scale 1:x
Table continued from previous page					
62	Siki	Searle		Y	7,920
68	Bulu, Talasea subdistrict	Williams			7,920
69	NoluKolu (Nalukoru) land, Talasea subdistrict	Williams			7,920
155	154 Kumbango Flooding map	Strong	1968		15,840
158	Notes on the soils of the Nakanai coastal areas	Hartley AC	1962		
162	Land use appraisal, Sale-Malasi area	Aland FB & Searle	1967		31,680
165	Bakada Land soil survey report	Aland FB & Torlach	1967	Y	31,522
168	Report on the north-west Pota Galai and Galai block	Zijsvelt	1968	Y	31,680
169	Interim report on the Mosa Block	Searle PGE	1965	Y	31,680
171	Kapiura -Gavuvu Purchases	Aland FB	1963	Y	50,000
172	Soils of the Cape Hoskins area, New Britain. Lavilelo-Waisisi	Hartley AC	1962	Y	7,920
173	Dagi River Land, Talasea subdistrict	Williams	1964		
174	(Dagi R area)				7,920
178	Ganoka Land, Talasea subdistrict	Williams	1966		15,840
179	Kaus-Benaule	Aland FB	1963	Y	7,920
180	Soil survey of Bibling land, West New Britain	Unwin	1964		
181	A reconnaissance soil survey of the Dagi River Valley, Talasea subdistrict	Graham	1951		63,360
182	Walindi	Aland FB		Y	3,960
415	Bugare, Togulo, Wakuku	Torlach			31,496
420	Dagi-Kapiura	McDonald	1976	Y	63,360
423	Kapiura-Ala			Y	63,360
432	Abiab-Veli Complex	Aland FB			50,000
433	Kavui	Strong			30,000
434	Kwe, West New Britain	Strong	1970		15,000
435	Lorko, West New Britain	Strong			15,000
No map	Cocoa/coconuts land evaluation West New Britain. Report 544	Tyrie GR			
No map	Kapiura soil survey-Kautu	Gasi & Gailaby	1992		
No map	Kapiura soil survey-Bilomi	Gasi & Gailaby	1993		
No map	Kapiura soil survey-Kaurausu	Gasi & Gailaby	1994		
No map	Soil characterisation of WNB trial sites (OPRA)	Siri M & Mindipi W	1996		
695	Soil survey of Garu and Numondo plantations, West New Britain Province	Baiga M & Huria I	1997	Y	25,000
No map	Soil analysis results for LSU in NBPOL plantations in 2000	Toreu B	2001		
No map	Agronomic aspects of smallholder surveys in Oro and Hoskins	Nelson P	2003		
	NBPOL soil survey	Betitis T	2003-04		

1. Original report has gone missing from DALLUS, and re-typed copy (Word document) is incomplete

Maps 505, 192, 166 and 440 were digitised from scans of the original maps or paper copies of the original maps. Maps 164, 176, 441 and 167 had been digitised earlier by PNGOPRA, however significant registration errors had to be corrected with large numbers of control points. Each map was assigned its map number and each map polygon was given a unique number. Each polygon was labeled with the original map unit label from the paper maps. Many of the map boundaries existed along major rivers. Linework on adjoining maps was modified along the river boundaries to provide a relatively seamless map. While some of the mapping aligns well with the current location of the rivers, many of the rivers have shifted significantly since the original mapping in the 1960s. Each of the maps were combined into a single map to allow GIS analysis.

There were 305 soil types recorded based on the component soils listed on the maps. Due to missing data for map192 and sections of map164, 92 soil types had no data. The soils are referred to as soil series in the reports and were based on important soil features in the top 120cm (50 inches). Each of the reports provided a grouping for the soils based on the authors interpretation of soil forming factors and local geomorphology. Most of the soils are developed on volcanic ash, pumice and gravel and are generally referred to as Andosols.

There are significant areas of volcanic soils that have been subject to alluvial action and minor areas of soils developed on basalt. A common feature of many soils is the multiple-horizon nature with bands of pumice gravel, dark ashy layers and sand to sandy clay loam horizons.

Each map unit had between 1 and 5 soil types and there were a few miscellaneous mapping units with no soil type recorded. Data on the soil types was recorded in a spreadsheet and taken from the soil reports where available or from the map legend where no report was found. The following data fields were derived from the soil profile descriptions to create some of the thematic maps:

- **DepthToDiscon**, Depth to discontinuous layer. Extracted from soil profile descriptions and attempts to list depth at which profile material changes significantly. In most cases this is pumice gravel layer but can also be marked decrease in texture or a rock or stony layer.
- **Discontype**, the type of material at the change
- **SurfaceTexture**, soil surface texture as listed in the reports. Generally the thin (<0.5 inch) layer of loam was ignored.
- **SubsoilTexture**, predominant subsoil texture. This was complicated by multiple texture horizons in most soils. Often refers to present day B horizon.

In instances where one of the soil types under the plantation MU did not match the soil type under the smallholder block a broader soil group was used to allow more matches to be made. The broad soil grouping adopted (here called Soil Profile From, SPF) was that used by the authors of map 176 and map 164. A description of the broad SPF groups is given in Table 2.

Table 2. Soil profile form classification used in original maps

SPF	Description
Organic	Soils dominated by organic matter, conspicuous decomposed plant material throughout the upper 30cm, organic matter content greater than 20% in coarse soils and greater than 50% in clays
Regular	Soils dominated by mineral fraction with small if any textural differences with depth
Increasing	Soils dominated by mineral fraction with increasingly finer texture with depth
Contrast	Soils dominated by mineral fraction with a texture contrast between A and B horizons of at least 1.5 to 2 texture groups increasingly finer texture with depth
Multiple	Soils dominated by mineral fraction with a disordered succession of layers with varying texture and abrupt horizons.

Several of the reports had reference soil pits marked on the maps. These were digitised as points and assigned the map number and site number (91 sites). Other soil site data included profile descriptions at 23 smallholder blocks and fertiliser trial sites (Siri and Mindipi, 1996, Table 1) and profile descriptions and soil analysis data (0-20, 20-40 and 40-60cm depths) for 20 smallholder blocks (2001 survey, reported by Nelson, 2003, Table 1), which were assigned to the polygon of the smallholder block. Although 30 blocks were sampled in that survey, block numbers did not match current block numbers for 10 of them.

The detailed procedure is described in Appendix 1.

Plantation MUs

The two companies operating in WNBP are New Britain Palm Oil Limited (NBPOL) and Hargy Oil Palms Limited (HOPL). The plantation MU maps that were provided by the

companies were combined into a single map (Figure 2) and assigned data fields to allow identification of plantation, MU id and fertiliser recommendations.

Fertiliser recommendations for each plantation MU were calculated by averaging the PNGOPRA recommendations for each MU over the years 2004-2006. Recommendations were only assigned to MUs that had mature palms and 3 years of recommendations.

The detailed procedure is described in Appendix 1.

Smallholder blocks

Smallholder block locations were obtained from OPIC Hoskins for blocks associated with NBPOL, and from HOPL for blocks associated with HOPL. In all, 4,300 of an estimated 10,000 blocks are included in the digital coverage (Figure 2). Most of the blocks not yet captured digitally are Village Oil Palm blocks; most of the Land Settlement Scheme blocks have been captured.

A single map was compiled from these sources and data fields were defined as below:

#BLOCK	block number
#AREA_CODE	3 number area code
#AREA	area name
#DIVISION	division name
#GRNAME	grower name
#Area_ha	area in hectares

The detailed procedure is described in Appendix 1.

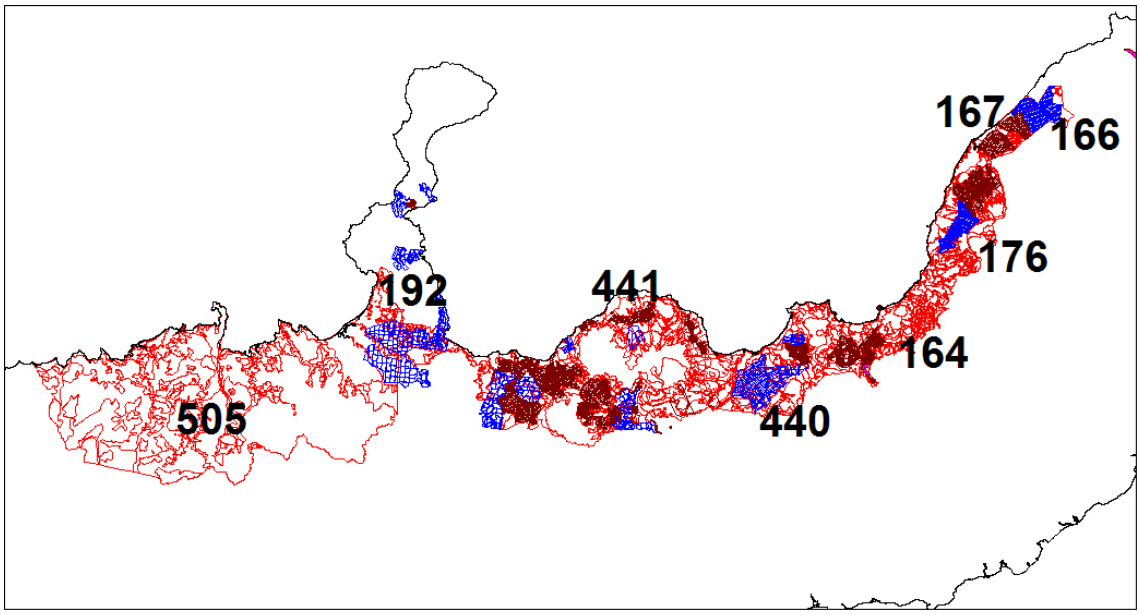

Figure 2. Smallholder blocks (brown), plantation MUs (blue) and soil map units (red), with soil map numbers given.

Other information

A Landsat image was used as the base map for the GIS (Figure 3). The following geological and topographic maps were scanned, georeferenced and incorporated into the GIS. Geological maps: 1:250,000 series, map sheets 'Talasea-Gasmata, New Britain' and 'Gazelle Peninsula, New Britain'. Topographic maps: 1:100,000 series, map sheets Aria 8786, Riebeck 8887, Namo 8886, Talasea 8987, Dagi 8986, Bangula 9087, Ania 9086, Ulawun 9187, Lolobau 9188, Pondo 9288, Kol 9287. A digital elevation model (DEM) was also included (Figure 4).

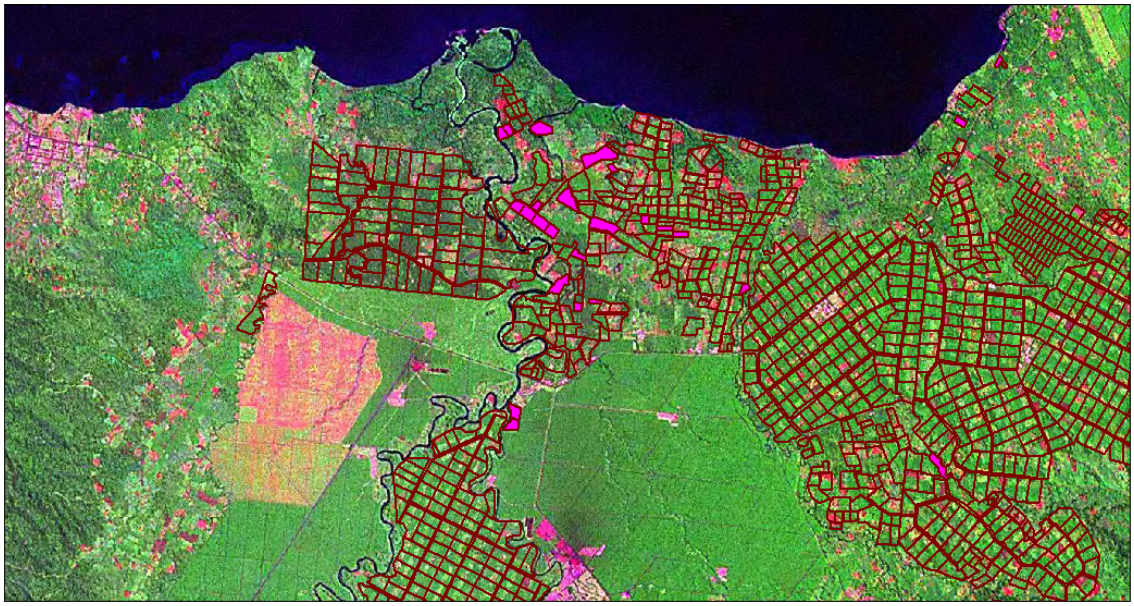

Figure 3. Landsat TM image and smallholder blocks in the Dagi River area.

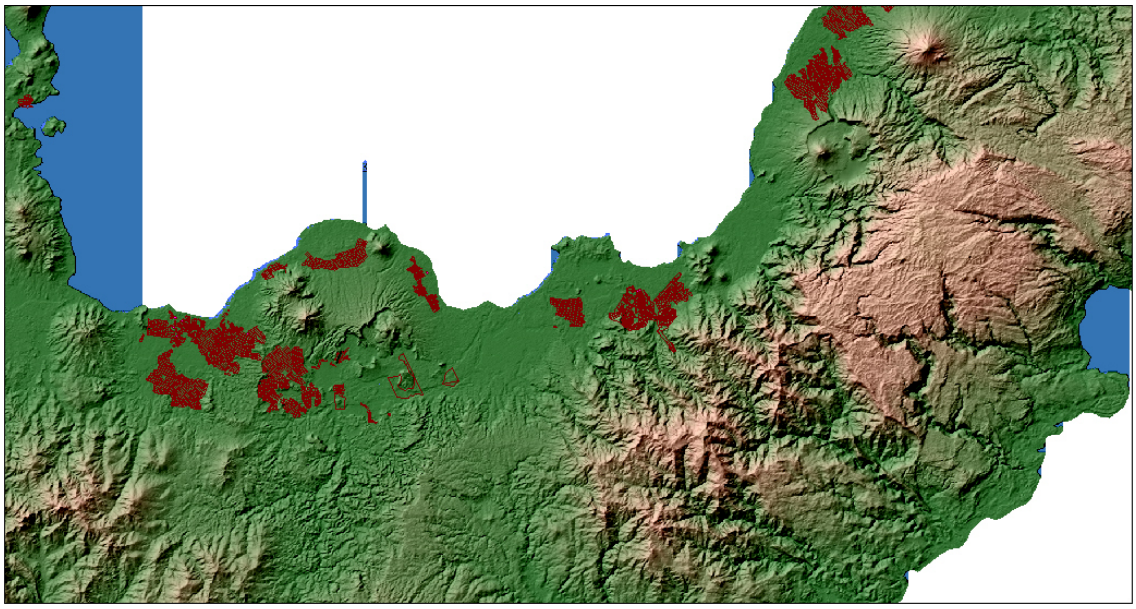

Figure 4. Topography of the study area from the digital elevation model (DEM) and smallholder blocks.

Field trip

In April 2006 we traveled through the main smallholder areas and briefly described soil profiles at 19 sites. The sites, with profile photos, are included in the GIS. Field trip notes are included in Appendix 2.

Figure 5. A multiple horizon soil at Siki, showing a distinct brown pumice layer in the subsoil and dark ash horizon in the topsoil.

Calculation of fertiliser recommendations

Fertiliser recommendations from the plantation MUs were transferred to the soil map polygons by splitting the MUs by soil type and assigning the recommendations to the dominant soil (soil1) of the map unit. The soil map that now had the fertiliser recommendations attached was then used to split the smallholder blocks and assign the recommendations to each portion of the block. The recommendations were then averaged over each block (Figure 6).

The detailed procedure is described in Appendix 1.

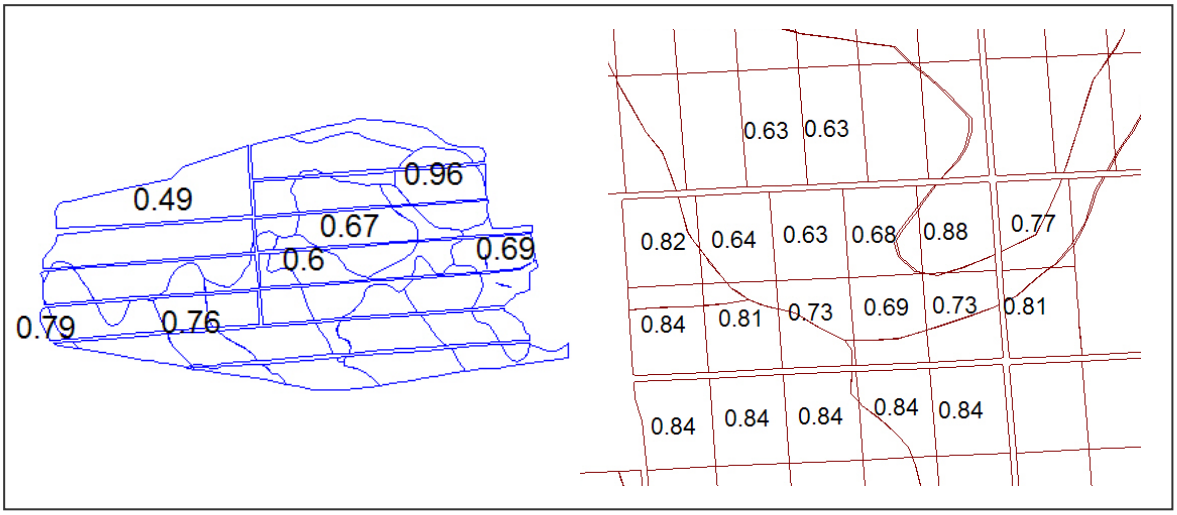

Figure 6. Fertiliser recommendations for soil map units (curved blue polygons) were derived from area-weighted averages of the MUs (rectangular blue polygons) overlapping each soil map unit. Fertiliser recommendations for each smallholder block (rectangular red polygons) were then derived from area-weighted averages of the soil map units (curved red polygons) underlying each smallholder block. The numbers in the figure refer to kg N/palm/year. For the final output these figures were converted to kg AC/palm/year and rounded up to the nearest 0.5 kg.

Dissemination of results

The results of the project, including this report, have been disseminated to relevant industry staff on a CD.

Conclusions and recommendations

This project is the first attempt to provide site-specific mature palm fertiliser recommendations for smallholder oil palm growers in WNBP. We have not been able to test the robustness of the method used, but geographical trends in the new recommendations consistent with known environmental gradients lead us to believe that they are an improvement on the current uniform recommendations. The recommendations have been determined for maximum economic benefit, assuming full harvesting. Other work is showing how incomplete harvesting reduces the benefit of fertiliser application.

The GIS framework established will allow incorporation of new data and facilitate development of new approaches.

The results of this project are intended to be modified and developed through consultations between PNGOPRA, OPIC and the plantation companies. We recommend regular meetings to decide on updates and regular dissemination of updated versions of the CD.

We learned the following:

1. There is much value in historical soil reports, although locating control points to georeference old maps and stitch them together can be difficult. Topographical and satellite base maps were essential for map control. Different capture dates give different data as rivers shift etc.
2. Combining data in GIS (point, region, imagery) adds value to the data and storage on CD provides a useful repository of historic data. A considerable effort is required to compile maps and reports and process data.
3. The process identifies data rich and data poor areas. The final product has to handle areas of limited data or data holes. GIS presentation of data also allows error checking. Preparing data is tedious.
4. Consistent and well-documented procedures for recording smallholder blocks, plantation MUs and other data would save considerable time in processing.

The procedures established will be useful for carrying out similar projects in other smallholder oil palm areas. In addition, the system established provides many opportunities for value adding in West New Britain or other areas, such as:

1. Mapping of pest monitoring data
2. Erosion and sustainability research and monitoring at landscape scales
3. Incorporation of smallholder yield data and yield mapping
4. Smallholder tissue analysis: planning of sampling strategies and mapping of results
5. Linking smallholder yields with transport management
6. Capturing scanned copies of reports etc
7. Improved soil maps using DEM and remote sensing data

Useful links

UPNG remote sensing center: http://gis.mortonblacketer.com.au/upngis/

Google Maps: http://earth.google.com/

3sec (90m) SRTM data links: http://www2.jpl.nasa.gov/srtm/cbanddataproducts.html

DEM from processed SRTM data: http://srtm.csi.cgiar.org/

Satellite images: https://zulu.ssc.nasa.gov/mrsid/

References

See Table 1 for soil survey references.

Machida H, Blong RJ, Specht J, Moriwaki H, Torrence R, Hayakawa Y, Talai B, Lolok D and Pain, CF. 1996. Holocene Explosive Eruptions of Witori and Dakataua Caldera Volcanoes in West New Britain, Papua New Guinea. Quaternary International 34-36, p 65-78.

Appendix 1. GIS procedures

Soil maps

all_soils

Soil maps 164, 176, 440, 441, 192, 505, 166 and 167 were combined into one coverage. Each of the maps was either digitised from georeferenced paper scans or an earlier GIS coverage that was re-rectified to remove distortion that was significant in most cases. Edges of maps were modified slightly to give a seamless coverage. Most map edges are along rivers so the task is relatively easy. 166 and 167 overlap a small amount, the combined map uses 167 in preference to 166. Each map table has the same structure to enable a combined table to be constructed. Each map coverage has uma number, map number and tag. The tag is the map unit symbol from the original paper copy. The tag is split into a series of fields that represent its component parts. The tag is split so that GIS analysis can be performed on the component parts. The tags were parsed in excel then linked to original coverages. Fields are all character fields except for Integer fields for Map and Uma Number;

A list of the fields is given below:

UmaNumber
MapNumber
Tag
Soil1, first soil in map symbol etc
Soil2
Soil3
Soil4
Soil5
Slope1, first slope in map symbol etc
Slope2
Slope3
Slope4
Drainage1, first drainage in map symbol etc
Drainage2
Landuse1, first landuse in map symbol etc
subclass1a, first limitation subclass in first landuse etc
subclass1b
Landuse2
subclass2a
subclass2b
MapSoil1, field to provide a unique id for the soils

all_soils_soiltype

Additional information was compiled for each soil1 found in all the component maps. These fields were used to construct thematic maps and perform further analysis. A complete list of all soil types was constructed from the soil lists in the reports (SoilType.xls- soilType worksheet). Once populated a subset of the data was linked back using the MapSoil1 field. (SoilType.xls- ToLink worksheet) All fields are character except NumberObs(Integer).

Below is a list of additional fields that were linked to all_soils

SoilNotes, short notes entered when reviewing material

NumberObs, total number of observations used to create the soil description for the entire map taken from the reports, includes phases and variants for each soil. A guide how extensive and thoroughly each soil is described. Is not the number of observations for the Uma.

SoilSeries, Series name from reports

SoilGroup, Soil group from reports, some reports did not give full lists of soils in each group.

ParentMaterial, Parent material as noted in the reports and in places estimated

Map, map number

Spf, Soil profile form as noted in the reports. This is a common grouping used by most of the authors. Where this was not provided the soil was classified to a SPF.

RepProfile, representative profile if noted in the report. See Profile coverage for listing

DepthToDiscon, Depth to discontinious layer. Extracted from soil profile descriptions and attempts to list depth at which profile material changes significantly. In most cases this is pumice gravel layer but can also be marked decrease in texture or rock.

Discontype, the type of material at the change

SurfaceTexture, surface texture as listed in the reports. Generally the thin (<0.5inch) layer of loam was ignored.

SubsoilTexture, predominant subsoil texture. This was complicated by multiple texture horizons in most soils. Often refers to present day B horizon.

FullTag, Map number and tag are used as a unique id to link to an index of html files via hotlink. Html includes information on Map unit (Uma) taken from the reports and presented in a readable form (Uma description, component soil descriptions, Suitability rating and limitation codes).

SoilType.xls has 2 worksheets, SoilType shows list of soils from the reports on the left and soil1 and map number from the maps on the right. There are soils missing on each side as only soil1 is extracted from the maps (only interested in dominant soil for analysis) and some maps have no reports. ***This worksheet is where any new soil data should be added.***

Fields in SoilType worksheet as described above

SoilName, from report

SoilNotes

NumberObs

SoilSeries

SoilGroup

ParentMaterial

Spf

Map

RepProfile

DepthToDiscon

DisconType

SurfaceTexture

SubsoilTexture

MapSoilName

MapSoil1, from maps

Map, from maps

Soil1, from maps

ToLink is a worksheet that is used to link to all_soils in mapinfo to create all_soils_soiltype.

Plantation MU and smallholder maps

plantation_mu

Coverage of all plantations compiled from individual plantation maps.

#PLANTATION	plantation name
#DIVISION	Division name
#MU_ID	Management unit/LSU ID
#MU_AREA_ha	Area in hectares
#N_AN_kg_palm	N by Ammonium nitrate fertiliser recommendation
#N_AC_kg_palm	N by Ammonium chloride fertiliser recommendation
#AN_kg_palm	Ammonium nitrate fertiliser recommendation
#AC_kg_palm	Ammonium chloride fertiliser recommendation
#DAP_kg_palm	Diammonium Phosphate fertiliser recommendation
#KIE_kg_palm	Kieserite fertiliser recommendation
#MOP_kg_palm	Murate of Potash fertiliser recommendation
#CaB_g_palm	Calcium Borate fertiliser recommendation

Includes Navo and Hargy LSUs that were compiled from plantation block files (LSU codes for blocks.xls) and grouped to give LSU/MU areas. Fertiliser recommendation data was linked using MU_ID from mu_fert_recs.xls.

mu_fert_recs.xls was compiled from fertiliser recommendation data provided by PNGOPRA and was averaged over three years (2004-2006) for mature palms. The nitrogen fertiliser recommendations were supplied as AN (NBPOL) and AC (HOPL), these were converted to N (34% N for AN and 28% N for AC) for GIS analysis. Yellow cells were no data and given a value of zero.

SH_blks

Coverage of smallholder blocks combined into one map. Areas assigned using code from NBPOL SH Block Code.xls. Fields in the table are listed below:

#BLOCK	block number
#AREA_CODE	number area code
#AREA	area name
#DIVISION	division name
#GRNAME	grower name
#Area_ha	area in hectares

Additional fields added when sh_fert_recs created

#N_kg_palm	Nitrogen fertiliser recommendation (nitrogen component of fertiliser)
#DAP_kg_palm	Diammonium phosphate fertiliser recommendation
#KIE_kg_palm	Kieserite fertiliser recommendation
#MOP_kg_palm	Muriate of potash fertiliser recommendation
#CaB_g_palm	Calcium borate fertiliser recommendation
#Match_type	'Soil1' if direct soil match with plantation MU, 'SPF' if match by more general soil group (soil profile form), 'nearest' if nearest smallholder block was used, 'plantation' for those smallholder blocks that were adjacent plantation MUs and outside the soil map. A few blocks had a combination of match type and were flagged with 'partial'.

Fertiliser recommendation maps are compiled from rounded values from sh_fert_recs where the N_kg_palm rate was converted to AC rates.

Files created during the assignment of fertiliser recommendations

Below is an outline on the process to create the fertiliser recommendations in MapInfo version 7. It assumes a reasonable working knowledge of MapInfo. The files created in the process were saved to a folder> Build files to allow rollback to a step in the process if errors were encountered. The names of the files are not important, however remember to save a copy of the tables in each step as a new name and to discard changes to the original file so as to keep a copy of each step. You will make the odd mistake!

Split the plantation MUs by soil type

1. Open plantation_mu and all_soils_soiltype.
2. Set plantation_mu as target and split using all_soils_soiltype. Use proportional area for MU_AREA_ha
3. Save as mu_split, discard changes to plantation_mu
4. Add MapSoil1 and SPF character fields to mu_split
5. Update column > MapSoil1 in mu_split using all_soils_soiltype, join where object of all_soils_soiltype contains object from mu_split. Calculate value of MapSoil1.
6. Do the same routine for SPF and save copy as mu_split_soil. Do not save changes to mu_split
7. Do query to select all where MapSoil1 and SPF are null and delete these, save copy as mu_split_soil_noblanks (this will discard areas that have no soils data for the regional match to smallholder blocks)
8. Pack both types of data for table mu_split_soil_noblanks
9. Combine objects using column> mu_split_soil_noblanks, group by MapSoil1, store in <New>, using table mu_split_soil_noblanks, (select) create> (on the next page select create> again) create>, save as mu_MapSoil1_combined. Data Aggregation> sum for MU_AREA_ha, all the fertiliser recommendations are average, weight by Area field(area of combined unit, the Area option below CaB in list), set the remaining fields to 'value'. Save file as mu_MapSoil1_combined. Plantation, Division and MU_ID are no longer valid and can be removed.

Now we transfer the weighted average fertiliser recommendations from the plantation MU (that are attached to the soil1 map units) to the rest of the soil map

10. Open all_soils_soiltype. Add new columns for each of the fertiliser recommendations, exactly as they are defined in mu_split_soil_noblanks and save.
11. From this saved file (all_soils_soiltype) Update column> all_soils_soiltype, update column N_kg_palm, get value from mu_MapSoil1_combined, join where MapSoil1 is common to both tables, calculate value of N_kg_palm. Repeat for each fertiliser recommendation.
12. Save changes to all_soils_MapSoil1_match, discard changes to all_soils_soiltype
13. Query to select all where N_kg_palm is zero, delete match, save results as all_soils_MapSoil1_match_full and save query1 as all_soils_MapSoil1_nomatch.
14. Open all_soils_MapSoil1_nomatch and mu_split_soil_noblanks and update the fertiliser recommendations of the soils coverage with those from the mu coverage, match where SPF are the same, save as all_soils_SPF_match.
15. Query all_soils_SPF_match where N_kg_palm is zero and save query as all_soils_nomatch and after query matches are deleted save as all_soils_SPF_match_full, remember to pack data.
16. Add a field Match_type to each of the following; all_soils_SPF_match_full, all_soils_MapSoil1_match_full and all_soils_nomatch and populate with string SPF, Soil1, none respectively.
17. Take any one of these maps and append the rows of the others so that you have one map of soil units that have fertiliser recommendations based on the match type (SPF, Soil1, none). Call this all_soils_match. In the build files I have coloured the SPF matches purple, the MapSoil1 matches black and the no matches green.

Prepare the smallholder blocks

18. Open sh_blks and add fields for fertiliser recommendations exactly as for all_soils_match
19. Set sh_blks as target and split using all_soils_match, use proportional area for Area_ha, value for all the rest, save as sh_blks_split.
20. Add a field in sh_blks_split called Match_type, character 10 width.
21. Open all_soils_match and update the fertiliser recommendations fields in the sh_blks with the corresponding field in all_soils_match, also update Match_type. The Match_type will need to be manually checked to pick up those blocks where soil map unit had a Match_type of none and SPF or Soil1. Also any blocks outside the soil map are flagged with ‘outside’ for the Match_type. The update column is done with a join on objects (contains). Save the results to sh_blks_split_match.

Now we do the weighted average for the blocks

22. Open sh_blks_split_match, combine objects using column> combine blocks, using table sh_blks_split_match, >create, save as sh_fert_recs, Data Aggregation> do wt ave (by area) for each of the fertiliser recommendations and sum the Area_ha.
23. The rounding up of fertiliser recommendations was done in Excel. Export sh_fert_recs as csv into excel, convert the N fertilizer recommendation figure to AC rate (divide by 0.28), round up then import back in to MapInfo and update columns. Make sure excel does not strip off leading zero in block numbers.
24. There will be some blocks that have no match, I assigned fertiliser recommendations based on ‘nearest’ block values where there were sh blocks nearby and ‘plantation’ MUs where blocks abutted plantations and were outside soil map.

Appendix 2. Field trip notes

Site	UTC (add 10hrs)	Easting	Northing	Notes
1	28-Apr-2006	301900	9434910	Navo, K25 field 4. Estimated position
2	28-Apr-2006	302500	9434900	200 m east of site 1 on road cutting, colours only. Estimated position
3	28-Apr-2006 0:44	302523	9435410	Cutting on plantation road, colours only
4	28-Apr-2006 1:18	300415	9437494	Cutting on plantation road, lower slope position, colours only
5	28-Apr-2006 1:44	295969	9429720	Soi, SH area
6	28-Apr-2006 2:41	292429	9430433	Edge of QA, Qk in Soi SH area
7	28-Apr-2006 2:53	291733	9431285	Flat coastal plain in Soi SH area
8	28-Apr-2006 4:28	291358	9421348	Porphyritic basalt site
9	28-Apr-2006 6:10	282012	9409943	Footy field
10	29-Apr-2006 0:12	284058	9406100	I6 unit
11	29-Apr-2006 1:46	277783	9391550	Tp20 unit, drain cutting
12	29-Apr-2006 2:24	267041	9389076	Waterlogged site in Tp41 unit. K deficiency
13	29-Apr-2006 3:18	266404	9386476	Road cutting, pumice in topsoil over basalt derived? Clay
14	29-Apr-2006 4:54	264175	9386989	River cutting
15	29-Apr-2006	263680	9385750	Road cutting, pumice in topsoil over clay. Estimated position
16	29-Apr-2006	253350	9387520	Drain cutting in slightly raised area on flat coastal plain within SH area. Estimated position
17	1-May-2006 4:54	192553	9376100	Sarakolok
18	1-May-2006 5:50	199532	9382445	Kapore
19	1-May-2006 6:32	208240	9378386	Buvussi
20	2-May-2006	218719	9394398	Siki, many horizons

Textures

K	coarse
F	fine
O	organic
Z	silty
S	sand
LS	loamy sand
SL	sandy loam
L	loam
SCL	sandy clay loam
CL	clay loam
LC	light clay
C	clay

Colours

G	grey
D	dark
B	brown
R	reddish
Y	yellowish

Site	1	**Easting**	301900	**Date**	28-Apr-06
Zone	56	**Northing**	9434910	**Location**	Navo, K25 Field 4
Notes	Estimated position from GIS maps. Road cutting, upper slope				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-60	6	5YR 2.5/2	KLS	Weakly friable	
60-72	6	5YR 4/6	KSL		
72-78	6		KS		
78-90	6	7.5YR 3/4	KSL		
90-95	6		KS		
95-110	6	7.5YR 3/4	SCL		
110-115	6	10YR 5/6	KS		
115-130	6		SL		
130-135	6		KS		
135-150	6	7.5YR 4/6	SCL		
150-163	6	7.5YR 3/1	KS		
163-180+	6	7.5YR 4/4	KSL		

Site	2	**Easting**	302500	**Date**	28-Apr-06
Zone	56	**Northing**	9434900	**Location**	Navo plantation
Notes	Estimated position from GIS maps. Road cutting, upper slope. Weak consistence throughout.				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-20		DB			
20-60		RB			
60-90		DB			
90-120		RB			
135-145		RB			
145-152		DB			
170-190		YB with Y inclusions			

Site	3	**Easting**	0302523	**Date**	28-Apr-06
Zone	56	**Northing**	9435410	**Location**	Navo plantation
Notes	Similar to previous sites				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-75		DB			
75-100		G	KS		
100-118		DRB			
118-122		G	KS		
122-133		DRB			
133-137		G	KS		
137-149		DRB			
149-153		G	KS		

Site	4	**Easting**	0300415	**Date**	28-Apr-06
Zone	56	**Northing**	9437494	**Location**	Navo plantation
Notes	Bottom of long gentle slope. Similar to previous sites				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-10		DB TO BLACK			
10-23		DRB			
23-30		G	KS		
30-55		DRB			
55-68		DB			
68-80		G	KS		
80-106		DRB			
106-123		DB			
123-144		DRB			20% pumice gravel
144-154		DYB			YB inclusions
154-170		G	KS		20%+ fine gravel
170-190+		DRB			

Site	5	**Easting**	0295965	**Date**	28-Apr-06
Zone	56	**Northing**	9429715	**Location**	Soi SH area
Notes					
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-20	6	7.5YR 3/2	SL+	Friable	Organic matter
20-50	6	7.5YR 4/4	SCL	Weak consistence, earthy fabric	
50-110	6	7.5YR 4/6	SCL	Weak consistence, earthy fabric	
110-200	6	7.5YR 4/6	CLS	Weak consistence, earthy fabric	

Site	6	**Easting**	0292429	**Date**	28-Apr-06
Zone	56	**Northing**	9430433	**Location**	Soi SH area
Notes	Edge of Qk, Qa Geol unit in Soi SH area. Near creek, not representative?				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-25	6	DB	SCL		
25-65	6	DG	S		
65-105	6	GB	LS		
105-120	6	GB with red mottles	S		
120+	6	GB	SCL		

Site	7	**Easting**	0291733	**Date**	28-Apr-06
Zone	56	**Northing**	9431285	**Location**	
Notes	Flat coastal plain in Soi SH area				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-8	6	5YR 2.5/1	SL	Coherent, friable	
8-15	6	5YR 3/2	SCL-	Weak, 5-10, SAB	
15-50	6	7.5YR 3/3	SCL	Earthy fabric	
50-85	6	7.5YR 3/2	SCL	Earthy fabric	
85-115+	6	7.5YR 4/4	LC	Weak, 10-20, SAB	Pores visible

Site	10	**Easting**	0284058	**Date**	29-Apr-06
Zone	56	**Northing**	9406098	**Location**	
Notes	In I6 unit on gentle slope in SH area				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-8	6	5YR 3/1	L	friable	
8-65	6	7.5YR 3/2	L	Moderate SAB, 5-10	Pores visible
65-85	6				
85-120	6	7.5YR 3/4	CL	Moderate SAB, 5-10	Pores visible
120+	6	7.5YR 3/2	L+	Moderate SAB, 5-10	Pores visible

Site	11	**Easting**		**Date**	29-Apr-06
Zone	56	**Northing**		**Location**	
Notes	Tp20 unit, drain cutting, quick observation. 1meter of alluvial wash (stones, LS) over mottled YB clay				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**

Site	12	**Easting**		**Date**	29-Apr-06
Zone	56	**Northing**		**Location**	
Notes	Waterlogged site in Tp41 unit. K deficiency. Free water at 40cm				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-4		DB	LFS		
4-14		DRB	FSCL		
14-24		GB	FSCL		
24-45+		G with orange mottles	FSCL		

Site	13	**Easting**	0266400	**Date**	29-Apr-06
Zone	56	**Northing**	9386284	**Location**	
Notes	Road cutting, pumice in loamy topsoil over basalt deriverd? Clay				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-14	7	7.5YR 2.5/1	L	friable	
14-65	6	10YR 5/6	KS	loose	Fine pumice gravel
65-90	5	7.5YR 3/4	CL	moderate, 5-10, SAB	Buried A
90-125	5.5	7.5YR 5/6	CL-	moderate, 5-10, SAB	
125+	6	7.5YR 4/6	LC	Strong, 5-10, SAB	

Site	14	**Easting**	0264140	**Date**	29-Apr-06
Zone	56	**Northing**	9387010	**Location**	
Notes	River cutting				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-15	6	10YR 3/2	SL	friable	
15-40	6	10YR 3/3	SL	friable	
40-50	6	10YR 4/6	KS	loose	Fine pumice gravel
50-60	6	10YR 4/6	SCL		
60-95	6	10YR 4/6	KS	loose	Fine pumice gravel
95-120	6	10YR 3/4	SCL	Weak, 5-10, SAB	20% river gravel
120+	5.5	10YR 4/3	FSCL	Earthy fabric	

Site	15	**Easting**	263680	**Date**	29-Apr-06
Zone	56	**Northing**	9385750	**Location**	
Notes	Road cutting at top of rise, pumice in topsoil over clay. Estimated position. K deficiency				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-20	6	7.5YR 2.5/2	SL	friable	
20-80	6	10YR 4/6	Pumice gravel	Loose	
80-100	6	7.5YR 3/4	LC	moderate, 10-20, SAB	Pores visible
100-220	5	7.5YR 4/4	CL	moderate, 10-20, SAB	Pores visible
220+	5.5	2.5YR 6/6	LC	moderate, 10-20, SAB	Pores visible

Site	16	**Easting**	253350	**Date**	29-Apr-06
Zone	56	**Northing**	9387520	**Location**	
Notes	Drain cutting in slightly raised area on flat coastal plain within SH area. Estimated position				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-2	6	5YR 2.5/2	SL	Coherent	
2-24	6	7.5YR 3/3	SL	Coherent	10% pumice gravel
24-38	6	10YR 4/4	FSL		Weakly indurated
38-47	6	10YR 5/6	SL	Coherent, earthy fabric	
47-130	6	10YR 5/6	KS		Pumice sand, gravel
130+	6.5	10YR 4/4	CLS		

Site	17	**Easting**	0192550	**Date**	1-May-06
Zone	56	**Northing**	9376102	**Location**	Sarakolok
Notes	Sarakolok SH				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-5	6	7.5YR 2.5/3	LFS	friable	
5-12	6	10YR 4/4	SL	Coherent, earthy fabric	
12-22	6	10YR 4/4	SL		
22-50	6	7.5YR 4/4	SL		Pumice gravel, 5-20mm
50-62	6	10YR 5/6	S		
62-67	6	10YR 3/4	SL	Coherent, earthy fabric	
67-85	6	10YR 5/6	SCL-	Coherent, earthy fabric	
85-130	6	10YR 6/3	Pumice gravel, 5-20mm		
130-138	6	10YR 5/1	S		
138-150+	6		SCL	Coherent, earthy fabric	

Site	18	**Easting**	0199531	**Date**	1-May-06
Zone	56	**Northing**	9382444	**Location**	Kapore
Notes	Kapore SH				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-10	6	7.5YR 2.5/2	SCL	Friable, 2-5mm, moderate polyhedral	
10-20	6	7.5YR 3/3	SCL		
20-32	6	7.5YR 4/4	Pumice sand and gravel, angular and rounded		
32-60	6		Multiple sand, gravel and SCL layers		
60-73	6	10YR 5/4	SL		Water worn pumice gravel
73-90	6	10YR 5/4	FSCL	Weakly coherent, earthy fabric	
90-105	6	10YR 4/1	S	loose	Light grey and black sand mixed
105-135	6	10YR 5/2	FSL	Weak, thin platty	faint orange mottles
135-145	6	10YR 4/1	S	Loose	Light grey and black sand mixed
145+	6	10YR 5/2	FSCL	Coherent, earthy fabric	faint orange mottles

Site	19	**Easting**	0208238	**Date**	1-May-06
Zone	56	**Northing**	9378387	**Location**	Buvussi
Notes	Buvussi SH				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-5	6	10YR 3/3	SCL	friable	
5-22	5.5	10YR 4/4	SCL	Moderate, 2-5mm, polyhedral	
22-34	6	10YR 4/4	FSCL	Moderate, 2-5mm, polyhedral	<20% pumice gravel
34-80	6	10YR 5/6	SL matrix		Pumice gravel, angular and some rounded
80-87	6.5	10YR 5/2	CKS	loose	
87-115	6.5	10YR 6/2	CKS, FSL-SCL		mixture
115-125	6.5	10YR 4/3	SCL	Coherent, earthy fabric	
125-140	6.5	10YR 4/3	LKS	Weakly coherent	
140-150+	6.5		Pumice gravel	loose	Light grey and black mixed

Site	20	**Easting**	0218719	**Date**	2-May-06
Zone	56	**Northing**	9394398	**Location**	Siki
Notes	Siki SH				
Depth	**PH**	**Colour**	**Texture**	**Structure**	**Notes**
0-10	6	7.5YR 2.5/1	OL	friable	>20% pumice gravel, 5-20mm
10-22	6	10YR 4/2	SL		> 70% fine pumice gravel
22-27	6	10YR 4/2	FSCL		
27-32	6	2.5Y 3/1	LFS		
32-42	6	10YR 3/2	SL		
42-52	6	10YR 4/4	KS	loose	Pumice sand
52-64	6	10YR 4/3	SL		
64-75	6	10YR 4/4	SL		Weak yellowish mottle
75-95	6	2.5Y 5/3	FSCL		
95-117	6	10YR 5/6	SCL matrix		> 80% rounded pumice gravel, 5-20mm,
117-140	6	2.5Y 6/3	KS		
140-152	6	2.5Y 6/3	KS		Rounded pumice gravel, 5-20mm
152+	6	10YR 5/4	SCL		