Spatial variability of soil nutrient in paddy plantation: Sites FELCRA Seberang Perak

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Abstract: The conventional methods currently used for rice cultivation for Malaysia unable to give maximum yield although the yield production of paddy is increasing. This is due to the conversional method unable to included soil properties as one of their parameter in agriculture management. Soil properties are vary spatially in farm scale due to differences in topography, parent material, vegetation or land management and soil characteristics as well as plantation productivity can varies significantly over small spatial scales. Knowledge of spatial variability in soil fertility is important for site specific nutrient management. Analysis of spatial variability of soil nutrient of nitrogen (N), phosphorus (P) and potassium (K) were conducted in this study with the aid of GIS (i.e ArcGIS) and statistical softwares. In this study different temporal and depths of soil nutrient were extracted on the field and further analysis of N,P,K content were analysed in the chemical laboratory and using spatially technique in GIS software. The result indicated that for the Seberang Perak site of 58 hectares area, N and K are met minimum requirements nutrient content as outlines by the MARDI for paddy cultivation. However, P indicated poor condition in the study area; therefore the soil needs further attention and treatment.

KEY WORDS: spatial variability, interpolation technique, GIS, paddy plantation

1. Introduction
1.1 Scenario paddy industry in world
Paddy is a major source of atmospheric methane, yet vast amounts of paddy is continue to be grown in order to meet increasing global food demand. Countries in the East Asia region such as China, Japan, Taiwan and Korea are an important rice growing region of the world (Maclean et al. 2002) with China is higher than other countries for rough paddy production in 6.23 (t/ha) which is 20% for cultivation area and 31.8 % for paddy production in the world reported by (Maclean et al. 2002) and requires large field area compared to the other plantations and estimated are about 90% of paddy cultivations produced in Asia. It indicates that Asia’s people need rice as staple food such as Malaysian people.

1.2 Overview paddy production in Malaysia
In Malaysia, paddy is one commodity that is given priority in the national food security the agenda. To ensure that food production is assured, many efforts have been taken by the government to increase the production of commodity (Firdaus et al. 2014). Every year, thousands of tones of rice are produced to fulfill demand of 29.34 million Malaysians(MOA 2012). However, the country's rice supply is still insufficient. (MOA 2011) Paddy by season which indicated that paddy production is increasing every year in Malaysia from 1980 to 2010. In 2010, Malaysia experienced 30% shortage of rice supply and caused Malaysia government importing 700,000 tones of rice from other countries (FELCRA 2013).
To solve this problem, the government initiated a goal for Malaysia to produce and supply 100% of the rice needs in 2015. The farmers also had problem with soil and element of fertilizer which is individual farms management usually practicing conventional method of fertilizer distribution. However, conventional methods unable to generate maximum yield of rice cultivation (Liu et al. 2014). Among the issues related tosoil are fertility problem and the fertilizer is not uniformly and equally distributed in paddy field area. Nutrient levels suitable for paddy cultivation are required to increase rice seedling growth and to achieve targeted production levels. Since soil nutrient levels vary across paddy regions, it will cause less paddy production. Therefore, soil treatment needs to be done. However, this approach leads to unnecessary financial costs and can have adverse effects on the environment waterways and weed pests. In addition, crop production will be affected. Soil fertility assessments commonly rely on a random soil sampling protocol to obtain an average fertility. Thus, spatial variability is ignored and, consequently, some parts may receive excessive fertilizer while other parts may suffer nutrient deficiency (Liu et al. 2014). The farmers should monitor their paddy plant by own since it is private individual lots of paddy. The problem normally facing by the farmers is related to soil fertility and unequal fertilizer distribution which normally associated with less paddy production. Many factors caused different in paddy yield, however, this research will only focuses on soil fertility condition and spatial fertilizer distribution.

1.3 Cultivation paddy in Malaysia
Paddy cultivation in Malaysia has two growing seasons. The season 1 (off-season) is between March to July which normally associated with drought condition for the Malaysia’s weather. Farmers have challenges to accept risks environment like drought due to water requirement is affected in paddy cultivation. During this season, the main requirement for paddy plantation is water supply that is pumping from the river. The season 2 (main season) is between August to February. In this season, of the paddy field normally receives alarge amount of rainfall which is a major of water supply for paddy plantation (MOA 2012). Figure 1 shows the growth phase of paddy cultivation in Malaysia. The average time for paddy cultivation is 90 days. Therefore, in this study, 2 different conditions and period of soil sampling were acquired for soil nutrient. The first sampling is before paddy cultivation which is land preparation stage by the farmer. In this period, the land is cleared, loosened and flattened before planting the rice seedlings and before fertilization stage. Secondly, soil sampling before the harvesting time approximately 100 days of paddy cultivations with soil fertilization has taken place (Figure 1). The first session of soil sampling was using an auger to carry out during the first preparation works of land. In this period, the land is cleared, loosened and flattened before planting the rice seedlings. The purpose of this soil sampling is to examine the soil fertility status of the land taken before the fertilizing process takes place. Soil sample was done systematically with one sample for each lot. One lot of total study area is equivalent to 1.03 hectares. For every lot soil sampling was taken at two different depths of 0-20cm and 20-40cm as normally practiced by the MARDI for soil sampling activity to extract soil chemical properties. After that process, appropriate soil treatment will able to be suggested.
2. Study area

2.1 Site of Felcra Seberang Perak, Perak

Felcra is a big organization estate plantation which established in Malaysia such as the Felcra Seberang Perak. Total granary area in Seberang Perak is about 16,437ha (MOA 2011). Figure 2 shows the study area of Felcra Seberang Perak. The farms management is managed by the Felcra Berhad. The study area is also research study site that conducted by Malaysia Agriculture Research Development Institute (MARDI) and Kawasan Pembangunan Pertanian Bersepadu (IADA) agencies at the small plots area Felcra Seberang Perak with estimated total area is 1.03 hectares. Felcra Seberang Perak is one of plantation estate managed by Felcra. This area is totally having a systematic management by Felcra and it’s proven in 2013, total rice production in the fields Felcra is 45,951.95 tones (Felcra 2013). Figure 4 is paddy plots field with estimated total area is 58 hectares. It is under MARDI Research Station authority. The fields have facilities of irrigation water from Perak River to canal and direct discharge of water to tertiary drains.

2.2 Soil sampling and laboratory analysis requirements

The soil cores of each point for every plot were collected that cover area of approximately 58 ha. Core sampler and auger was used to collect topsoil samples at depth 0-20cm with the soil surface cleared from coarse rice straw debris. Soil samples were collected inside the box rather than at grid intersection in order to reflect the entire field. After activity of soil sampling is done in the field the samples were taken to soil chemist laboratory and marking it using a systematic numbering. Analysis of nitrogen using a method kjedahl (Zarina Zakaria, Alina Rahayu Mohamed 2013), then phosphorus (P) and potassium (K) will be derived (Figure 3).

![Figure 1. Phase growth of paddy](image1)

![Figure 2. Site location of soil sampling](image2)

![Figure 3. Flow chart of sampling and laboratory works.](image3)

According to (Eltaib1 et al. 2002) the distribution of soil chemical properties, especially the amount of nitrogen (N), available phosphorus (P), and converted Potassium (K). It is important for farm management practices and to assess the impact agriculture on the environment. The range of the
concentration for the soil parameter is classified according to the Department of Agriculture (DoA) as shown in Table 1.

Table 1. Soil classification of nutrient content; N, P, K (Source: DoA, 1997)

| Nutrients       | N (g/kg) | P (mg/kg) | K (cmol(+)/kg) |
|-----------------|----------|-----------|----------------|
| Very High       | > 10     | >45       | >1.40          |
| High            | 6-10     | 25-45     | 0.80-1.40      |
| Moderate        | 3-6      | 10-25     | 0.45-0.80      |
| Low             | 1-3      | 3-10      | 0.14-0.45      |
| Very Low        | <1       | <3        | <0.14          |

Table 2. Optimum soils chemical properties value for paddy requirement

| Chemical Property | Optimum requirement |
|-------------------|---------------------|
| Total Nitrogen (%)| 0.2-0.3             |
| Available P (mg/kg)| >40                 |
| Exchangeable K cmol(+)kg | >0.1               |

In this study GIS analysis was used to derive nutrient content of N, P, and K classification. In comparison of soil nutrients this research will adopt optimum values of soil nutrients for paddy planting as recommended by Malaysian Agriculture Research and Development Institute (MARDI) (Table 2). The levels for each variable on the spatial maps were set based on the standard range for paddy soil, recommended by MARDI.

2.4 Geostatistical analysis in soil management of paddy plantations

This study will use Geographic Information System (GIS) as mapping technique and and SPSS as geostatistical analysis method. According to (Xu et al. 2013) techniques of geostatistics are used to perform traditional statistical analysis and spatial structural analysis with ArcGIS, geostatistical software GS+ and statistical software SPSS in order to obtain the knowledge of characteristics of distribution and spatial variability of soil nutrients. Software ArcGIS geostatistical analyst is an extension that provides capability for surface modeling using deterministic and geostatistical methods. (Qiu et al. 2011) also mentioned geostatistics coupled with geographic information system (GIS) technologies has substantial potential to discern spatial patterns. (Qiang et al. 2011) stated that descriptive analysis and Kolmogorov-Smirnov (KS) test were carried out on SPSS17.0 and calculation of experimental semivariogram, model fitting and map drawing were completed on ArcGIS 9.3 software. (Aishah et al. 2010) Geostatistical analyses were applied to examine the within-field spatial variability using semivariograms and kriged maps (Junusi & Hasmadi 2009) in the previous research is 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 N, P, and K content. The use of spatial information for managing plant nutrients focuses on using maps and map soil to determine appropriate application of fertilizer can be added or subtracted to correct the deficiencies, saving input costs, and make the field more uniform.

3. Result and Discussion

3.1 Temporal soil nutrient spatial mapping

The data consists of 49 sampling points in Seberang Perak site. Variables of Nitrogen (N) which is measured in term of gram/kilogram (g/kg), phosphorus (P) is measured in as part per million (ppm or mg/kg) and potassium (K) is measured in cmol (+)/kg. Figure 6 illustrates spatial analysis distribution of variable N, P, K for two different times sampling which are before and after fertilization. The results of variables N, P, K were analyzed according to Table 2 that shows the range of the optimum soil chemicals properties values for paddy requirement is classified according to the MARDI guidelines. Table 3 shows the mean value for 1st cycle samples of N, P, K on depth of 0-20cm with the results of 1.783g/kg, 9.938mg/kg, 0.399cmol(+)/kg respectively. For the 2nd cycle sample on depth 0-20cm in the study area were 2.0485g/kg, 12.868mg/kg, 0.7649cmol (+)/kg respectively.
However these mean value for 1st circle shows low contents of N, P, K in the soil compared to the range reported by DOA (refer Table 2). In the 2nd session cycle sample indicated values of N and K higher and achieved optimum range 2.0485g/kg and 0.7649 cmol(+)kg as compared to variable P of 1.9678mg/kg which is very low. The optimum range as stipulated by the MARDI guidelines for variable P is 40mg/kg.

Table 4. Summary of N, P, K content on depth 20-40 in two (2) circle sampling at study area Seberang Perak

| Variables | Circle sampling | N(g/kg) | P(mg/kg) | K(cmol +/kg) |
|-----------|-----------------|---------|----------|--------------|
|           | 1st             | 2nd     | 1st      | 2nd          | 1st          | 2nd          |
| Standard deviation(δ) | 0.1598 | 0.1572 | 0.5051 | 0.908 | 0.0360 | 0.0951 |
| Mean(μ) | 1.1271 | 1.5461 | 2.5213 | 5.702 | 0.3126 | 0.6149 |
| Coefficient of variation (%) δ/μ*100 | 14.18 | 10.17 | 20.03 | 15.92 | 11.52 | 15.47 |

Table 3. Summary of N, P, K content on depth 0-20cm in two (2) circle sampling at study area Seberang Perak

| Variables | Circle sampling | N(g/kg) | P(mg/kg) | K(cmol +/kg) |
|-----------|-----------------|---------|----------|--------------|
|           | 1st             | 2nd     | 1st      | 2nd          | 1st          | 2nd          |
| Standard deviation(δ) | 0.308 | 0.309 | 2.204 | 1.968 | 0.065 | 0.264 |
| Mean(μ) | 1.783 | 2.0485 | 9.938 | 12.868 | 0.399 | 0.7649 |
| Coefficient of variation (%) δ/μ*100 | 17.27 | 15.08 | 22.17 | 15.29 | 16.29 | 34.51 |

Figure 4. Spatial analysis distribution of N, P,K values on depth 0-20cm in Seberang Perak

Figure 5. Spatial analysis distribution of N, P, K values on depth 20-40cm in Seberang Perak
Table 4 shows the mean value of 1st circle sample of N, P, K on depth of 20-40cm of 1.1271g/kg, 2.5213mg/kg and 0.3126cmol (+)/kg respectively. For the 2nd cycle sample variable of N, P, K on depth of 20-40cm were 1.5461g/kg, 5.705mg/kg and 0.6149cmol (+)/kg respectively. The results indicated that the values of N, P, and K in two different depths are not much difference to each other’s (Figure 7). In term of soil sample depth, (Aminuddin et al. 2003) reported assessment of paddy soil degradation has significant different result for two different layers of depth. The studies had proven soil sampling at two different soil layers which is in the top soil (0-20cm) has more reflected the soil degradation and the sub soil (20-40cm) which represent the subsoil indicated least affected soil degradation.

4. Conclusions
The spatial mapping of the N, P, and K soil nutrient indicated varies result for both condition of before and after fertilization as well as two different depths. The result derived on the study site was compared to the optimum values of soil chemical properties recommended by MARDI. The results showed that the study needs further treatment of soil fertilization of N, P, and K distribution. Furthermore, the result revealed that the variable P are very minimal with mean value range of 9.938mg/kg to 12.868mg/kg and 2.5213mg/kg to 5.702mg/kg in two sampling cycles respectively compared to minimum requirements of 40mg/kg. Therefore, further, nutrient treatment of value of phosphorus (P) is needed for this study area of the Felcra Seberang Perak. It is hope that with the geospatial analysis as conducted in this study, the plantation management such as paddy plantation able to makes better decision making which regard to soil nutrient fertilization and management in order to minimizing cost and maximizing paddy production.

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