Soil Nutrient Varibility Mapping in UiTM Research Station, Arau, Perlis Using Landsat TM and Geostatistical Analysis

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Abstract: -Spatial variability of N, P, and K using a systematic soil sampling were studied in the UiTM Perlis Branch Campus Research Station field at Arau, Perlis. A total of 54 surface soil samples at 0-15 cm depth were collected at 80 m x 80 m grid pattern and analyzed to determine total N, available P and K in the plots. A GeoExplorer II Global Positioning System (GPS) was used to record the coordinates of the soil sampling points. All the samples were then analysed in the Soil Science Laboratory, Universiti Putra Malaysia, Serdang to determine soil selected elements of nitrogen, phosphorous and potassium (N, P, K). Soil mapping variability was later analyzed using the Geostatistics software. Kriging analysis was used to determine the value of each point in the area of study. A semi variogram was developed to describe the spatial relationship between the locations where the value of a soil property was estimated and characterized. It was found that the presence of N, P, and K varied from 0.098 -0.147 %, 10.0 -24.2 ppm and 62 -129 ppm, respectively. Field maps were prepared with point-kriged estimates and showed that the northern portion of the field (80 % of the study area) is under shortage of nutrients perhaps due to the barren condition of the exposed soil. It was also visually observed that there is a reduction of the planted crop growth in both of the first, second and third quadrant of the of the study plot which were opened-up areas. Therefore, it is strongly recommended that of fertilizer, lime and organic matter be applied in these quadrants of the study area to improve the soil condition compared to the right bottom side of the quadrant. This study implies that sitespecific or precision agriculture provides a useful management tool in the forecasting of crop yield and future market intelligence. Further research with respect to integrating the use of remotely sensed data especially airborne hyperspectral sensing with GPS and GIS to improve accuracy of systematic variability mapping in UiTM Farm Research Station should be attempted.

Keywords: - precision farming, soil nutrient, mapping, kriging, geostatistics, GPS, GIS

1 Introduction

Soil nutrient are essential for crop growth. Spatial variability of nutrient can be occur in various scale, between region, field or within field especially in variation in soil properties (Burrough, 1993). Soil investigation, survey and mapping are among the field to be studied by remote sensing applications. Remote sensing information is capable to identify the soil organic matter content where it can differentiate higher and low organic matter from the soil spectral response of the imagery (Yang and Anderson, 1996). A majority of the studies examining quantitative relationship between remotely sensed data and soil properties have focused on the reflective region of the spectrum (0.3 to 2.8 μ m), with some relationship established from data in the thermal and microwave regions (Edward *et al.*2003). Remotely sensed images are also can be used in direct soil sampling as they are willing to define the spatial zone within the fields for obtaining the samples.

Information on soil properties in crop field is very important and useful for not only for fertilizer requirement but specific management of the crop and soil. The availability of nitrogen, phosphorus and potassium (NPK), whether in soils or plants is among of the most of the nutrient work in remote sensing studies. Soil physical properties such as organic matter have been correlated to specific spectral responses (Dalal and Henry, 1986; Shonk et al., 1991). Therefore, multispectral images have shown potential for the automated classification of soil mapping units (Leone et al., 1995). Although direct applications of remote sensing for soil mapping are limited because several other variables can affect soil reflectance such as crops practices and moisture content. However, bare soil reflectance could have an indirect application in interpolating the results of gridded soil samples. For instance leaf color measurements conducted at the ground level have correlated well with corn plant N status (Blackmer et al., 1996).

The objective of the study is to 1; map and determine of NPK status in UiTM research station, and 2; to investigate the relationship between nutrient status of the soil and remotely sensed imagery.

2 Material and method



Figure 1: A map of Peninsular Malaysia showing the location of study area

2.1 Study area

The study area was carried out in an area of 127.3 acre at UiTM Research Station, Arau, Perlis. The geographical coordinates of the study area is 100° 16' 40" E to 100° 17' 15" E and 6° 27' 05" N to 6° 27"40" N, respectively. Figure 1 showing the location of study area.

2.2 Satellite imagery

Satellite image used in this analysis was a Landsat TM -5 of path/row 128/56 acquired on 2nd The 2005. geometrically February and radiometrically corrected image was subset to the representative study area for further analysis. The representative image is totally free cloud cover and was geometrically registered to the horizontal coordinate system WGS 84. The TM sensor of this satellite provides data in 7 spectral bands with the following characteristics; 30m spatial resolution for band 1-5(from the visible and medium infrared) and band 7 (far infrared), and 120m for band 6 (thermal).

2.3 Soil data

A total of 54 soil sample sites were collected and analyzed. Soil samples were taken using

systematically sampling within distance of 80 by 80 m in the whole study area as shown in Figure 2. Laboratory analyses were performed for soil properties such as total N, available P and exchangeable K.

2.4 Digital image analysis

2.4.1 Image normalization (at-sensor reflectance)

Removing the noises arising from atmospheric effect, illumination and instrument error of satellite –based image was conducted before further processing was made. Without considering the effect of topography, the normalization process was done using Markham and Barker (1986) equation as follows:

$$\rho_{BandN} = \frac{\pi (L_{BandN} * Gain_{BandN} + Bias_{BandN}) * D^2}{E_{BandN} * (COS((90 - \theta) * \pi / 180))}$$

where,

 $\rho_{BandN} = Reflectance for Band N$ $L_{bandN} = Digital Number for Band N$ D = Normalized Earth-Sun Distance $E_{bandN} = Solar Irradiance for Band N$

This equation was created spatial image that converts the image's digital numbers to atsensor radiance. Image normalization improves the ability to enhance the consistency of image pixels and relatively does not change the distribution of the data.

2.4.2 Image analysis

Several tasks of digital image processing of Landsat TM were conducted in order to extract the soil information from the image data. This comprises the image processing steps such as band selection, image enhancement and filtering. Further steps involve pixel segmentation and extraction of pixel values. In image enhancement using linear enhancement and resetting some degree of brightness was enough to improve the visual to the appreciable degree. Visual analysis of the enhanced image Bands 4, 5, 3) clearly showed separability between vegetation and soil information in the area. Low pass filter 3 x 3 window is used to refine the visual effect. Median filter was chosen for this study due to its clear and smooth results and on

the other hand it preserved the image sharp edges.



Figure 2: Soil samples collection sites using systematic sampling

To analyze the soil properties distribution in the study area, soil properties extraction is conducted using the value of the radiance from the value of digital number in Landsat TM of red, green and near infra red band. At the same time in segmentation techniques by selecting pixels of the 15 training area is carried out using supervised classification by applying maximum likelihood classification (MLC) approach method of Landsat TM false color image (band 4,5,3), after conducted ground verification. MLC assumes a normal distribution based on the mean and variance of the training area for each class. A total of 54 sample locations were taken instead of 57. Three samples were excluded due to their location are outside the area of study, and 13 samples location of pixel on imagery were covered by vegetation.

2.4.3 Statistical analysis

Descriptive statistic of nutrient of NPK status in soil and spectral reflectance of pixels was analyzed using SPSS tool. Variation of NPK in soil and spatial distribution of imagery on the study location were examined using analysis of variance (ANOVA). Coefficient of variation (CV) value describes as a classification scheme in identify the extent of variability of the nutrient in soil and image pixel. The relation between variables was investigated using correlation analysis; pearson correlation coefficient (r^2) is appropriate for investigating the relationship of the variables and measured significant and the strength of the the relationship. In order to obtain good prediction of the association among variables regression analysis is also used. The summarized of overall processes of data analysis including satellite imagery, nutrient content of the soil and geostatistic is illustrated in the flowchart as shown in Figure 3.



Figure 3: Flowchart of the overall processes of data analysis

3 Result and discussion

3.1 Kriged maps of NPK

Semivariograms and kriged map produced from geostatistical software, GS+, version 3.1. From semivariogaram evaluation, the spatial variability of soil properties and their relation to lag of the samples and semivariance were generated. The spatial distribution of total N, availability of P, and exchangeable K in the soil after kriging process are shown in Figure 4 to Figure 6.



Figure 4: Spatial distribution of total N (%) in soil



Figure 5: Spatial distribution of available P (ppm) in soil.



Figure 6: Spatial distribution of exchangeable K (ppm) in soil.

The kriged map from Figure 4-Figure 6, indicated the concentration of NPK in the study area were varied from 0.098 % to 0.147 % for N, 10.0 ppm to 24.2 ppm for P and 62.0 ppm to 129.0 ppm for K, respectively. As a classification, the NPK availability in the study area can be classified according to DOA (1997) as shown in Table 1.

Table 1: Classification of NPK availability in the study area

| Classification | | | | | | | | | |
|----------------|-------|------|---------|-------|----------|--|--|--|--|
| | Very | High | Moderat | Low | Very low | | | | |
| | high | - | e | | - | | | | |
| Ν | - | - | - | 0.118 | 0.098 | | | | |
| (%) | | | | to | to | | | | |
| | | | | 0.147 | 0.118 | | | | |
| Р | - | - | 15.7- | 10.0 | < 10.0 | | | | |
| (ppm) | | | 24.2 | to | | | | | |
| | | | | 15.7 | | | | | |
| K | 89.0 | 62.0 | < 62.0 | - | - | | | | |
| (ppm) | to | to | | | | | | | |
| | 129.0 | 89.0 | | | | | | | |

From the table it can be shown the study area has low N, moderate to very low P and very high to moderate K. The higher K element in soil properties proportion is common because K ions removal by crop is high, about three to four times higher than P and equal to N ions absorption (Brady, 1990). Based on the kriged map of soil analysis site specific management can be planned and consider to be applied for this study area. The map result in applying how much the element of NPK requires to be used to support the crop growth.

3.2 Spatial variable of NPK in soil and remotely sensed imagery

A close-up of a satellite imagery of the area is made to select soil pixel and match the soil sample location to the imagery (Figure 7). As a result to the investigation of correlation of soil properties (NPK) with satellite imagery, reflectance of soil is stronger in the visible wavelength of red (0.7 -0.8 µm) and green (0.6-0.7 μ m) but lower in the near infrared (0.8-1.1 µm). In this result the difference of reflectance clearly shows the bare soil without vegetation cover appeared brighter. However certain soil pixels shows lower reflectance and appeared darker may be affected from the moisture content in the soils. The correlation of NPK in soil and pixel of satellite imagery is shown in Table 2.



Figure 7: A close-up of Landsat TM of the study area (4x zoom)

Table 2: Correlation matrix of remotely sensed data and soil (n=54)

| | | - / | | | | |
|----|--------|------|-------|------|------|------|
| | Ν | Р | K | R | G | IR |
| Ν | 1.00 | | | | | |
| Р | -0.43 | 1.00 | | | | |
| Κ | .203 | .019 | 1.00 | | | |
| R | 077 | 052 | 038 | 1.00 | | |
| G | 188 | 092 | .113* | .112 | 1.00 | |
| IR | .244** | - | 094 | .125 | .177 | 1.00 |
| | | 133* | | | | |

Note: N,P,K concentration in soil at sample point.

R, *G*,*IR* : *Red*, *Green and Infra red channel of Landsat TM*. *,** Correlation significant at 5%, and 1% respectively.

Table 1 showed that the infra red channel had a significant correlation ($p \leq 0.05$) with the N properties $(r^2 = 0.12)$ and P in the soil $(r^2 = 0.14)$. The G channel also indicated a correlation with K ($p \le 0.01$) in the soil ($r^2 = 0.15$). The strength of R channel with the soil properties can be classified as weak ($r^2 = 0.03$). The r^2 of 0.03 indicated that the R channel is not capable in predicting soil properties in this case. This result is found similar with the studied by Tamaludin (2002) and concluded that the R channel is not recommended to be used in correlation of soil properties with the Landsat TM imagery. Although some channel of the satellite data can be used to investigate soil properties from spectral reflectance, this can vary depend on the angle of satellite sensor, mineral composition, soil moisture, organic matter content and soil texture (Shonk et al., 1991).

3.3 Analysis of spectral reflectance curves

Soil reflectance properties depend on numerous soil characteristic such as mineral composition, texture (particle size), structure (surface roughness), percentage of organic matter, and moisture content (Bunnik, 1981). These factors are interrelated but too complex and varies. The analysis of spectral curve in this study has identified the different between light and dark toned soil pixel in the remotely sensed data. Details analysis of the NPK or other composition is not possible due to inadequate data and the limitation of imagery used. The soil has easily distinguished in the visible and infra red wavelength. The light soil pixel toned indicated low in organic matter and moisture content and dark soil pixel toned indicate high in the organic matter and moisture content. The spectral reflectance curves of dark and light toned of soil in the study area is showed in Figure 8. Soil reflectance curves of both soil (light and dark tone) shows increasingly trend with wavelength in the visible and infra red spectrums. In infra red image soil with high moisture content appear darker compared to the dry soil dry. As the moisture content in the soil increase, the reflectance decreases and more significantly at the water absorption wavelength spectrum.

3.4. Image classification

Classification of Landsat TM data was conducted with intention to categorize the study area into thematic map. Supervised classification was done using maximum likelihood classifier and the result of the classification is shown in Figure 7. Classification was transformed each pixels of features in the image to the similar value of digital number where it's belong to (Lillesand and Kiefer, 1994). Thus it can't be used to support the correlation analysis with nutrient content. The area can be classified into two categories namely open area indicated in grey with soil covered and vegetation indicated in green which mostly by rubber, shrub and grass. Approximately more than 80% of the study area is an open or bare land.



Figure 7: Classification result of study area.



Figure 8: Spectral curves responses of light and dark toned of soil

4 Conclusions

The introduction of precision agriculture or sitespecific crop production systems assumes a detailed knowledge of the soil as the main production resource. Intensive sampling with GPS for location detection of the topsoil yielded data from which the spatial variability of macronutrients (N, P, and K) could be described by geostatistical techniques.and partly remote sensing data. : The variability in nutrients was characterized by semi-variograms, which can be used to define the size of management cells in spatially variable field management. For example, semi variogram analysis using geostatistics is capable of producing kriged map of N, P, K distribution in the study area with various level (N = 0.098 - 0.147 %, P = 10 - 24ppm and K = 62 - 129 ppm). The above study suggested improving the soil fertility in the northern portion of the farm by applying fertilizer, organic matter and lime. By this approach, the major soil nutrient maps could help the UiTM Farm Research Station Director in the identification and removal of the factors responsible for lower crop yield at those locations.

Prediction of NPK using Landsat TM image analysis and soil properties were found significant in infra red channel for N and P, even though the r^2 for N and P estimates in the study area is only within the range of 0.12 and 0.14. The use of remote sensing data alone has limitation in developing robust assessment of soil properties. However, imagery does show a potential in providing information for direct sampling and field specific management. Obtaining the soil properties information within field can improve the ability to manage the soil in the study area, however there may be considerable time elapsed between data collection and image availability.

Overall, this study suggest can that implementation of precision farming practices within the area could reveal both difficulties and opportunities with environmentally friendly awareness It is highly recommended in the future that combination of a very high resolution sensed especially remotely data airborne hyperspectral imaging, ground based sensor data (eg. Spectroradiometer) and other ancillary data integrated through appropriate model could improve the soil map with limited direct sampling.

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