OMP Fertilizer Planner™

A computer decision support tool for the preparation of cost-effective and site-specific fertilizer recommendations using data stored in OMP™

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Use of a 'glass-box' computerized decision support tool (CDST) for the preparation of fertilizer recommendations in oil palm plantations.

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Abstract

Fertilizer is the largest variable cost of production in oil palm cultivation. The preparation of fertilizer recommendations is a complex task that should make use of all agronomic data accumulated by a plantation company. The OMP™ agronomic database, now widely used in the oil palm industry, provides the means to store and analyze agronomic data for large-scale plantations. In this paper, we describe a computerized decision support tool (CDST) that provides agronomists with the means to interrogate all agronomic data (leaf and soil analysis, production, field conditions) stored in OMP™ using customized queries for the purpose of estimating nutrient requirements. The user can set up the CDST to determine the least costly source of mineral fertilizers and a fully-costed fertilizer program for each block within a plantation. The CDST provides transparency in terms of methodology, opportunities for peer review by company management and external consultants whilst securing the company's agronomic intellectual property.

1. Introduction

Fertilizers are the most costly input used in oil palm cultivation, typically accounting for 70–80% of the variable costs of production (Goh and Teo, 2008). Nevertheless, fertilizers play a key role in oil palm cultivation as they provide the means to increase yields by 50–80% on the predominantly poor fertility status soils where the crop is grown (Tohiruddin et al., 2010), leading to a typical value-cost ratio of greater than 2:1. Optimizing fertilizer inputs is therefore a key requirement for any oil palm plantation looking to maximize its profitability and efficiency.

The usual practice is to prepare fertilizer recommendations for each block of 30–50 ha (i.e., the smallest unit of field recording). When defining fertilizer recommendations, measured variation in palm nutritional status, soil fertility, agronomic practices and field management between the different blocks should be taken into account. The overall aim is to close the yield gap (i.e., the difference between maximum economic yield and actual yield) as efficiently as possible (Goh et al, 2004). Typically, this may mean applying different amounts of fertilizers in each block, or even applying no or little fertilizer in blocks where yield is limited primarily by agronomic or field management practices that should first be corrected. Thus, in an estate of 10,000 ha there will be 200–300 individual fertilizer recommendations, to supply the recommended doses for nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), boron (B), copper (Cu) and sulphur (S) in each block.

In order to derive effective fertilizer recommendations it is first necessary to estimate the nutrient requirements of each block. As with many other crops, soil fertility test data alone is a poor basis for determining nutrient requirements and thus fertilizer rates (Foster, 2003), but can be useful to characterize 'fertilizer recommendation domains' consisting of sets of blocks similar in terms of soil fertility, planting material, and palm age. By contrast, foliar diagnosis has been used successfully as the basis for estimating nutrient requirements, particularly when the nutrient status of both leaf and rachis tissue is taken into account (Foster and Prabowo, 2002). Access to data from factorial fertilizer response experiments is also essential to determine critical or target leaf and rachis nutrient concentrations, to estimate the response of leaf nutrient levels to fertilizer application (particularly where interactions between nutrients are found), and to determine maximum economic yield (Teoh et al., 1988).

Significant savings in fertilizer costs can be achieved by reducing fertilizer recommendations, compared to the 'standard' rate suggested by foliar diagnosis and fertilizer response experiments, in individual blocks where particular management or agronomic constraints limit yield or reduce the effectiveness of fertilizer application (Table 1). For example, issues such as poor drainage, soil erosion, lack of soil conservation or insufficient ground cover may mean that more fertilizer would need to be applied to achieve the desired increase in the leaf nutrient levels. In extreme cases, the required fertilizer rate might even be so high that it is economically preferable to reduce or even cancel the fertilizer application in these blocks. Furthermore, other limitations (e.g., over-pruning, water deficits) may mean that the block yield cannot be increased even if the leaf nutrient levels are raised to the optimum level. In such cases, the nutrient targets should be reduced to maintenance levels until these other limitations are removed.

Finally, incomplete crop recovery (e.g., due to labour shortage or insufficient weeding/harvester access) may mean

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that an increase in fruit production does not translate to an increase in the harvested yield, rendering nutrient applications economically inefficient. These examples illustrate that it is crucial to take into account management standards and field agronomy constraints as well as the results of foliar diagnosis when adjusting the standard nutrient recommendations on a block-by-block basis. The data required to make these adjustments can be collected with little additional effort by an agronomist or an agronomy team during annual leaf sampling (Table 1). A mobile device can be used to record such information during leaf sampling and imported into the company agronomic database. Typically, a fit agronomist can inspect 1,000–1,500 ha per day when doing transect walks to make the necessary assessments (i.e., 7–10 days are required to cover an estate of 10,000 ha).

Once the requirement for each nutrient in each block has been determined, the recommendations must be converted from nutrients (kg/palm) into the least costly combination of mineral fertilizers that are available on the market (Fairhurst et al., 2005). At this point it is also useful to take into account the amount of nutrients supplied in the form of crop residues (i.e., palm oil mill effluent, empty fruit bunches, decanter cake). Subtracting this contribution to nutrient supply from the total nutrient requirements in each block reduces the amount of nutrients that must be supplied in the form of mineral fertilizers. In addition, the fertilizer programme should be spread evenly over the year (i.e., within constraints due to the local climate) so that the company can organize fertilizer application as a continuous operation, leading to greater application efficiency.

Table 1. Suggested categories for nine key parameters assessed during leaf sampling that can be invoked when preparing fertilizer recommendations.

Parameter	Possible categories
Crop recovery	complete, incomplete, large crop losses.
Harvest access	complete, missing paths, missing footbridges, missing paths and footbridges.
Pruning	correct, over pruned, under pruned, rehabilitation pruning required.
Drainage	well-drained, poorly drained, water-logged, seasonal flooding.
Soil erosion	surface wash, rills, gullys, no soil loss.
Soil conservation	meets recommendations, insufficient.
Ground cover	legume cover plants, soft weeds and grasses, shrubs and hard weeds, bare soil.
Evidence of etiolation	yes, no.
Thinning	done, not done.

Clearly, generating accurate and cost-effective fertilizer recommendations is a highly complex task and requires the analysis of large amounts of agronomic data for each block in a plantation. It is advantageous to automate this process as much as possible using suitable computerized decision support tools (CDSTs) that are well suited to tackling the mathematical optimization problem of finding the least costly combination of fertilizers to supply the required nutrients. Of course, such a program must allow agronomists to review the results it has generated and to apply manual adjustments where needed.

The preparation of fertilizer recommendations is never a purely empirical exercise and, like other inputs, the opportunity cost of investments in fertilizers must be considered. For example:

- It makes no sense to invest in large fertilizer application rates where there is a requirement to first improve field access for harvesting, ground cover, pruning or drainage.
- Significant nutrient deficiencies detected in the field should be corrected incrementally, over a number of years, starting with the nutrients that most constrain production.

A CDST can be set up to accommodate such situations, provided it has access to the relevant data on field agronomy standards.

It is useful for the fertilizer agronomist to prepare several fertilizer recommendations scenarios that impose different levels of stringency for review by senior management. For example:

- The total amount of N fertilizer required is less if corrective doses are restricted to blocks where drainage is adequate.
- The total amount of Mg fertilizer required is less where corrective doses are restricted to blocks showing both low leaf Mg levels and a high incidence of deficiency symptoms.

A CDST should therefore provide the means to prepare several 'scenarios' each year. Further, it must be possible to set up the CDST to spread investment in fertilizer nutrients between blocks according to need in a very systematic way and based on evidence collected in the field and stored in an agronomic database.

In this paper we describe a CDST called OMP Fertilizer Planner, which was developed by Agrisoft Systems and Tropical Crop Consultants Limited. The OMP Fertilizer Planner has been built to meet the general requirements outlined above while offering the flexibility to be adjusted to the specific situation of any estate or geographic region. In the OMP Fertilizer Planner, the user prepares 'rulesets' that are used to interrogate long-term agronomic data sets stored in the dedicated oil palm agronomic database OMP™, and to assign block-specific nutrient targets. The program then calculates the least costly combination of mineral fertilizers based on the price ($/t) and nutrient content of locally available fertilizer materials to meet these nutrient targets and work towards maximum economic yield.

2. Transparency in decision making

Decision-makers in oil palm plantations are often placed in a difficult position when 'signing off' on fertilizer budgets, because the fertilizer agronomist, who may be an external consultant, is often unwilling to disclose the precise methods (i.e., the so-called 'black box') used in preparing the fertilizer recommendations. As fertilizer costs account for up to 70% of variable costs (in an estate of 10,000 ha, the total cost of fertilizers may exceed USD 5 million), this is an important and sensitive issue. Our CDST embodies a 'glass box' approach in which all assumptions are clearly declared and reported at all stages of the process. Thus, the company can invite external agronomists to assist in preparing rulesets that nevertheless remain part of the company's intellectual property and which can be presented to top management for review. Furthermore, the company can engage other agronomists in a peer review process to investigate opportunities to refine and improve the rulesets that have already been developed. The CDST also provides opportunities to flag blocks that require 'ground survey' before finalizing fertilizer recommendations, based on user-definable attributes. For example:

- Management constraints (e.g., large yield gaps caused by poor crop recovery) must be corrected before recommending large fertilizer application doses for blocks with poor nutritional status.
- Drainage should be corrected in poorly drained blocks before additional N fertilizer is applied to correct low leaf N levels.

3. Storage of agronomic data in OMP

As mentioned above, the CDST presented here is designed specifically to work with OMP™, a computer database programme designed to store, consolidate and analyse agronomic data in oil palm plantations (Fairhurst et al., 2003). OMP stores agronomic data under the following categories:

- General information on each block (e.g., soil type, planting material, planting date, previous land use);
- Production data and calculated yield components (e.g., t/ha fruit bunches, bunches/palm, bunch weight, t/manday);
- Historical leaf and soil analysis data;
- Qualitative scoring of field upkeep standards (e.g., pruning, harvester access, drainage);
- Historical use of all fertilizers and crop residues;
- Historical pest and disease incidence;
- Palm census data (all planting points categorized as new planting or supply, immature, mature, dead, abnormal and un-plantable); and
- Climate data (including calculated water deficits).

OMP has the capability to import data, where necessary, from other plantation management information software and accounting packages. At a minimum, one year of data (yield, leaf analysis, soil analysis, palm census, qualitative assessment of agronomic parameters) is required to run the CDST. Stored information on management and agronomic conditions can be queried and invoked as the basis for making adjustments to fertilizer recommendations that are driven primarily by the results of foliar analysis. The CDST thus 'adds value' to the data stored in OMP by taking into account all known information on block characteristics when preparing fertilizer recommendations.

4. Preparation of fertilizer recommendations using CDST

We now outline the main steps involved in preparing a set of fertilizer recommendations using the CDST. The order of the various steps is depicted in flowchart form in Annex I.

Scenarios, doses, rules and rulesets

The first task of the CDST is to derive nutrient targets for each block by interrogating the agronomic data stored in OMP. To do this, the user must define a set of nutrient application doses together with associated application rules. These rules can be defined as 'a set of arguments that, when met in a particular block, invoke a corresponding nutrient dose for the block'. Multiple doses can be set up for each nutrient, and each dose is categorized as:

- 'Maintenance' (i.e., to maintain present nutrient status);
- 'Corrective' (i.e., to correct a nutrient deficiency); or
- 'Priority' (i.e, to correct severe deficiencies and address interactions between individual nutrients).

Recommended doses are cumulative so, for example, the total recommendation for N in a block identified as deficient may include *corrective* and *priority* doses in addition to a *maintenance* dose if the block meets the criteria specified for all these doses. It is also possible to include what we call 'override rules' that define criteria where a nutrient application should be cancelled even though a block may meet the normal dose criteria (e.g., for blocks due to be replanted).

Each dose can invoke one or more application rules that depend on, for example, leaf and rachis analysis data, soil analysis data, or qualitative scores for other agronomic parameters stored in OMP (Table 1). A strength of the present CDST is that users have almost unlimited flexibility in creating doses and rules utilizing data parameters stored in OMP.

By contrast with other fertilizer recommendation tools, the OMP Fertilizer Planner has no hardcoded 'formula' for nutrient recommendations that is typically only suited to a particular geographic region. Instead, the program can be adjusted for use in any oil palm growing region in the world and can take into account estate-specific factors.

A particular set of 'doses' and 'rules' together is referred to as a 'nutrient ruleset'. The overall data set consisting of the nutrient targets, fertilizer recommendations and all settings used to derive them are saved together in the CDST as a single 'fertilizer recommendation scenario'. It is thus possible to create multiple scenarios for the same estate and year, making it straightforward to test and evaluate different assumptions and compare how they affect overall fertilizer requirements and costs.

Nutrient ruleset settings can be saved and reused (or loaded and then modified) in different scenarios. The use of doses and rules is illustrated in the following examples for N, P, K and Cu. As emphasized above, these are only examples and the program has almost unlimited options to adjust rules and doses to any site.

A crucial component of defining an effective nutrient ruleset is choosing reasonable sizes or nutrient amounts for the incremental doses. In particular the maximum accuracy with which fertilizer amounts can be measured off and applied in the field should be taken into account. This point is expanded further in Annex II.

We will now review examples of a simple ruleset for determining application rates for N, P, K and Cu.

Ruleset for nitrogen

Recommendations for N application to mature blocks might comprise several doses:

- A maintenance dose of 0.5 kg/palm N to all blocks.
- A 1st corrective dose of an additional 0.5 kg/palm N where leaf N is <2.4% *and* rachis N is <0.4% *and* drainage assessment is 'well drained'.
- A 2nd corrective dose of an additional 0.5 kg/palm N where leaf N is <2.3% *and* drainage assessment is 'well drained'.

The restriction to only mature areas is most easily implemented using a suitable 'override rule', rather than including this restriction in the rules of every dose. The three doses defined in this example are shown in Figure 1.

OMP provides population data analysis of leaf data in the form of histograms that can be used to estimate and select critical values for nutrient concentrations in leaf and rachis tissue. These estimates should of course be used together with an analysis of available fertilizer trial data that is appropriate to the geographic region and soil conditions of the plantation site in question. Rules involving foliar diagnosis data can be set up to refer to the previous year's leaf analysis results or, alternatively, to mean values for the previous three years.

As mentioned above, the CDST accesses the OMP data set covering all aspects of the plantation agronomy. This gives great flexibility when designing rules for dose assignment using the OMP Fertilizer Planner rule builder (Figure 2).

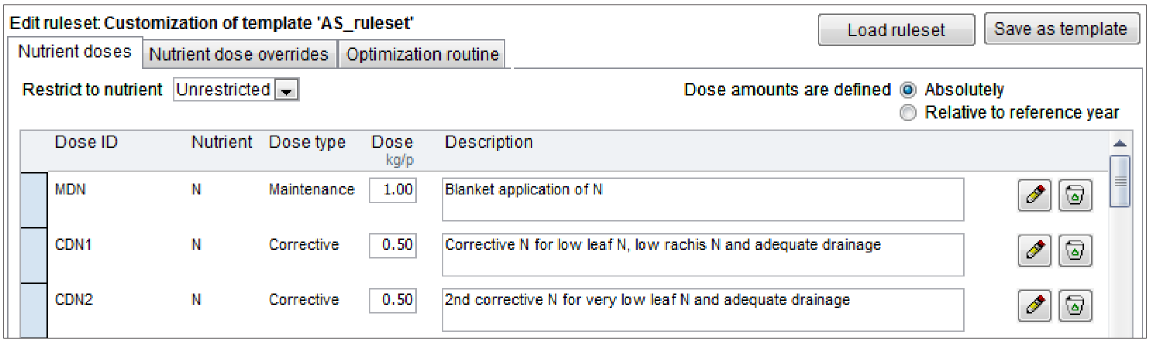


Figure 1. Ruleset with three doses for application of N fertilizer.

For the case of N, it may in particular be useful to take into account other, more qualitative variables such as erosion, soil conservation, pruning, drainage, field access and ground cover in addition to foliar diagnosis results. Such qualitative information can be collected conveniently during leaf sampling, when a trained team inspects every tenth palm in every ten palm rows in each block and awards the mode score from a predefined list of options for each parameter. Thus, in the example above, corrective applications of N fertilizer are restricted to blocks where drainage was assessed, at the time of leaf sampling, to be adequate.

As N is the main driver of vegetative growth it may also be useful to invoke rules using the petiole cross section (PCS, a proxy indicator of palm vegetative growth), provided critical values for PCS by palm age have been determined by reference to fertilizer experiment data (or provided by the seed supplier).

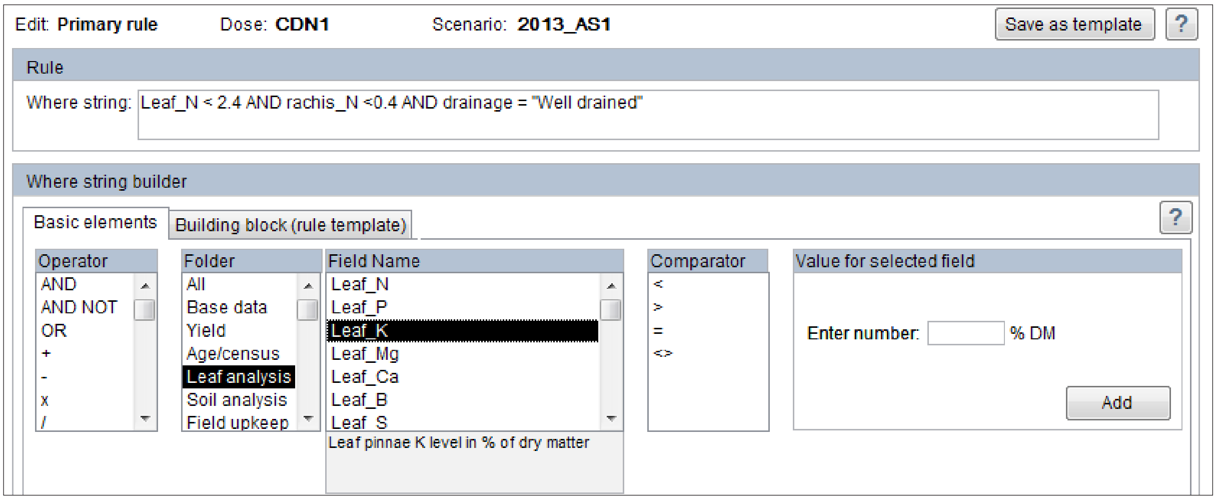


Figure 2. The OMP Fertilizer Planner rule editor.

Rulesets for phosphorus

Recommendations for P might also comprise several doses. In the following example, we have chosen doses that invoke both leaf P and a calculated critical value for leaf P based on leaf N concentration:

- A maintenance dose of 0.5 kg/palm P2O5 to all blocks.
- A 1st corrective dose of an additional 0.5 kg/palm P2O5 where leaf P is <0.16% and rachis P is <0.09% and leaf P is less than calculated critical leaf P value.

Clearly, invoking leaf and rachis P concentration as well as a calculated critical value for leaf P is a more stringent assessment of leaf P status than an assessment based solely on leaf P concentration.

Rulesets for potassium

Recommendations for K might comprise several doses, with rules that invoke both leaf N and K status, because of interactions between these two nutrients:

- A maintenance dose of 1.0 kg/palm K2O to all blocks.

- A 1st corrective dose of an additional 0.5 kg/palm K2O where leaf K is <1.0% and rachis K is <1.4%.
- A 2nd corrective dose of an additional 0.5 kg/palm N where leaf K <1.0% and rachis K is >1.4%.

In this case, instead of applying a 2nd corrective dose of K_2O where leaf K status is low and rachis K status is high, additional N is applied to mobilize K stored in the rachis into the leaflets where leaf K status is low and rachis K status is high (Foster, 2003).

Rulesets for copper

Recommendations for Cu might comprise a dose that uses rules that invoke leaf Cu status and soil type, because Cu fertilizer is usually only required on peat and coarse textured sandy soils that contain small amounts of Cu. A choice of doses could be:

- A maintenance dose of 0.1 kg/palm Cu to all blocks on 'peat' or 'coarse textured sandy soil'.
- A 1st corrective dose of an additional 0.1 kg/palm Cu where leaf Cu is <5 mg/kg *and* soil type is 'peat' or 'coarse textured sandy soil.'

Rulesets for Boron

Recommendations for B might comprise:

- A maintenance dose of 0.1 kg/palm B to all blocks.
- A 1st corrective dose of an additional 0.05 kg/palm B where leaf B is <15 mg/kg *and* score for visual symptoms of B deficiency is 3.

Visual deficiency symptoms for N, K, Mg, B and Cu that are collected during leaf sampling and recorded in OMP may also be taken into account when defining rules, as in the sample ruleset for B given above. This adds additional rigour to decision making on, for example, the use of Mg fertilizers, where the use of Mg fertilizer may be restricted to blocks exhibiting low leaf and rachis Mg status as well as high incidence of Mg deficiency symptoms.

Fertilizer material menu and crop residue contribution

Once rulesets have been set up for all nutrients under consideration, the CDST will evaluate the rules by referencing the data for each block that is stored in OMP to determine the relevant nutrient targets, i.e., the amount of nutrients that should be applied in the form of mineral or organic fertilizers.

Recommendations for crop residue (e.g., empty fruit bunches, decanter cake) application can be included in the CDST and their contribution to nutrient supply taken into account when estimating mineral fertilizer requirements. The tool thus supports efficient use of crop residue nutrients to minimize the cost of mineral fertilizers. Alternatively, nutrients supplied by crop residues can be excluded from the calculation of nutrient targets for mineral fertilizers (e.g., where empty bunches are applied to provide only mulch).

The next step is to convert the nutrient targets into recommendations of mineral fertilizer products. To do this, the user must first set up a menu of fertilizer choices, where each fertilizer to be considered as a nutrient source in recommendations is tagged as 'available' and listed together with its price, freight, and application cost ($/t) as well as its nutrient content. The CDST uses special algorithms to calculate the least costly combination of fertilizer products required to fulfil the nutrient targets, with the possibility of taking into account various side conditions, including rounding and maximum/minimum application amounts.

At the same time as defining the list of available fertilizers, the user specifies the required timing of application for each fertilizer type (i.e., percentage of annual dose applied each month). Thus, for example, N fertilizer application can be restricted to months where, based on meteorological records in OMP, there is sufficient rainfall to minimize N losses due to volatilization and surface water run-off.

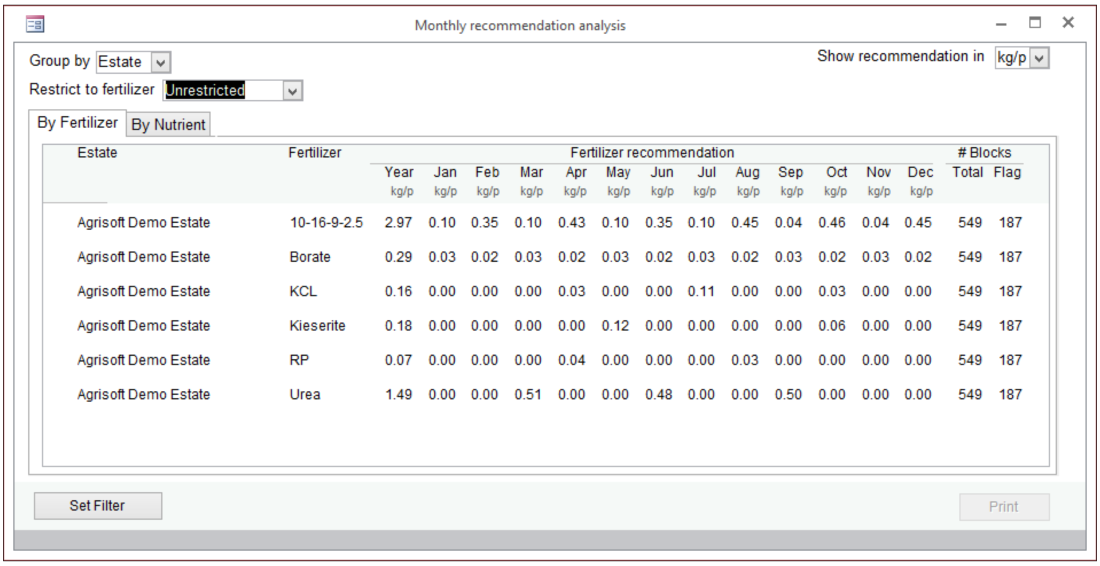
Running the model

Once fertilizer materials have been selected and rulesets have been set up, the model can be run and a draft set of fertilizer recommendations prepared. Since OMP stores palm census data, the quantity of fertilizer required in each block is based upon the number of normal palms, whilst abnormal and dead palms as well as un-plantable points are excluded from the calculations. Recommendations made in kg/palm of nutrient are converted into the least costly combination of mineral fertilizer products, based on the list of available fertilizer materials, their cost and nutrient content.

The CDST can accommodate all fertilizer types, including both straight fertilizers and compounds. Because nutrients are generally more costly in the form of compounds, we recommend running the model using available straight fertilizers as a first step, and then investigating the cost of substituting compound fertilizers for straights. A minimum total amount for each fertilizer can be specified to avoid generating recommendations that require the use of small amounts of particular fertilizer materials.

Block 'flagging' and review of fertilizer recommendations

The CDST provides summary reports that detail the cost of fertilizer ($, $/palm, $/ha) as well as the amounts required (t, kg/palm, kg/ha) (Figure 3). After scrutinizing the results, it may be necessary to adjust particular rulesets and re-run the model. Thus, to obtain optimal results it is usually necessary to go through several iterations of tweaking rules and doses and reviewing the preliminary results.



Estate	Fertilizer	Year kg/p	Jan kg/p	Feb kg/p	Mar kg/p	Apr kg/p	May kg/p	Jun kg/p	Jul kg/p	Aug kg/p	Sep kg/p	Oct kg/p	Nov kg/p	Dec kg/p	# Blocks Total	# Blocks Flag
Agrisoft Demo Estate	10-16-9-2.5	2.97	0.10	0.35	0.10	0.43	0.10	0.35	0.10	0.45	0.04	0.46	0.04	0.45	549	187
Agrisoft Demo Estate	Borate	0.29	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	549	187
Agrisoft Demo Estate	KCL	0.16	0.00	0.00	0.00	0.03	0.00	0.00	0.11	0.00	0.00	0.03	0.00	0.00	549	187
Agrisoft Demo Estate	Kieserite	0.18	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.06	0.00	0.00	549	187
Agrisoft Demo Estate	RP	0.07	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	549	187
Agrisoft Demo Estate	Urea	1.49	0.00	0.00	0.51	0.00	0.00	0.48	0.00	0.00	0.50	0.00	0.00	0.00	549	187

Figure 3. Example of CDST output, in this case summarizing application rates (kg/palm) for an estate.

To help with the review of the preliminary results, blocks meeting certain user-defined criteria can be 'flagged' by the CDST for further attention. These blocks should be inspected in more detail before fertilizer recommendations are finalized. Because field inspections are time consuming and costly, it is useful to 'flag' blocks where further investigation is required to make sure that time and effort can be concentrated on the most important cases. For example:

- There may be constraints other than nutrition in blocks where the yield gap (i.e., the difference between site yield potential and actual yield) is large (i.e., greater than a predefined margin (e.g., >50%)). Thus, large fertilizer application rates can be avoided in blocks where other constraints must first be corrected.
- With reference to the ruleset for Cu, blocks with low Cu status that are *not* planted on peat or coarse textured sandy soils can be flagged for further field checking.
- Blocks where the previous year's fertilizer recommendation for a particular nutrient was not applied in full can be flagged since this, rather than insufficient fertilizer recommendations, may explain current poor leaf nutrient status.

The OMP Fertilizer Planner flags blocks by evaluating the chosen flagging rules against the OMP block data, saving time and reducing errors as agronomists no longer have to look through the data of the individual blocks one by one. In this way, information collected by field staff that is useful for the preparation of fertilizer recommendations is integrated into the process, mitigating the possibility that the fertilizer recommendation agronomist is working without recourse to essential information on field conditions.

The user can save rule sets as 'scenarios' that differ in terms of stringency and therefore fertilizer cost. Thus, it is not necessary to build new scenarios each year, but rather, the user can load and adjust rulesets that have been saved in scenarios used in previous years. The OMP Fertilizer Planner includes the possibility to manually adjust individual fertilizer recommendations to manage blocks where nutrient requirements are so specific that they cannot be covered adequately by a general fertilizer ruleset.

5. Summary and conclusions

Whilst site-specific fertilizer responses and critical leaf and rachis levels can be determined quite accurately by statistical analysis of factorial fertilizer experiments, the preparation of fertilizer recommendations is a more complex endeavour. As discussed, in addition to leaf analysis data it is necessary to take into account the opportunity cost of investments in fertilizer as well as many other agronomic factors that can vary between blocks. Clearly, a model that only interrogates leaf and rachis analysis data is likely to produce spurious recommendations, particularly where field agronomic conditions vary greatly from block to block. The Fertilizer Planner™ is designed to help avoid investing scarce funds in fertilizers for blocks where yields are limited by other factors that first require improvement.

Most companies collect large amounts of agronomic data each year. When such data is organised in a computer database such as OMP, we have shown that it is possible to use the data to complement the use of leaf and rachis analysis results in estimating fertilizer requirements. All assumptions and variables are clearly declared in the CDST, providing opportunities for open discussions and peer review of recommendations. Furthermore, when all agronomic data is stored meticulously in OMP, it is possible to carry out *ex-ante* analysis to assess the effectiveness of fertilizer recommendations over time. A particular advantage of using OMP in combination with the CDST is that all rules, assumptions and the underlying data remain the property of the company can be reviewed and adjusted easily and as required. Over a period of years, the OMP Fertilizer Planner database becomes a repository for knowledge gained in nutrient management.

We are confident that the OMP Fertilizer Planner provides oil palm plantations with a robust, comprehensive and pragmatic tool for the preparation of fertilizer recommendations (Box 1).

Box 1. Key advantages of the OMP Fertilizer Planner

1. **Transparency:** All assumptions and rules are transparent and readily accessible for peer review.
2. **Cost minimization:** The least costly source of mineral fertilizers is selected from a list of available sources.
3. **Site-specific:** Scenarios and rules can be customized for each location.
4. **Nutrient substitution:** Crop residues can be integrated as nutrient sources.
5. **Data utilization:** Maximum utilization of agronomic data stored in OMP. Fertilizer recommendations can be adjusted to take into account field upkeep conditions in addition to leaf and soil analysis.
6. **Flexibility:** Multiple scenarios with differing levels of stringency can be prepared to take into account price developments.
7. **Time-saving:** Time required for the preparation of fertilizer recommendations is significantly reduced.
8. **Intellectual property:** The company retains full ownership of its intellectual property with regard to nutrient management.

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Acknowledgements

We would like to acknowledge the work of Armin Gfroerer-Kerstan (RIP), who developed the first versions of the OMP software, and William Griffiths and Gregory Simbahan, who contributed to the thinking behind an earlier version of the CDST. We also acknowledge the work of Christian Witt and Achim Dobermann, who contributed to the development of the FertChooser software.

Annex I: The OMP Fertilizer Planner process

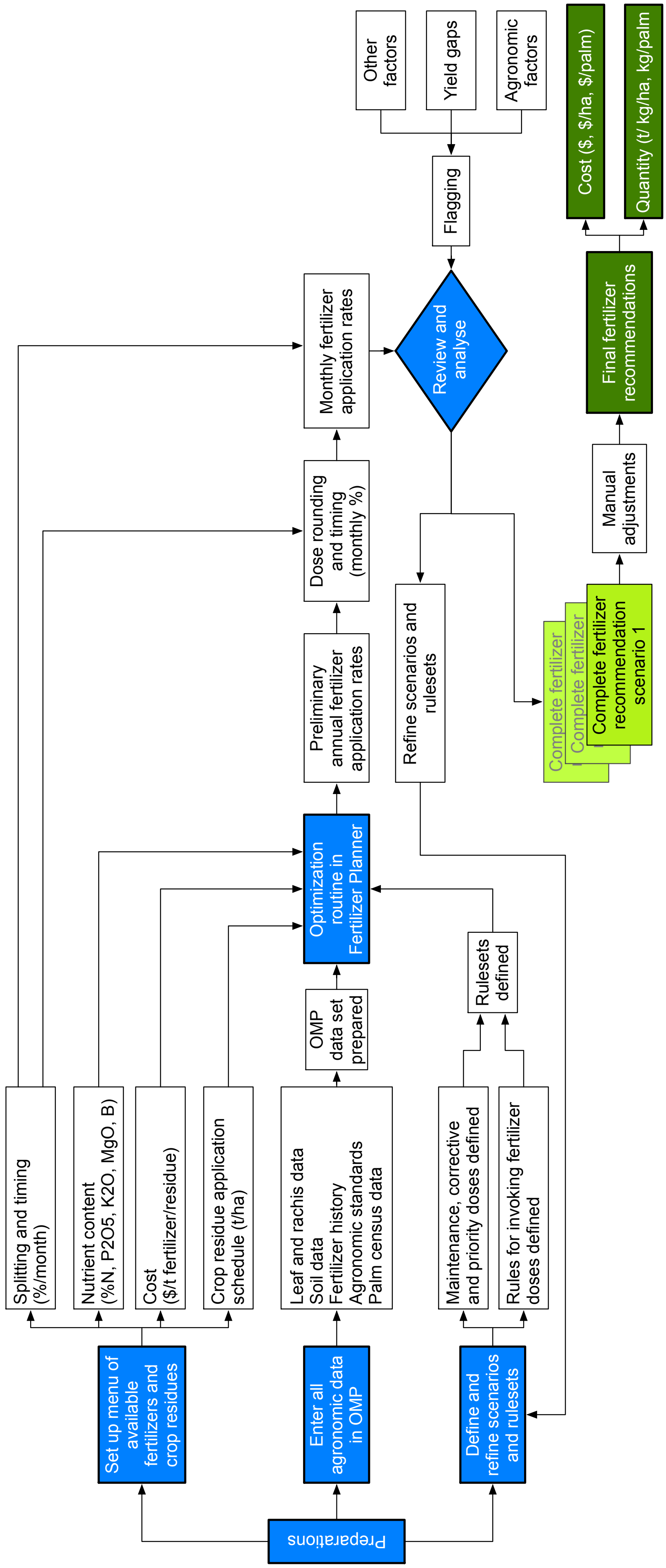

Figure 4. Flowchart of the process of generating fertilizer recommendations with OMP Fertilizer Planner.

Annex II: Size of incremental dose

Based on field tests using both manual and mechanical fertilizer application methods, we have found that it is possible to weight and apply fertilizer with an error of ±15% (e.g., 1 ±0.15 kg/palm). For urea, the equivalent error of a dose of 1 kg/palm in fertilizer nutrients would be 0.46 ±0.07 kg N/palm. It therefore makes sense to restrict the variation in fertilizer nutrient doses between blocks to increments greater than the amount that may be attributable to application error. Otherwise, the level of precision implied in the recommendations may likely not be realised in the field. Furthermore, very small doses are more costly to apply in the field. Suggested minimal fertilizer nutrient increments and their equivalence in straight fertilizers are provided in Table 1.

Table 1. Suggested minimum increments of fertilizer nutrients and their equivalent amounts in selected straight fertilizers.

Fertilizer nutrient	Fertilizer nutrient increment (kg/palm)	Equivalent incremental amount of fertilizer (kg/palm)
N	0.25	0.54 kg urea; 1.19 kg AS; 0.74 kg AN; 1 kg ACl
P_2O_5	0.25	0.54 kg TSP; 0.83 kg RP; 0.69 kg SP36
K_2O	0.45	0.75 kg KCl
MgO	0.15	0.56 kg Kieserite; 0.60 kg dolomite
B	0.01	0.08 kg sodium borate

In most plantations, fertilizers are applied by hand. To achieve accurate application, a calibrated vessel (e.g., cup, bowl or plate) of the correct volume capacity (cm^3) must therefore be issued to workers. Thus, calibrated vessels must be prepared for each fertilizer material which contain the respective volume of fertilizer (i.e., weight adjusted for bulk density) to supply the correct amount (kg). For this purpose it may be useful to round the incremental fertilizer amounts of Table 1 slightly (e.g., to work in steps of 0.5 kg urea instead of 0.54 kg).