Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 36 (2011) 3159-3163

ISSN: 2229-712X

Plants nutrient variability of oil palm and its correlation to fresh fruit bunch yield

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ARTICLE INFO

Article history:

Received: 29 April 2011;
Received in revised form: 18 June 2011;
Accepted: 27 June 2011;

Keywords

Plants nutrients status,
Geostatistics,
Correlation analysis,
Oil palm yield.

ABSTRACT

In recent times, among of the major problems in oil palm plantations is the lack of proper interpretation of yield maps for site-specific management. The ability to determine and diagnose leaf factors that influencing yield variability of oil palm will benefits in managing the plantation for better yield. A study on spatial variability of N, P, K, Mg and Ca in oil palm leaf was carried out at the Dusun Durian Estate of Golden Hope Plantations Berhad in Selangor, Malaysia. The aim of this study is to obtain accurate and timely information on the spatial distribution and status of N, P, K, Mg and Ca in leaf using semivariogram analysis and geographical information system (GIS), and its correlation to oil palm fresh fruit bunch (FFB) yield. The collection of leaf tissue data was conducted using systematic sampling. A GPS device (AgGPS Trimble) was used to precisely determine samples locations. Geostatistics software and classical statistics were used for data analysis. Correlation analysis was used to determine the strength of the relationship between nutrient content in leaf tissue and FFB yield. From kriged map, results indicate that about 32.2% of the area is low in yield, 51.6% is moderate and 16.2% is high in yield, respectively. Correlation analyses shown the total of N and available of P in the leaf have strong positive relationship (r^2 = 0.84 and 0.83) with FFB yields. Thus, result implies that N and P in leaf tissue can be used to determine the FFB yields for oil palm production.

Introduction

The Malaysian oil palm industry is one of the most highly organized sectors of any national agriculture system of the world. Currently Malaysia is the world's largest producer and exporter of palm oil with share about 44% of world production (Basiron, 2007). Malaysian oil palm cultivation began in 1917, but growth was initially very slow. It was only during the last 50 years that plantation development was accelerated through large-scale investments in the cultivation of the oil palm as one of the approved crops for diversifying the country's agricultural development. Over the last 50 years, research and development activities and technological advances have helped raise yields and reduce inputs, thereby maximising oil production from a smaller land area than used for other food crops. Palm oil is now a major source of sustainable and renewable raw material for the world's food, oleo-chemical and biofuel industries. Traditionally, the management of oil palm plantations is based on large-scale extensive agricultural practices. The general practice is to demarcate the plantations into similar management zones that are based on much generalized soil information, palm age, terrain, and available infrastructure for similar input. Currently, the typical management zone ranges between 40 ha and 100 ha (Goh et al., 2000). However, it is probably too large, and the present fertilizer which was recommended based on the extremely general soil information may not be an effective way to reduce production cost and maximize profit; the most important factors towards sustainable oil palm production. In fact adequate N fertilizer management is a great importance as these macronutrients are the bulk of the fertilizer bill. However, excessive N fertilizer could result in a higher risk of nutrient losses through surface run-off (Kee et al., 2000), and leaching (Foong, 1993), which may contaminate ground water. Similarly, under estimation of fertilizer rates may restrict oil palm growth and lead to sub-optimal production.

Precision farming, defined as a spatial variable management in order to increase efficiency in the management of agricultural practices, productivity and profitability, and reduce the environmental impact. Precision farming seems to offer some solutions to the aforementioned problems. However, the success and applicability of precision farming technique for oil palm plantations lies in the existence of manageable fresh fruit bunch (FFB) yield variations (Goh et al., 1994), which is the single most important factor influencing profit (Ong, 2000), and soil variations, which affect fertilizer input, the largest cost item in oil palm production (Kee and Chew,1996). In other words, the real opportunity to optimize fertilizer inputs through site-specific management zoning lies in the understanding of the large variation that exists in plantation. Proper management zoning needs to be taken into the account of FFB's spatial yield variations. Besides, the existing of soil variability for optimum oil palm growth and production should also be considered with the invention of new technologies. This includes proper interpretation and identification of year yield maps, and understanding the factors affecting the yield variations of oil palm production. Therefore this study was carried out to obtain accurate and timely information on the spatial distribution and

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status of N, P, K, Mg and Ca in oil palm leaf using semivariogram analysis and geographical information system (GIS), and its correlation to oil palm fresh fruit bunch (FFB) yield.

Materials and methods

Description of study area

The 15 ha of Dusun Durian Estate of the Golden Hope Plantation Bhd. Banting in Selangor was chosen as a study area. It is a coastal oil palm plantation in Peninsular Malaysia (Figure 1). The study plots were located parallel to the main road to Jugra, which is about 15 km from Banting. The plot is lying within latitude 101o27.509'N to 101o27.635'N and longitude 2o45.882'E to 2o45.810'E. The dominant soil type in the area is Selangor series. The Selangor series is a fine, mixed, isohyperthermic, developed from the marine alluvial plains typical of the West Coast of Peninsular Malaysia (Paramananthan, 2000). The Selangor series is classified as Fluvaquentic Endoaquepts in USDA Soil Taxonomy System. The climate of the study area is humid tropical with heavy rainfall. Monthly rainfall is more than 100 mm per month on the average, except in the month of February. Total annual rainfall is about 1,951 mm per year, with minimum rainfall occurring in February, at 75 mm per month, and maximum rainfall of 276 mm per month, in November. The drainage system is very intensive due to the high water table during the rainy season. Most of the Selangor series are moderately well drained to about 50 cm depth and is usually poorly drained at deeper layers (Paramananthan, 2003). There are three types of drains in the study area namely field drains, collecting drains and outlet drains. Field drains run parallel to palm rows, whereas the collecting drains are drains that collect water from field drains, which runs parallel with the collecting roads. The outlet drains are the main drains that carry water from a number of collecting drains that run direct to the main outlet.

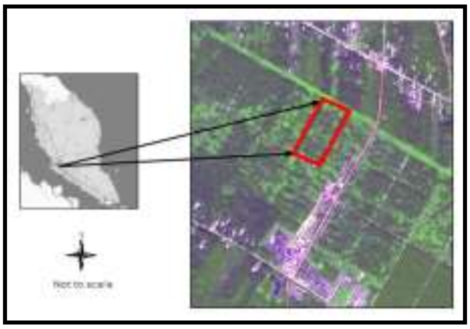

Figure 1. A map of Peninsular Malaysia showing a study site

Data collection and analyses

Leaves and FFB data were collected in 2003. Leaf samples were collected using systematic sampling method. A Trimble AgGPS was used to obtain the accurate position of every sample points. A total of sixty three leaf sample sites were selected systematically within distance of 505 m x 454 m in the entire of the study area (Figure 2). Leaf samples were collected from the 17th fronds, which is a representative of leaf tissue sample that were taken out during the morning hours (0700 to 1200 hours). The leaves were selected from both sides of the centre of the frond for about 20 leaves. The leaves were bulked together in a clean polythene bag and were brought back directly to laboratory for analysis. The middle 25 cm of the leaf were cut and retained for laboratory tests N, P, K, Mg and Ca, while it ends was discarded. The FFB yields were collected from the same palms as for the leaf samples. The weight of bunches were recorded at every harvesting round and conducted twice a month. At every harvesting round, the FFB of each palm samples were weighted individually. The FFB production was derived from the total weight of all bunches of each palm samples per month. Yield was collected by weighing out the FFB of each palm sample, due to the limited time available in the field. Once completed, the rover files then transferred into the computer. Data analyses and processing include nutrient content in the leaf tissue, FFB yields, classical statistic, geostatistics and GIS processes. The flowchart of the process is showing in Figure 3.

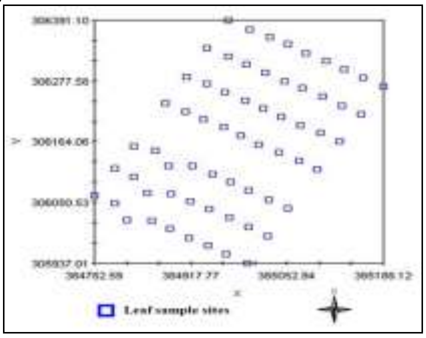

Figure 2. Leaf sample sites in study area

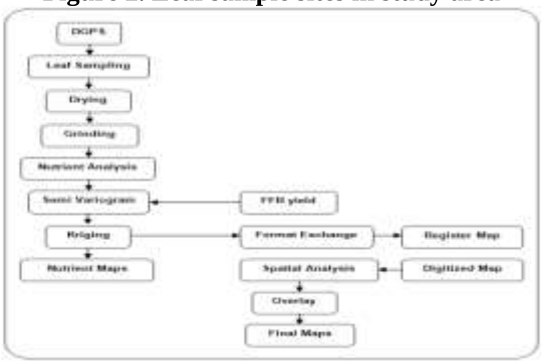

Figure 3. Flowchart of the study processes

Determination of N, P, K, Mg and Ca

The first step in leaf tissue nutrient analysis is the pre-sampling. The green leaflet were cleaned on both sides using a clean lint less cloth soaked in water and pressed to make it just wet. The water was changed at frequent intervals. After cleaning, half of the leaflets plus mid-rib were rejected. The lamina for analysis were cut into some pieces of about 2 to 3 cm long and transferred into a labeled paper-bag for oven drying. Leaflets were dried in an air-dry oven at 60oC to 70oC for 16 hours of overnight drying. At the end of the drying period, the warm dried leaves were crushed manually with the aid of a polythene bag, manually homogenized and stored in a clean polythene bag. The second step involved grinding and ashing. Ground samples were used for analysis of N, whereas ashes samples were used for analysis of P, K, Mg and Ca, respectively. Nitrogen is present in plant material usually in the form of protein, but on occasion it may be present as nitrate. The concentration of N in leaf tissue was determined by the use of Kjeldahl method and the amount of ammonia ion was measured colorimetrically using Autoanalyzer. Phosphorous was determined colorimetrically using the yellow phosphovanadate complex and K was determined by flame photometry. Ca and Mg were determined using Atomic Absorption Spectrophometer.

Geostatistical and GIS analyses

In this study, the best model in isotropic form was used to fit the data to describe the variograms considering the lowest value of residual sum of square (RSS) (McBratney and Pingle, 1997; Robertson 2000; Brodsky *et al.*, 2004). A map of each variable was computed subsequently using point kriging, by taking account of the data within the range. Kriged map of laef nutrient spatial variability was conducted based on nutrient level concentration in oil palm leaf (three levels) for Peninsular Malaysia (Table 1). A MapInfo version 5.0- GIS software was used for spatial analysis of kriged map of each variable. Kriged maps was imported into MapInfo format, registered and digitized separately for each layers. The digitization process was conducted to calculate the area for each layer. Finally, all the layers were overlaid for the final maps.

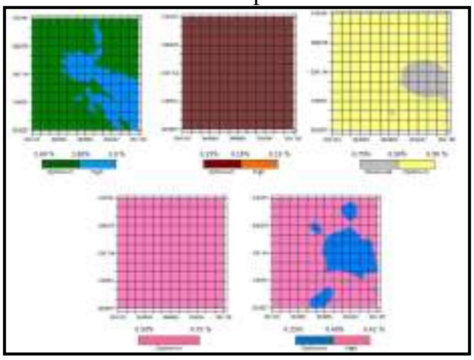

Figure 4. Spatial distribution of the N, P, K, Ca and Mg (from top left) concentration in leaf tissue

Results and Discussion

Spatial variability of N, P, K, Mg and Ca in leaf tissue

Results of the spatial variability of the N, P, K, Ca and Mg in leaf tissue are showing in Figure 4. The concentrations of N, P, K, Mg and Ca in leaf tissue are illustrated in Table 2. The percentage of mean value of N, P, K, Ca and Mg were 2.79, 0.1, 1.02, 0.62 and 0.45, respectively. Therefore, N, P, K, Mg and Ca concentration in this area was classified as sufficient for normal oil palm growth (Von Uexkull and Fairhurst, 1991). However, the coefficient of variation (CV) of N, P, K and Ca concentration were considered low, while Mg was moderate.

The semivariance analyses for concentration of N, P, K, Mg and Ca in leaf tissue were characterized by semivariogram. The features of semivariograms and best fit models of the concentration of N, P, K, Mg and Ca in leaf tissue are shown in (Figure 5). The best fit models used were linear and spherical model. The nugget variance (Co), sill (Co+C), range (Ao), residual sums of squares (RSS) and nugget ratio (Co/Co+C) values were estimated from each of these semivariograms as shown in Table 3.

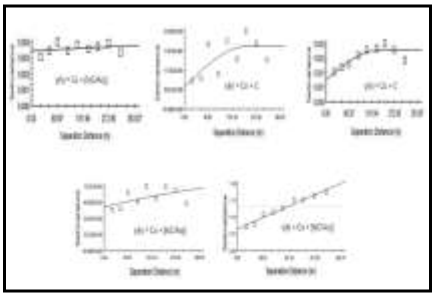

Figure 5. Semivariograms of concentration of N, P, K, Ca and Mg (from top left) concentration in leaf tissue

The Co for all nutrient studied were low (0.000067 to 0.00072), indicate the tiny error of the estimation processes. The sources of error are due to factors such as sampling intensity, positioning, chemical analysis and data recording. The low RSS values indicate the models are fitted to the variogram analysis. Results also demonstrate that future sampling of leaf nutrient could be taken within 311 m and 314 m in this area.

Spatial Variability of Fresh Fruit Bunch (FFB)

Based on record, the FFB in the field was 385.5 kg ha-1 . Table 4 shows the concentration of FFB of the study area. The variability of FFB yield can be classified as high. Figure 6 is a kriged map of FFB yield that showed the spatial distribution of FFB in the field. The FFB yield was classified into three categories namely, low from 0 kg to 160 kg FFB palm-1, moderate from 161 kg to 180 kg FFB palm-1 and greater than 180 kg FFB palm-1 (Table 5).

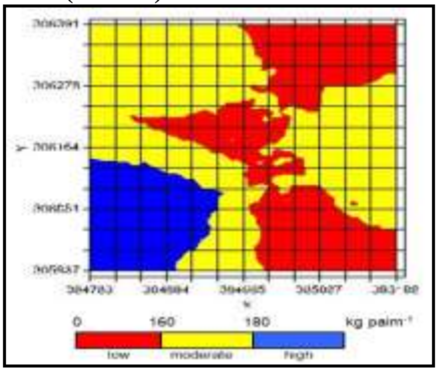

Figure 6: Spatial distribution of FFB result related to N,P,K,Ca and Mg in oil palm leaf

A Kriged map indicated that about 32.2% of the area is low in yield, 51.6% is moderate and 16.2% is high in yield, respectively. In order to investigate the relationship between FFB yield and leaf nutrient variability in leaf tissue, correlation analysis was performed to determine the strength of the relationship. The correlation matrix is shown in Table 6. K, Mg and Ca shown a weak correlation with FFB yields, meanwhile N and P were high. There were significant correlation between FFB yield, N and P concentrations in leaf tissue. These results showed that the total of N and available of P in the leaf have strong positive relationship (r2 = 0.83 and 0.83) with FFB yields. The r2 value of 0.839 and 0.833 for N and P indicates that about, 83.9% and 83.3 %t of the variance in Y can be explained by the independent variable X. The ability to use one variable as a predictor to another, also tells us a great deal about the underlying relationship between the two variables.

Semivariance analysis of FFB yield with the feature of semivariogram and best fit model is shown in Figure 7. The model was expected to appear linear with the estimated nugget variance (Co), sill (Co+C), range (Ao), residual sum of squares (RSS) and nugget ratio (Co/Co+C) values as shown in Table 7. The linear model was the best fit-model for semivariance analysis of FFB yield. The low nugget and RSS indicate a good model that fits the variogram data with small error estimation. Tthe spatial dependence of FFB was classified as a moderate spatial dependence with the lag distance of 310 m to 314 m. This result implies that the maximum lag distance for yield analysis of FFB is 314 m. Any pair of FFB values by a lag distance greater than 314 m should be classified as spatially independent.

Conclusions

Based on the study N, P, K, Mg and Ca nutrient content in leaf tissue are sufficient for oil palm growth. Semivariance analysis indicated that the leaf nutrients have a moderate spatially dependence with variable lag distances of 31.3 to 31.4 m for nutrients. On that ranges all samples by distance are spatially correlated and those samples greater than the range are not spatially correlated. The semivariogram of this range can be used to suggest appropriate sampling design strategies for future field surveys. A spatial kriged map produced indicates that about 32.2% of the area is low in FFB yield, 51.6% is moderate and 16.2% is high. There were strong relationships between FFB yield and N and P in leaf tissue. This result implies that N and P in leaf tissue can be used to determine the FFB production for oil palm plantations.

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Table 1. Nutrients concentration in leaf tissue associated with deficiency, optimum and excess in mature palms

Nutrient	Deficiency	Optimum		Excess
	-----------------------%---------------------------			
N	< 2.3	2.40	2.80	> 3.00
P	< 0.14	0.15	0.18	> 0.25
K	< 0.75	0.90	1.20	> 1.60
Mg	< 0.20	0.25	0.40	> 0.70
Ca	< 0.20	0.50	0.75	> 1.00

Source: Von Uexkull and Fairhust (1991)

Table 2. The N, P, K, Ca and Mg concentrations in leaf tissue

Nutrients	Min. value (%)	Max. value (%)	Mean (%)	CV (%)	SE
N	2.68	2.94	2.79	2.1	0.00761
P	0.1	0.18	0.16	1.9	0.0004
K	0.83	1.02	0.93	1.9	0.005
Mg	0.33	0.45	0.39	7.2	0.0035
Ca	0.46	0.62	0.54	7.2	0.0034

No. of samples: 63 oil palm trees

Table 3. Geostatistical parameters of N, P, K, Ca and Mg in leaf tissue

Nutrient	Model	Nugget (Co)(m)	Sill (Co+C) (m)	Range (Ao) (m)	RSS	Nugget ratio (Co/Co+C)
N	Linear	0.00348	0.00376	314	0.9×10^{-6}	0.926
P	Spherical	0.000067	0.000190	230	1.3×10^{-8}	0.353
K	Spherical	0.00094	0.00232	205	3.1×10^{-7}	0.410
Mg	Linear	0.00037	0.00091	94	1.1×10^{-8}	0.407
Ca	Linear	0.00072	0.00072	314	7.4×10^{-8}	0.0

Table 4. The FFB concentration in the study area

Min. value (%)	Max. value (%)	Mean (%)	CV (%)	SE
110	385.5	235.7	26.0	7.73

No. of samples: 63 oil palm trees

Table 5. Rating for FFB yields per palm

Rating	Kg FFB palm^{-1}
High	> 180
Moderate	161 – 180
Low	0 – 160

Table 6. Correlation matrix for FFB and leaf nutrient

	N	P	K	Mg	Ca	FFB
N	1.000					
P	0.088	1.000				
K	0.080	0.214	1.000			
Mg	0.101	0.118	-0.483	1.000		
Ca	0.006	0.079	-0.357	0.329	1.000	
FFB	0.839*	0.833*	0.026	-0.077	0.024	1.000

Note: Concentration of N, P, K, Ca and Mg in leaf tissue
FFB : Fresh Fruits Bunch, *: Significant correlation at 5%.

Table 7. Geostatistical parameters of FFB

Model	Nugget (Co) (m)	Sill (C+C) (m)	Range (Ao) (m)	RSS	Nugget ratio (Co/Co+C)
Linear	3113	6227	311	1.0×10^6	0.50