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Detecting and Mapping Nutrients Concentration in Oil Palm Plantation Using Remote Sensing and Geographic Information System

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Abstract

Nutrient concentration in the soil is one of the major factors that determined the performance of oil palm crop growth. Shortages of nutrients are normally overcome through the application of chemical fertilizers. High cost of chemical fertilizers had contributed to high production cost. Efficient and proper management in term of fertilizer application is therefore a necessary measure to ensure better returns. Complete and detailed information regarding soil condition across the oil palm plantation is greatly required for aiding farm managers and operators in day-to-day management decision. The main focus of this paper is to examine the ability of remote sensing technique in detecting and quantifying the foliar nutrient in the oil palm crop. Results of this study that have been carried out in the Malaysian Palm Oil Board (MPOB) Research Station in Kluang Johore showed a strong relationship between measured foliar nutrient and the spectral reflectance measured using spectroradiometer at micro level, which can in turn be regressed at macro-level with appropriate satellite data to map nutrient status for large areal extent.

INTRODUCTION

Precision farm management requires accurate and timely information regarding crop and soil conditions. Remote sensing has been cited as a technology that can be utilized to provide many of the information required for these needs (Moran et al., 1997). One of the first applications of remote sensing data is in the study to detect the relative differences in plant canopy density (Jordan, 1969). Pinter et al, (1994) have shown the relationship between reflectance data and plant characteristics such as plant biomass or fraction of intercepted photosynthetically active radiation (FPAR).

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The red and near-infrared portions of the spectrum have been found particularly useful in vegetation monitoring. Korobov and Railyan (1993) found that the near-infrared (NIR) and red portions of the spectrum had the highest correlation with plant variables such as height, density, and percent cover. Gupta (1993) noted that the ratio of the NIR to Red channels provided a higher correlation with crop development in the early and late stages of growth, while the Normalized Difference Vegetation Index (NDVI) had a near linear correlation to crop growth over plant covers of 15 to 80%. Keeping in view the above facts, the present study carried out in UTM is to examine the ability of remotely sensed data in detecting growth spatial variability of oil palm including the foliar nutrients. In the later study was carried out to analyse micro-nutrients (N, P, K, Mg, Ca), typically found in inland plantation.

SOIL NUTRIENT AND OIL PALM TREE GROWTH VARIABILITY

Factor affecting plant growth and yield are complicated and are influenced by many factors such as climate, soil type, moisture, diseases, pest, mineral nutrition, and genetic control. Soil nutrients are always considered to be one of the most important parameter that determines the oil palm crop performance. Oil palm has two growth phases: the immature and the production phase. The nutrient requirements were normally determined by weighing the dry matter production, yield and nutrient uptake of palm from one up to ten years after planting. Studies that have been carried out showed that oil palm requires more nutrients both for early growth and for mature production compared to rubber (Ng and Thamboo, 1967, Ng et al. 1968). Figure 1 showed the level of nutrient up-take of oil palms for the first ten years after planting.

Results of those studies showed very obviously that oil palms need a soil with a high inherent fertility level. However analysis regarding most of the oil palms planted in Malaysia and also in many other part of the Southeast Asia countries indicated that oil palms are grown on acidic and low fertility soil (Muterd, 1999). Most of the soils are found to have low to very low contents of nitrogen (N), available phosphorus (P), and exchangeable potassium (K). The lack of adequate mineral availability from most of the topsoils in this region is subjected to leaching due high rainfall. One of the measures that have been taken to overcome problems of nutrients shortages is by applying fertilizer. In fact, one of the major factors that have lead to the advancement of sustainable oil palm yield in Malaysia is due to the application of fertilizer. Currently, the total fertilizer consumption in Malaysia is about one million nutrient tones, and about 62.7% of these total are been used for the oil palm plantation. Figure 2 showed the trend of fertilizer consumption in Malaysia. Large amount of fertilizer usage had contributed to an increased in the production cost, and it was estimated that about 24 percent of the total cost of oil palm production in Malaysia is for fertilizer. An increased in the price of imported fertilizers, together with the current unpredictable economic situation will definitely led to a further increased in the production cost of the oil palm.

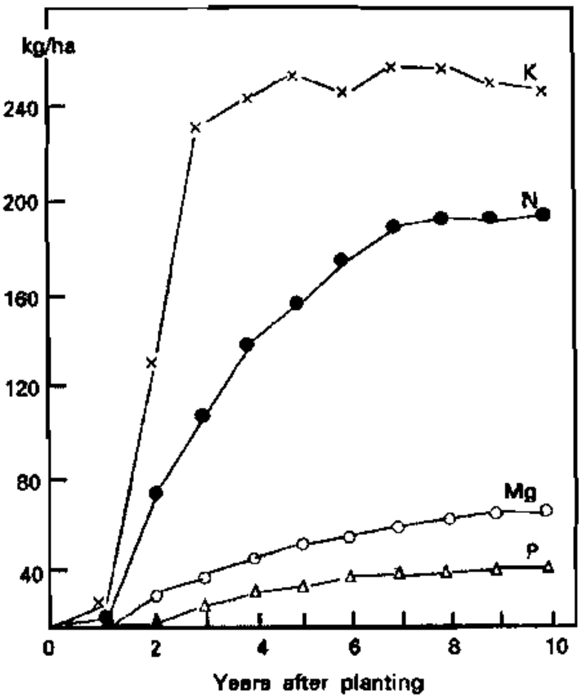


Figure 1. Nutrient up-take of oil palms for the first 10 years after planting.
Source: Ng (1977)

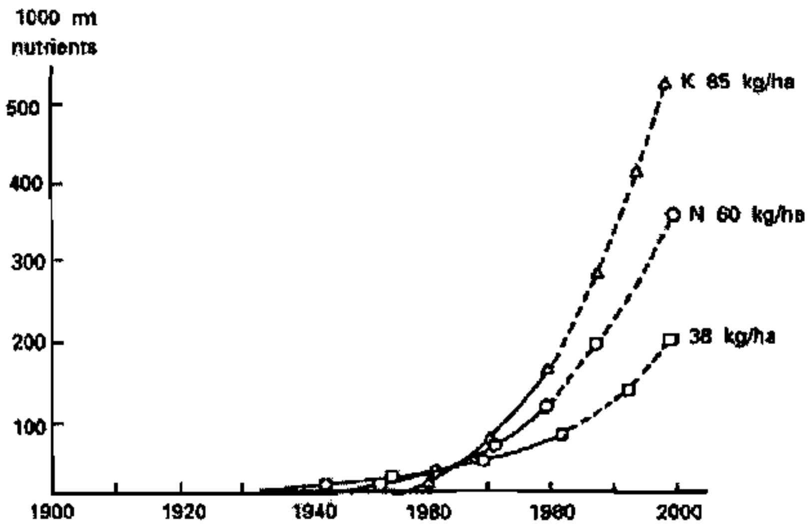


Figure 2. Trend in fertilizer consumption in Malaysia (1900-2000)
Source: von Uexkull (1983)

Proper management of fertilizer application is therefore very important to ensure efficient uptake, high sustainable yield and maximum benefits from the high expenditure cost. Application of fertilizer according to traditional recommendation methods usually based on manual analysis of the soil nutritional status in the oil palm plantation through foliar analysis. This traditional method of data collection and analysis found to be laborious, time consuming and also very costly.

The development of remote sensing technology especially in term of its application in agricultural practice will be a very useful technique that can helped to improve fertilizer management.

MATERIAL AND METHODS

Study Area.

This study was carried out in the Malaysian Palm Oil Board (MPOB) Research Station, Kluang, located in the northern region of Johor (Figure 3). The study area consisted of 16 experimental plots established in June 1984 after the felling of a 23-year-old oil palm plantation (Khalid and Anderson, 2000). All plots with an area of 0.15ha were laid out in a randomized complete block design (RCBD) with two plots representing each of the biomass.

Four types of biomass treatments that were established were Chipped and Shredded (C/S), Complete Removal (C/R), Chipped and Pulverized (C/P) and Partial burning (P/B). For Chipped and Shredded (CS) treatments, the palm trunks were chopped into pieces of about 10cm thick across at 45^0 - 60^0 angles. Prior this treatment, the operator cleared and vacated an area about 1.5m square in between old stands for new planting points and then spread the shredded materials evenly at about 3m - 4m wide to avoid thick pile formation. For Complete Removal (C/R) treatment, the felled trunks were cut into several pieces at about 2 m - 3m lengths without chipping. These materials and other palm components were completely removed using lorries.

Chipped and Pulverized (C/P) is the treatment alike the C/S treatment where the palm trunks and fronds were chipped shredded and spread. However after one week, these residues were pulverized into small pieces using pulverizing machine mounted on a tractor. Finally for the Partial Burning (P/B) treatment, treatment similar to C/S treatment were done and one months later, half portion of the residues were burnt, leaving another 50% of the chipped trunks to decompose in the field.

Legume plants were established after all the treatments had been completed, approximately one week after the P/B treatment. The base lines of old planting rows were scrutinized for reference to help mark new plating points between old stands. Palm seedlings D x P 12-month were field planted at 8.8m x 8.8m x 8.8m triangular spacing in late August 1994. No fertilizers are applied during the experimental period except for an initial treatment of 250g of phosphate rock in each planting hole at the time of field planting. In normal cultivation practice, inorganic fertilizers are applied at six months and 12 months after field planting but this practiced were intentionally overlooked in this experiment.

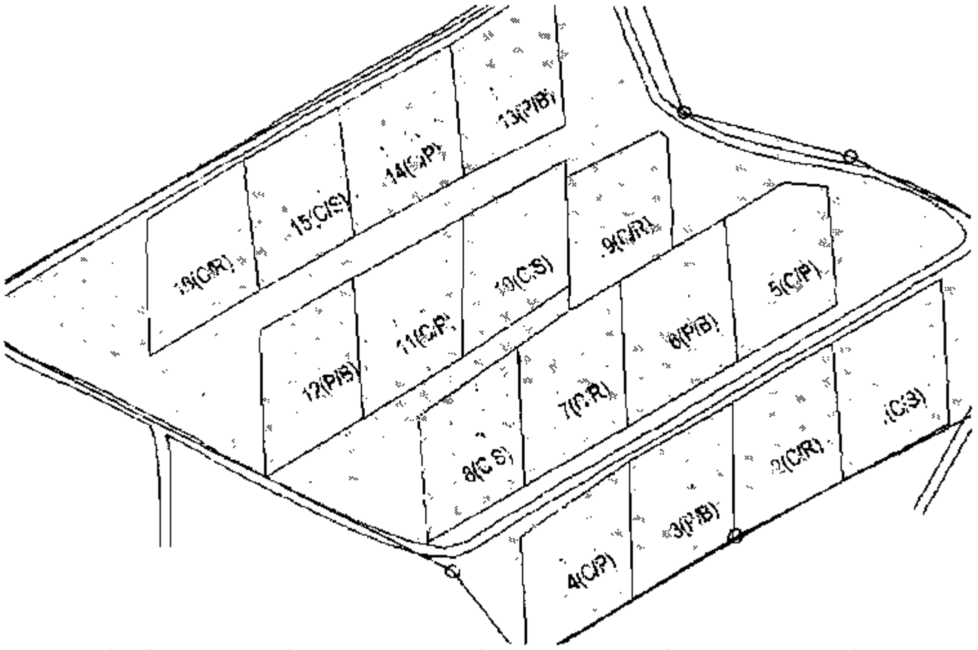


Figure 3. Oil Palm Plots in the Study Area According to Type of Biomass Treatment

Data Acquisition

Three types of data have been used in this study are soil nutrient data from foliar analysis, spectral reflectance from field radiometer and Landsat-5 TM satellite data. The reflectance from leaves taken from frond 17 of palm number 8 from each of the 16 plots was measured using field radiometer. These measurements were carried out in the month of November 2000 and a number of twenty readings were taken from each sample. The radiometer was fixed onto a tripod about 0.7 meters above the leaves that were arranged on the white paper to avoid interferences from other factors. The reflectance from the sample candidates were observed continuously in the wavelengths range of 300 – 1100 nm at an interval of 5nm. However 300 – 400 nm are the ultraviolet region, and reflectance within this region are unexplained, thereby not included in the analysis. The remaining reflectances were categorized into selected ranges, similar to the range of wavelength of the corresponding band of satellite data to be used in this study, that Landsat-5 band 1 to band 4). After the spectral measurements were done, the same leaves were then taken to MPOB laboratory for foliar analyses. From this analysis, the percentage amounts of nutrients concentration in leaves were obtained.

Analysis and Discussion

In this section, the spectral reflectance from oil palm leaves and the amounts of nutrients obtained from foliar analysis were examined, analysed and then an evaluation of the relationship between these two variables were made. The basis for this relationship or correlations was established by stepwise multiple linear regression techniques between nutrient concentration from foliar analysis and the reflectance at wavelength which is equivalent to the range of wavelength of band 1 (450-520nm), band 2 (520-600nm), band 3 (630 – 690nm) and band 4 (760 – 900nm) of Landsat-5 (*Lillesand and Kiefer, 2000*e 2).

Therefore the reflectances reading from spectroradiometer used for this analysis were first calculated to obtain the mean value of reading within the range of these wavelengths.

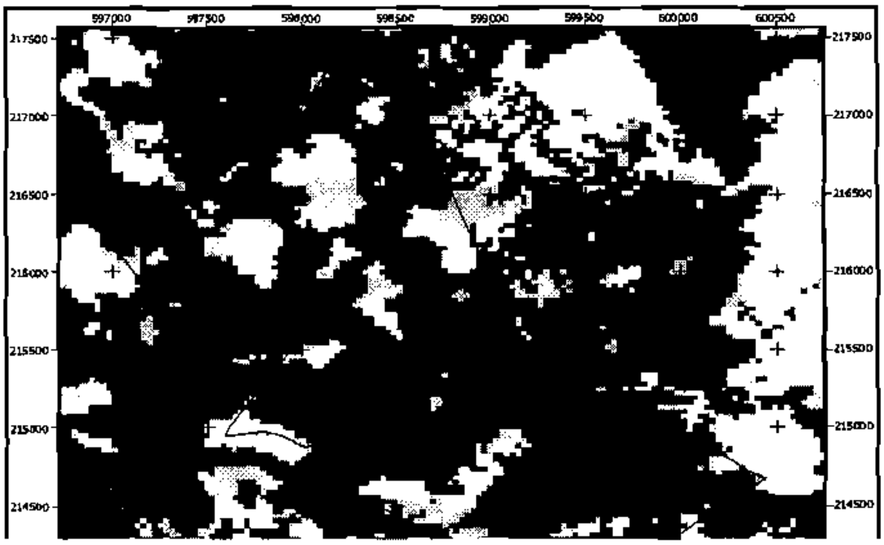
Before regression analysis was performed, the data set was divided into two independents mutual sets, set A and set B. The first set, (Set A) was used for the establishment of relationship (r^2), and the second set, (Set B) was used for testing the accuracy of the estimated value of nutrient obtained using regression model that have been developed compared to the foliar determined through laboratory analysis.Regression models produced demonstrate that, there is a correlation between nutrients and the reflectance, and these indicate that the amount of nutrient (**N, P, Ca, Mg**) can be estimated using the reflectance value at various bands. The concentration of **N** can be estimated using the combination of band 2, band1 and band 4 of the Landsat-5 TM (r^2 **0.664**). The combination of band 2, band 1, band 4, and band 3 of Landsat-5 can be used to estimate **P** (r^2 **0.691**), the concentration of **Ca** can be obtained using band 2 and band 1 (r^2 **0.685**) and **Mg** using band 4, band 1 and band 2 (r^2 **0.441**). Further data analysis is needed to determine how well the model can predict the nutrients level. Regression models that have been produced were used to estimate the nutrient concentration in the study area. Table 3 demonstrates the values of nutrients concentration in the study area, and the low values of RMSE obtained indicate a high degree of accuracy.

Results of this analysis shows that nutrient concentration at the micro-level can be successfully detected using remote sensing technique. Further analysis using information from Landsat-5 TM satellite data shows that remote sensing can also be applied to detect and mapped the nutrient concentration at Macro level. For this purpose, Landsat-5 TM images have been processed and image maps showing the distribution of nutrient

TABLE 3. ESTIMATED VALUE OF NUTRIENT CONCENTRATION IN THE STUDY AREA

Plot	$N_{estimated}$	$N_{measured}$	$P_{estimated}$	$P_{measured}$	$Ca_{estimated}$	$Ca_{measured}$	$Mg_{estimated}$	$Mg_{measured}$
Plot01	2.89	2.79	0.162	0.151	0.70	0.55	0.26	0.32
Plot02	2.88	2.80	0.162	0.155	0.71	0.73	0.25	0.31
Plot03	2.86	2.79	0.163	0.158	0.67	0.58	0.31	0.25
Plot04	2.83	2.76	0.163	0.150	0.69	0.59	0.27	0.31
Plot05	2.81	2.89	0.161	0.162	0.70	0.69	0.25	0.31
Plot06	2.85	2.77	0.161	0.164	0.70	0.64	0.26	0.28
Plot07	2.82	2.97	0.161	0.155	0.70	0.73	0.25	0.25
Plot08	2.78	2.91	0.159	0.142	0.70	0.72	0.23	0.29
Plot09	2.82	2.82	0.161	0.133	0.69	0.69	0.26	0.30
Plot10	2.80	2.86	0.161	0.140	0.71	0.75	0.24	0.36
Plot11	2.81	2.68	0.161	0.151	0.71	0.64	0.24	0.36
Plot12	2.84	2.71	0.161	0.132	0.70	0.65	0.26	0.33
Plot13	2.82	2.85	0.160	0.161	0.70	0.67	0.25	0.33
Plot14	2.86	2.72	0.162	0.151	0.70	0.65	0.27	0.34
Plot15	2.84	2.84	0.162	0.139	0.69	0.76	0.27	0.33
Plot16	2.81	2.77	0.160	0.115	0.70	0.62	0.24	0.30
	RMSE	**0.120**	***RMSE***	**0.019**	***RMSE***	**0.073**	***RMSE***	**0.070**

concentration in the study area have been produced (Figure 4, Figure 5, Figure 6 and Figure 7). The production of this maps were made possible with the application *spatial modeler* technique obtained from Erdas 8.5 image processing software.



% Nitrogen

Figure 4. Percentage of Nitrogen Concentration, MPOB Research Station, Kluang Johor.

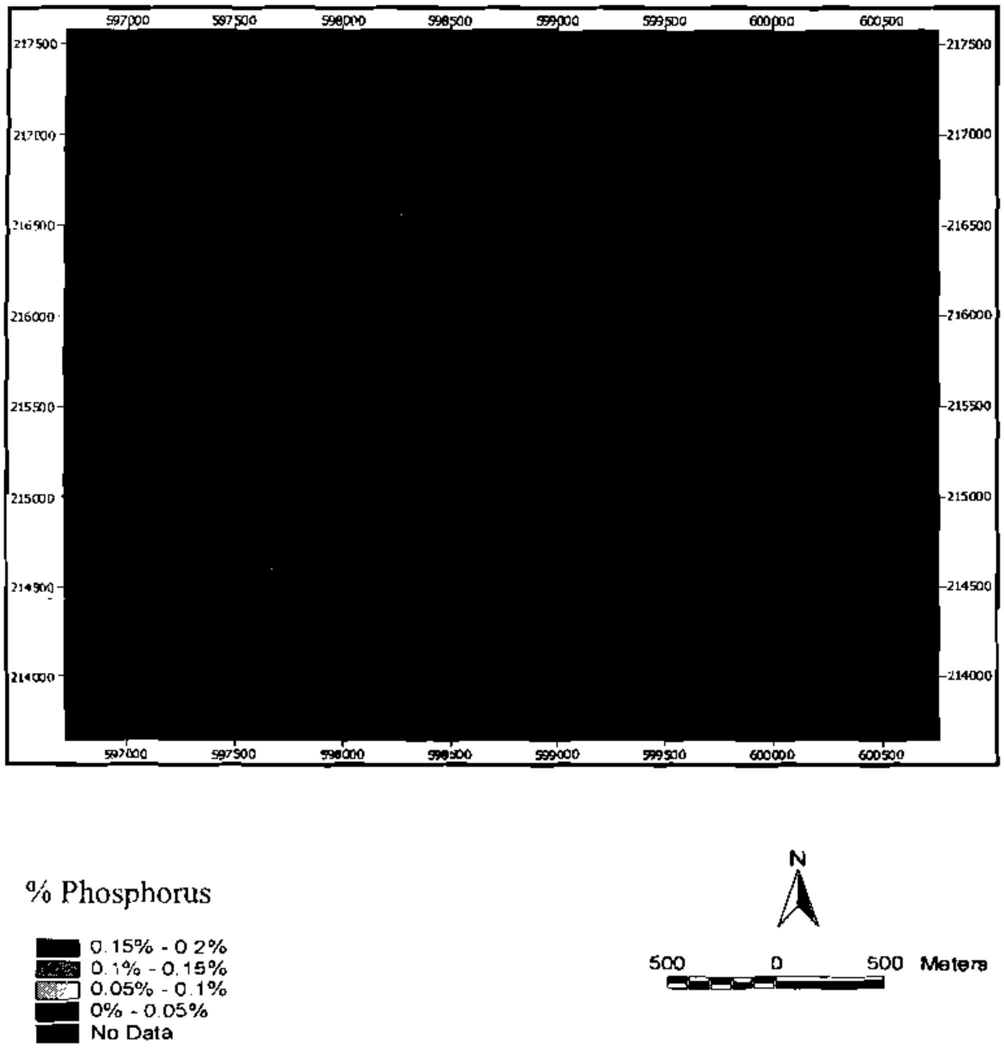


Figure 5. Percentage of Phosphorus Concentration, MPOB Research Station, Kluang Johor.

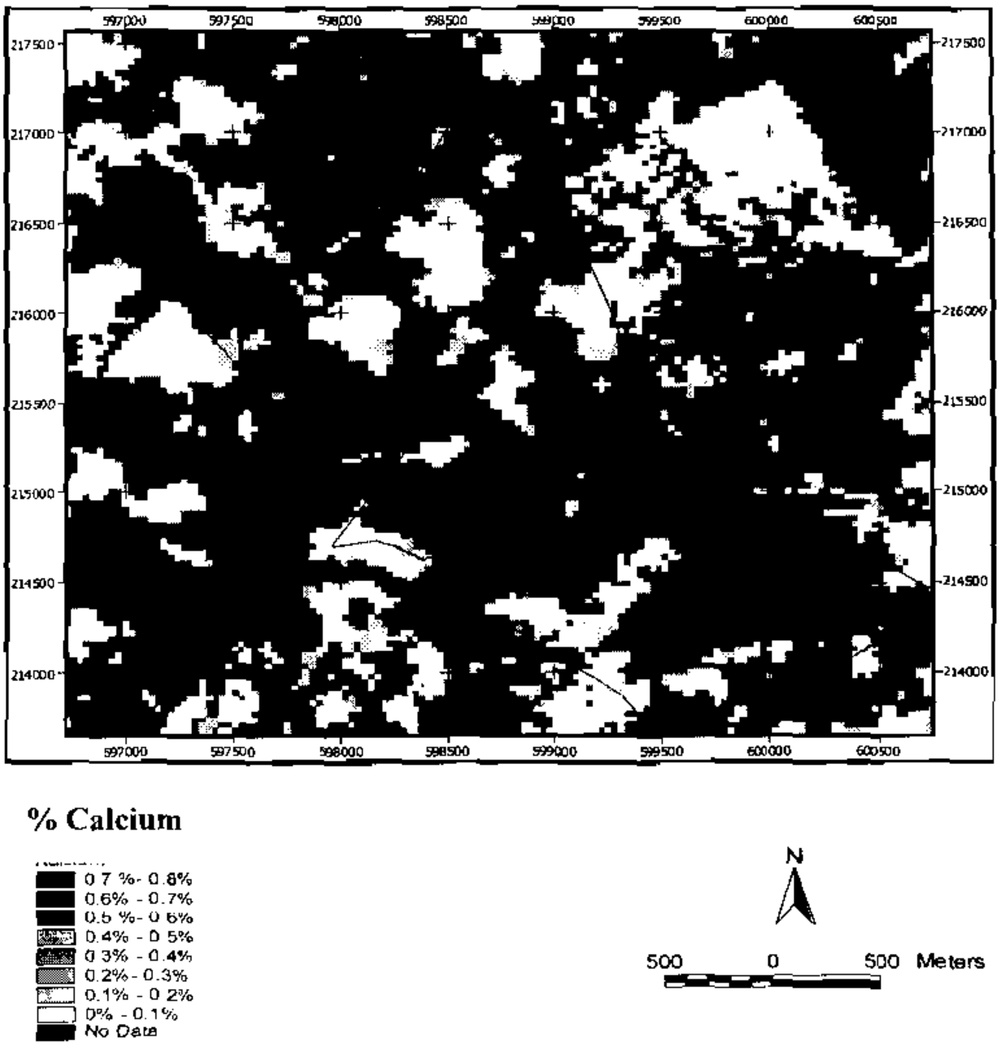


Figure 6. Percentage of Calcium Concentration, MPOB Research Station, Kluang Johor.

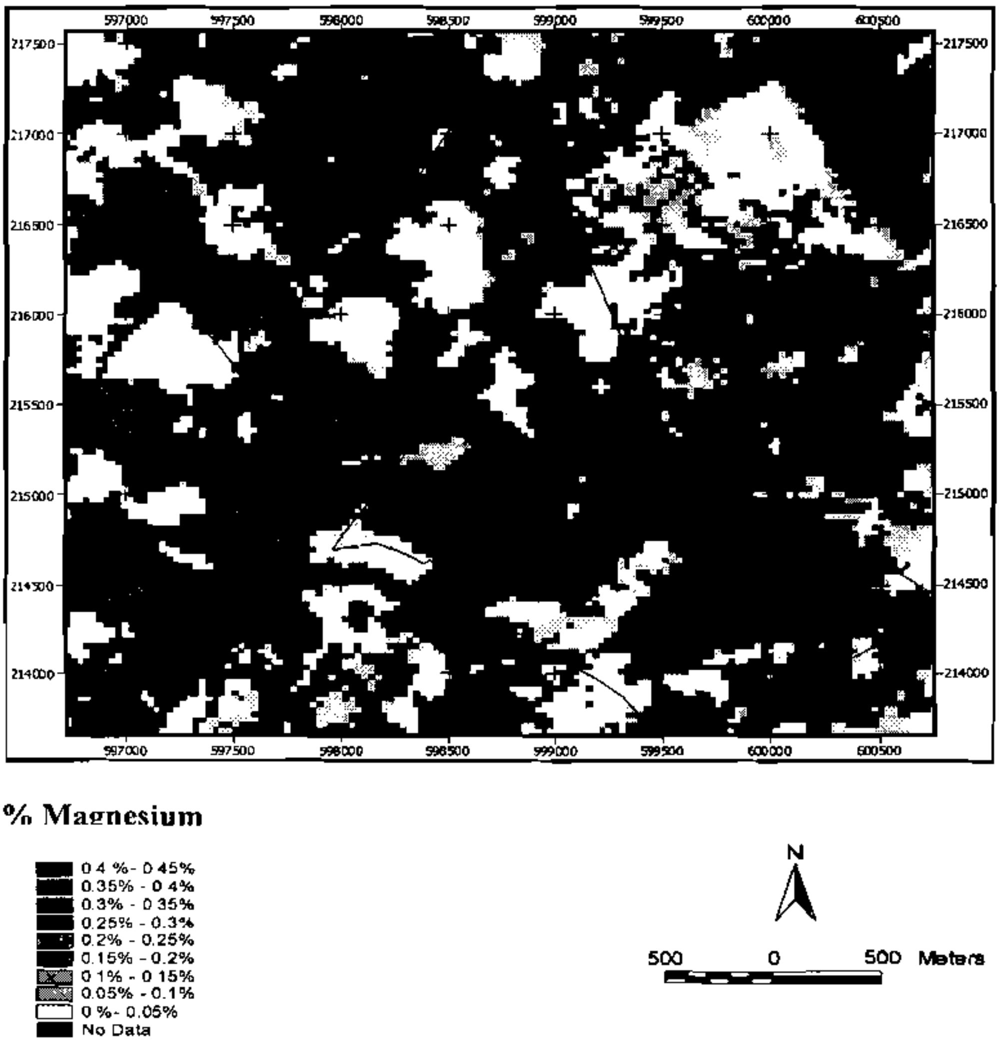


Figure 7. Percentage of Magnesium Concentration, MPOB Research Station, Kluang Johor.

CONCLUSION

The ability of remotely sensed data to quantitatively detect and estimate the nutrient concentration in the soil would helped to improved yield forecasts and also would provide useful information for farm managers in making day-to-day management decision. Moved to change from the traditional time consuming and costly method of soil analysis to this new technique of data analysis have to be made to ensure better and efficient farm management.

Compared to foliar analysis conducted in oil palm plantation which came from samples of blocks in which each block are made of substantial acreage, approximately about 10 – 25 ha, mapping of nutrient with remote sensing technique generated in this study is far better in recording and exhibiting the spatial variability of nutrient concentration.

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