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# Soil NPK Variability Mapping for Harumanis Mango Grown in Greenhouse at Perlis, Malaysia

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***Abstract*— Soil is essential for plant growth. The soil provides support for plant, medium for root growth, and most importantly it offers nutrients for plant uptake. The nutrients variability in soil is vary depending on several factors such as soil type, soil microbes, and soil pH. Therefore, nutrients available in the soil is important to be mapped to investigate the state of nutrient present. In this study, the available content of Nitrogen (N), Phosphorus (P) and Potassium (K) were determined for a high-density planting systems of Harumanis mango plants grown in the greenhouse. Thirty-two soil samples were collected from a greenhouse for analysis of NPK content in top soil. The soil was analyzed using the Kjeldahl method, UV Spectrophotometer and Atomic Absorption Spectroscopy (AAS) for N, P, and K content respectively. These amount of macronutrients were then mapped with respective georeferenced location to produce NPK nutrients maps using standard classification in ArcGIS software. Results have indicated that N, P, and K were ranged between 0.06 - 0.12% (very low), 4 - 648 ppm (low-very high) and 0.02 -1.37 cmol/kg (low-high) accordingly. Overall, it can be concluded, soil in selected greenhouse is poor in N, high in P and moderate in K content. Hence, it is suggested more N and adequate amount of K fertilizer should be supplied to increase the plant's productivity. The produced maps give a new perspective in a farming management concept in term of variable rate fertilizer application for Harumanis mango plants grown in the greenhouse.**

***Keywords*— soil nutrient; ArcGIS mapping; precision farming; variable rate fertiliser; harumanis mango.**

## I. INTRODUCTION

Mango is one of the popular tropical fruits in South Asia including Malaysia. Mango or Mangifera indica have several varieties. The most popular mango variety in Perlis is ‘Harumanis’ which is due to its aroma, texture, and sweetness. The demand of Harumanis is increasing year by year, and the selling price per kilogram is almost tripled compared to other varieties. This situation has encouraged the local growers to enlarge their Harumanis farming. Thus, making Harumanis a premium mango fruit being produced in Perlis.

It has been reported that the export of Harumanis mango in 2010 has reached 3.1 metric tonnes [1]. Most of the production was exported to Japan as Japanese has a positive acceptance towards Harumanis mango and their tendency to buy is high whenever the fruits are available in their market [2]. The climate condition in Perlis is a major factor of why this Harumanis variety is suitable to be grown here. Harumanis mango tree needs a significantly dry period to initiate the flowering. The flowers start to bloom from January to February and the fruit-bearing period is from March to April. The fruits are harvested from May to June every year.

Apart from climate, the soil also plays a great influence on Harumanis growth as the soil is a major source of nutrient needed by plants. The main nutrients in the soil are the most important soil nutrients are nitrogen (N), phosphorus (P), and potassium (K). The presence of nitrogen is important and crucial for crop growth.

The presence of nitrogen is important and crucial for crop growth. Nitrogen stimulates vegetative growth and ensures high rates of flower formation, fruit-set, and assimilation inflow into developing fruits [3]. Lack of nitrogen will cause decreases in plant productivity and fruit quality [4] while excessive nitrate contribute to contamination of water sources through volatilization, denitrification, and leaching.

Phosphorus is the second most essential nutrient responsible for plant growth. It is a constituent of plant cells, essential for cell division and development of the leaf. Phosphorus in the soil is available in two forms, primarily as monovalent phosphate anion and divalent anion. The deficient of P will restrict the root and tree and make the plant growth is retarded. Previous research shows that daily, a rapidly growing crop may take up the equivalent of about 2.5 kg $P^2O_5$ per hectare for phosphorus [5].

Other than nitrogen and phosphorus, potassium plays as an important nutrient for photosynthesis, respiration, and growth in the expansion and development of cells in the plant. Recent investigations have raised awareness of the impact of Potassium on the soil structure and its ability to capture water. It was reported that the application of mineral K fertilizers enhances the water-holding capacity of soils and also improves the structural stability of sandy soil in particular [6]. In contrast to nitrate deficiency and phosphorous deficiency, potassium deficiency rarely results in the accumulation of starch, whereas accumulation of sugars was often observed in K-deficient leaves [7]. Therefore, a sufficient amount of nutrient especially N, P, and K in soil and suitable climate are crucial to maximize the growth of Harumanis for better production of a premium mango fruit.

Currently, as part of normal practice, the local growers plant Harumanis tree in an open farming system. However, there are some limitations in the open farming system. Climate and nutrient are beyond control. The climate is solely depending on the season while some nutrients added to the soil through the fertilizer might lose due to run off as an effect of precipitation. Besides that, plants are highly exposed to pest and disease. Therefore, most growers use heavy pesticides and chemicals which lead to pollution. Hence, greenhouse farming systems are introduced to replace open farming systems for Harumanis production to overcome the limitations.

The greenhouse farming systems were approach with high-density planting system (HDPS). This to ensure sustainable crop production through the advanced agricultural approach of high-density planting system (HDPS). The implementation of HDPS will allow all year round of Harumanis production by staggering the flowering and fruiting of the plant. The innovative way of monitoring soil nutrients and climate can be done positively by applying the precision farming concept.

Precision farming (PF) is a concept based on the recognition of spatial and temporal variability in crop production [8]. This concept has been recognised in improving crop productivity while reducing environmental risks [9]. The worldwide perspective of precision farming has been intensely discussed, and Malaysia includes in several countries that had started the precision farming practice ([10]-[11]). The finding showed that the adoption of the precision farming among farmers in the Integrated Agriculture Development Area (IADA) Barat Laut Selangor, Malaysia is at a high level [8].

The high technology PF requires several elements such as Geographic Positioning System (GPS) and Geographic Information System (GIS). The use of GPS is very important to make sure the prescribed location on earth is mapped accurately. Well documented record of GPS data in GIS is a vital process for immediate accountability, plotting historical trend and ultimately provide better management of nutrient and water [12]. The use of these two systems helps in focusing on a specific location as the farm's input and practices can be adjusted to maximize benefit from mapped location.

The information on plant nutrient status in the nutrient map is useful not only for fertilizer requirement but also for a specific crop and soil management of variable rate fertilizer application. Thus, researchers are focusing on mapping the macronutrients in soil such as Nitrogen (N), Phosphorus (P), and Potassium (K) which is vital for plant growth. The spatial distribution maps of these selected nutrients were normally produced using GIS software. GIS software may help researchers in forecasting in real time and establish various types of map, i.e. yield, soil, and nutrient map ([13]-[16]). Soil nutrient content of NPK has been analyzed and mapped based on its location to observe its variation and availability level ([17]-[18]). In another study, ArcGIS also has been utilized to forecast the ideal condition for effective and more consistent Harumanis mango production [19]. However, all of these studies were done in open field farming, and no report was found on NPK nutrients mapping in the control environment using ArcGIS. Therefore, in this study the nutrient map of N, P and K were established to evaluate the nutrient status and its variation under controlled environment (greenhouse).

## II. Material and Method

The study was conducted in a greenhouse (GH03) at the Institute of Sustainable Agrotechnology (InSAT), Universiti Malaysia Perlis (UniMAP) Padang Besar, Perlis, Malaysia (Fig. 1). The GPS position of this study is N6.65203, E100.260908, at 53m above the sea level.

Fig. 1 Greenhouse GH03 in InSAT

The area is characterized by drought season from January to March and the rainy season from September to December with the maximum temperature recorded up to 40°C. Generally, the soil in the greenhouse comprises of clay soil which made up from extremely fine particles that have high water-holding capacity.

The greenhouse covers an area of 0.2 hectares and has a dimension of 24.2 m width with 84 m length. This double-bay greenhouse is planted with a total of 208 Harumanis mango plants. The age of the Harumanis plant inside the greenhouse is 1 year. The soil in the study area comprises of clay soil which has extremely fine particles and has a high water holding capacity. The planting procedure follows the standard crop husbandry practice for high-density planting except for pruning and micro-climate controlled. Plants are watered every day by a drip irrigation system installed. The fertilizer is scheduled to be supplied to the plant annually. This study followed the research flow process as indicated in Fig. 2.

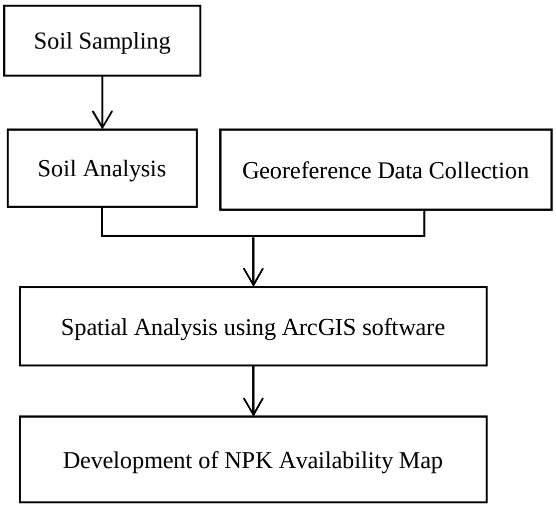


Fig. 2 Research flow process

### 1) *Soil Sampling and Analysis*

Soil samples were collected based on the staggered grid sampling method. Soil auger of a bucket type was used to take 32 soil samples for the analysis of NPK. The samples were taken at 15 cm depth below the ground surface at a radius of 15 cm from the plant's trunk in an area of the active root zone (Fig. 3). The time scheduled for the soil sampling was in the morning from 9 am to 11 am.

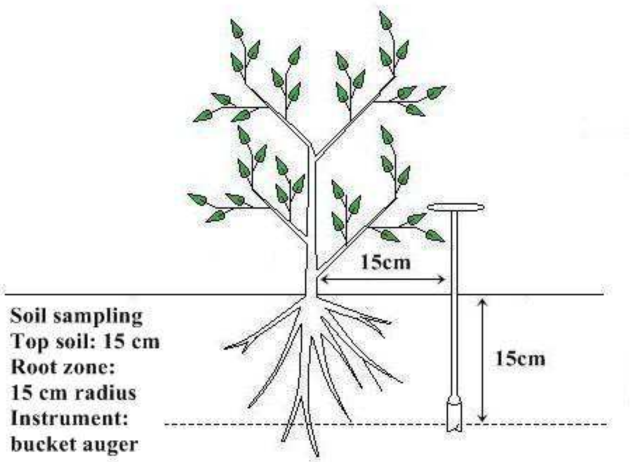


Fig. 3 Soil Sampling

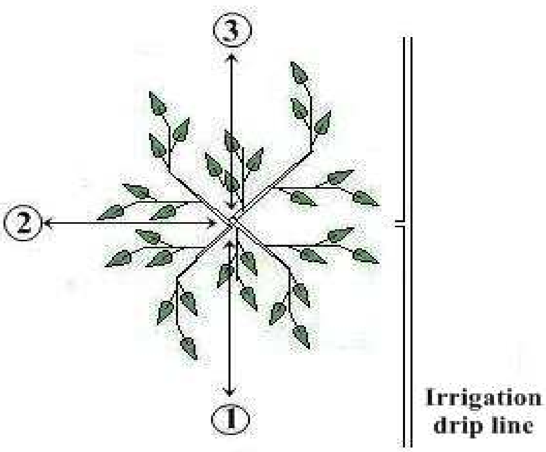


Fig. 4 The position of composite soil sampling (3 composite soil per tree)

The soil samples were collected compositely for each selected tree (Fig. 4) as composite soil sample should represent a uniform field area that has a similar crop and fertilizer history for at least the last two years. The soil samples were sent to the Soil Laboratory at the Department of Agriculture for standard soil analysis test.

The soil was analyzed using the Kjeldahl method [20], UV Spectrophotometer and Atomic Absorption Spectroscopy (AAS) for N, P, and K content respectively. Kjeldahl method or Kjeldahl digestion is the method used to determine total nitrogen content in the organic material. The method consists of three steps; digestion, distillation and titration of the nitrogen/ammonia. The UV Spectrophotometer was used to measure phosphate and phosphorus content of the soil sample by comparing its absorbance at a specific wavelength to a standard phosphate curve. The AAS method is an analytical technique that used to determine the concentration of a particular element either in solution or solid sample. In this study, the AAS method was used to determine the concentration of potassium in a soil sample taken.

### 2) *Georeference Data Collection*

Georeference location of each sample was identified using GPSMAP 76 CSx. Each georeferences or coordinate data consists of latitude, longitude, and elevation data. Latitude and longitude data, in general, refer to northing and easting, respectively. This geographic coordinate system was converted to the projected coordinate system for mapping purpose. The projected coordinate system normally has constant lengths, angles, and areas on a flat, two-dimensional surface.


Fig. 5 GPSMAP 76CSx used for georeferenced data collection [21]

### 3) *Spatial Analysis and NPK Mapping*

The spatial analyst was used to provide data set of spatial analysis for both raster (cell-based) and feature (vector) data in this study. The data of NPK content and its respective georeference locations were imported into GIS software. GIS software is a software used to store, retrieve, manage, display, and analyze all types of geographic and spatial data. Specifically, geostatistical analyst tools from ArcGIS software version 10.1 [22] was used in producing a map to show the spatial distribution of the NPK content of the study area.

The NPK availability map was produced by using inverse distance weighting to represent current soil nutrient status in the greenhouse. Inverse distance weighting is a type of interpolation method that is commonly used. In this method, the assigned values to unknown points are calculated with a weighted average of the values available at the known points [23]. The mapping was coloured by using raster data set color map function instead of grey scale based on designated unique value. Thus, the three mapping developed in this study are; N availability mapping, P availability mapping and K availability mapping.

## III. Result and Discussion

### *1) Soil Sampling and Analysis*

There is a total of 32 data samples which have N, P and K data based on selected sampling location. The data were analysed and summarised as shown in Table I. Whereas the variation of a data sample of each nutrient was shown in Fig. 6, 7 and 8.

TABLE I
Classification of N Content

| | N (%) | P (ppm) | K (cmol/kg) |
|---|---|---|---|
| Minimum | 0.060 | 4.000 | 0.010 |
| 1st Quartile | 0.070 | 6.000 | 0.058 |
| Median | 0.070 | 11.500 | 0.125 |
| 3rd Quartile | 0.080 | 79.250 | 1.033 |
| Maximum | 0.120 | 648.000 | 1.370 |
| Mean | 0.076 | 89.375 | 0.428 |

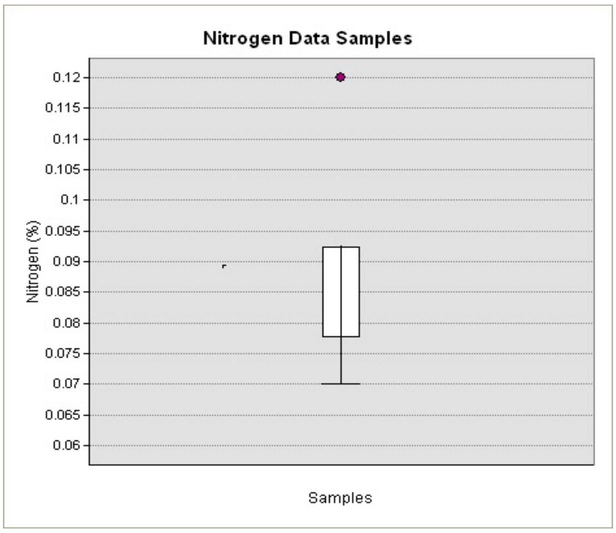


Fig. 6 Boxplot of the nitrogen data sample

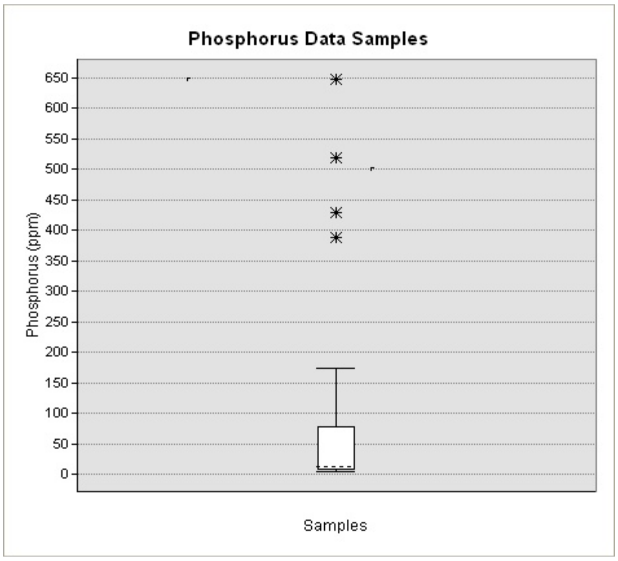


Fig. 7 Boxplot of the phosphorus data sample

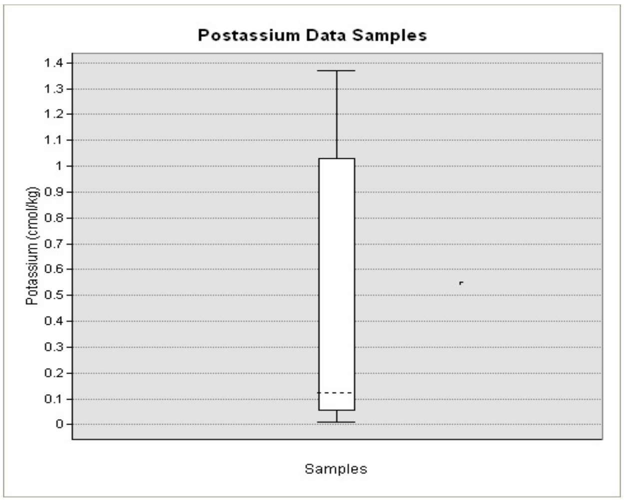


Fig. 8 Boxplot of the potassium data sample

### *2) Georeference Data Location*

Overall, there are 32 georeferenced data in this study. The data shows that the study area lies between latitude 6° 39' 15.1014" to 6° 39' 16.128" N and longitude 100° 15' 54.684" to 100° 15' 55.4184" E. The area has an average elevation of 54 meters above sea level.

### *3) Spatial Analysis and NPK Mapping*

For NPK content status, a classification of available nutrient was made according to standard produced by the Department of Agriculture (DOA), Malaysia [24]. The values of each nutrient contents were graded into five classes; very high, high, moderate, low and very low with a respective value. The N content in the greenhouse GH03 ranged between 0.06% and 0.12 %. Table II shows that 28 out of 32 samples were classified as very low. Four remaining samples were classified as low.

TABLE II
CLASSIFICATION OF N CONTENT

| Class | N (%) | Number of Samples |
|---|---|---|
| Very High | >1.0 | 0 |
| High | 0.6 – 1.0 | 0 |
| Moderate | 0.3 – 0.6 | 0 |
| Low | 0.1 – 0.3 | 4 |
| Very Low | <0.1 | 28 |

The spatial variability map of total N in the study area is shown in Fig. 4. The map shows 90% of the study area is in the red colored region (very low concentration of N). Only a few spotted areas are in the orange region (low concentration of N). This indicated that the soil in a greenhouse is poor with N content. This might be due to denitrified, leached or volatilized N from soil [19]. Insufficient amount of N will affect the development rate, protein and finally yield as nitrogen is vital for plant cell division. Therefore, more N should be added to the soil to meet the required amount of nitrogen applied to the mango plant, which is 100g/tree/year [25].

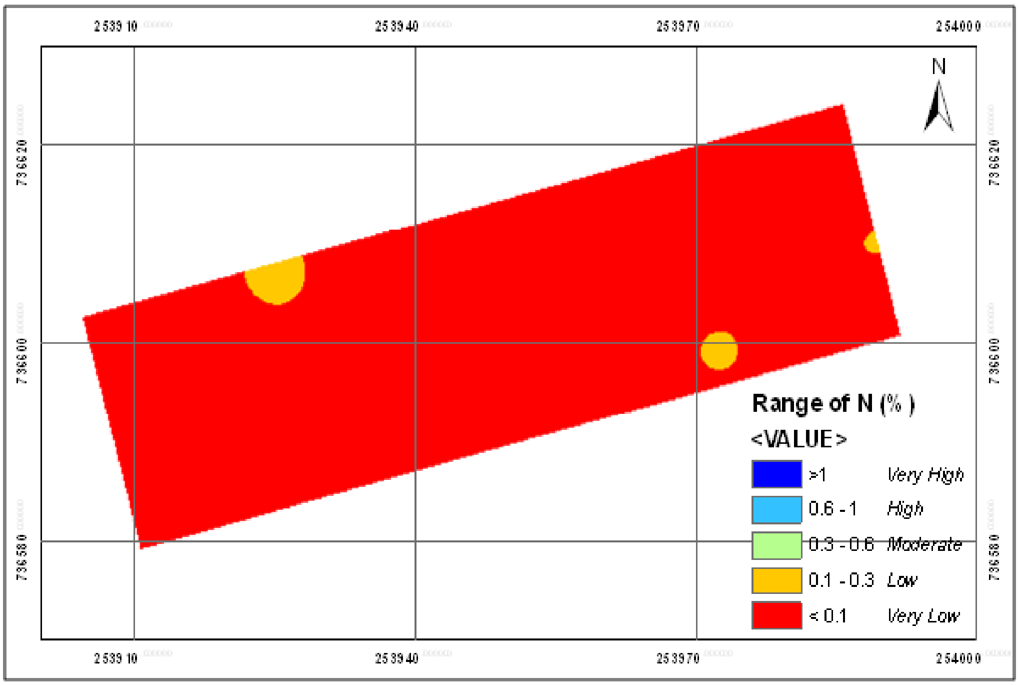


Fig. 9 Spatial distribution of available N (%) in soil

From the result obtained in soil analysis, the amount of available P in the soil ranged from 4 to 648 ppm. Table III shows all 32 samples of P data were distributed to all classes from very high to low, except for very low class.

TABLE II
CLASSIFICATION OF P CONTENT

| Class | P (ppm) | Number of Samples |
|---|---|---|
| Very High | > 45 | 10 |
| High | 25 – 45 | 3 |
| Moderate | 10 – 24 | 5 |
| Low | 3 – 9 | 14 |
| Very Low | <3 | 0 |

The spatial distribution of available P in the soil after interpolation process using Geospatial Analyst in ArcGIS is presented in Figure 10. 70% of the greenhouse area was covered with blue color, which indicated that the soil has high to a very high concentration of P. Only a few regions were colored with green and orange colour. As overall, the soil in the greenhouse has a very high content of phosphorus. The high amount of P (>30 ppm) indicated the soil has sufficient amount of phosphorus for Harumanis plants. Therefore, zero amount of $P_2O_5$ (fertilizer) is needed [25].

The use of solid fertilizer has been widely practiced for nutrient supply [26]. However, the fertiliser takes a longer time to mineralize than crop life-cycles ([27]-[28]). This slow-release characteristic promotes the use of liquid fertiliser to fulfill nutrient required for crop production [29] in which are currently applied technique in this greenhouse GH03.

The data of K content ranged between 0.01cmol/kg and 1.37cmol/kg. Table IV shows that, out of 32 samples, 10, 11 and 11 samples were classified as very low, low and high, respectively.

TABLE IIV
CLASSIFICATION OF K CONTENT

| Class | K (cmol/kg) | Number of Samples |
|---|---|---|
| Very High | > 1.4 | 0 |
| High | 0.8 – 1.4 | 10 |
| Moderate | 0.4 – 0.8 | 0 |
| Low | 0.1 – 0.4 | 11 |
| Very Low | < 0.1 | 11 |

The spatial content map of exchangeable K in soil as illustrated in Fig. 11. The map shows that the content of K was classified into two regions of the low and moderate level. However, there is an area with slightly higher K. This variation of K content in soil might be due to the supply of nutrients, soil properties and moisture availability [30].

Reference [19] convinced that higher present of K at topsoil is because of decomposition of organic matter adds K content in soil and K was stable in that layer compared to another subsoil layer. As most of the greenhouse area has less than 0.8 cmol/kg K in the soil, $K_2O$ should be applied with the amount of 80g/plant to cover the insufficiency of the nutrient [25].

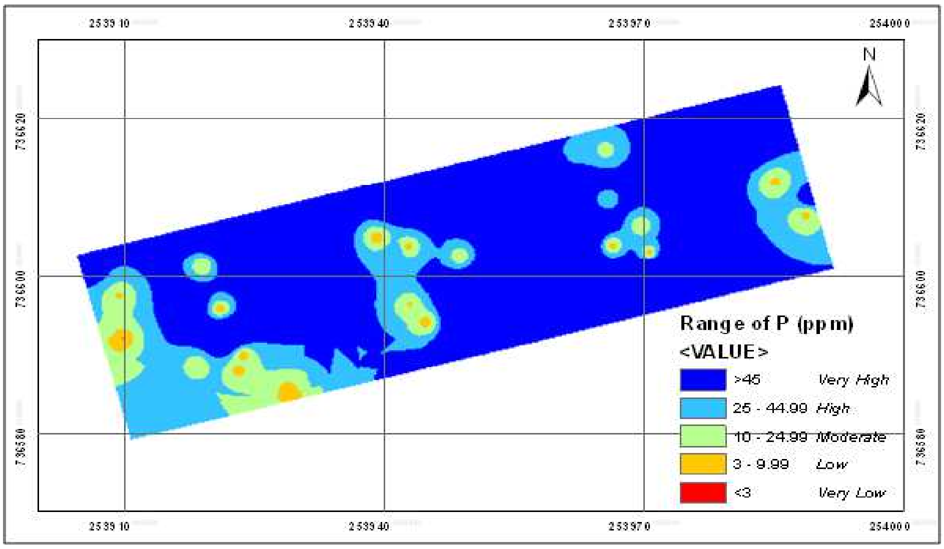


Fig. 10 Spatial distribution of available P (ppm) in soil

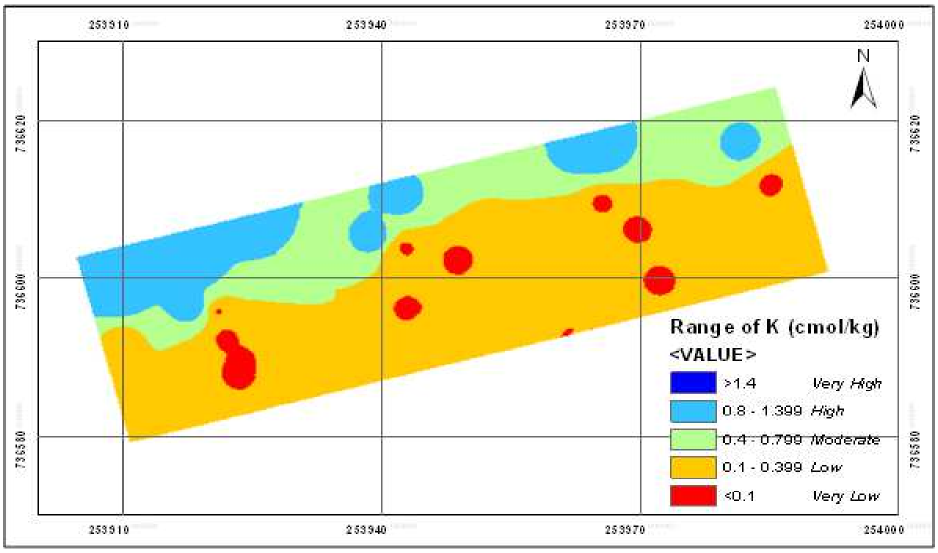


Fig. 11 Spatial distribution of available K (cmol/kg) in soil

## IV. CONCLUSIONS

From the study, nutrient mapping of NPK has been established by using the Geostatistical Analyst tool in ArcGIS for greenhouse GH03. The results showed NPK content in the soil were spatially ranging from 0.06 and 0.12 % (N), 4 and 648 ppm (P), 0.01cmol/kg and 1.37cmol/kg (K), respectively. The spatial distribution maps revealed that the soil in a greenhouse is poor in N, high in P and moderate in K content. Thus, more N and adequate amount of K fertilizer should be supplied to increase the plant's productivity. The nutrient maps produced in this study gives a new perspective on a farming management concept in term of variable rate fertilizer application for Harumanis mango plants grown under HDPS.

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