Site-Specific Fertilizer Recommendations for Oil Palm Smallholders Using Information from Large Plantations

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Research in Papua New Guinea developed a way of transferring to smallholder oil palm growers the fertilizer recommendations that have been developed for nearby plantation fields using large fertilizer trials. The procedures used were developed into a conceptual framework, which is transferable to other regions and also updateable as new information becomes available.

Intensification of land use can lead to soil fertility decline (Bailey et al., 2009), and often, even when fertilizer is used, it may not be sufficient to replace losses or balance other forms of supply. To maintain soil nutrient status at a particular level, nutrients lost in the crop and through other pathways must be replaced. In commercial practice, such replacement is only regarded as necessary when crops begin to respond to individual nutrient additions. However, producing the most appropriate fertilizer recommendations for smallholders in terms of type, timing of application, and balance is challenging due to variability in climate, soils, crop management, and the large number of farmers. While these challenges have been addressed in some regions and for some crops (Schnier et al., 1997; Das et al., 2009; Haefele and Konboon, 2009) there has been little attention to improving fertilizer recommendations for smallholder oil palm growers. Yet smallholders in PNG, typically those cultivating <10 ha, account for 37 to 40% of the area under oil palm and contribute about 33% of total palm oil production (Vermeulen and Goad, 2006). The mismatch between percent area planted and percent contribution to palm oil production represents a 'yield-gap' between smallholders and large-scale plantations. It is commonly believed by the oil palm industry that the lower production by smallholders can, among other things, be attributed to nutrient deficiencies and ineffective nutrient management. Therefore, methods are needed to improve smallholder fertilizer management in order to improve productivity and farmer incomes.

Plantation companies often invest considerable resources to develop optimum fertilizer regimes, and it would be beneficial to nearby smallholders if this information could be applied to their blocks. Fertilizer recommendations on plantation estates are usually made on a block-by-block basis. Irrespective of how these fertilizer decisions are made, such block-by-block information is usually not available to local smallholder farmers. In addition, as fertilizer represents a substantial cost for smallholders, recommendations should be based on fertilizer responses known to be economically justifiable. The objective of this study was to find a way in which the nutrient management information generated in large plantations could be transferred to surrounding smallholder growers in the largest oil palm-growing region of PNG.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Mg = magnesium; B = boron. PNG = Papua New Guinea; GIS = geographic information systems; MU = management unit.

The project was carried out in West New Britain Province (WNBP), where two companies, New Britain Palm Oil Ltd. (NBPOL) and Hargy Oil Palms Ltd. (HOPL), and 10,800 smallholders grow oil palm on a total of 43,800 ha (company area) and 36,960 ha (smallholder area). Smallholders are grouped into two project areas—Hoskins and Bialla. Virtually all of the study area has soils classified as Andisols (mostly Vitrands), formed in air-fall or alluvially-redeposited tephra (ash and pumice) ejected within the last 6,000 years (Bleeker, 1983; Machida et al., 1996). The area receives between 3,500 and 4,500 mm rainfall annually in a humid tropical climate.

To determine fertilizer recommendations, the physical attributes of plantation management units (MUs) were matched with those of smallholder blocks using soil map information. Eight soil maps and accompanying documentation of oil palm-growing areas in WNBP were obtained from the Department of Agriculture and Livestock Land Use Section (**Table 1**). These maps were digitized, rectified, and saved into a GIS as a single layer. Digital maps of all plantation MUs and 4342 smallholder blocks were obtained from Oil Palm Industry Corporation (OPIC) and the two plantation companies (**Figure 1**). While GIS information was available for all plantation MUs, less

Table 1. Soil surveys and maps used to generate base soil map in West New Britain Province (WNBP).

Map No.	Title	Author and date	Scale
164	Soil survey of WNBP. The Tiaru-Ala area	Aland, F.B. and P.G.E. Searle, 1966	1:50,000
176	Soil survey of WNB. The Balima-Tiauru area. Dept. of Ag., Stock and Fisheries. Soil Survey Report No. 1	Hartley, A.C., F.B. Aland, and P.G.E. Searle, 1967	1:50,000
440	Soil survey and land use potential of the Ala-Kapiura area, WNB, PNG. Dept. of Ag., Stock and Fisheries. Res. Bull. No. 17	Zijsvelt, M.F.W. and D.A. Torlach, 1975	1:50,000
441	Soil survey and land use potential of the Kapiura-Dagi area, WNB. DPI Res. Bull. No. 19	Zijsvelt, M.F.W., 1977	1:50,000
505	No report. Map title: Kapuluk (Gaho-Kulu).	Tyrie, G.R., 1986	1:100,000
192	No report. Map title: Dagi-Kulu Soils	Hartley, A.C., (no date)	1:50,000
167	Soil land soil survey report	Alland, F.B. and D.A. Torlach, 1971	1:31,522
166	Navo land soil survey report	Murty, 1967	1:31,522

than half of the smallholder blocks had been georeferenced.

Fertilizer recommendations (N, P, K, Mg, B) for each MU were added to the plantation MU layer. The recommendations used for this work were the mean of those made over the previous 3 years by PNG Oil Palm Research Association (PNGOPRA), but the period considered could be changed as appropriate. Soil maps were used to 'split' the MUs according to soil type. For each soil type, a fertilizer recommendation was calculated using an area-weighted average of all MUs containing that soil type. Thus each soil type has a fertilizer recommendation based on the oil palm company's fertilizer recommendations (**Figure 2**).

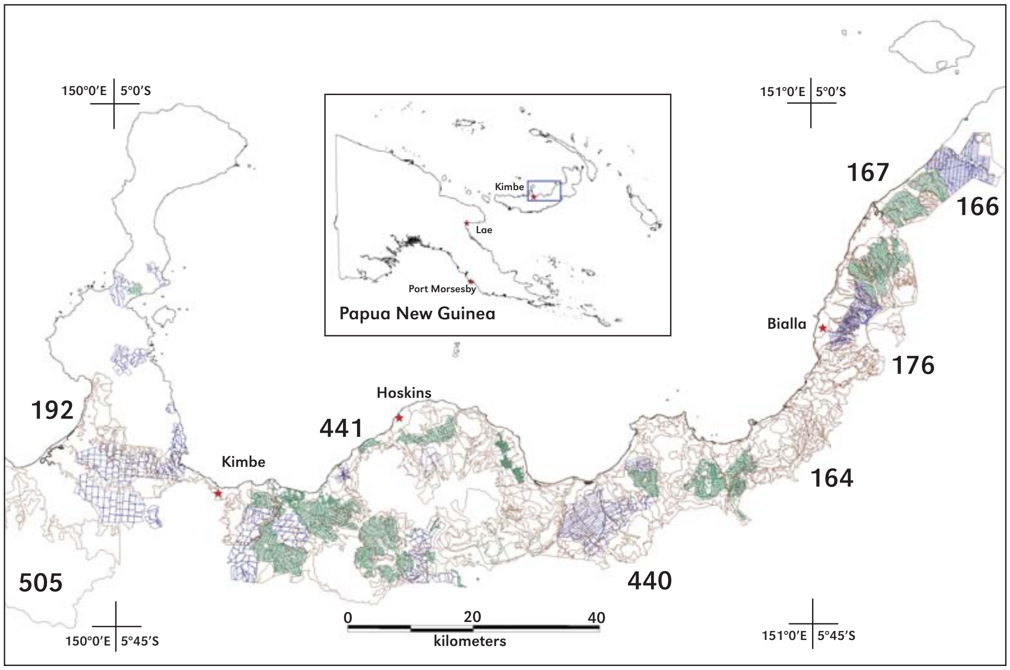

Figure 1. The GIS layers for soil (brown), plantation blocks (blue), and smallholder blocks (green) showing their relative distribution across the study area.

The smallholder blocks were also 'split' using the soil type map. Fertilizer recommendations for each smallholder block were then calculated from the area-weighted average of the fertilizer recommendation for the soil type underlying that block (**Figure 3**). Where an exact match was not possible, a recommendation was made based on the closest smallholder block that had a match, or the closest plantation MU, as appropriate. Those smallholder blocks constituted less than 3% of the 4,342 blocks considered. Smallholder recommendations for each nutrient were converted to units of fertilizer, rounded up to the next 0.5 kg (or 0.05 kg for calcium borate), displayed as maps (**Figure 4**) or tables (**Table 2**), and distributed to the milling companies, OPIC, and PNGOPRA. A more detailed account of the methodology can be found in Rogers et al. (2006).

Table 2. Typical fertilizer recommendation by smallholder block.

Block No.	Area, ha	AC[1]	DAP[2]	KIE[3]	MOP[4]	CaB[5]
		- - - - - - - - - - kg/ha/yr - - - - - - - - - - -				
A-1	7.49	3.0	0.5	0.5	0.5	0.15
A-6	7.30	1.5	-	1.0	0.5	0.10
B-9	6.97	1.5	-	1.0	-	0.10
E-5	5.20	2.0	1.5	1.5	0.5	0.15

[1]AC is ammonium chloride; [2]DAP is diammonium phosphate; [3]KIE is kieserite (magnesium sulfate); [4]MOP is muriate of potash (potassium chloride); [5]CaB is calcium borate.

Framework Development and Discussion

Through the process described above, it was possible to make individual fertilizer recommendations for 4,342 smallholders based on existing data. Recommendations were possible only for blocks that had been georeferenced and were in the GIS. However, as more smallholder blocks are included in the GIS, the number of individual recommendations can be increased accordingly.

This work relied on the existence of soil maps at an appropriate scale covering the area of interest. However, in many parts of PNG and the world, soil maps are not available at that level of detail. Nevertheless, digital elevation data, available globally from the shuttle radar mission, can be used to improve the precision of broad-scale soil maps, and this has recently been done for PNG (Bryan and Shearman, 2008). While within-block variability in soil fertility is bound to exist in smallholder oil palm blocks, the framework used here represents a first step away from regionally uniform fertilizer recommendations to much more site-specific recommendations. Indeed, if smallholders also had access to leaf tissue nutrient analysis, some of these issues could be addressed more appropriately. A major part of the work involved obtaining copies of the original soil maps, digitizing and georeferencing them—a one-time requirement. Therefore, if plantation fertilizer recommendations change or as more smallholder blocks are georeferenced, the fertilizer recommendations can be easily updated.

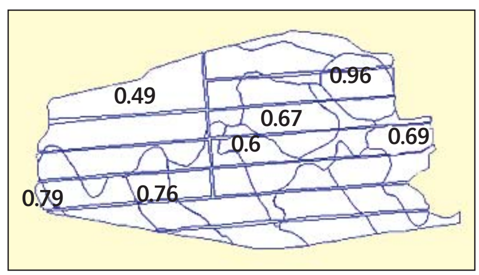

Figure 2. Fertilizer recommendations for soil map units (curved blue polygons) were derived from area-weighted averages of the MUs (rectangular blue polygons) overlapping each soil map unit. The numbers refer to kg N/palm/yr.

Incomplete harvesting, which is a common constraint to productivity by smallholders (Koczberski and Curry, 2008), drastically reduces the benefit:cost ratio of fertilizer application. Therefore, smallholders who are under-harvesting should be identified, and the constraints to full harvesting be addressed, before fertilizer recommendations are made.

It should be possible within 3 years of implementation of the framework to differentiate between farmers who are able to realize the benefits of fertilizer application as higher production (the high producers) and those who, for various socio-cultural reasons, are unable to realize fully the income gains from fertilizer because of under-harvesting. Thus, in future, fertilizer recommendations may also be able to accommodate some of the socio-cultural factors affecting smallholder productivity.

A logical plan for application of this framework

1. Use plantation fertilizer recommendations (averaged over the last few years), soil maps, and GIS to provide initial fertilizer recommendations.
2. Use plantation data from comparable fields to estimate realistic potential yield under similar growing conditions.
3. Determine current (or average over a few years) yield of the smallholder block.
4. Determine the increased economic returns to be gained if fertilizer recommendations were followed.
5. Explore options for additional labor to meet the increased demand (fertilizer application, weeding, pruning, harvesting, etc) in balance with other economic and social commitments.
6. Re-evaluate steps 3 and 4 above to determine a practical and achievable harvested yield.
7. Determine fertilizer requirements to achieve that harvested yield consistently.
8. Develop a financial and management strategy to implement the plan.

Summary

The framework developed here enables production of fertilizer recommendations for individual smallholder oil palm growers using existing biophysical information. Adoption of the suggested framework would provide more appropriate fertilizer recommendations at the level of the individual grower than the current method of a single region-wide recommendation. More appropriate fertilizer recommendations at this scale are likely to improve the efficacy of fertilizer application and the returns to growers. BC

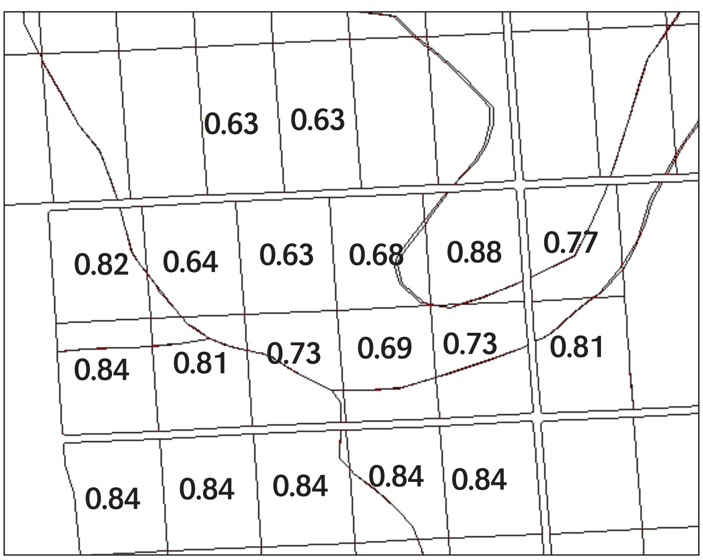

Figure 3. Fertilizer recommendations for each smallholder block (rectangular red polygons) were derived from area-weight averages of soil map unit (curved red polygons) fertilizer recommendations underlying each smallholder block. The numbers refer to kg N/palm/yr.

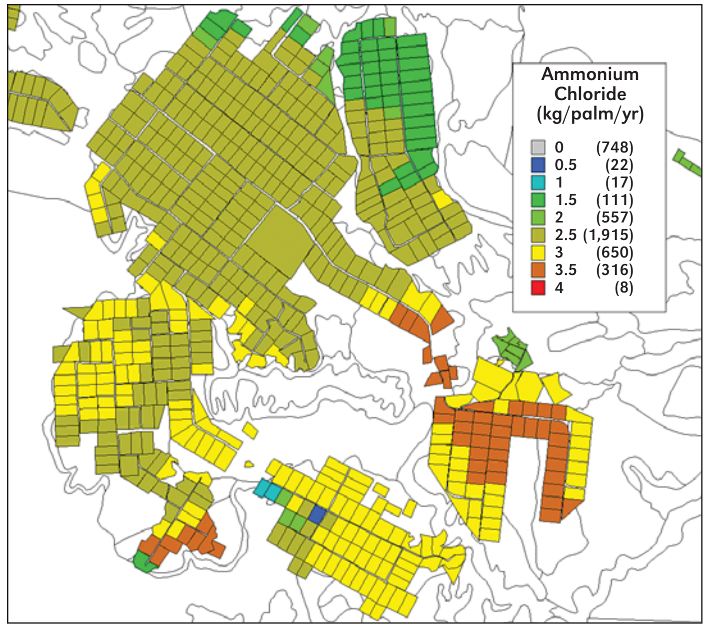

Figure 4. Example of a map of smallholder blocks with fertilizer N recommendations in 0.5 kg increments of ammonium chloride (only a portion of the total map is shown). The numbers in parenthesis refer to the number of blocks in each category out of the 4,344 blocks mapped and assessed. The 0 to 0.5 (gray) category mostly refers to blocks for which it was not possible to make a match with the plantation soil types and therefore not possible to make a reliable recommendation.

Acknowledgement

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