Identification and elimination of yield gaps in oil palm. Use of OMP7 and GIS [1]

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1 Abstract

The increasing competitiveness of other vegetable oil crops, declining commodity prices, scarcity and cost of labor, and reduced availability of land for further expansion are some of the reasons driving a requirement for increased productivity in oil palm plantations in Southeast Asia (Foong and Lee, 2000; Fry, 2000; Goh, 2000; Gurmit Singh, 1999; Kuruvilla, 2000; Paramananthan, 2000; Stringfellow, 2000; Teo, 2001). At the same time it is clear that yields lag behind the potential in many oil palm plantations. Furthermore, more stringent controls on environmental impact are a consequence of the market's demand for certified sources of 'clean' crude palm oil produced in sustainable production systems (Kuruvilla ***et al.***, 2002). In all oil palm plantations, it is essential to identify the potential yield for each soil type and planting material, establish realistic yield targets, by implementing Best Management Practices (BMPs) on representative soil types, and then identify and eliminate yield gaps by site specific field management.

We are presently implementing a program of BMPs in selected blocks in the Pacific Rim Plantations Group (PACRIM) so that the potential yield, limited only by soil type, planting material and climate, is fully expressed. We use OMP7, a computer database system, to store and analyze all historical information on yield, nutrient use, leaf and soil analysis, tree stand and selected environmental parameters for each block. Agronomic information is portrayed in block history reports, using OMP7, and maps, using GIS software with OMP7 as the data source.

Blocks that have performed poorly are identified by calculating the gap between site-specific potential yield and actual yield. Lists and maps that include information on agronomic constraints for each poorly performing block are produced from OMP7 to provide a quantitative basis for field inspections. An action plan is then drawn up including a program of activities that will eliminate those agronomic constraints amenable to management control. This approach constitutes a change from the use of routine field upkeep programs to site-specific management of the factors that constrain yield on a block-by-block basis. We are presently implementing this approach as part of the PACRIM group's strategy to achieve yields in excess of 8 t ha^{-1} palm products.

2 Introduction

In today's very competitive investment markets, large, 'listed' plantation companies are under enormous pressure to increase the returns for their shareholders. Over the past twenty years, the main strategy has been to increase the planted area by taking advantage of the availability of large tracts of suitable land in Sumatra, Kalimantan, Sabah and Sarawak. The area of land planted to oil palm increased by almost 8% per year over the past twenty years (Figure 1) with expansion centered on low soil fertility status soils (Ultisols, Alfisols, Histosols) in the islands of Borneo and Sumatra. During this period, DxP planting materials

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with high yield potential were available that greatly improved the potential productivity of new plantings and replantings (Rajanaidu, 1998).

Over the past five years it has become clear that the possibilities for further expansion are now greatly reduced due to the low availability of suitable land, problems with finding suitable land not occupied by indigenous people, and pressure from NGOs concerned with the reduction in forested land reserves in areas of ecological significance and high biodiversity value. In any case, in their pursuit of increased revenues, plantation companies are concerned about the capital outlays required to plant new areas and the time delay between planting and the start of revenue flows. These are some of the reasons why there is now great concern to increase the productivity of land already planted. In some companies, where plantations were established rapidly and thus the age distribution of plantings is narrow, there is a requirement to speed up the process of replanting, particularly where the effects of Ganoderma disease have reduced the effective tree stand and thus productivity.

The central argument of this paper is that there is tremendous scope to further increase the productivity of existing plantings by greater attention to details of field management. To achieve the necessary productivity gains, managers must use modern information technology tools to analyze agronomic data, identify factors that explain poor productivity and implement site-specific corrective measures to increase palm performance. Decision support tools are not considered to be a substitute for field inspections by management staff but rather they provide the necessary quantitative basis for more informed and analytical field visits. In this paper we discuss methods to determine 'potential yield', and procedures to identify poorly performing blocks and implement remedial measures using Milne Bay Estates in Papua New Guinea as an example.

3 Estimation of potential yield and yield gaps

3.1 Definition and identification of potential yield

Potential yield (Y_p) is defined as:

> ***The yield of fruit bunches for palms planted at the optimal plant spacing for a given soil type and planting material for each year of production from the onset of harvest to the end of the production cycle where productivity is not limited by nutrient supply, pests, diseases, weeds, soil damage and other factors amenable to management control.***

In most environments in Southeast Asia, yields peak between seven and ten years after planting (YAP). The decline in yield that often occurs in subsequent years is related to reduced tree stand due to pest and disease infestations, and poor fruit bunch recovery due to difficulties with harvesting very tall palms. The potential yield should be extrapolated forward from the year where yield peaks and should not be reduced arbitrarily towards the end of the production cycle because the difference between actual yield (Y_a) and Y_p is an important criterion for selecting candidate fields for replanting.

Yield in a particular year is always affected by climatic conditions in past years and thus records used to establish potential yield profiles for each combination of soil type and planting material should, if possible, be drawn from records of fields that have not been constrained by unfavorable climatic conditions in the previous three years.

Where can the estate manager obtain information on Y_p? Records from optimal treatments in properly implemented fertilizer experiments are a useful source of information but usually only provide data for a few years in the production cycle. A further source of information is seed suppliers who may have conducted trials in representative soil types to estimate the productivity of particular planting materials in different environments. As we shall see, it may also be possible to make use of past yield records and estimate Y_p based on the performance of the top 90th percentile (top decile) for each year of production for each soil type and planting material. Perhaps the most appropriate approach to estimating Y_p, however, is for the estate to implement BMPs in selected fields, with a full tree stand at the optimal density, that represent the dominant land classes found on the estate. Ideally, such fields are selected and BMPs installed soon after planting has been completed. Management must ensure that the following criteria are met in the selected BMP blocks:

- The soil is managed to minimize soil erosion and surface run off (platforms, terraces and contour bunds installed according to need).
- A full stand of healthy trees has been established at the optimal plant spacing (high density plantings may require thinning if inter-palm competition becomes evident in later years).
- A balanced and optimal amount of all required of nutrients is supplied (optimal treatments from fertilizer experiments should be used for each land class).
- All ripe fruit is harvested and removed from the field following standard estate procedures (harvest paths and bridges must be maintained so that harvester performance is unimpaired).
- Pests, diseases and weeds are controlled according to estate standards (an early warning system should be implemented to prompt control measures where economic pest attacks occur).

The estimation of Y_p is an on-going exercise and yield profiles for each soil type and planting material can be updated as new and more representative information comes to hand. It is not feasible to install BMP fields for each tree age and the manager's discretion must be relied upon to select sufficient fields to provide the required information.

3.2 Yield analysis in Milne Bay Estates (MBE).

Historical production data was analyzed for MBE, comprising 6,750 ha in 195 planted fields with an average size 34.6 ha. Fields were planted between 1985-1990 (Figure 2) are grouped together under three land classes: 'hills', 'alluvium', and 'interfluves' (Figure 3). Mean yields can be calculated for each tree age and land class using OMP7 (Appendix 1).

Yield was greater in fields planted on the land class 'alluvium', particularly during the period from the start of harvest to 9 years after planting (YAP) (Figure 4a) due to greater bunch number and larger bunch weights (Figure 4b,c). Average cumulative yields were about 50 t ha^{-1} greater by 15 YAP in the land class 'alluvium' compared with 'hills' and 'interfluves', equivalent to almost two years production at average yield levels (Figure 4d).

Tentative Y_p profiles were estimated prior to the present analysis for each land class based on a preliminary assessment of past productivity and reference to fertilizer experiments located on two of the dominant land classes.

4 Identification of yield gaps

Conventional approaches to plantation management usually include the implementation of programmed field maintenance and upkeep programs in each administrative unit or division within the estate together with field visits by management staff to review the quality of implementation and provide corrective advice. Yield data (t ha^{-1} fruit bunches, bunch weight, bunch number per palm) for individual fields and administrative units may be compared in an attempt to identify areas with low productivity. This does not necessarily provide a high return on investments in management inputs since there is no guarantee that the manager's time is spent in those areas where corrective agronomic measures are required.

An estate achieves the greatest return to the inputs of management staff when attention is focused on fields where the yield gap (Y_p-Y_a) is greatest. It is not an easy task to calculate yield gaps since each field of palms may differ in terms of planting date, soil type and planting material, the three factors that determine the potential yield. For example, in a MBE with 6750 ha, six planting years (Figure 2), three land classes (Figure 3), and one planting material, there may be 18 different 'potential yields' for each year of production. In other estates with several planting materials, planting years and land classes there may be more than 30 'potential yields' for each year of production. Clearly, it is not an easy task to identify those blocks that are under-performing without the use of computerized database tools.

4.1 Use of OMP7 and GIS

Central to our approach is the use of integrated decision support tools comprising OMP7™, a computer database system for the storage and analysis of agronomic data (Rankine ***et al.***, 2001), and geographical information systems (GIS) for the spatial analysis of agronomic information (Fairhurst ***et al.***, 2000). Each block is classified according to planting date, planting material and land class and yield profiles are described for each land class. Thus, the potential yield (not adjusted for variation in rainfall) is identified automatically and correctly for each field each year. The 'yield gap' is then calculated as the difference between Y_p and Y_a.

In MBE, mean yields have consistently lagged behind Yp in each land class (Figure 5). Yield in the upper 10^{th} percentile for the 'hills' and 'interfluves' land classes equaled or exceeded Y_p in most years (Figure 5a,c). This suggests that Y_p has not been overestimated for these two land classes and that mean yields could be increased by applying corrective measures to blocks where the yield gap is greatest. There was a large yield gap in the 'alluvial' land class where yield in the top 10^{th} percentile blocks did not equal Y_p in any YAP and Y_p was over estimated (Figure 5b). The tentative first approximations for potential yield should now be adjusted, based on retrospective yield analysis, particularly for the 'alluvial' land class.

In general, yield gaps were much greater in 1999 compared with 2000 (Figure 6 and 7) and yield gaps were greatest in the alluvial' land class in fields planted 1988-1989 (Figure 6) partly because the potential yield for trees of this age in the 'alluvial' land class was over estimated.

5 Conclusions

Yield gap analysis is a powerful tool to identify poorly performing blocks according to tree age, planting material and land class. Yield gap analysis requires that all agronomic information for each field and year of production is stored in a computer database together with Y_p projections for each land class and planting material. It is then possible to produce maps showing poorly performing areas in the estate that merit site-specific remedial action and greater inputs from management staff. Reports can be prepared that list blocks sorted according to yield gap and provide background historical information on yield, nutritional status and maintenance standards.

Such maps and reports provide essential quantitative information that can be used to compliment the time worn procedure of field visits so that programs for remedial and corrective action can be devised focusing on areas of the estate where the return on investment in management effort as well as labor and materials is greatest.

6 Acknowledgements

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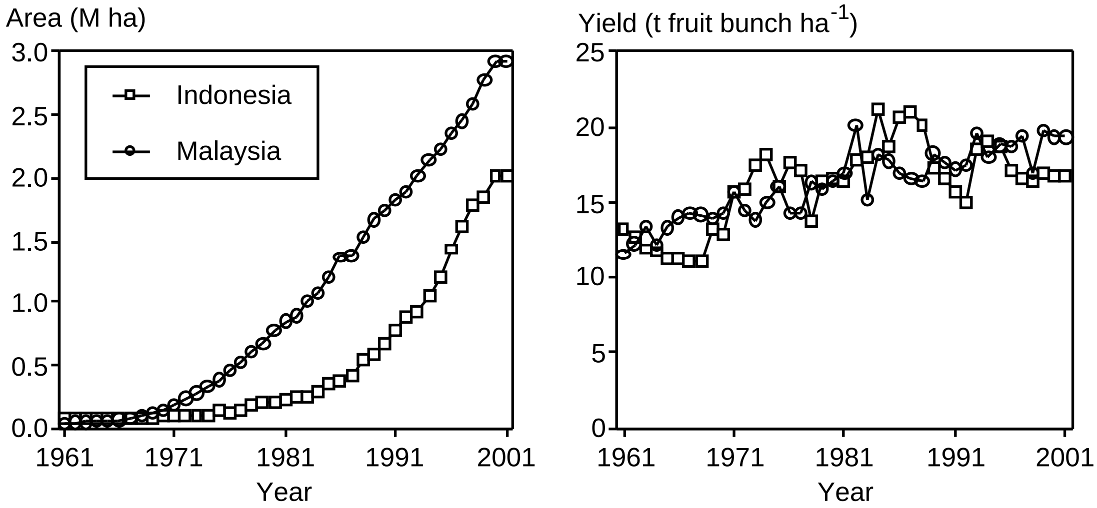

Figure 1. Area and productivity of oil palm in Indonesia and Malaysia (FAO, 2001).

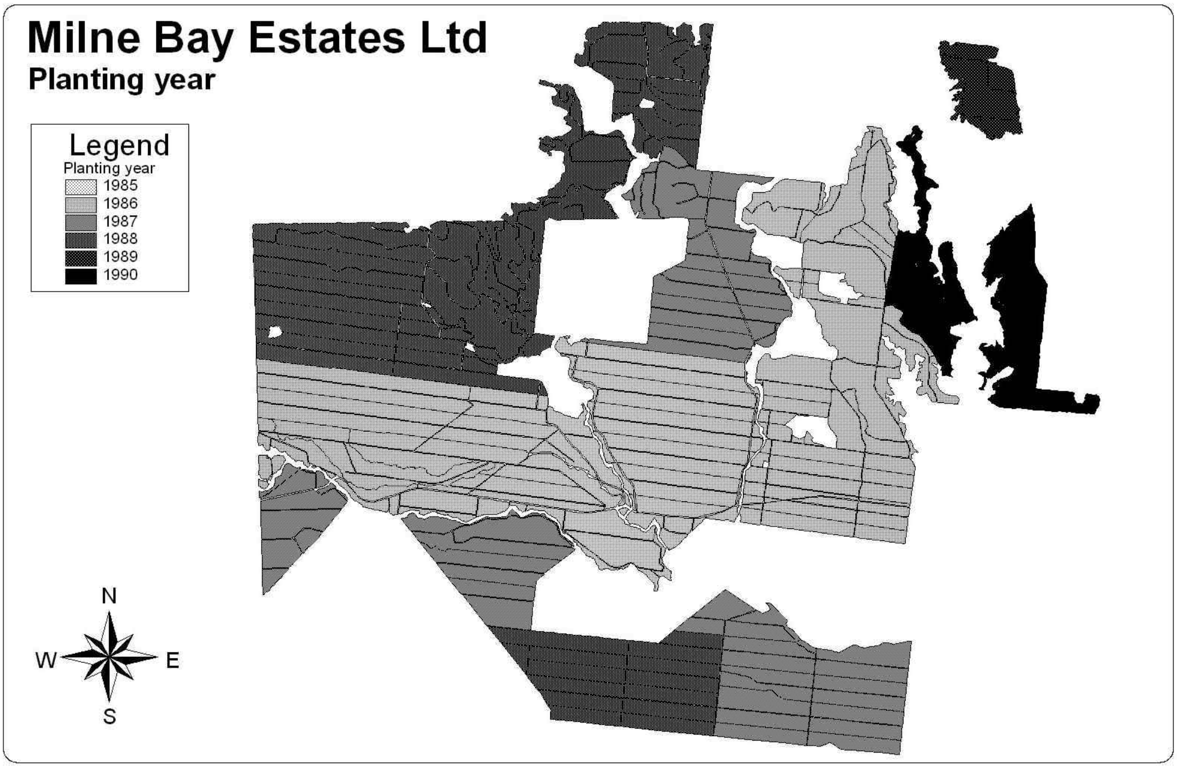

Figure 2. Map showing Planting years in Milne Bay Estates.

Figure 3. Map showing land classes Milne Bay Estates.

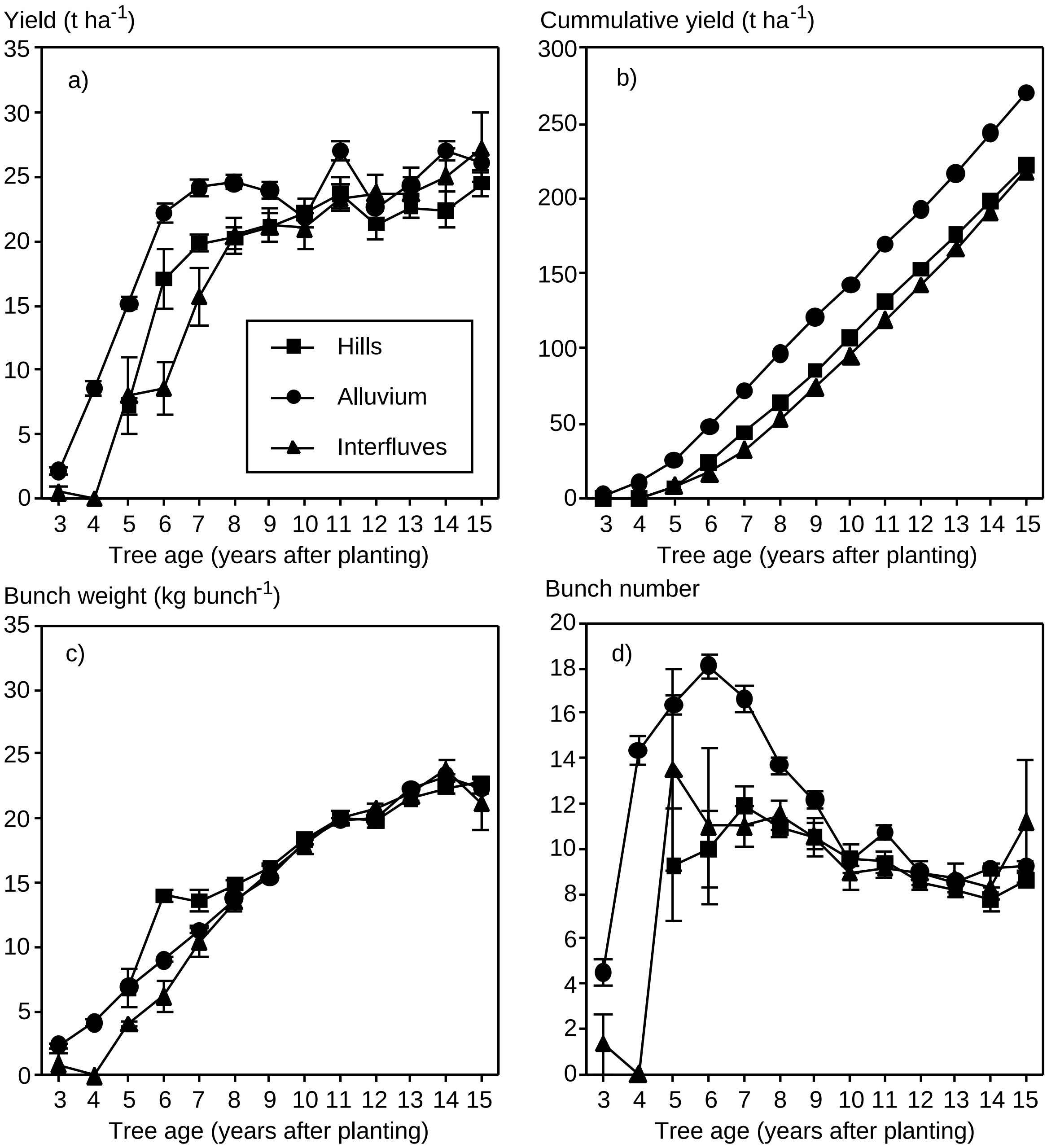

Figure 4. Yield, cumulative yield, bunch weight and bunch number for three land capability classes for trees aged 3-16 years after planting in Milne Bay Estates, Papua New Guinea.

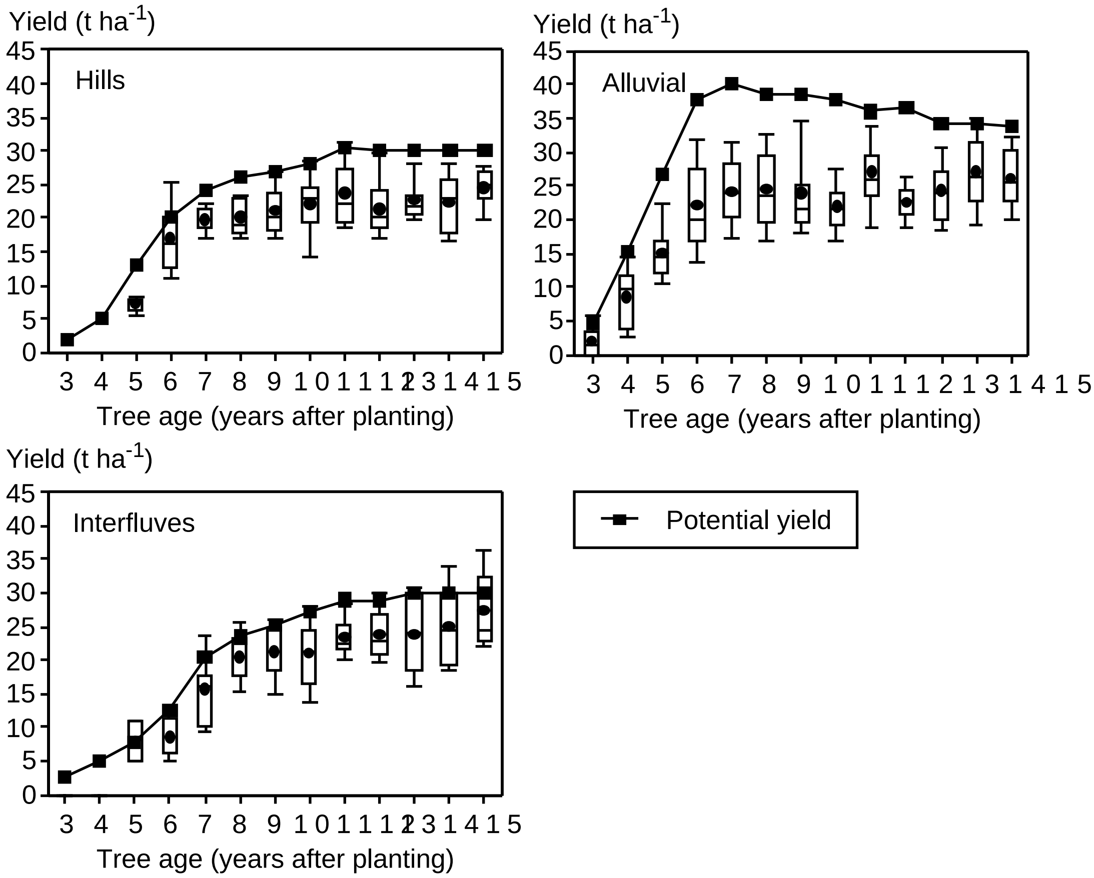

Figure 5. Yield profile for alluvium land class for tree ages 3-15 years after planting for alluvium land class in Milne Bay Estates, papua new Guinea. Box plots for each year of production show the 75th percentile (top line), 25th percentile (bottom line) and 50th percentile. Whiskers indicate the 10th percentile (bottom) and 90th percentile (top).

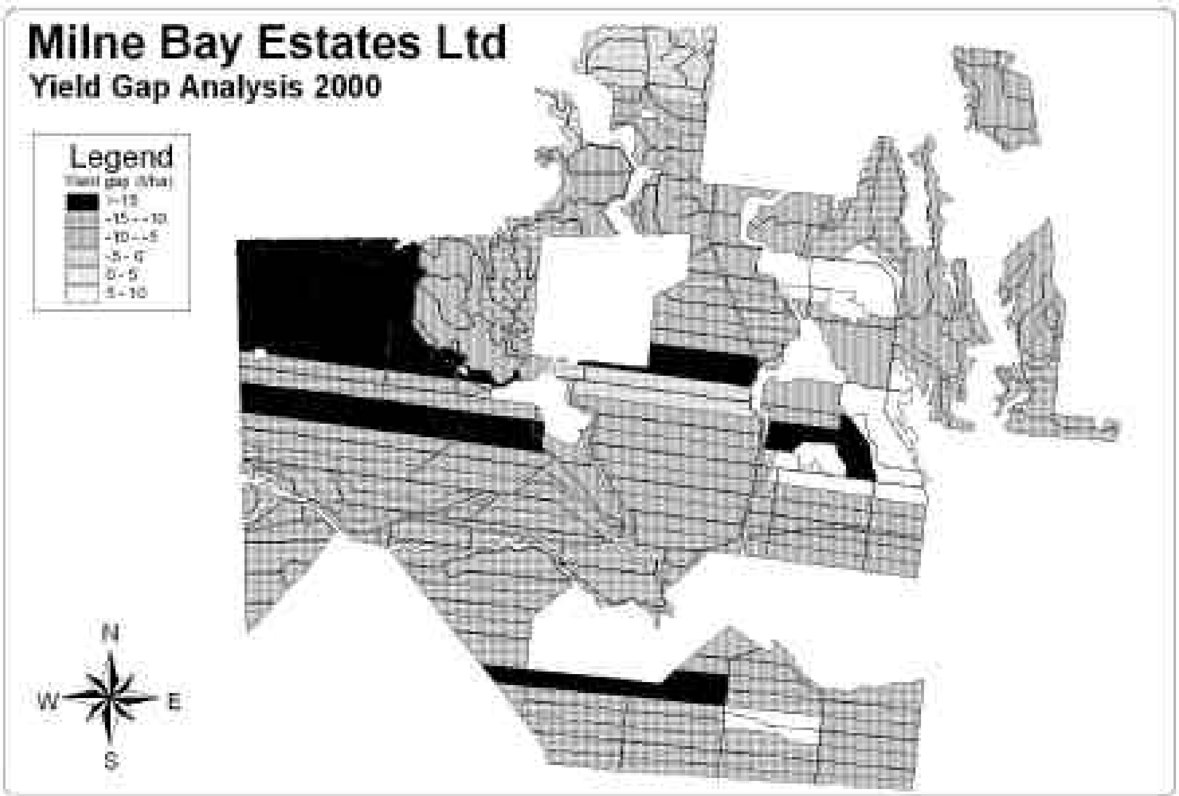

Figure 6. Map showing yield gaps in 1999 in Milne Bay Estates. The yield gap for each block is calculated based on actual yield and potential yield for each soil type and tree age.

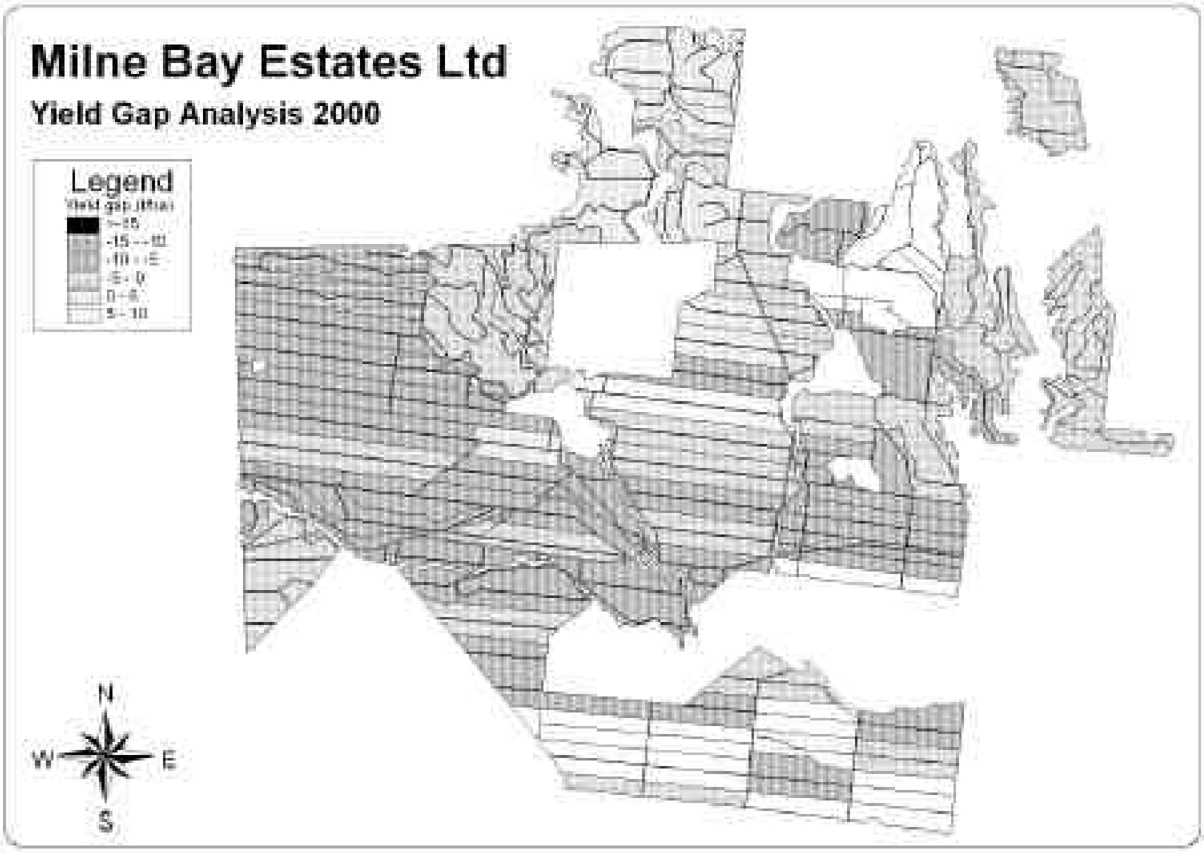

Figure 7. Map showing yield gaps in 2000 Milne Bay Estates. The yield gap for each block is calculated based on actual yield and potential yield for each soil type and tree age.

Appendix 1

OMP 7 *Pacrim Milne Bay Estate:*

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Production by tree age

Data Analysis

FILTER: Age: 3 - 16, Soil type: * alluvium,

Tree age	Production				Leaf Analysis				Reps
	Production	Yield	Bunch weight	Bunches	N	P	K	Mg	
	tonnes	t/ha	kg/bunch	No/tree	%				
3	3,290	1.9	2.4	4	2.34	0.14	0.68	0.43	68
4	13,105	8.6	4.1	14	2.55	0.15	0.69	0.42	53
5	35,424	15.2	6.8	16	2.67	0.16	0.70	0.38	79
6	51,263	21.8	9.0	18	2.52	0.15	0.65	0.39	78
7	68,213	23.3	11.3	17	2.49	0.15	0.68	0.32	92
8	94,884	24.1	13.8	14	2.48	0.15	0.66	0.32	122
9	115,677	23.4	15.3	12	2.43	0.15	0.63	0.32	143
10	91,462	21.3	18.1	9	2.38	0.15	0.65	0.32	122
11	90,522	25.5	19.9	11	2.40	0.15	0.65	0.31	96
12	80,100	22.6	20.0	9	2.34	0.15	0.61	0.33	96
13	62,934	23.7	22.3	9	2.31	0.14	0.64	0.32	66
14	67,948	26.2	23.3	9	2.34	0.15	0.66	0.31	65
15	53,086	26.4	22.3	9	2.33	0.16	0.63	0.33	51
16	21,189	21.0	24.1	7	2.27	0.15	0.62	0.34	21
Total/avge	849,096	20.4	15.2	11	2.42	0.15	0.65	0.35	1152

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