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Soil Nutrient and Texture Mapping Using GIS for Rice Precision Farming

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Soil mapping using Global Information System (GIS) software is a method that can provide basic information on soil nutrient and texture status that could be presented accurately rather than using the random sampling method for a rice cultivation area. The objective of this study is to determine the level of soil nutrient and texture status for rice precision farming which involves chemical and texture analysis of local soil. The study was conducted during the first planting season of 2016 at PPK Estate of Sungai Limau Dalam, Batu 17, Yan, Kedah and covering an area of 9.5 hectares. A total of 96 soil samples with depths of 0-20 cm were taken using 40 m x 40 m grid sampling method marked with GPS before being analyzed and mapped. Overall, the study area consists of clay soil with the middle part of the rice field is silty clay loam. The fertility status indicated 7.65% of area was pH 5.5-6.5, 0.2% area with CEC 20.0-20.9 cmolc/kg, total N 0.20-0.30% covering 92.5% of the area, total P with 316.0-441.19 mg/kg was 86.3% of the study area, 53.2% area with exchangeable K 0.51-0.94 cmolc/kg and 74.8% of the area with 2.0-3.0% organic carbon. The findings of this study are very important in providing basic and accurate information on the status of soil nutrient and texture in this area.

Keywords: soil, mapping, precision farming, rice, global information system (GIS)

I. INTRODUCTION

Rice soils are heterogeneous about their physic-chemical properties in which has an impact on rice productivity (Aminuddin *et al.*, 2003). Currently, farmers had issues managing their soil and fertilizer application of their field. They usually practice conventional method when applying fertilizer without understand about soil properties as one of their parameters in agriculture practice (Kamarudin *et al.*, 2016). Imbalance fertilizer use may result in damaging effect on the long-term productivity (Yousof *et al.*, 2017), environmental pollution and health problems (Choudhury *et al.*, 2005). Thus, in conserving and managing the rice soils, it is vital to have information in hand of soil characteristics including soil nutrient and texture status. The ability to store and analyse the data is very essential. Digital maps are the most powerful tools to achieve this. Maps relate the feature to any given geographical location has a strong visualization (Ray et al., 2012).

The GeoGIS and geostatistical technique has been proved to be one of the most systematic and analytical ways to analyse the characteristics of soil nutrient spatial distribution. The pattern of variation would assist farmers or crop consultants for better nutrient management and as a scientific reference in developing site-specific management strategies (Kumar *et al.*, 2016). The approach of Global Positioning System (GPS) offers accurate methods for reliable positional information to be incorporated into field management decisions (Goswani *et al.*, 2012). According to Ramamurthy *et al.* (2009), the behaviour and response to field management and soil-based fertilizer recommendations should be preferred, in order to achieve

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precision in farming and thus to maximise crop production while maintaining soil health and minimising fertilizer misapplication. Research done by Kamali *et al.* (2017) in assessing the soil fertility indicated the fertility maps established using Geographic Information System (GIS) could be helpful for decision makers.

Proper fertilization is important for crop yield and quality. Xu *et al.* (2013) mentioned that in order to avoid under or over fertilization, the information of characteristic of distribution, pattern, spatial variability of soil nutrient and texture status may be used as a guide for precise fertilization based on the actual content of soil nutrient and soil characteristics. Therefore, in order to improve yield and proper soil-fertilizer management, this study has been done with the objective to determine the level of soil nutrient and texture status for rice precision farming which involves chemical and texture analysis of local soil.

II. MATERIALS AND METHOD

A. Study Area and Soil Sampling

The study was conducted during the first planting season of 2016 at PPK Estate of Sungai Limau Dalam, Batu 17, Yan, Kedah, covering an area of 9.5 hectares. It consisted of 20 small plots under rice precision farming project. The area is situated at latitude 5.89◦N, 100.44◦E longitude and at the elevation of 5 m above sea level. The location is shown in

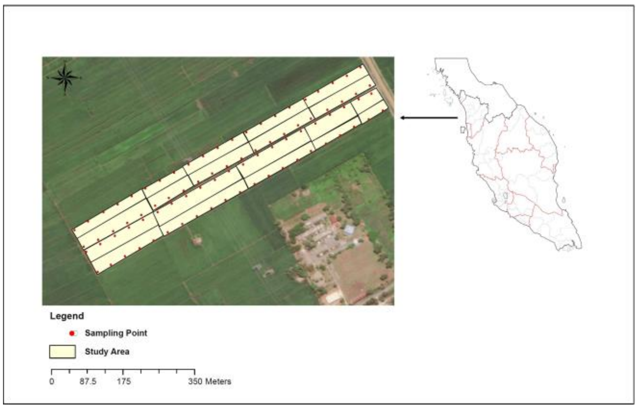

Figure 1. Typical map of the study area and soil sampling points

Samples were taken from 0-20 cm depths using 40 m x 40 m grid system. The total number of soil samples were 96 samples. Soil sampling, sampling locations (point) are georeferenced. This is accomplished using GPS equipment and mobile software. The collected soil samples were independently analysed for soil nutrient (pH, CEC, total N, total P, exchangeable K and organic carbon) and texture (soil texture). The analysis of soil pH was measured with pH meter on suspension of soil in distilled wa- ter at a 2:5 soil:solution ratio. Total N was determined using Kjeldahl Digestion method. Total P was analysed using Molybdenum Yellows method (Holman, 1943). CEC was determined measured Calorimetrically on auto analyser after leaching with NH4O and exchangeable K were determined by Flame Photometer method after leaching with NH4O. Organic carbon was determined using the potassium dichromate and H2SO4 di- gestion method (Walkley & Black, 1934). While soil texture was determined by using pipette method.

B. Assessment of Soil Nutrient and Texture Status

This study was using the QGIS 2.2 software in producing map to show the spatial distribution of soil nutrient and soil texture, and SPSS statistical software version 20 for geostatistical analysis method (Kamarudin *et al.*, 2016). Inverse Distance Weighting (IDW) interpolation using QGIS is a local interpolator that estimates the value at non-sampled location using a combination of samples weighted by an inverse function of distance from the point of interest to the sampled points, it is widely used as estimation techniques (Olena & Clayton, 2009). According to Mitas & Mitasova (1999), IDW produces local maxima and minima at the sample points. The general equation for IDW method is given in Equation 1.

$$Z_o = \frac{\sum_{i=1}^{s} Z_i \frac{1}{d_j^k}}{\sum_{i=1}^{s} \frac{1}{d_j^k}}. \quad (1)$$

In the equation above, Zo is the estimated value at unsampled point o, Zi is Z value at control point i, dj is distance between sample point i and point o, s is the number of sample points used in estimation, and k is the power factor. The IDW using QGIS 2.2 software allowing visualization in the form of raster and vector maps for the distribution and classifying of soil nutrient and texture with different colours rep- resent different values.

III. RESULT AND DISCUSSION

A. *Distribution Map of pH, CEC, Total N, Total P, Exchangeable K and Organic Carbon*

The spatial mapping of pH, CEC, total N, total P, exchangeable K and organic carbon of the study area are shown in Figure 2 to Figure 7. The variables of total N and organic carbon are measured in percentage, total P is measured in part per million (ppm or mg/kg), meanwhile the exchangeable K and CEC are measured in cmolc/kg.

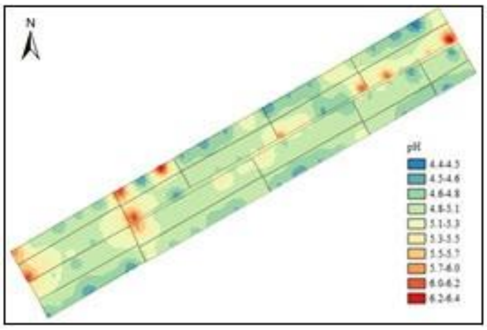

Figure 2. pH distribution map

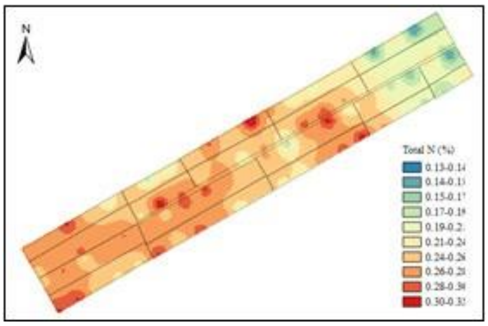

Figure 3. Total N% distribution map

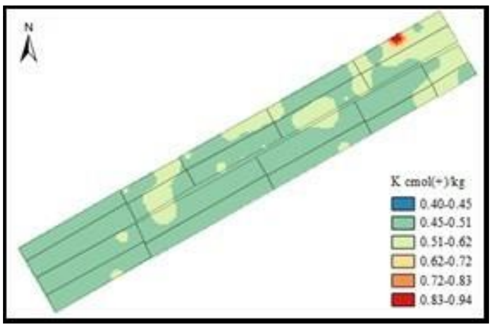

Figure 4. K (cmolc/kg) distribution map

The pH in the study area was range between 4.3 and 6.4 as showed in Table 1. While based on the acquired information from the mapping, it demonstrates that the status of the soil in the study area for pH was 7.65 with the range of 5.5-6.5 which slightly higher value compared to paddy soils in Barat Laut Paddy Project area in Selangor which range of 4.0-4.5 (Aishah *et al.*, 2010).

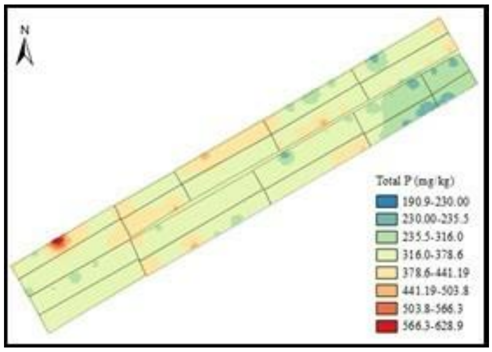

Figure 5. Total P (mg/kg) distribution map

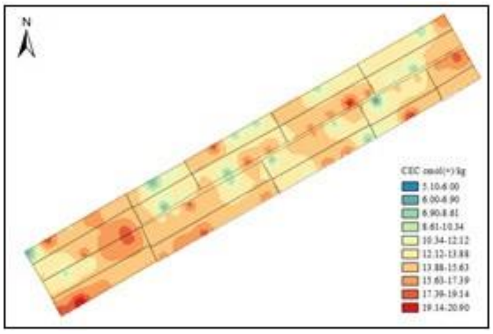

Figure 6. CEC cmolc/kg distribution map

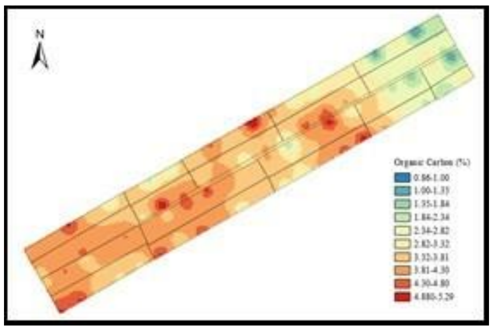

Figure 7. Organic carbon % distribution map

The total N was range between 0.13 and 0.32 (Table 1.) with 92.5 was in range of 0.20-0.30 which was lower compared to paddy soils in Barat Laut Paddy Project area in Selangor which range of 0.30-0.40 (Aishah *et al.*, 2010). While in study area of FELCRA Seberang Perak, Kamarudin *et al.* (2016)

indicated the total N was in the range of 0.17-0.20. This variability of results indicated that it is very important to have the soil nutrient information for a better crop management.

The exchangeable K was determined in the range of 0.40 and 0.94 (Table 1) with 53.2 was in range of 0.51-0.94 cmolc/kg which was higher compared to study done by Aishah *et al.* (2010) with the range of 0.01-0.45 cmolc/kg, while Kamarudin *et al.* (2016) indicated the range was 0.39-0.76 cmolc/kg in FELCRA Seberang Perak.

Table 1. Descriptive statistics of soil nutrients

Soil Properties	Minimum	Maximum	Mean value	Standard Deviation	C.V (%)
pH	4.4	6.4	5.0	0.5	0.10
Organic Carbon (%)	0.86	5.29	2.79	1.07	0.38
CEC cmol(+)/kg	5.05	20.9	14.0	3.62	0.26
Total Nitrogen (%)	0.13	0.32	0.24	0.04	0.17
Total P (mg/kg)	190.9	628.9	350.9	73.3	0.21
Exchangeable K cmol(+)/kg	0.40	0.94	0.50	0.06	0.13

Table 2. Correlation coefficient matrix among the variables

	pH	OC	CEC	Total N	Total P	K
pH	1					
OC	0.073	1				
CEC	-0.122	0.48	1			
Total N	0.155	0.433**	0.052	1		
Total P	0.268*	0.144	0.000	0.471**	1	
K	0.043	-0.111	-0.034	-0.044	0.149	1

The organic carbon indicated between 0.63 and 5.29 (Table 1) with 74.8 in 2.00-3.00 which was also in the range of study done by Aishah et al. (2010) with the range of 3 and 5. While total P was observed in between 30.6 and 628.9 mg/kg which observed most heterogenous in the study area. 86.3 of the total P was in range of 316.0-441.19 mg/kg. The value for CEC was determined in between 5.05 and 20.92 cmolc/kg (Table 1), with 0.2 was 20.0-20.9 cmolc/kg.

Pearson correlation analysis indicated moderate positive relation between N and Organic carbon at $p < 0.01$. This is shown in Table 2.

Weiguo *et al.* (2016) determined the soil organic carbon and total N were highly correlated in long-term experiment in Yamagata, Japan. While Aishah *et al.* (2010) found weak positive correlation among the two nutrients. In this study, there is also moderate positive relation between N and total P observed (Table 2), similar correlation was also observed by Hu *et al.* (2019) in investigating the fraction distribution and release of phosphorus from soil aggregates structure under different land uses in Sanjiang Plain, China.

B. Texture Distribution Map: Soil Texture

As shown in Figure 8, the study area consists of clay soil with the middle part of the rice field is silty clay loam. The USDA Land Texture Triangle is used to classify the soil in which refers to sand composition percentages where sand is 2.00-0.05 mm, silt is 0.05-0.002 mm where else clay is with a diameter smaller than 0.002 mm.

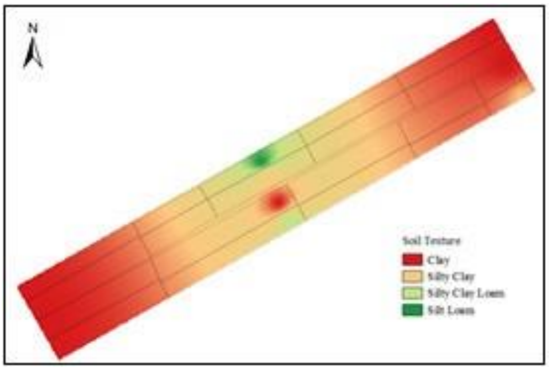

Figure 8. Soil texture distribution map

IV. CONCLUSION

The findings are vital in providing accurate information on the status of soil nutrients and textures in the studied area. This mapping can be used as a visual guide to provide nutrient in- formation based on yield targets, especially for rice cultivation. This method is most preferable as compared to the conventional methods where samplings are randomly taken and without map ping. Therefore, generally this GIS mapping can be used for the development of nutrient management strategies for intensive small plantation systems (Chatterjee *et al*., 2015).

V. ACKNOWLEDGEMENT

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