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Plantation Intelligence Applied Oil Palm Operations: Unlocking Value by Analysing Commercial Data

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Plantation intelligence [PI] applies the concept of business intelligence, which is analysis of company data, to oil palm production. Plantations already have collected monthly data of block yield but do not use them to enhance financial performance. These data were analysed for a whole plantation to rank individual blocks according to their ability to respond to applied fertiliser. Blocks were classified according to their average fertiliser productivity (AFP), which was associated with the block's soil management group (SMG). AFP varied between years depending on rainfall and SMG. The ranking was used to guide fertiliser management by diverting fertiliser from unresponsive blocks to those that are more responsive. Although the inferences lack statistical validity they appear robust from a practical viewpoint. They are easy to evaluate in the field, since they require no upscaling from or interpretation of experimental data. They provide managers with a tool to evaluate the variable effect of fertiliser over the whole plantation in different years and to improve financial performance.

Keywords*: Plantation intelligence, fertiliser response, soil management group, financial performance.*

Information management is a vital component of success for all businesses, but commercial agriculture has lagged in adopting it. Most agricultural managers lack information about performance, risks and values of field operations on which to make key decisions. In oil palm plantations, uncertainty has also increased because of rapid expansion and change. The goal of Plantation Intelligence (PI) is to accelerate the adoption of information management in the palm oil industry to support the profitable adoption of best management practices and other changes.

CONCEPTS

Plantation intelligence

Strategy in the business sense is planning a company's next move. In contrast, 'tactics' is the process of physically carrying out that plan. Business intelligence is any tool, activity or process that is used to analyse a company's data to support better decision making, to identify new opportunities and to reduce costs. A company uses both strategic and tactical intelligence to develop and implement its business plan. The primary difference between tactical and strategic intelligence is the timing regarding the business environment.

Strategic intelligence allows decision makers to visualise the company's future direction in accordance with its stated mission and goals. Tactical intelligence deals with the present. It provides the necessary information to monitor the company's current operating environment and identify new opportunities.

Tactical intelligence offers analysis of current conditions and identifies the actions needed to achieve the company's strategic objectives. Tactical intelligence focuses on the resources available such as people, time and money for achieving the strategic goals. Tactical planning helps a company make the most efficient use of resources to deliver value to its stakeholders.

PI applies the concepts of both strategic and tactical business intelligence to the palm oil industry. PI is directed towards management of the components of the production system, which managers and analysts together determine sources of variation that managers deem to be important. The process starts with acquiring the data, preliminary analysis and discussion with management. The analysis is then refined, further discussed with management, which is followed by a further comprehensive review.

PI link to plantation business performance

The American management consultant Peter Drucker told us that we all have a business model in mind when we try to manage any entity, even if we do not realise it. A business model is the conceptual structure supporting the viability of a business. It outlines the way a firm captures value, including its purpose, its goals and its ongoing plans for achieving them. All business processes and policies are part of that model. According to Magretta (2002), a business model answers Drucker's key questions: Who is your customer, what does the customer value, and how do you deliver value at an appropriate cost? A firm without a viable business model may not last for long. Oil palm producers, whether large or small, are no different from anyone else and each has a business model whether they acknowledge it or not. Large oil palm plantations undoubtedly have business models, which are not usually published in detail, but profit for shareholders must be one important objective, amongst others. Shareholder profit for oil palm businesses primarily comes from profitable production of palm oil, that is the value of palm oil produced is greater than the cost of producing it. The business model is created around (a) business case(s), i.e. actual opportunities that the team are looking forward to harness. A business case clarifies "what if questions". For example: "does the investment into a changed fertiliser management practice justify the expense". It is usually organised around a single action or decision and its alternatives, and helps to anticipate impacts from such action, by being based on a cost model and a benefit rationale.

A business plan is similar to a business model but it is more detailed, specifying all the elements required to demonstrate the feasibility of the prospective business. A business plan is therefore a formal statement of business goals, why they are attainable, and the plans to reach them. The plan may also contain information about the organisation or team that is attempting to reach those goals. Business plans answer questions about the future of the business, and are regularly updated to account for changes in external conditions (for example climate change), including changes in perception and branding by the customer, the client, or the larger community. Major changes to an existing plan or plans for a new venture usually require a three to five-year business plan, which is the timeframe most investors require. The business plan focuses on the business performance, by quantifying major components of income such as yield, margins or revenues. Being based on the business model, it shows where and how the business makes money.

Plantations collect copious amounts of operational data, which cannot be analysed because the data are not captured in a management information system (MIS). The only data that are used are of inputs and costs, which are presented as summaries, which masks actual variations in performance. Their value as tools for learning is lost.

The value of the data already being collected will come from analyses that provide insight into companies' operations. The analyses can unlock the value that the data contain and relate them to real experiences. PI is a mechanism that brings together insights derived from data analyses of agronomic understanding including research to provide guidance to plantation management. It provides valuable input to the business plans of palm oil plantations by clarifying the agronomic performance of an operation. This allows quantification of the opportunities provided by the management of key resources and key activities. It helps to clarify how specific business cases impact on the cost structure and revenue streams.

HOW PI SUPPORTS AN OIL PALM PLANTATION'S BUSINESS PLAN

Palm oil

The global trade in crude palm oil (CPO) has increased from 1.5 million tonnes in 1961, worth $1.3 billion, to about 56 million tonnes in 2013/2014, worth over $ 40 billion (in constant 2004-2006 US$). Most of the increase came from Malaysia and Indonesia, which account for over 80 per cent of global production (USDA, 2014). Although the yield per unit area has increased somewhat since 1961, most of the increase came from greatly increased area planted to oil palm, which has led to increasing external criticism of the industry. The critics claim that plantations have been established in pristine rainforest and drained peatlands. Burning of these lands releases greenhouse gases and impacts the biodiversity of native plants and animals, especially of charismatic megafauna. The truth appears more nuanced, but the industry is conscious of the need to take steps to avoid widespread censure.

Global demand for CPO is forecast to continue to grow for at least the next 10 years, which further increases the pressure to expand the area of oil palm. One way to reduce criticism while meeting the increased demand, which appears to be feasible, is to reduce the gap between actual plantation yields and those that can be achieved with improved management.

The major ongoing operational costs for palm oil plantations are for fertiliser and labour for harvesting. There are data that suggest the amount of labour used for harvesting is causally correlated with field yield of fresh fruit bunches (FFB). Plantation managers, however, undoubtedly allocate labour for harvest to each block depending on their subjective assessment of block yield, so causality is moot. Nevertheless, managers are continually confronted with the need to provide adequate labour for harvesting to ensure that the yield taken (FFB harvested) is as close as possible to the yield made, that is the FFB available for harvest. The problem is confounded by external social and political pressures, further discussion of which are outside the scope of this article.

Yield gaps

Analysts have used the concept of 'yield gap' to address issues improving farmers' yields, including forecasting the effects of climate change on future food security. While avoiding the technical aspects, the authors think that the concept is useful to address some of the issues confronting palm oil industry. Scientists talk of biological potential yield, that is the yield possible when all conditions for plant growth are optimal. A more practical concept, however, is the best achievable farm yield, that is the yield that an experienced, prudent farmer might achieve on good land in a good season, but hedging against normal risks. It indicates what yield a farming system might obtain if all farmers used the best available technology. The yield gap is the difference between this best achievable yield and the actual yields that farmers obtain. There are many reasons why yield gaps are not zero, chief amongst them that farmers not only take different approaches to risk but they assess risk differently.

The maximum recorded yields of oil palm are 9-10 tonnes per hectare per year CPO, while maximum yields from whole blocks in plantations are 7-8 tonnes per hectare per year. Best reported plantation yields are about 6 tonnes per hectare per year CPO but the average over most of Indonesia and Malaysia is about 4 tonnes per hectare per year, much higher than the average elsewhere in the world (*Figure 1*).

FFB yield

Plantations record the yield of FFB from each block as it is harvested. Analysis of these data reveal the intrinsic performance of each block as a component of the plantation. They also show block yield responds to uncontrollable factors like rainfall and to controllable factors of plantation management. These are all components of PI and provide guides to the execution of the business plan.

FFB yields increase in young palms until they reach a plateau from 7-18 years, after which they decline (*Figure 2*). Plantations normally replant after about 25 years. Yield analyses remove the effects of palm age and identify the effects of uncontrollable effects to identify the intrinsic yield capacity of each block.

The intrinsic yield capacity of each block is little used by plantation management. But it

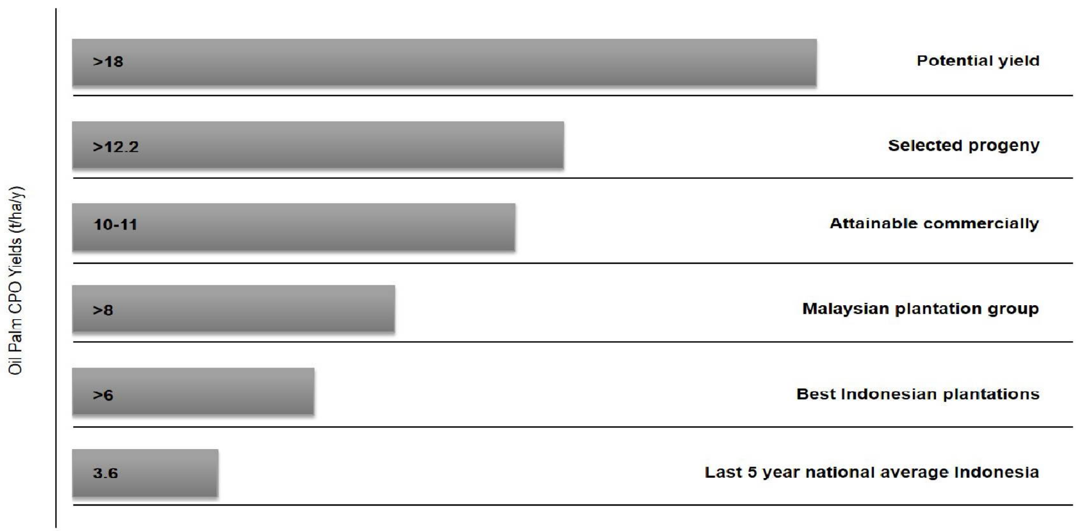
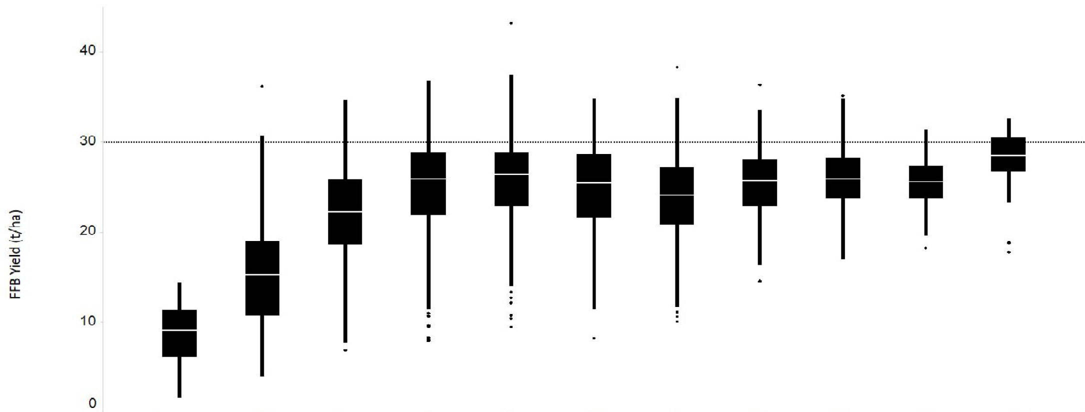


Figure 1   Examples of reported oil palm yields at various spatial scales



	3	4	5	6	7	8	9	10	11	12	13
Count	16	161	280	312	322	330	299	231	106	49	26
Median	9.17	15.38	22.27	25.94	26.43	25.48	24.11	25.74	25.95	25.59	28.55
StdDev	3.77	5.61	5.32	5.45	4.85	4.81	4.54	3.76	3.65	3.01	3.62
Avg	8.62	14.93	21.84	25.26	25.81	24.96	24.07	25.53	25.67	25.62	27.87

Tree Age

Figure 2 *FFB yield age profile (age on x-axis, FFB on y-axis), showing sharp ascent to 5 years old, followed by plateau. The dotted line at 30 t/ha is provided for easy visualisation*

is a valuable tool that could be used to improve profitability by eliminating low-yielding blocks, either according them low priority in resource allocation (labour, fertiliser) or removing them from production. The logical analysis is gross margin (*Figure 3*), which can readily be calculated from plantation data. If the intrinsic yield is higher than actual block yield because of controllable factors that can be rectified, there are two questions for management to consider. How much additional resources and cost will it take to bring the yield up to the

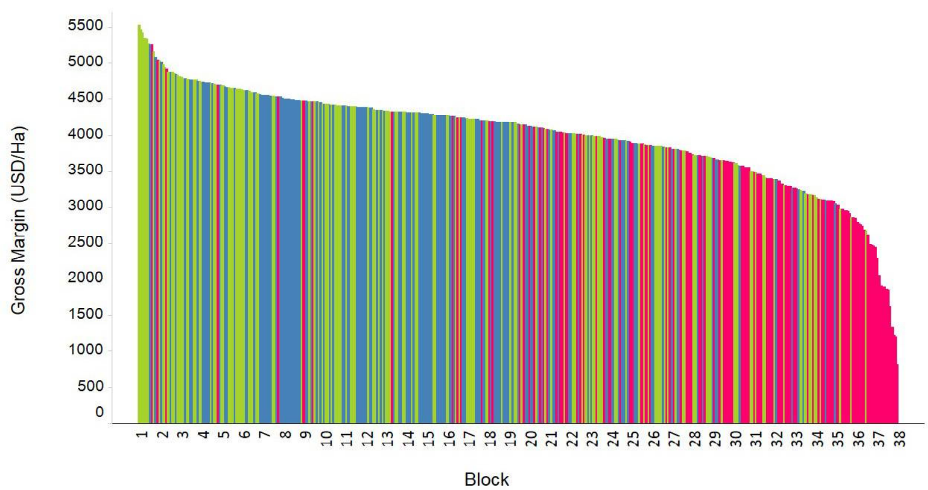


Figure 3 *An example of a "Simple Gross Margins" analyses, showing blocks on the x-axis and monetary return on the y-axis. The different colours indicate the estate to which a block belongs*

intrinsic level, and is there enough time left in the block's life cycle to recoup the additional investment. PI can answer both questions.

HOW PI SUPPORTS A PLANTATION'S CONCRETE BUSINESS CASE

Application of PI to fertiliser

Each tonne of FFB contains 22-35 kg of the macronutrients N, P, K and Mg (see for example Ng & Thamboo, 1967; Ng *et al.*, 1968), which must be replaced with fertiliser if yields are to be maintained. A crop yielding 20 tonnes per hectare per year FFB requires 450-700 kg per hectare per year of a mixture of fertilisers containing these macronutrients, which can account for as much as 50 per cent of the plantation operational costs. The management of fertiliser is therefore a major determinant of profitability of the plantation.

The management unit of oil palm at the plantation level is a block of 20 - 80 ha, planted at the same time and given uniform management. Agronomists assist in recommending the allocation of amounts of fertiliser applied to each block, usually by extrapolating existing knowledge from experiments on yield response to fertilisers. But the company management's overall financial budget controls fertiliser policy at the plantation level. The emphasis at the company budgeting level is on cost control and there is little attempt to determine whether the fertiliser applied to each block is profitable. That is, applications at the commercial block level are not generally tailored to the actual measured responsiveness of the palms to which they are applied. This is because the commercial data are rarely analysed systematically to address this issue.

Plantations maintain records of the numbers of FFB harvested from each block. They estimate the mean weight of the bunches of each block from each collected load of bunches delivered to the mill and use it to calculate the FFB yield of each block. Bunches within any one load delivered to the mill may not all come from the same block. Nevertheless, numbers of bunches harvested from each block are reliable and due to the very large numbers of bunches involved small discrepancies in bunch weight are unlikely to be important.

IPNI and collaborators worked with plantation management to help make fertiliser application to oil palm more profitable (IPNI, 2015). Although fertiliser accounts for about half of a plantation's annual budget expenditures, plantation management does not know how profitable this expenditure is. They do know, however, that if they stop fertilising, yields fall and can take years to recover.

FFB yield varies a lot between blocks, often for reasons that are not identified. Position in the landscape and soil are important, but other things such as genetics, agronomic management and pests and diseases also play a part. The IPNI researchers sought to use plantation historical records to identify blocks with high yield potential from those that yield poorly.

On the face of it, this might seem an easy task, but oil palm is a complicated plant. It takes over three years from the time a fruit bunch is initiated as a tiny bud weighing a few milligrammes to when it is a "fresh fruit bunch" ready for harvest weighing over 20 kg in mature palms. There are several critical stages during this development process (Breure, 2003). When they initiate about 39 months before the harvest, the vestigial flowers in an oil palm inflorescence include both male and female types. After another 12 to 15 months growth, the final sex of the developing inflorescence is determined, about 60 per cent become females that develop into fruit bunches and the remainder become males that provide pollen to fertilise the female inflorescences at anthesis. Stress at this stage can alter the ratio of females to males and hence affect subsequent yield.

The next vulnerable stage is when the inflorescence starts to expand in size. Stress at this stage can be severe enough that the developing inflorescences abort.

The final vulnerable stage is post-anthesis after the male flowers release pollen that insects convey to the female flowers and that fertilises them. The pollinated bunch develops and matures over the last six months of the process, and obviously stress during this stage can cause the developing bunches to fail and reduce both fruit and oil yield.

Fertiliser has both direct and indirect effects on crop yield. Adequate nitrogen supply is necessary to develop a full canopy that is needed for the palms to produce adequate photosynthate for fruit production. Potassium influences oil yield and its quality. But because inadequate nutrient status during at least the last two years of fruit development can affect yield of FFB, the researchers need to take account of the fertiliser applied over the whole of this time.

Examination of the data suggested that fertiliser applied between sex differentiation and anthesis, that is 6-18 months before harvest, has greatest effect on FFB yield. Fertiliser applied before sex differentiation or during fruit production after anthesis does affect yield but to a lesser extent. Accordingly, the IPNI team weighted the fertiliser applied in the three yearly periods prior to harvest in the ratio 0.5:1.0:0.5.

Data used in the IPNI analysis

Cook and his colleagues obtained data for the years 2010-2014 for a commercial plantation in central Kalimantan, Indonesia that covers 17 700 ha and consists of 447 individual blocks. Data for each block included total and planted area, year of planting, total number of palms, the predominant soil type for each block and its slope class. Soils were classified into soil management groups (SMGs, *Table 1*) after the plantation was developed, based on soil depth, texture, drainage and estimated fertility. Monthly rainfall data and the number of rainy days applied to the whole plantation. Yield data consisted of monthly FFB yield and the number of bunches for each block. Fertiliser data were the annual amounts of each fertiliser applied to each block. The team summed the elements N, P, K, and Mg in the individual fertilisers to obtain the total amount of elemental NPKMg applied annually.

Managers know that block yields vary widely on even the best-managed estates over apparently uniform land. But managers want to know whether blocks or areas perform as expected. They therefore want to see how yield in a particular block varies from the average to understand better what drives or constrains profitability. Did the FFB yield meet expectations, given the age of the palms, their yield history and other issues such as drought or excess water? Did the block pay for its fertiliser?

Data for a whole plantation do not provide the design control used in normal field plot experiments. As expected, the plantation data were confounded with uncontrolled factors, which made precise interpretation difficult. The researchers therefore calculated the coefficients of variation (CVs) of FFB yield over all blocks for the five years, which they used to isolate the effects of uncontrolled external variables. This procedure differs from the analysis of a designed experiment where variation is used to test the statistical confidence of the effects of applied treatments. The

TABLE 1
SOIL MANAGEMENT GROUPS (SMGS)

SMG: with soil types[a] included	*Major soil characteristics*	*Main agronomic limitations*
A: Typic kandiudult, Typic kanhapludult.	Moderate to deep (>50 to >100 cm depth); well drained. Texture: sandy clay to sandy clay loam. Subsoil with platy iron-coated gravel.	Moderate to low soil fertility. High iron content leading to high P-fixation. High porosity hence crops prone to water stress
B: Typic Paleudult	Deep; well- to moderately well-drained (20-50% gleying within 100 cm or 50-80% gleying below 100 cm). Texture: sandy clay to sandy clay loam. Developed over sub-recent alluvium.	Moderate to low soil fertility. Slopes erosion-prone.
C: Aquic Paleudult, Aeric Haplaquult, Typic Paleaquult	Deep; imperfectly (50-80% gleying below 75 cm, or 20-50% gleying below 50 cm) to poorly drained (50-80% gleying within 50 cm). Texture: sandy clay to sandy clay loam.	Low soil fertility, especially P and K. Poor drainage hence flood-prone.
D: Typic Haplohumod	Shallow (<50 cm) to moderately deep. Structureless sandy soils with cemented layer.	Very low nutrient and moisture-holding capacity. Cemented layer, poor anchorage. Flooding in rainy season, moisture stress in dry season.

[a] – *Soil Taxonomy (USDA)*

researchers therefore presented the results as simple analyses from several perspectives, which together provided insights on which management can act. An important part of the process was to include the skills of the managers and agronomists in all stages of the analysis. Below is a selection of the analysis and dialogue process.

Results from analysis, inferences and decisions supported

Cook and his colleagues used CVs to reduce the confounding effects of uncontrolled external variables to focus on the effect of applied fertilisers on FFB yield. They then identified high- and low-yielding blocks and their association with different soil management groups to support which blocks merited more or less fertiliser (*Table 2*).

Stage one estimated average fertiliser productivity (AFP) for all blocks without regard to tree age or soil management group (SMG). Younger trees yielded far less than older trees, but also received less fertiliser so that AFP is confounded with tree age. Trees over five years old have stable yield and similar rate of fertiliser year-by-year. Each kilogramme of applied fertiliser produces about 4 kg of FFB (*Figure 4*). The data show a wide scatter around the general relationship. The response of FFB to applied fertiliser differed between SMGs. SMG C gave the highest of 8 kg per kg followed by SMG A with 4 kg per kg. SMGs

TABLE 2
INFERENCES AND DECISIONS SUPPORTED BY RESULTS IN SUCCESSIVE STAGES IN ANALYSIS

Stage in analysis	*Result(s) from analysis*	*Example(s) of possible inference*	*Decision(s) supported*
1	Overall, average fertiliser productivity (AFP) is 16 kg FFB per kg of additional nutrients applied.	Secure inference not possible because of confounding by tree age.	None.
2	For palms >5 years old, AFP is 4 kg per kg of additional nutrients applied. For palms ≤5 years old, AFP is 11 kg per kg of additional nutrients applied.	Overall picture is clearer but substantial unexplained variation remains.	Further analysis required before fertiliser response can be inferred.
3	For palms >5 years old, AFP differs for each soil management group (SMG) as follows: SMG A = 4 kg/kg SMG B = 0 kg/kg SMG C = 8 kg/kg SMG D = 0 kg/kg.	Substantial unexplained variation remains but SMG C seems the most responsive to fertilisers. SMG D is a difficult soil to manage and yields lower than the other SMGs.	Possible increase fertiliser applications on SMG A. Review year-to-year performance on SMGs B, C and D.
4	For the period 2010-2014, response varies year-by-year, with strong interactions evident between year and SMG	2013 a difficult year for most SMGs. Strong recovery in 2014 from SMGs B, C and D. SMGs B and C show similar pattern of high FFB, low response 2010-2012, then strong response in 2014.	SMGs A and C high yielding, with high responsive. SMG D low yielding but potentially responsive with management input

B and D appeared to be unresponsive (*Figure 5*).

The SMGs responded differently between years, which suggests that there is an interaction between SMG's and climate (*Figure 6*), principally rainfall. The drought year of 2011 reduced yields of FFB in 2013 by 3 tonnes per hectare, and only SMG C responded to fertiliser. Performance rebounded in 2014, with SMG C responding strongly to applied fertiliser followed by SMG A. There is no clear trend for SMG A in 2014. There are no data to explain the lack of response in years 2010-2012, but low levels of applied fertiliser may be responsible. Blocks in SMG D, a podzol soil performed poorly in all years. Podzols are known to be vulnerable to both drought and waterlogging, so if the intrinsic yield of blocks with SMG D is low, then it could make economic sense to apply less fertiliser to these blocks.

The data for SMGs across estates

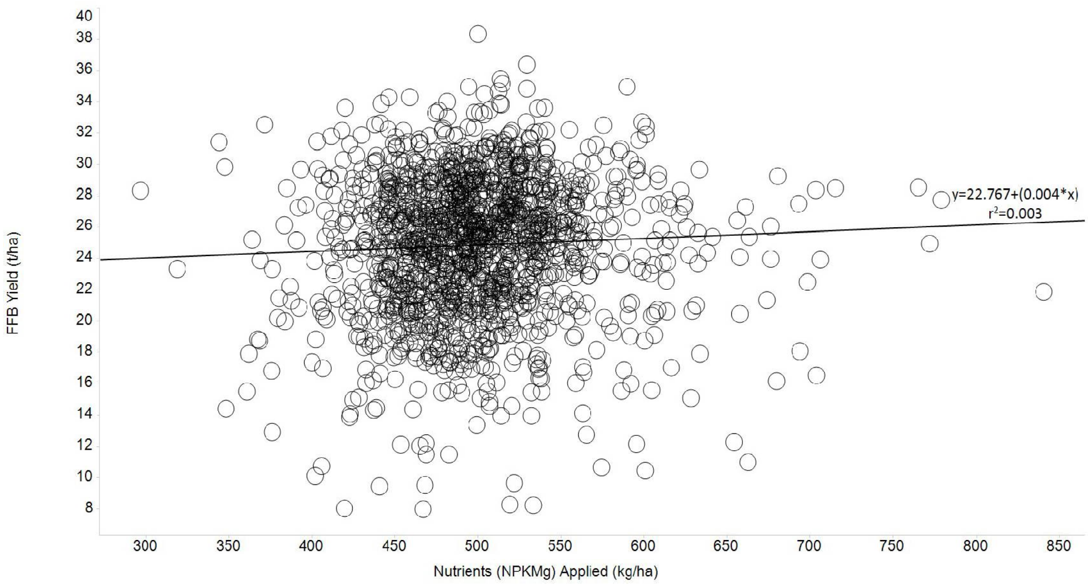


Figure 4 Overall yield response to 2-year weighted total fertilisers applied for all blocks of trees >5 years old

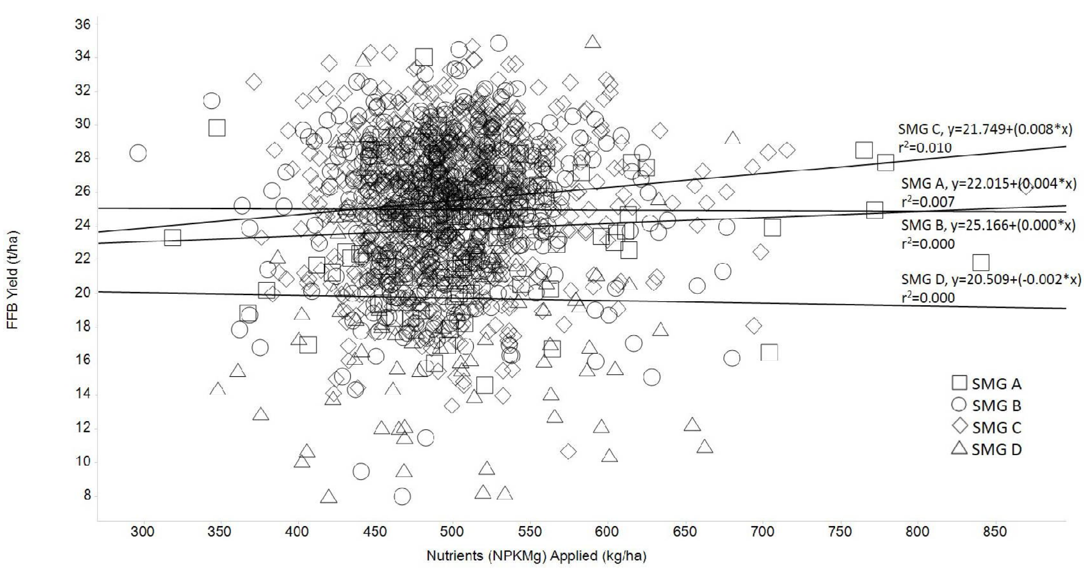


Figure 5 Yield response to fertilisers segregated by four soil management groups (SMG). The lines are the regressions of FFB yield against 2-year weighted sum of NPKMg applied, for all blocks of trees >5 years old

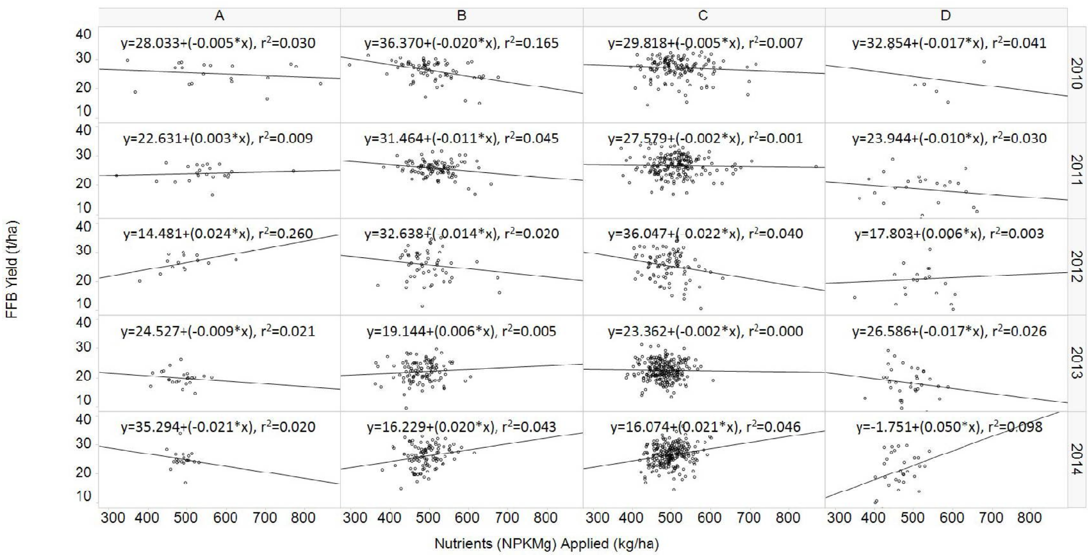


Figure 6 Yield response variation over 5 years in different soil management groups. Lines represent the regression of FFB yield against 2-year weighted sum of NPKMg applied for each soil management group and year, for all blocks of trees >5 years old. Each row represents a year. Columns represent soil management groups. The dotted line at 30 t/ha is to aid comparison

(*Figure 7*), show that FFB yields of Estate 3 responded more strongly than in Estate 1 for the same soil types. There is no clear explanation nor could the team explain the negative response to fertiliser on SMG B in Estate 2.

CONCLUDING REMARKS

Interpreting analysis of noisy commercial data

Plantation managers confront many linked factors such as variable block productivity, cost of fertiliser, labour availability and cost, soil, and weather. Each of these factors varies in space and time, which introduces uncertainty. The goal of the analysis was to provide a tool to allow managers to evaluate the variable effect of fertiliser over the whole plantation in different years, and to understand the factors that control it. Managers could then make rational decisions on how to modify fertiliser rates according to block responsiveness. Agronomists can use the insights from the analysis to improve the understanding that they use to recommend application rates for plantations.

Although the data did not reach statistical significance, the analysis was practically and commercially important to managers. They started using the information to guide fertiliser application on the plantations for which they were responsible.

The analysis also helped managers assess and manage risk with regard to the interaction between soil, climate and fertiliser. It provided objective information about field responses to applied fertiliser on the actual estate and at the same scale at which management is required to make decisions. Although the inferences lack statistical validity they appear robust from a practical viewpoint. They are easy to evaluate

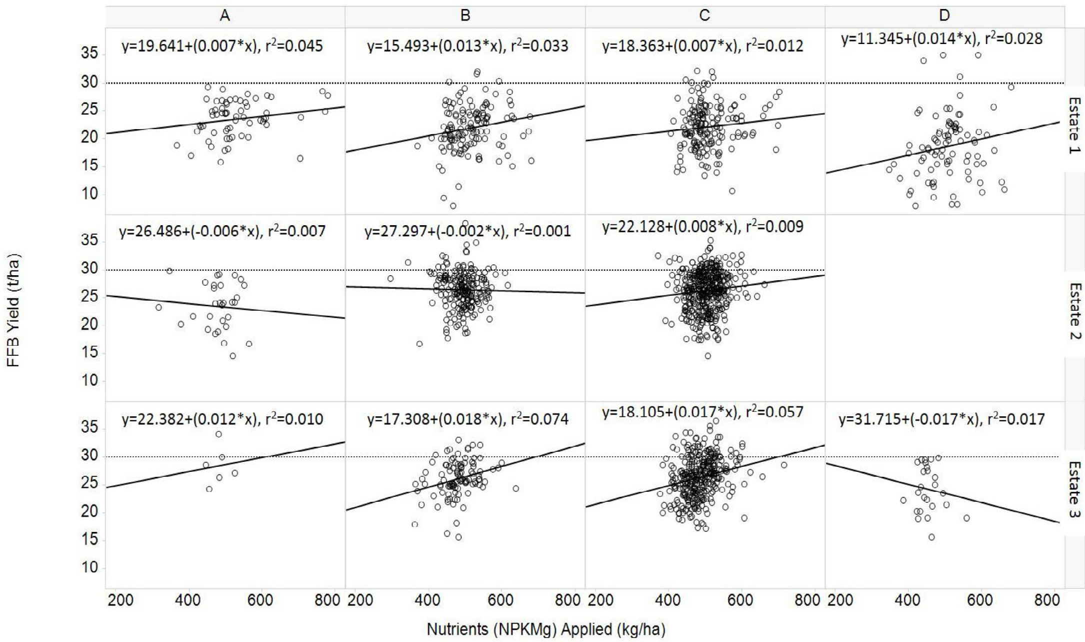


Figure 7 Yield response variation over three estates in different soil management groups. Lines represent the regression of FFB yield against 2-year weighted sum of NPKMg applied for each soil management group and year, for all blocks of trees >5 years old. Each row represents an estate. Columns represent soil management groups

in the field, since they require no upscaling from or interpretation of experimental data.

The analysis made use of data available from the entire production area of a plantation, which is routinely used for accounting and operational management, but which has broader utility. The analysis of fertiliser response the IPNI team developed used data from the same set of blocks to which the conclusions are intended to apply. In this way, it removed the uncertainty of applying generalised responses that may not be relevant in all circumstances.

Some pitfalls

Analysts need to be aware that external factors such as labour availability may cause discrepancies between yield made and yield taken. The team emphasises that conclusions derived from analysis of commercial data can only be applied to the area from which the data came. Managers may, however, not feel so constrained and may use their experience to extrapolate insights to other areas they consider similar.

In contrast to formal experiments, plantation data are unlikely to include zero treatments so that they are unlikely to provide data structures that give clear results. Moreover, the results are confounded by uncontrolled variables such as climate, which lie beyond the analysts' control. Nevertheless, this is the first time plantation data have been used to identify the response of oil palm to fertiliser at a commercial scale.

The IPNI team offers oil palm plantations a clear recommendation. All commerciallymanaged plantations have similar data that are routinely collected and available. Analysis of these data can indicate those blocks that are responsive to applied fertiliser and those that are not. Then managers can divert at least some of the fertiliser from the unresponsive blocks to the responsive blocks. This will lead to greater fertiliser use efficiency as well as increasing the profitability of the fertiliser applied. This form of analysis could become a core tool for managers to enhance performance as the requirement to intensify production increases in the future.

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