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Determining and Mapping Soil Nutrient Content Using Geostatistical Technique in a Durian Orchard in Malaysia

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Abstract

Soil nutrient are essential for crop growth. Spatial variability of nutrient can be occurred in various scales, between region, field or within field especially in variation in soil properties. Precision farming is a technology currently available for sustainable agriculture. This technology enables farm management is based on small-scale spatial variability of soil and crop parameters in the field. This study was carried out in a Durian Orchard at Bendang Man Agrotourism Project, Sik, Kedah, Malaysia. The objectives of this study are to determine and map soil nutrient content especially Nitrogen, Phosphorus and Potassium (NPK) variability in a durian orchard using geostatistical technique. The NPK was analyzed and mapped by Geostatistic Plus (GS++) to quantify the level of spatial nutrient available and predict nutrient values at unsampled location. Results indicated that NPK ranged from < 0.1 to 1.0 % (N), < 3 to > 45 ppm (P) and 0.8 to >1.4 cmol(+)/kg (K), respectively. Nutrient map showed that the area has less sufficient of N, while P and K were sufficient. This study revealed the potential and ability of geostatistical-variogram in determining and mapping soil nutrient content in a durian orchard. Furthermore NPK map can be used to apply fertilizer to an area, where less NPK content for efficient fertilizer management.

Keywords: Soil nutrient mapping, Precision farming, Soil nutrient analysis, Geostatistical technique, Durian orchard

1. Introduction

Precision farming is a management practice that has been enabled by Geospatial Information Technology (GIT) application and provides the framework within which arable managers can more accurately understand and control more precisely what happens on their farm (Mc Cauley *et al.,* 1997). Precision farming has become increasingly significant in the agricultural operations for the site-specific management. The management and manipulation of farming operation are vital decision-making process in improving crop productivity where there is a need to ensure efficiency in the management of agriculture. Information on soil properties in crop field is very important and useful for fertilizer requirement and also to the 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 studied in precision farming concept (Malek *et al.,* 2007).

Therefore, the general objective of the study was to produce a spatial digital map of NPK variability in a fruit orchard in Bendang Man, Kedah, Malaysia. The specific objectives are to determine and map soil nutrient content especially Nitrogen, Phosphorus and Potassium (NPK) variability in a durian orchard using Geostatistics. Latter, this map will be used for efficient fertilizer management.

2. Methodology

2.1 *Soil sampling and analysis*

The soil samples were collected at Bendang Man Agrotourism Project, Sik, Kedah. The durian orchard farm has an area of 3.75 ha with latitude 5°51'29"N to 5°51'34"N and longitude 100°49'33"E to 100°49'42"E. A total of 122 soil samples were taken at the base of the standing durian trees. Soil samples were taken for NPK analysis and the location of specific soil samples were identified using a Differential Global Positioning System (DGPS). Each soil was taken at 2 different depths i.e. 0 – 15 cm (top soil) and 15 – 30 cm (subsoil). Samples were then kept in labeled plastic bags and brought back to the laboratory for further treatment and analyses.

The soil samples were air-dried and sieved to pass 2 mm mesh sieve. The analysis carried out were Total nitrogen (by Kjeldahl digestion procedure (Anon, 1995), Total phosphorus (determined by double acid and Mehlich (Ball *et al*., 1979), and Exchangeable potassium (determined by ammonium acetate (Cole *et al.,* 1968). Semivariograms and kriged map produced from geostatistical software GS^{++}, version 3.1. From semivariogaram evaluation, the spatial variability of soil properties was generated. Descriptive statistic and variation of NPK nutrient status in soil was analyzed using SPSS tool. GIS software was used in producing map to show the spatial distribution of the NPK content. The classification of the nutrient content is classified according to Department of Agriculture Malaysia (1997).

3. Results and Discussion

The spatial variability map for total N [mol (+)/kg] in the study area is shown in Figure 1. The total N at 15 cm (topsoil) and 30 cm depth (subsoil) ranged between <0.1 and 0.3 %, <0.1 to 1.0 % respectively. According to Soil Survey Staff (1997), these ranges could be classified as very low and low (topsoil) and very low and high (subsoil). The total N in the soil comprises of two forms, namely organic N and inorganic N. However, inorganic N in the soil at any moment was only a small fraction of total N (Lindsay, 1979). About 82.68 % of the study area (0-15 cm) was classified as low level and 17.32 % was very low whereas, for 15-30 cm, 0.1 % was classified high, 2.21% (moderate), 36.50 % (low) and 61.19 % (very low). The low content of the total N in the area were due to denitrified, leached or volatilized N from soil. In general, total N under subsoil was higher than total N at topsoil. At the topsoil, about 17.32% of the study area especially at the central was found having very low N which might be due to high slope (more 10 %). Higher slope usually move away the N to downward direction. However, the variation of total N in the area was not significant due low ranges as shown in Table 1. Meanwhile, the availability of total N is presented in Table 2.

The total P content was more than 45 ppm for topsoil, while for subsoil the content was ranged between ±3 to ±45 ppm (Figure 2). ANOVA table for P was presented in Table 3, while Table 4 showed that availability of P for the topsoil can be classified as very high (99.9 %) to very low (0.1%), respectively. However, the P content for subsoil were less than topsoil ranging between low to moderate, high and very high, which represented 1.05%, 31.7%, 56.08% and 11.17% of the study area. The differences is due to fertilizer is usually applied to the topsoil and P does not leaching easily like NO_3. Moreover, topsoil received nutrients from tree leafs and organic matter by decomposition.

The southern and northern regions of the study area contain high P (25-45 ppm) because the slopes of the areas were low (less than 3%) and P content represent about 56.8 % of the total area. The central and far northern regions represent about 31.7% where P content was moderate (10-24 ppm). The slope in these areas was higher more than 10%. Hence, the higher content of P was occurred in low slope areas. A significant variation of P content was found between the two soil-depths and also in difference slope classes

The spatial content of the exchangeable K in the soil were illustrated in Figure 3.The map showed that the content of exchangeable K for topsoil and subsoil were classified into two classes as high and very high. Significant variations of K between two soil layers were as shown in Table 5. As classification the exchangeable K content were very high in both soil layers, more than 1.4 cmol(+)/kg, where topsoil represent 95.96% and subsoil 87.54% of total study area (Table 6). It noticed that the amount of Potassium in the topsoil much higher than subsoil, due to high organic matter present in the topsoil. Similarly, K was found higher in topsoil than subsoil because K was stable in the topsoil and decomposition of organic matter adds K content in the soil

4. Conclusion

From the study it can be concluded that by using Geostatistical –variogram analysis and spatial interpolation (kriging), there is possible to determine and mapped of NPK distribution in a Durian orchard at Bendang Man Agrotourism Project, Sik, Kedah, Malaysia. In fact, result showed that the NPK variability in soil were spatially ranging from two soil depth from <0.1 and 0.3% (N), <0.1 to 1.0% (N), <3 and >45 ppm (P),<3 to >45 ppm (P), 0.8 to >1.4 cmol(+)/kg (K), 0.8 to >1.4 cmol(+)/kg, respectively. Thus the NPK content in soil analysed in this study revealed that the Durian orchard is poor in N. Therefore it requires more N fertilizer inputs if durian productivity is to be increased. Meanwhile, P and K are sufficient for this site, and the management does not need to add more P and K fertilizers to the orchard.

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Table 1. Anova for Total Nitrogen

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sampling locations	0.865459	60	0.014424	1.079648	0.383792	1.534314
Soil layers	0.013562	1	0.013562	1.015106	0.317729	4.001194
Error	0.801612	60	0.01336			
Total	1.680634	121				

Table 2. Classification of total N availability in the study area

Class	N%	Area (%)	
		Topsoil	Subsoil
High	0.6 – 1.0	0	0.1
Moderate	0.3 – 0.6	0	2.21
Low	0.1 – 0.3	82.68	36.5
Very Low	<0.1	17.32	61.19

Table 3. Anova for Phosphorus

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sampling locations	116341.4	60	1939.024	1.938375	0.005703	1.534314
Soil layers	27462	1	27462	27.45281	0.000002	4.001194
Error	60020.08	60	1000.335			
Total	203823.5	121				

Table 4. Classification of P in the study area.

Class	P (ppm)	Area (%)	
		Topsoil	Subsoil
Very High	> 45	99.9	11.17
High	25 – 45	0	56.08
Moderate	10 – 24	0	31.7
Low	3 – 9	0	1.05
Very Low	< 3	0.1	0

Table 5. Anova for Exchangeable Potassium

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	109.4631475	60	1.824386	6.679857	0.0000000	1.534314
Columns	8.57275082	1	8.572751	31.38851	0.0000007	4.001194
Error	16.38704918	60	0.273117			
Total	134.4229475	121				

Table 6. Classification of Exchangeable K in the study area.

Class	K [cmol(+)/kg]	Area (%)	
		Topsoil	Subsoil
Very High	> 1.4	95.96	87.54
High	0.8 – 1.4	4.04	12.46

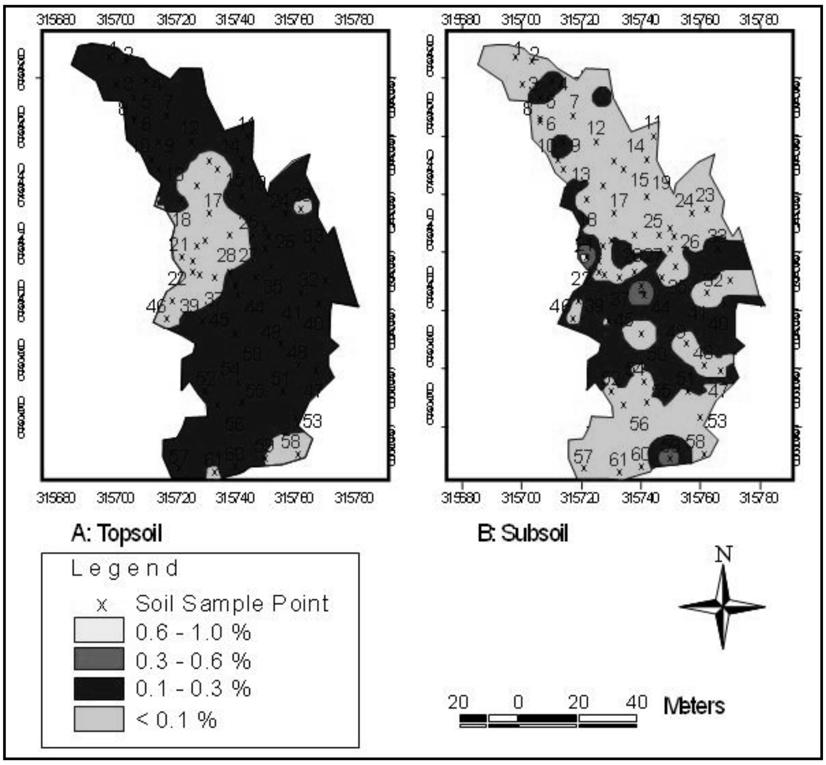

Figure 1. Spatial distribution of total N in soil

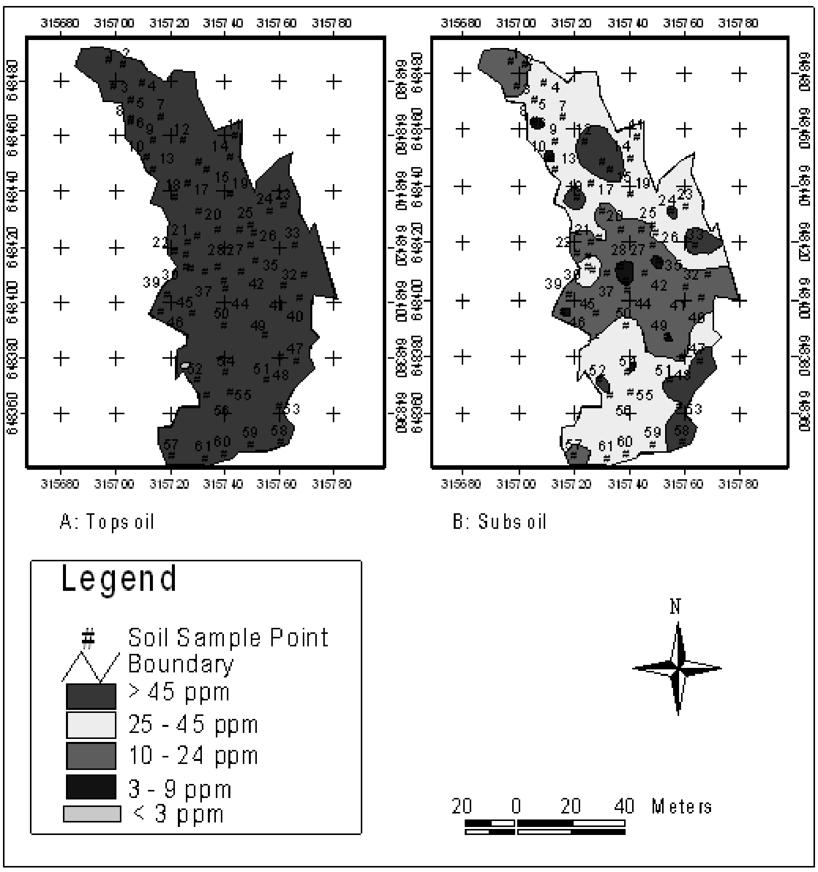

Figure 2. Spatial distribution of P in soil

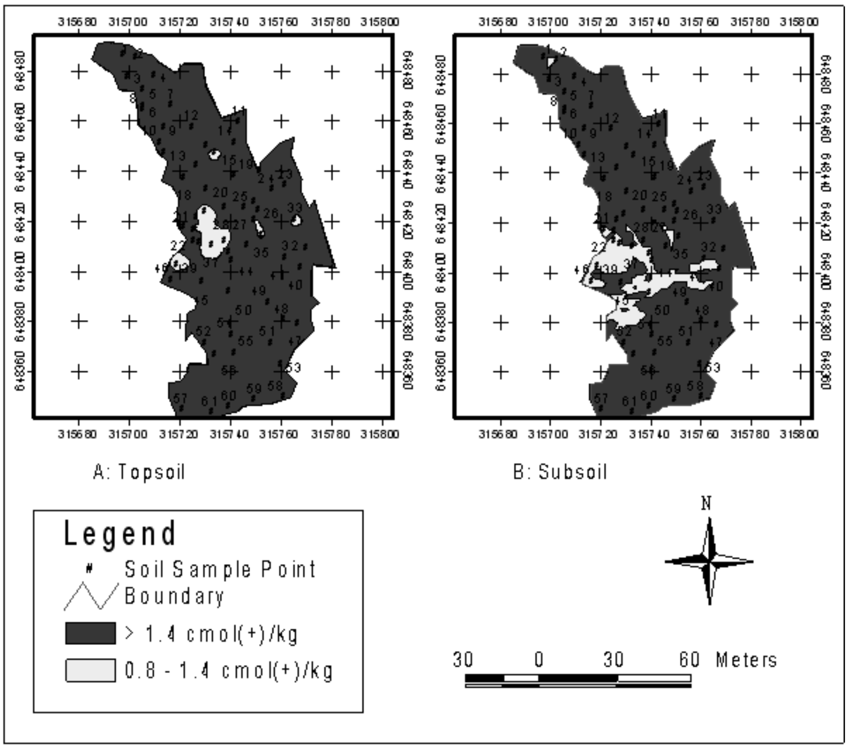

Figure 3. Spatial distribution of Exchangeable K in soil