CERTIFICATION OF APPROVAL

Spatial Variability of Soil pH and Phosphorus Content at UTP Campus

by

Nuraini Binti Darail

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Approved by,

(Dr. Rezaur Rahman Bhuiyan)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURAINI BINTI DARAIL

ABSTRACT

This study was done to determine the spatial variability of soil pH and Phosphorus content at University Technology PETRONAS (UTP) in Tronoh, Perak. This study is important to determine the spatial variability of the soil pH and Phosphorus content that may be useful in the field management zones and could maximize application benefits. Accurate information on the spatial variability of these soil properties is very essential to develop site-specific management for this study area. This study was done by applying geostatistical methods to characterize the spatial variability of soil pH and Phosphorus at UTP campus geostatistically and correlate it to the environment practices and characteristics. An evaluation of the scale of variability of soil pH and Phosphorus at UTP campus was conducted using autocorrelation analysis of 50 samples which were grid-sampled by 50m spacing. The locations of sample were determined by geo-rid positioning done by using a Global Positioning System (GPS) receiver. The samples were then collected at depth of 0-20 cm by using soil auger and clean plastics to preserve its properties. Collection of the soil samples was done in order to cover all types of the soil series dominant in the study area. The soil samples were then analyzed to determine its pH and Phosphorus content. From the laboratory results, geostatistical analyses; semivariogram and kriging were done. The semivariogram analysis examines the autocorrelation among the data set using GS+ software while kriging method enables mapping of soil pH and Phosphorus content over the entire study area using Surfer32 software. Results indicate that significant spatial variability of soil pH and Phosphorus exist. Nugget-to-sill ratio for both soil pH and Phosphorus are lower than 25%. This indicates that both pH and Phosphorus has a strong dependency.

ACKNOWLEDGEMENT

This project would not have been possible without the assistance and guidance of certain individuals and organization whose contributions have helped in its completion. Therefore, I would like to take this opportunity to extend my sincere thanks and appreciation to the following persons and organizations who have directly or indirectly given generous contributions towards the success of this project.

First of all and most importantly, I would like to express my sincere thanks and utmost appreciation to the project supervisor, Dr. Rezaur Rahman Bhuiyan for his valuable input and guidance throughout the course of this project. Without his patience and excellent supervision, it is impossible for me to complete this project successfully. His cooperation, knowledge and willingness in teaching me are really appreciated.

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A lot of thanks to my friends; Miss Rodzleana and Miss Noorhidayah for lending me a helping hand in ensuring me finished up my project within the time limit. They also have pushed me to do my very best, which without them; this project would take a longer time to finish.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Soil pH and phosphorus content vary spatially and temporally from a field scale to a large regional scale and are influenced by both intrinsic and extrinsic factors. Intrinsic factors are caused by composition of parent rocks, soil formation process and soil organisms while extrinsic factors are due to regional climate, vegetation and fertilization. Soil properties are usually studied by taking samples on some grid or other pattern with the assumption that properties measured at a point also represent the properties of the neighborhood soil that were not sampled. The validity of this assumption is valid depends on the degree of spatial dependence that exists among the samples.

The variability of soil pH and Phosphorus within the field is often described by classical method, which assumes that the variation is randomly distributed within mapping units. Different rate of nutrient application is possible only if experts can give correct site-specific recommendations. Therefore, precise information about nutrient status of soil is required. The translation of the field information into site-specific recommendation could be done when the spatial variation in nutrient status across a field is quantified (Eltaib S. M. et.al, 2002).

Spatial variability is characterized by different values for an observed attribute or property that are measured at different geographic locations in an area. The geographic locations are recorded using global positioning systems (GPS) while the attribute's spatial variability is assessed using spatial descriptive statistics such as the mean, standard deviation, coefficient of variation or regression or geostatistics parameters such as range, nugget and sill.

Geostatistics provides a set of statistical tools for the analysis of data distributed in space and time. It allows the description of spatial patterns in the data, the incorporation of multiple sources of information in the mapping of environmental attributes, the modeling of the spatial uncertainty and its propagation through decision-making. Geostatistics has emerged as the primary tool for spatial data analysis in various fields, ranging from earth and atmospheric sciences, to agriculture, soil science, environmental studies, and more recently exposure assessment and environmental epidemiology (Bohling G.,2005).

Soil pH depends on the activity of hydrogen ions (H+) in a solution. The pH of soil or more precisely the pH of the soil solution is very important because soil solution carries in it nutrients such as Nitrogen (N), Potassium (K), and Phosphorus (P) that plants need in specific amounts to grow, thrive, and fight off diseases. If the pH of the soil solution is increased above 5.5, Nitrogen (in the form of nitrate) is made available to plants. Phosphorus, on the other hand, is available to plants when soil pH is between 6.0 and 7.0 (Adamchuk V. I., 2006).

The pH value of a soil is influenced by the kinds of parent materials from which the soil was formed. Soils developed from basic rocks generally have higher pH values than those formed from acid rocks. Rainfall also affects soil pH. Water passing through the soil leaches basic nutrients such as calcium and magnesium from the soil. They are replaced by acidic elements such as aluminum and iron. For this reason, soils formed under high rainfall conditions are more acidic than those formed under arid (dry) conditions. Human distractions like pollution alter the pH of soil. Researches have also revealed that soil pH is affected by the vehicular and ongoing traffic. This largely hampers the soil pH and in turns the primary productivity by compacting the soil and decreasing its friability. Application of fertilizers containing ammonium or urea speeds up the rate at which acidity develops. The decomposition of organic matter also adds to soil acidity.

Phosphorus (P) is a naturally occurring element that exists in minerals, soil, living organisms and water. Plant growth and development requires phosphorus in large amounts. Phosphorus is essential for early root development and hastens plant maturity. The forms of phosphorus present in soil can include organic, soluble or bound forms. Phosphorus is the least mobile of the major plant nutrients. Fields with high losses of phosphorus must have both a high source potential and a mechanism to transport phosphorus to bodies of water. Phosphorus can travel to surface water attached to particles of soil or manure. Phosphorous also can dissolve into runoff water as it passes over the surface of the field.

1.2 Problem Statement

Soil pH and phosphorus content vary spatially and temporarily due to intrinsic (e.g. soil formation process, composition of parent rocks, soil organisms) and extrinsic factor (e.g., regional climate, vegetation, soil management practices, and fertilization). Spatial variability causes difficulty in representing a soil with a determined or defined set of characteristics and precludes characterization of soil nutrients.

1.3 Objectives

The objective of this study is to determine the spatial variability of soil pH and phosphorus content in University Technology PETRONAS (UTP) campus. During the execution of the study, the semivariogram of soil pH and phosphorus content can be examined and interpreted geostatistically.

1.4 Scopes of Study

The scope of study of this project is to determine the spatial variability of soil nutrient properties within UTP campus. This study comprises of getting information on soil properties; pH and Phosphorus, geogrid positioning by using GPS receiver, soil sampling work, laboratory analysis; pH measurement and Phosphorus analysis, geostatistical analysis; semivariogram and kriging maps and statistical analysis. The results will be analyzed so that the spatial distribution of soil properties can be clearly seen. The results will be in parameters of semivariogram, statistical values, interpolated semivariograms and contour maps.

CHAPTER 2
LITERATURE REVIEW

Soil properties vary considerably with pH the least variable in a soil mapping unit; cation exchange capacity showing moderate variability; and organic matter and potassium having high variability (Yates and Warrick, 2002). The mean and variance are used to describe and compare soil nutrient variation in classical statistical analysis. This variation has also been characterized by the coefficient of variation which ranges from 50 to 300% for selected soil properties (Yates and Warrick, 2002).

Spatial variability is one of the most interesting issues to ecologists when they study ecosystem patterns and processes at different scales (Li et al., 2000). Since samples are assumed to be independent, the traditional statistical measurements have often neglected spatial relationships. Moreover, spatial dependence is particularly important in the analysis of spatially varying organism distribution and environmental variables (Rossi et al., 2002).

Soil variability is the outcome of many processes acting and interacting across a field of spatial and temporal scales and is inherently scale dependent. The variability of soil properties within fields is often described by classical statistical methods, which assume that variation is randomly distributed within mapping units. Land use has become the main reason in the variation of soil nutrients within an area. Over the past decades, land use change has been a common phenomenon with climate changes and human disturbances, and now it has become an important ecological issue.

In this study, the geostatistical tools are used to study on the spatial variability of the soil pH and Phosphorus at the study area. Geostatistical method is used in order to differentiate the results with the statistical method as the results are more precise. Geostatistics is a set of tools where the assumptions of sample independence and homogeneity are removed (Upchurch et al., 1991). These tools measure the degree of dependence of samples. They have been applied extensively in mining and petroleum exploration with the objective of quantifying resources, but have been used on a limited basis in soil science (Bourgault et al., 1997; Isaaks & Srivastava, 1989).

Geostatistics provide a tool for improving sampling design by utilizing the spatial dependence of soil properties within a sampling region and useful to illustrate spatial inter-relationship of collected data and it reduces error, biasness and increases accuracy of data for Kriging (Myers, 1997).

Prediction of the value of a soil property at any particular site from the measured values at sample points needs taking into account the lateral soil variation. In general terms, two different approaches can be followed to achieve this purpose: soil classification and mapping, on the one hand, and kriging between sample sites, on the other (Voltz and Webster, 1990). Variogram models can be fit for mapping. Nested spherical models were fit to empirical variograms for pH, respectively (Gallichand et al., 1992; Trangmar et al., 1985). Exponential models were fit to data from soil pH, potassium (K), nitrogen (N) and phosphorus (P) (Yost et al., 1982).

A geostatistical analysis of soil nutrients could consist of exploratory data analysis using descriptive statistics, and spatial continuity of soil nutrients (Deutsch & Journel, 1998; Goovaerts, 1997). Spatial continuity of variables has led to the theory of regionalized variables. A random function is a set of random variables defined over multiple locations, u. The mathematical representation of this spatial variability may be provided by a random function concept (Isaaks & Srivastava, 1989).

Spatial modeling begins with determining the variogram parameters for a particular model. Variogram analysis can be used to compare observations at different distances and directions. Soil nutrients have significant large scale variability. Researchers found this distance to vary from 4 m for pH, 32 km for phosphorus and 10 and 32 km for potassium (Trangmar et al., 1985; Gallichand et al., 1992).

CHAPTER 3
METHODOLOGY

3.1 Methodology

The study comprises of field work, laboratory, and computer analysis. 50 soil samples were taken from the study area determined by using geogrid positioning method. Based on longitude and latitude value of 2 known landmark in the study area, the geogrid points were identified. The map was divided by geogrid lines.

The soil sampling works were done by using an iron soil auger. The samples were collected between December 2007 and April 2008. After soil samples were taken, laboratory analyses were done. The analyses were pH test and Phosphorus analysis. The data produced from the laboratory analysis were then being used for computer analysis.

To study on spatial variability of soil pH and Phosphorus content, geostatistical methods were used. The methods are interpolation of kriging map and semivariogram analysis. The geostatistical methods will provide the spatial distribution pattern of soil pH and Phosphorus content and spatial autocorrelation among the data. Figure 3.1 is showing the work flow of the study.

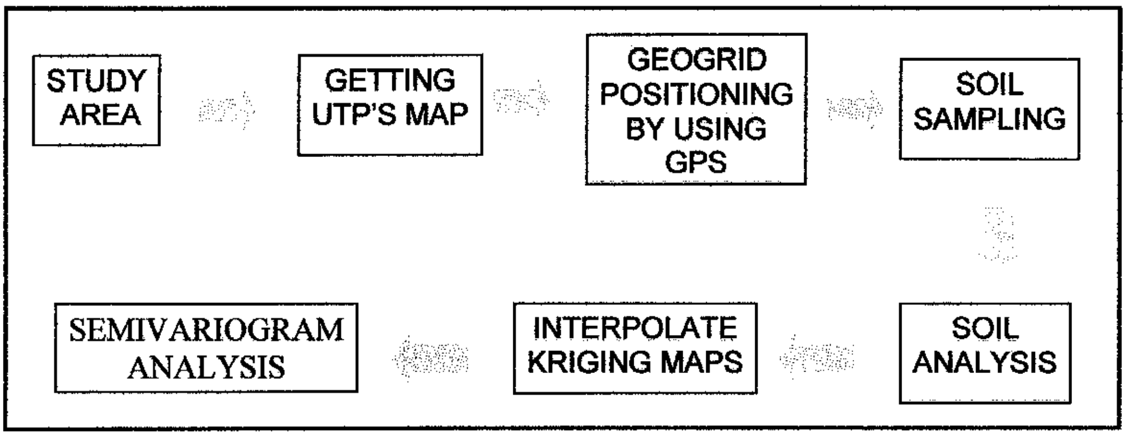

FIGURE 3.1: The Flow of Project

3.2 Study Area

The study was conducted at University Technology PETRONAS (UTP) campus. The study area is 400 hectare. UTP located in the district of Tronoh, Perak and surrounded by lakes and deep forest.

The UTP area is lies between longitude 100° 57' 28.18015" E to 100° 58' 34.20999" E and latitude 4° 22' 16.91637" N to 4° 23' 25.7225" N. The study area can be divided into 2 areas, undisturbed area where land is congested with forest and disturbed area where construction taken place. In this study, the student focused the analysis within the disturbed area and small portion of undisturbed area. This is due to time constraint and unreachable point in the deep forest.

The climate of UTP campus is typical of the humid tropics. The climate varies from high temperature to seasonal heavy rain. The temperature of the study area ranges from 25°C to 32°C. The yearly rainfall of the study area ranges from 1700 to 2500mm (Tourism Malaysia Portal, 2008). The soil conditions in UTP campus are usually very dry during dry periods and very wet during the seasonal heavy rain.

3.3 Map of University Technology PETRONAS

UTP's map is a main tool for this project execution. This project involving both field and laboratory works. Before proceed with the laboratory work or analysis, the soil samples were collected first. The samples were collected at points based on a geogrid map. This means, before proceed with the soil sampling work, a geogrid positioning work was done first. The UTP's map was provided by UTP's Maintenance Department. The UTP's map is as showed in FIGURE 3.2.

The map was used as a base map for kriging map interpolation. Before being used as a base map, the map was digitalized by using DigXY Software. During the digitalized process, two coordinates of known landmark in UTP was inserted. The landmark chose were Multi Purpose Hall (100°58'15.29499'E longitude and 4°23'03.05825'N latitude) and Heli Pad (100°57'57.28015'E longitude and 4°22'48.28137'N latitude).

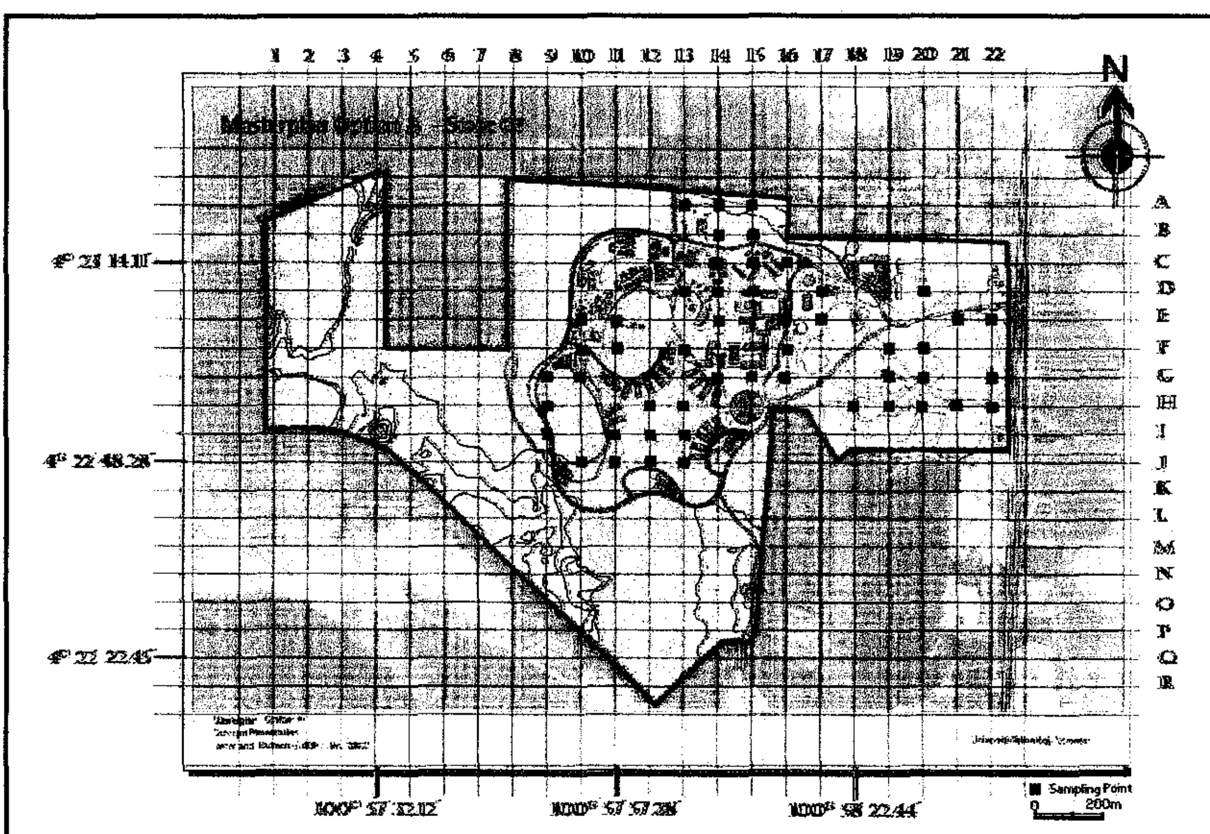

FIGURE 3.2: Map of the Study Area.

FIGURE 3.3: Topographic Map of the Study Area.

Figure 3.3 shows a topographic map of UTP campus. This topographic map was very essential in determining the land use pattern in UTP area. By referring to this map, the student has easily correlated the spatial variability with the land use practices. To correlate the spatial variability of soil pH and Phosphorus content to the environment practices and characteristics, the map was digitized by using CorelDraw 9.0 software. The map was digitized into 5 layers. Each layer represents different attributes or characteristics. The layers digitized are UTP's boundary, contour lines,road, building, and lake.

At the end of the study, the study area's map will provide information on the soil pH and Phosphorus content at point's location and the geogrid reference for the soil properties. The soil samples, the point's location, the geogrid position and the samples properties produced a spatial data set. The spatial data set determined the spatial variability of soil pH and Phosphorus content at UTP area.

3.4 Hazard Analysis

Before proceed with the study, potential work hazards has been identified. The hazards were identified based on the job steps of the study. Work hazards were very dangerous. It will result to a minor injury as well as lead to a major injury where malfunction of body system happened. To avoid this, it must be identified in order to ensure that the students can perform the work safely. In identifying the hazards, the job steps were analyzed at all angles.

Once the hazards were identified, control measures were determined. Control measures are actually a measures or guideline that was constructed in order to apply a safe work practices. Table 3.1 shows a list of work hazard and its control measures. In this study, potential work hazards were identified in the geogrid positioning work, soil sampling, and laboratory analysis. The hazards were trip and fall, sharp edges, heavy equipment, burn and chemical splashes.

In determining the potential work hazards, the risk rating and who and what might injure were identified as well. There were three rates of the risk ratings, low, medium and high. And the hazards were likely to happen to either a person or equipment. The potential work hazards, risk rating, who might injured and the control measures identified based on the work steps of this study are described in Table 3.1.

TABLE 3.1: Hazard Identification.

JOB STEPS	POTENTIAL HAZARDS	WHO MIGHT INJURED (PERSON / EQUIPMENT)	RISK RATING	CONTROLS
1. Geogrid positioning	1.1 Trip and fall	Student, equipment	Low	1.1.1 Wear proper shoes during handling the equipment. 1.1.2 Hold the GPS receiver tools tightly to avoid it from falling. 1.1.3 Supervisor to assist the students during the work execution.
2. Soil sampling	2.1 Sharp edge and heavy equipment	Student	Medium	2.1.1 Wear proper shoes during handling the equipment. 2.1.2 Wear hand glove during the work execution. 2.1.3 Hold the equipment tightly. 2.1.4 Use the equipment as stated in the procedure. 2.1.5 Supervisor to assist the student during work execution.
3. Soil analysis	3.1 Fall	Student, equipment	Low	3.1.1 Wear proper shoes and lab coat during working in the laboratory 3.1.2 Don't place the test equipment at the edge of the table.
	3.2 Burn	Student	Medium	3.2.1 Wear hand gloves during handling hot equipment. 3.2.2 Put the vial on the vial rack during handling the hot vial.
	3.3 Chemical splashes	Student	Medium	3.3.1 Wear protective glasses, lab coat, hand gloves and proper shoes during handling chemical. 3.3.2 Follow the procedure of handling the chemical.

3.5 Geogrid Positioning

Geogrid positioning method was used to determine the points of soil sampling. The geogrid positioning was done by using Global Positioning System Tools. The survey was done at 2 known landmark in UTP. They are Multi Purpose Hall and Helipad, which located near Building 14. At those landmarks, longitude and latitude coordinate were determined. The result of the Global Positioning System (GPS) done is attached in the APPENDIX; Table A-1. The Multi Purpose Hall is located at 100° 58' 15.29499E longitude and 4° 23' 03.05825N latitude while the Helipad is at 100° 57' 57.28015E longitude and 4° 22' 48.28137" N latitude.

From the known latitude and longitude value, the length between those 2 landmarks and the coordinate of each point within the study area were determined. The map was then divided by geogrid lines. Each point was divided by the length of 100m. Figure 3.2 shows the geogrid lines that subdivide the study area.

When the geogrid positioning process was done, the locations of points were determined and selected. The points were collected at location scattered around the study area. The points for soil sampling were then marked so that, the student can does the soil sampling easily. Figure 3.2 shows the points where the soil samples were taken. The points were marked with red color.

3.6 Soil Sampling

Soil samples were taken at the predetermined grid points as showed in Figure 3.2. 50 soil samples were taken from the study area. A soil auger was used for collection of soil sample. The samples were taken at depth of 0 to 20cm only. This soil depth is considered as topsoil. The soil samples were then put into a clear plastic bag. The plastic bag was used in order to ensure that the pH and Phosphorus properties were not change. The soil samples were then brought to the Environmental Lab for soil analysis.

The soil auger used was made by iron and its size was 23cm length and 3.5cm diameter. Refer Figure 3.4 to see the soil auger. Before doing the sampling process, the inner part of the auger was applied with grease. The grease was function as a lubricant that minimizes the friction between the auger and the soil sample. This can reduce the compaction of the soil and easier to extrude the sample from the auger.

At the sampling location, grass was cleared so that the auger can easily penetrate into the soil. The chance of possibilities of samples disturbances was reduced. The soil auger was pressed into 20cm of soil depth. Refer Figure 3.15 to see the soil sampling process. The soil samples were extruded from the auger by using an extruder. The extruder was made by solid iron (Refer Figure 3.4). The soil samples were then inserted into a sealed plastic bag to preserve its moisture content. The soil samples were then used for laboratory analysis. pH and Phosphorus analysis were done to the soil samples.

FIGURE 3.4: Soil Auger and Extruder.

FIGURE 3.5: Soil Sampling Work.

3.7 Soil Analysis

The soil samples collected were brought to the Environment Laboratory for analysis. The samples were prepared before analyzed. The samples preparation was very essential because the samples must be in soluble state before being tested. The analyses done were pH and Phosphorus analysis.

3.7.1 Samples Preparation

Samples preparation was very essential for pH and Phosphorus analysis. To do the pH and Phosphorus analysis, the solid soil samples were transformed into soluble state first. For preparation of samples, American Society for Testing and Materials (ASTM) Standard was referred. ASTM is a technical standard for a wide range of materials, products, systems, and services. The standard test method for soil samples preparation was found in the Environmental Testing Section.

To prepare the samples, 50g of air-dried soil samples was sieve through a 1.18mm sieve. The sieve is as showed in Figure 3.6. This is to separate the fine and coarse soil samples. The fine soil samples were then poured with 250 ml of distilled water. Shake the mixture for an hour by using an orbital shaker (Refer Figure 3.7). The orbital shaker was adjusted to 250rpm. After an hour, the sample solution was filtered through a vacuum pump. The vacuum pump filtered out the solid soils and dissolved some of the soil into the solution.

FIGURE 3.6: 1.18mm sieve

FIGURE 3.7: Orbital Shaker

3.7.2 pH Test

Procedure for pH test was referred to ASTM standard test method. The areas of application are water, waste water and environmental testing. The pH of diluted soil samples were determined by using pH meter. Before using the pH meter, the edge of the electrode was inspected of any presence of gel. The dispenser button was press to ooze the gel out from the tube. The electrode was then placed into the samples. Before taking the reading, the electrode was ensured to fully submerge in the samples and that there was no presence of air bubbles under the electrode. The soil pH reading was recorded once the reading value stable. Below is the figure of pH meter used in the analysis.

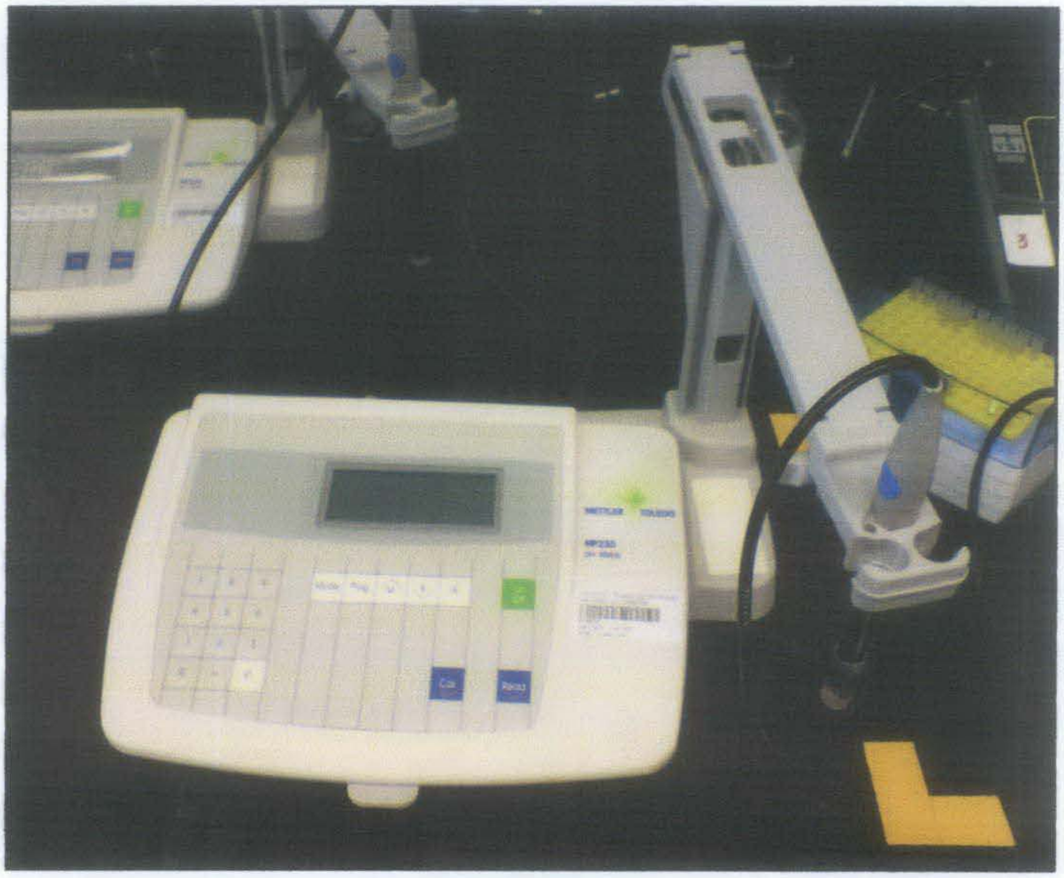

FIGURE 3.8: pH Meter

3.7.3 Phosphorus (P) Analysis

To determine Phosphorus content, ascorbic acid method was used. Before starting the analysis, the DRB200 Reactor was preheated to 150°C. For Phosphorus analysis, **536 P Total/AH PV TNT** was selected from the test list. The light shield in cell compartment #2 was installed. Figure 3.9 shows the DRB200 Reactor used in the Phosphorus analysis.

FIGURE 3.9: DRB200 Reactor

A TenSette® Pipet was used to add 5.0mL of sample to a Total and Acid Hydrolyzable Test Vial. One Potassium Persulfate Powder Pillow for Phosphonate was added to the vial by using a funnel (Refer Figure 3.10). The vial was cap tightly and shakes to dissolve. When the vial was prepared, it was inserted into the preheated DRB200 Reactor. Heat the vial at 150°C for 30 minutes.

FIGURE 3.10: Potassium Persulfate Powder Pillow.

When the timer expired, the hot vial was carefully removed from the reactor. The vial was put in a test tube rack and was let to cool to room temperature. 2mL of 1.45 N Sodium Hydroxide Standard Solution was added to the vial. The Sodium Hydroxide Standard Solution is showed in Figure 3.11. The vial was cap tightly and shakes to mix. The outside of the vial was wiped by using a damp cloth followed by a dry one.

The vial was inserted into a 16mm cell holder and a **ZERO** button was pressed. The holder display showed 0.00mg/L PO_4^{3-}. One PhosVer 3 Powder Pillow was added to the vial by using a funnel (Refer Figure 3.12). The vial was then immediately caps and shakes for 20-30 seconds to ensure the reagent was fully dissolve. After 2 minutes, the vial was wiped with a wet towel followed by a dry one. The prepared sample was then inserted into the 16mm DR2800 cell holder. **READ** button was pressed and the Phosphorus content reading was recorded. The DR2800 cell holder used is as in Figure 3.13.

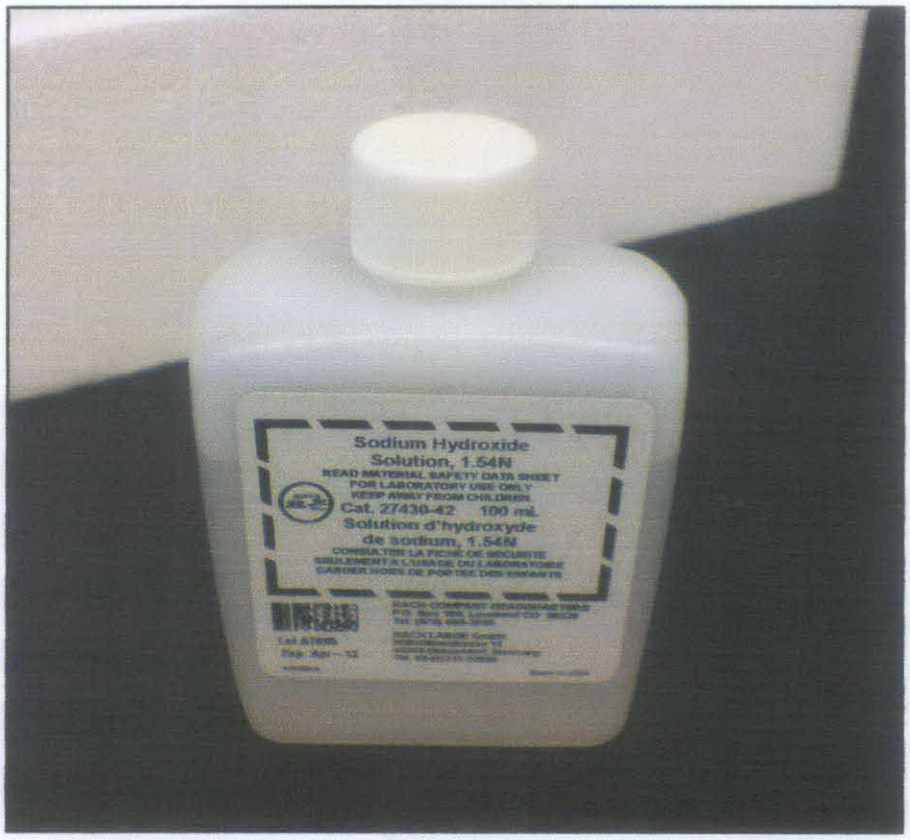

FIGURE 3.11: Sodium Hydroxide Standard Solution

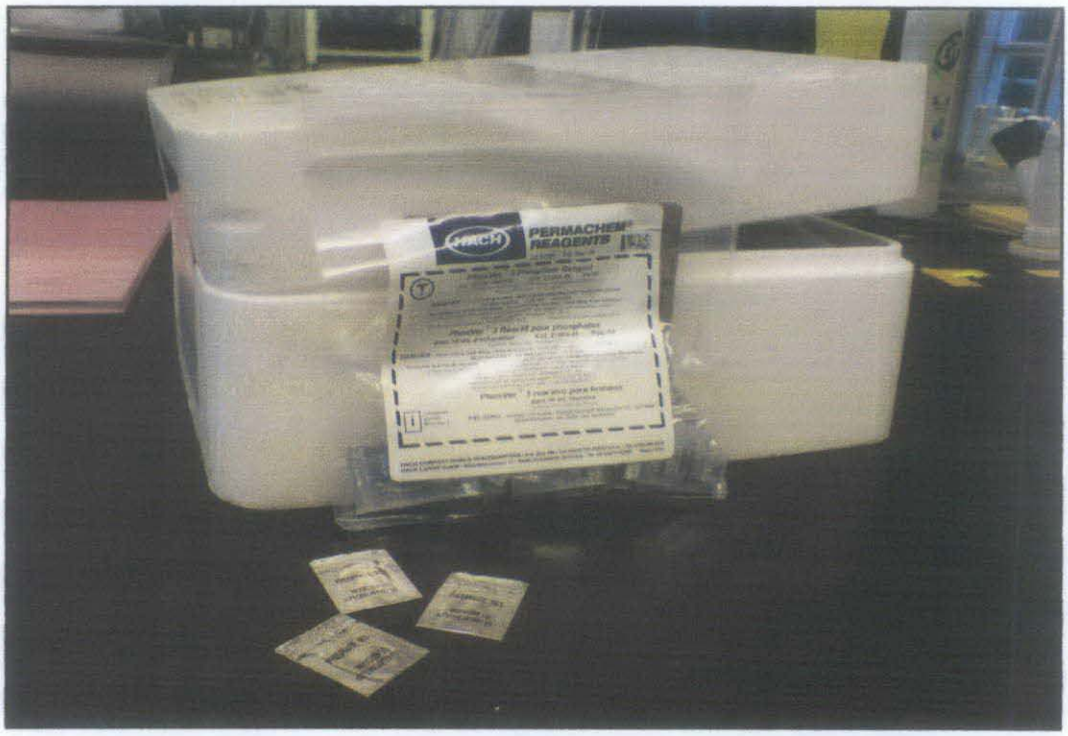

FIGURE 3.12: PhosVer 3 Powder Pillow.

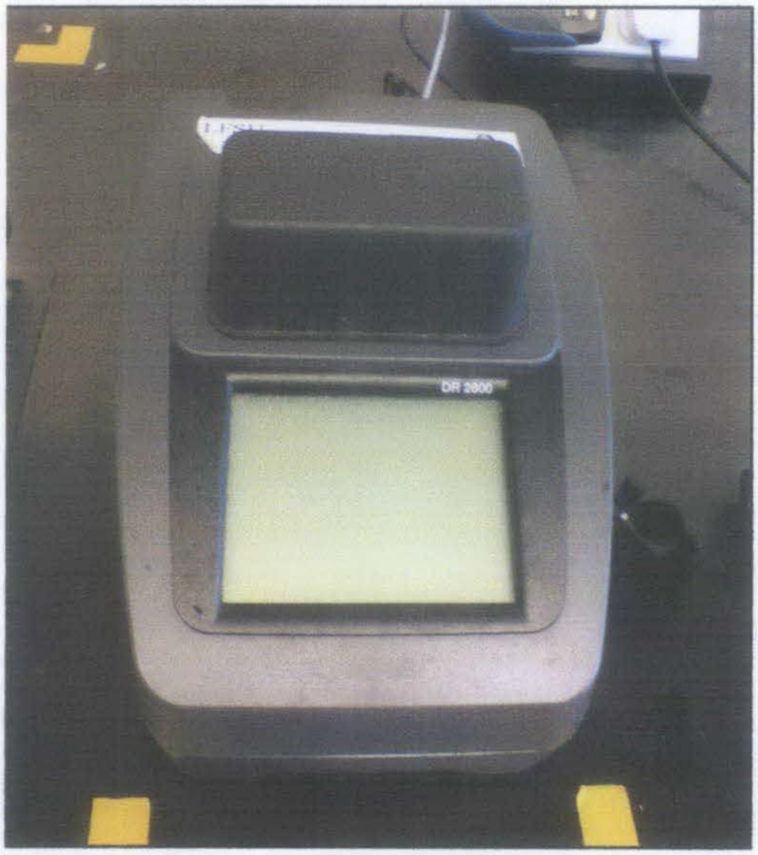

FIGURE 3.13: DR 2800 Cell Holder to Determine Phosphorus Content.

3.8 Statistical and Geostatistical Analysis

The data gained from the laboratory analysis were then used for statistical and geostatistical analysis. In the statistical analysis, the maximum, minimum, mean, median, standard deviation, variance and coefficient of variance were determined. The results of the statistical analysis showed the distribution of the soil properties in the study area.

Geostatistical analyses used in this study are kriging map and semivariogram analysis. From the kriging map, the distribution of soil properties in the study area was clearly seen. The highest and lowest values were differentiated by different shades of colour or colour contour. The semivariogram analysis provides the semivariogram factor like range, nugget, sill, nugget-to-sill ratio, structural variance and spatial dependence.

3.8.1 Statistical Analysis

Statistical analysis is a method that traditionally used to determine the distribution of variability of a set of data. In this study, statistical analysis was applied in determining the distribution of soil pH and Phosphorus content variability. In statistical method, the laboratory analysis results were calculated to get the maximum, minimum, mean, median, standard deviation, variance and coefficient of variance value. The maximum and minimum value indicates the maximum and minimum concentration of pH and Phosphorus in the study area.

Mean is just the average of the data. It was very easy to calculate. All the data were added up and then divided by how many data were there. In this study, the number of data was 50. In other words, mean is the sum divided by the count. To calculate the median value, the data were placed in value order. The middle number was the value of median. But, if the number of data was even, the middle pair value were added up and dividing by two.

Standard deviation is a measure of the scatter between a set of data. It measures the variability of the data. To calculate the standard deviation, the mean value was calculated first. The basic method for calculating standard deviation for a set of items is to calculate the square root of the average value of the squares of the distances of each item from the mean for the whole set. The method was expressed in this formula:

$$s = \sqrt{\frac{1}{N}\sum_{i-1}^{N}\left(\chi_i - \overline{\chi}\right)^2}$$

Where,

s - standard deviation

N - number of data

χ - value of the data

$\overline{\chi}$ - mean of the data

The formula for the variance by the raw score method is mathematically equivalent to the deviation score method. The method was expressed in the following formula:

$$\sigma^2 = \frac{\sum \chi^2 - \frac{\left(\sum \chi\right)^2}{N}}{N}$$

Where,

N - number of data

$\sum \chi^2$ - the sum of squared individual data

$\sum \chi$ - the sum of all data

The coefficient of variance (CV) measures the precision of a set of data. The higher the precision of a set of data, the % of coefficient of variance is lower. To calculate the coefficient of variance, this formula was used:

$$CV = \frac{s}{\chi} \times 100$$

Where,

s - standard deviation

χ - mean of the data

3.8.2 Geostatistical Analysis

Geostatistical method correlates the elements of a series of data and others from the same series separated from them by a given interval. It is a way of describing the spatial autocorrelation data. The spatial autocorrelation can be determined by using correlation, semivariance and covariance. To determine the spatial variability of soil pH and Phosphorus content, the characterization of spatial correlation, optimal interpolation and employs semivariogram model were done. The geostatistical analysis is optimal when the data are normally distributed and stationary. The data is considered stationary when the mean and variance do not vary significantly in space.

Spherical model was the model that best fit the semivariograms of soil pH and Phosphorus content at UTP campus. The spherical model can be defined by:

$$\gamma(h) = \lambda_0 + \lambda\left[1.5\left(\frac{h}{\beta}\right) - 0.5\left(\frac{h}{\beta}\right)^3\right] \qquad \textit{for } h \le \beta$$

$$\gamma(h) = \lambda_0 + \lambda \qquad \textit{for } h > \beta$$

Where,

λ - Structural Variance

λ_0 - Nugget Variance

β - Range

$\lambda + \lambda_0$ - Sill

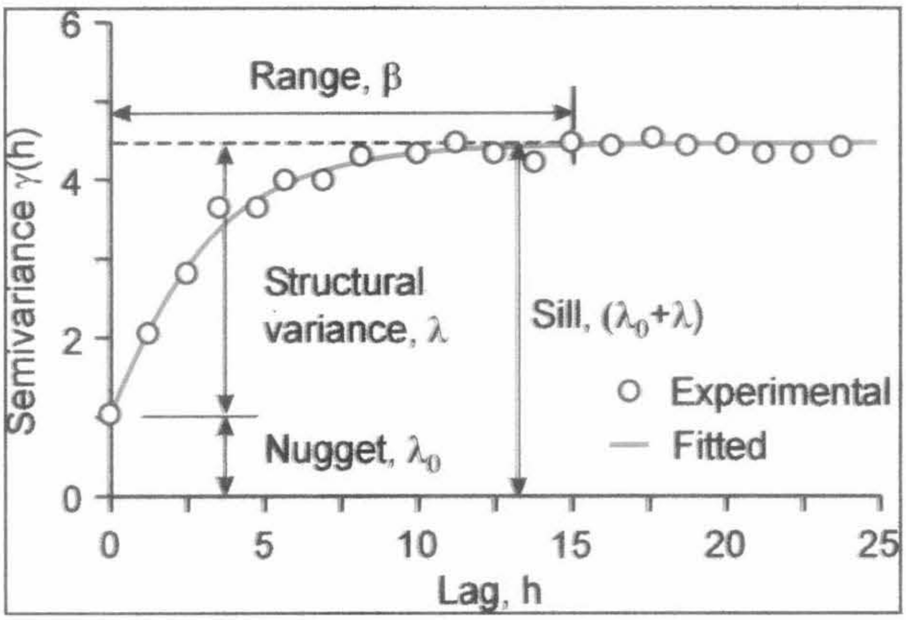

FIGURE 3.14: Semivariogram and its Parameters.

As showed in Figure 3.14, from the semivariogram interpolated, the parameters like range, nugget, sill, nugget-to-sill ratio, structural variance and spatial dependence were determined. Sill *(λ_0 + λ)* is the semivariance value at which the variogram levels off. It indicates the amplitude of a certain component of the semivariogram. It showed the maximum value of a set of data. The lag distance at which the semivariogram component reaches the maximum (sill) value is known as range, β. Beyond the range, the autocorrelation is essentially zero or there are no relativity of the data. Range also indicates the distance over which spatial dependence of the data is apparent.

Nugget, λ_0 showed the variability of unaccounted spatial variability at distances smaller than the smallest typical lag, including the measurement error. In theory, the semivariogram value at the origin should be zero (0 lag). If it is significantly different from zero for lags very close to zero. The structural variance, *Sv* is the variation of data due to spatial auto correlation while semivariance *(γ)* is a measure of the dissimilarity of the soil properties in the study area. Semivariance can be defined as:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(\chi_i) - z(\chi_i + h)]^2$$

Where,

$z(\chi_i)$	- Variable under consideration as a function of spatial location, χ_i.
χ_i	- Interval of spatial coordinates or the location of the samples.
h	- Lag interval representing separation between 2 spatial locations.
$z(\chi_i + h)$	- Lagged version of variable under consideration; the samples data at location $\chi_i + h$.
$N(h)$	- The number of sample pairs that are separated by the lag factor, h.

Nugget-to-sill ratio [$\lambda_0 / (\lambda_0 + \lambda)$], is defined as the spatial dependency of the data. The dependency of the data is considered strong if the ratio is less than 25%. A moderate spatial dependency is determined when the ratio is between 25% and 75%. For nugget-to-sill ratio above than 75%, the spatial dependency of the soil properties is considered weak.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Statistical Characteristics of Soil pH and Phosphorus Content.

Traditional statistical method was used in determining the spatial distribution of soil pH and Phosphorus content at UTP campus. In statistical method, the laboratory analysis results (the laboratory results are attached in the APPENDIX; Table A-2) were calculated to get the maximum, minimum, mean, median, standard deviation, variance and coefficient of variance value. The maximum and minimum value indicates the maximum and minimum concentration of pH and Phosphorus in the study area. Table 4.1 is showing the result of the statistical analysis.

TABLE 4.1: Sample size; N, Maximum, Minimum, Mean, Standard Deviation; SD, and Coefficient of Variation; CV of Soil pH and Phosphorus Content.

Soil Properties	N	Max	Min	Mean	Median	Standard Deviation (SD)	Variance	Coefficient of Variation (CV)
pH	50	7.607	4.148	6.19954	6.3134	0.86572	0.74946	13.96
Phosphorus	50	19.63	0.39	5.4672	2.11	5.62495	31.64001	102.89

The value of mean indicates the average value of the soil properties in the study area. When compared the mean and the median value, type of distribution of soil pH and Phosphorus can be determined. Base on the results in Figure 4.1, the median value of pH and Phosphorus is slightly the same with the mean value thus; both soil pH and Phosphorus has a normal distribution. Standard deviation value is used to determine the scatter around the value of mean. Standard deviation of Phosphorus is higher than soil pH. This showed that the value of Phosphorus variability scatter around its mean value is higher than pH.

Coefficient of variation indicates the variability of the soil pH and Phosphorus in the study area. It also showed the precision of the variability of soil pH and Phosphorus within the study area. Coefficient of variation of Phosphorus is higher than soil pH. Thus; Phosphorus has an irregular distribution across the study area. Since pH has a lower coefficient of variation, pH has a more balance distribution within the study area compared to Phosphorus.

There are several factors that lead to the variation of the soil properties. They are intrinsic and extrinsic factors. When compared to the topographic condition of UTP campus, the variation is caused by forest clearance, soil alteration, runoff, climate, backfilling and vegetation.

4.2 Spatial Dependence by Semivariogram Analysis

Spherical model of semivariogram was plotted for soil properties, pH and Phosphorus content. Spherical model seems the best model compared to exponential, linear, linear to sill and Gaussian model. Figure 4.1 and 4.2 show the isotropic variogram of soil pH and Phosphorus. Base on these semivariogram, all the semivariogram parameters are analyzed and summarized in Table 4.2.

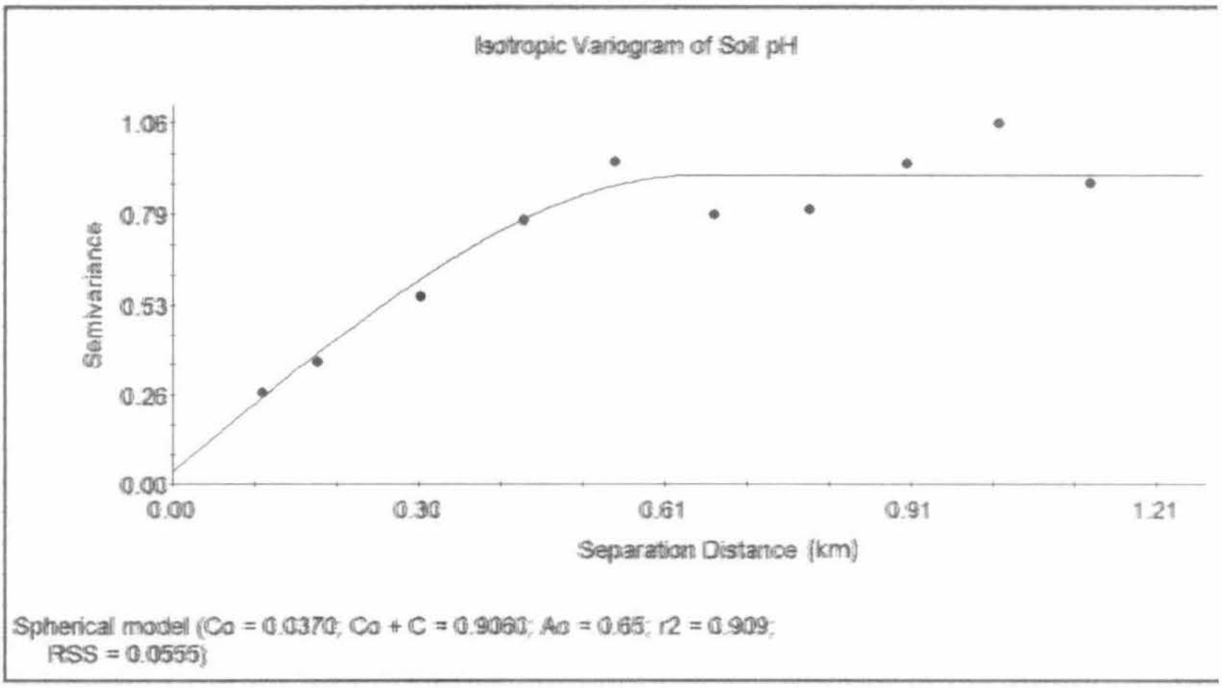

FIGURE 4.1: Semivariogram of Soil pH.

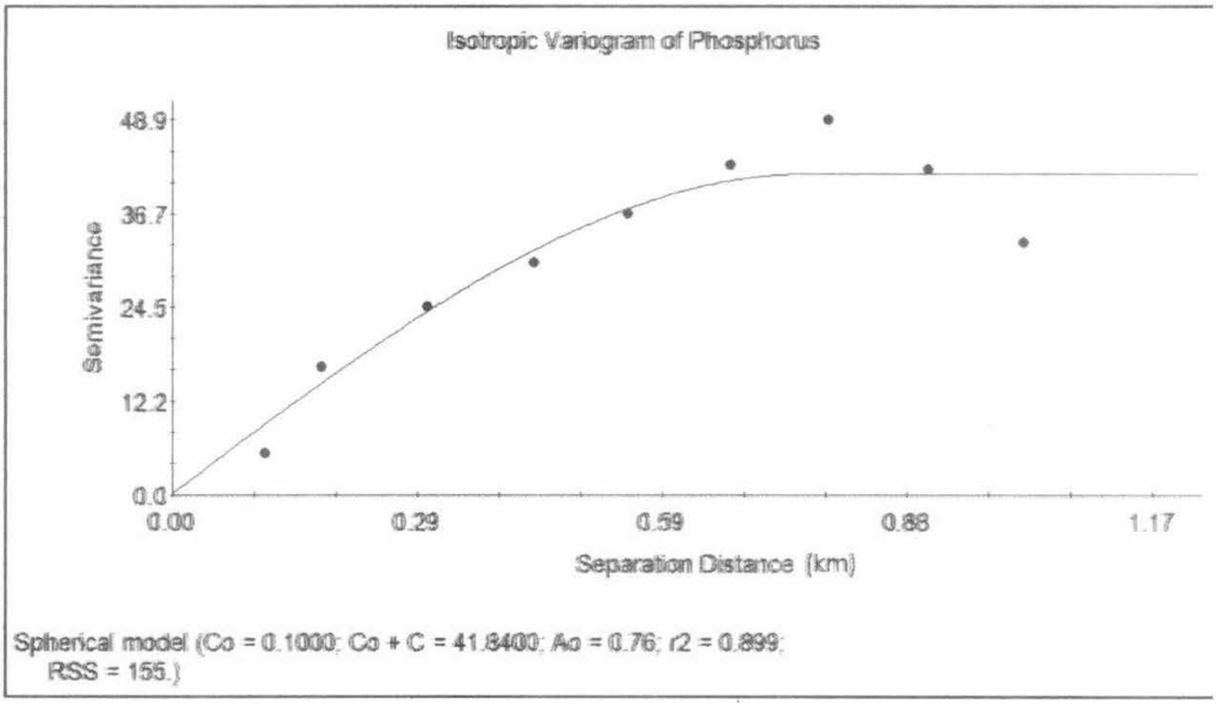

FIGURE 4.2: Semivariogram of Phosphorus Content.

Based on the semivariogram, different spatial dependence levels have been indicated; in terms of semivariogram parameters – range, nugget, sill, nugget-to-sill ratio and structural variance, S_v. The result of the semivariogram parameters is showed in Table 4.2. Range is the lag distance at which the semivariogram component reaches the maximum value (reaches sill). The autocorrelation is essentially zero beyond the range value. This is because, beyond the range value, there is no relativity of the data. Range also indicates the distance over which spatial dependence of the data is apparent. From Table 4.2, Phosphorus has bigger range than pH. Phosphorus range is 0.7580 km while 0.6470 km for pH. Thus; when the semivariogram component of Phosphorus reaches zero, its lag distance is 0.7580 km. The lag distance of pH is 0.6470 when the semivariogram of pH reaches zero.

TABLE 4.2: Characteristics of Semivariogram Parameters of Soil pH and Phosphorus Content.

Soil Properties	Model	Range (km)	Nugget (λ_0)	Sill ($\lambda_0 + \lambda$)	S_v (%) (λ)	Ratio (%) $\lambda_0/(\lambda_0 + \lambda)$	Spatial Dependence
pH	Spherical	0.6470	0.03700	0.90600	95.92	0.959	Strong
Phosphorus	Spherical	0.7580	0.10000	41.84000	99.76	0.998	Strong

Nugget is the variability of unaccounted spatial variability at distances smaller than the smallest lag, including the measurement error. Phosphorus has a bigger nugget value (0.1) compared to pH (0.037) thus; pH shows less variation at distances smaller than the smallest lag while Phosphorus showed relatively larger variation at distances smaller than the smallest lag.

Sill is the semivariance value at which the variogram levels off. It indicates the maximum semivariance value of the soil properties. Sill measures the variability of the soil properties in the study area. Phosphorus has a highest value of sill which is 41.84 while pH has the lowest sill, 0.906. Thus, the variability of Phosphorus in the study area is large while variability of pH is the least. The structural variance, S_v of pH is 95.92% while for Phosphorus, 99.76%. The structural variance indicates the variation of the soil properties due to spatial autocorrelation.

Nugget-to-sill ratio indicates the spatial dependence of the soil properties. From Table 4.2, soil pH and Phosphorus showed a similar value of ratio, 0.959% for pH and 0.998% for Phosphorus. Goderya et al., 1996 has indicates that; the dependency of the data is considered strong if the ratio is less than 25%, moderate if the ratio is between 25% and 75% and above than 75%, the spatial dependency of the soil properties is considered weak. From results show in Table 4.2, both soil pH and Phosphorus has a nugget-to-sill ratio that less than 25% thus; both pH and Phosphorus has a strong spatial dependence. This is due to the low variability of soil formations and soil management practices factors.

4.3 Spatial Distribution by Kriging Method

The data represents the soil pH and Phosphorus content at the predetermined sampled locations. By interpolation of samples of location, the distribution of the data was determined as well as the value of unsampled location. Kriging weights the surrounding measured value to derive prediction for an unmeasured location. The kriging was done based on the semivariograms of the soil properties at sampled location.

In this study, Kriging method was used in determining the spatial distribution of the data because kriging is an optimal prediction method designed for geophysical variables with a continuous distribution. It assures the return of the observed sample values and unbiased. It analyzes the statistical variation in values over different distances and in different directions to determine the shape and size of the point selection area. It also allows better visualize and spatial distribution trends of the soil properties in the study area.

The kriging method used in this study resulting kriging maps that showed the distribution of soil pH and Phosphorus content associate with the topographic condition of the study area. Figure 4.3 and 4.4 represent the spatial distribution of soil pH and Phosphorus content at UTP campus. In the kriging map, the contour was determined by usage of colour shades. Different shading represents different concentration of soil properties. The darker shades indicate higher concentration while lighter shades represents lower soil properties concentration.

From Figure 4.3, the spatial distribution of soil pH can be clearly seen. The higher pH was found at the small area at the top quadrant and at the area near the centre of the map. The highest pH is 7.607 situated at 100° 57' 57.28015"E and 4° 22' 51.97137"N. When compared to the topographic condition of the study area, the soil pH is high at disturbed area that congested with academic building. The construction of the building has involving land alteration, backfilling and forest clearance activities. These activities have led to alteration of soil properties and thus increase its pH. The lowest soil pH is 4.148. The lowest soil pH is situated at 100° 57' 57.28015"E and 4° 23' 06.73137"N where no significant land alteration and construction taken place. This area is known as undisturbed area with forest zone.

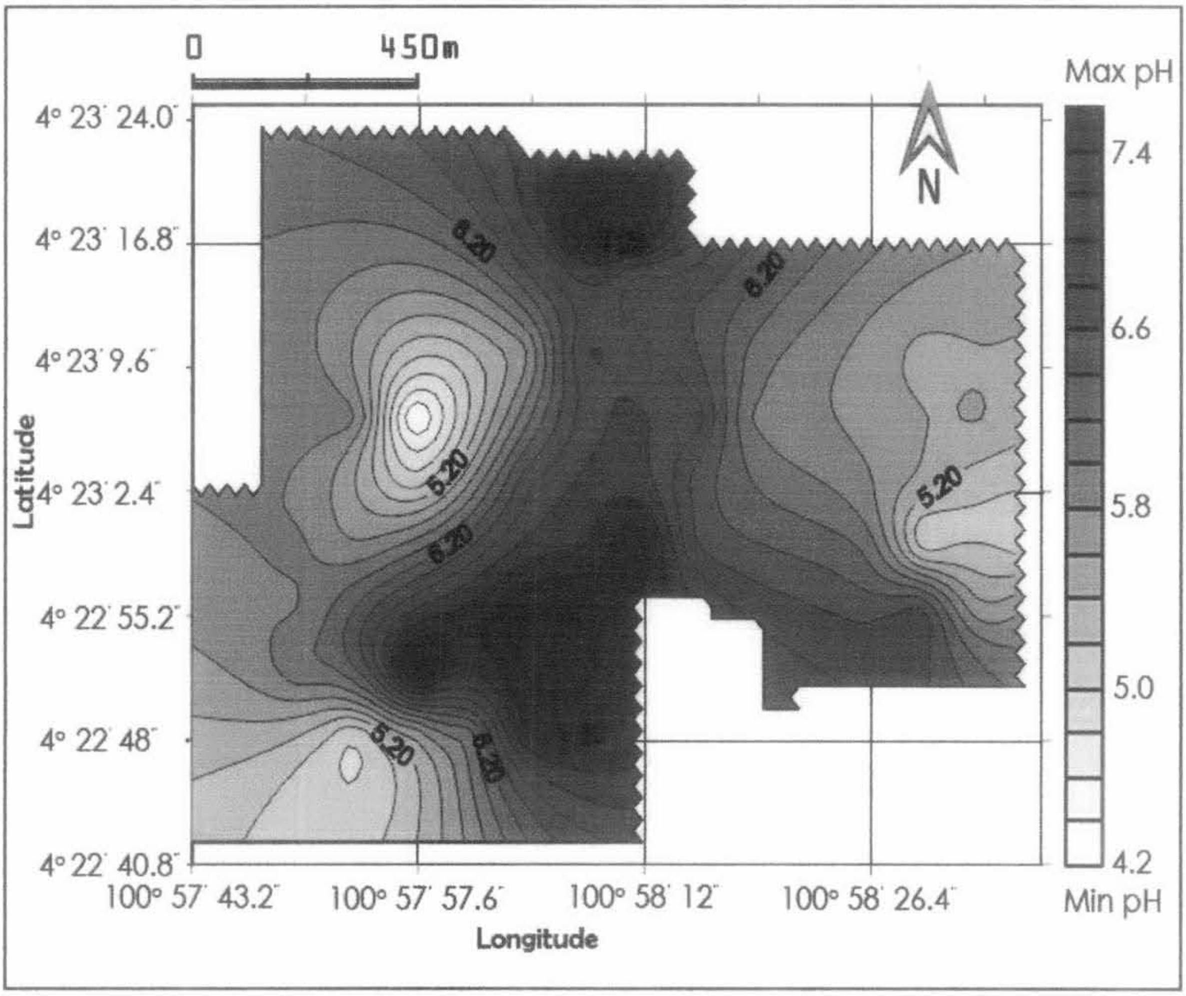

FIGURE 4.3: Kriging Map of Soil pH.

The spatial variation of Phosphorus content over the study area is clearly showed in Figure 4.4. The highest Phosphorus situated at the top quadrant and at the centre of the map. The highest Phosphorus content is 19.63 mg/L, situated at 100° 58' 04.46785"E and 4° 23' 03.4137"N. When compared to the topographic condition of the study area, Phosphorus is high at the disturbed area where again; land alteration is the main factor that influenced the variability of Phosphorus. Land alteration, backfilling and forest clearance are activities done during construction of the academic building. These activities have caused the alteration to the soil properties and thus increase the concentration of Phosphorus. Besides that, the type of soil also affects the pH of the soil. At the disturbed area, the higher pH value might due to the availability of acidic soil type in the soil.

The Phosphorus concentration is lowest at the bottom left and right map. The lowest Phosphorus is 0.39 mg/L, situated at 100° 58' 00.87400"E and 4° 22' 51.97137"N. The Phosphorus concentration is lowest at undisturbed and lakes area. At undisturbed area, the forest zone is quite deep. No development happened at the area thus, no alteration to the soil properties. At the lakes area, the Phosphorus concentration is lower due to water runoff.

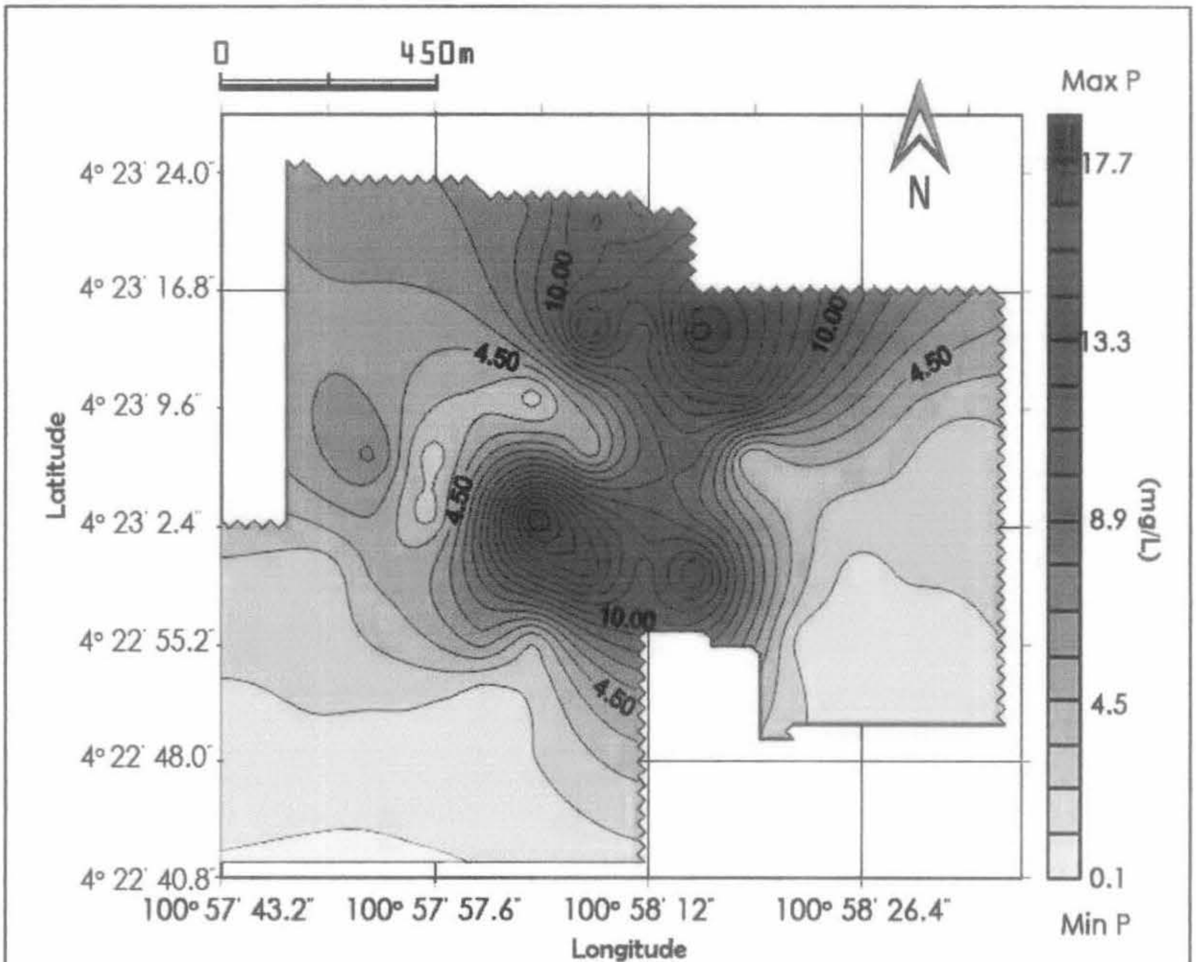

FIGURE 4.4: Kriging Map of Phosphorus Content.

4.4 Variation of Soil Properties on Land Use Conditions.

While statistical and geostatistical analysis of soil pH and Phosphorus provide strong evidence due to the intrinsic and extrinsic factors, the land use pattern of the study area provide a variation of the soil properties due to the effect of land use changes.

The study area was divided to 3 types of areas; forest, disturbed and pond area (Refer Figure 4.5). The effect of land use changes on the variability of soil pH and Phosphorus were then examined through this categorization of areas. The mean of each soil pH and Phosphorus were calculated for each area and compared by using bar chart.

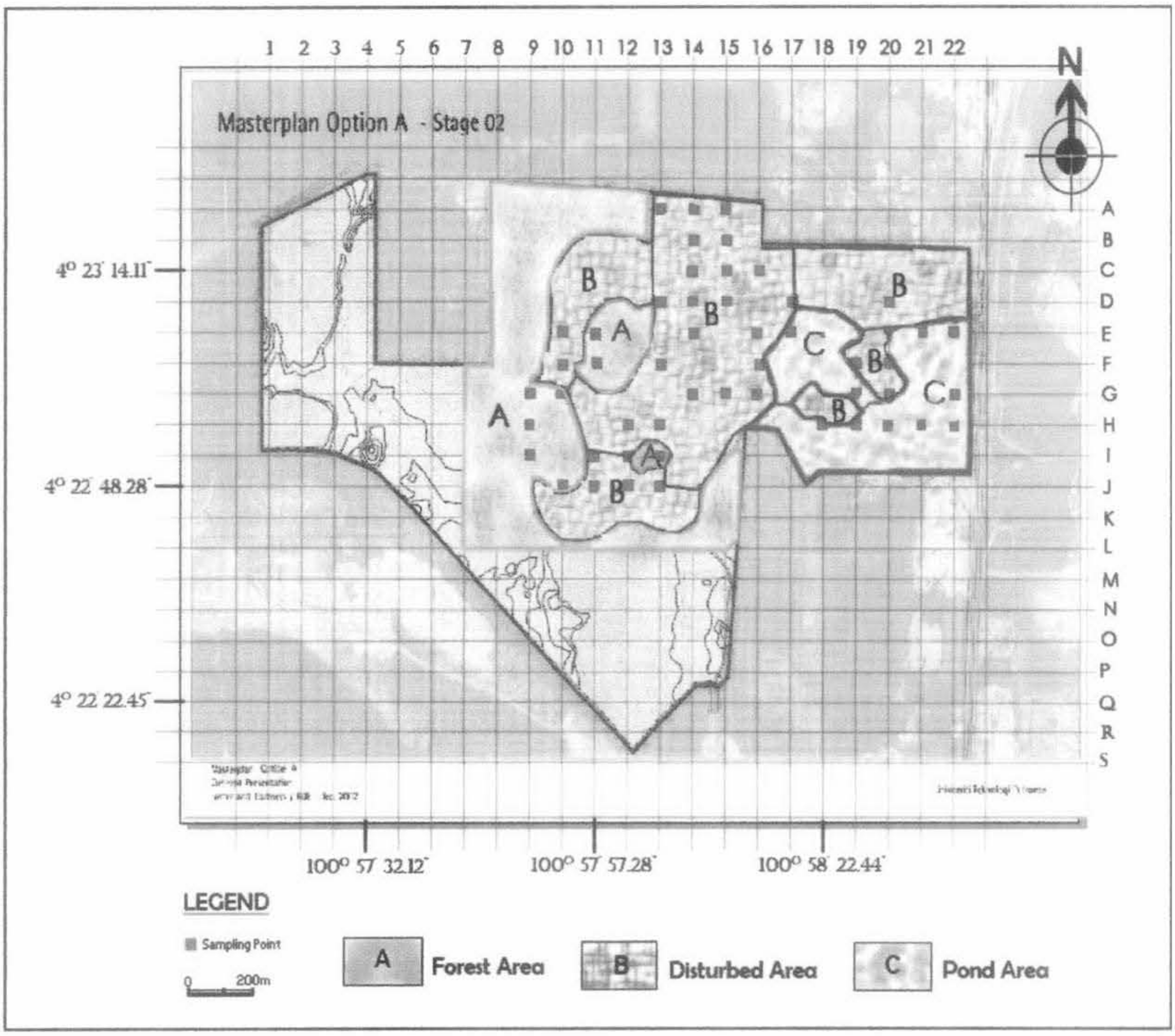

FIGURE 4.5: Map of Study Area and Land Use Pattern.

Forest area (Area A) is the area congested with trees and where the deep forest is taken place. There is no significant land alteration has taken place in this area. The soil at this area is not compact. Disturbed area (Area B) is the area where the land was altered due to the construction of academic building, road and pavement. The activities involved during the constructions were ground alteration, forest clearance and backfilling. The land alteration activity done at this area has resulted to a very compacted soil. Pond area (Area C) is the area congested with ponds. The soil here is not very compact.

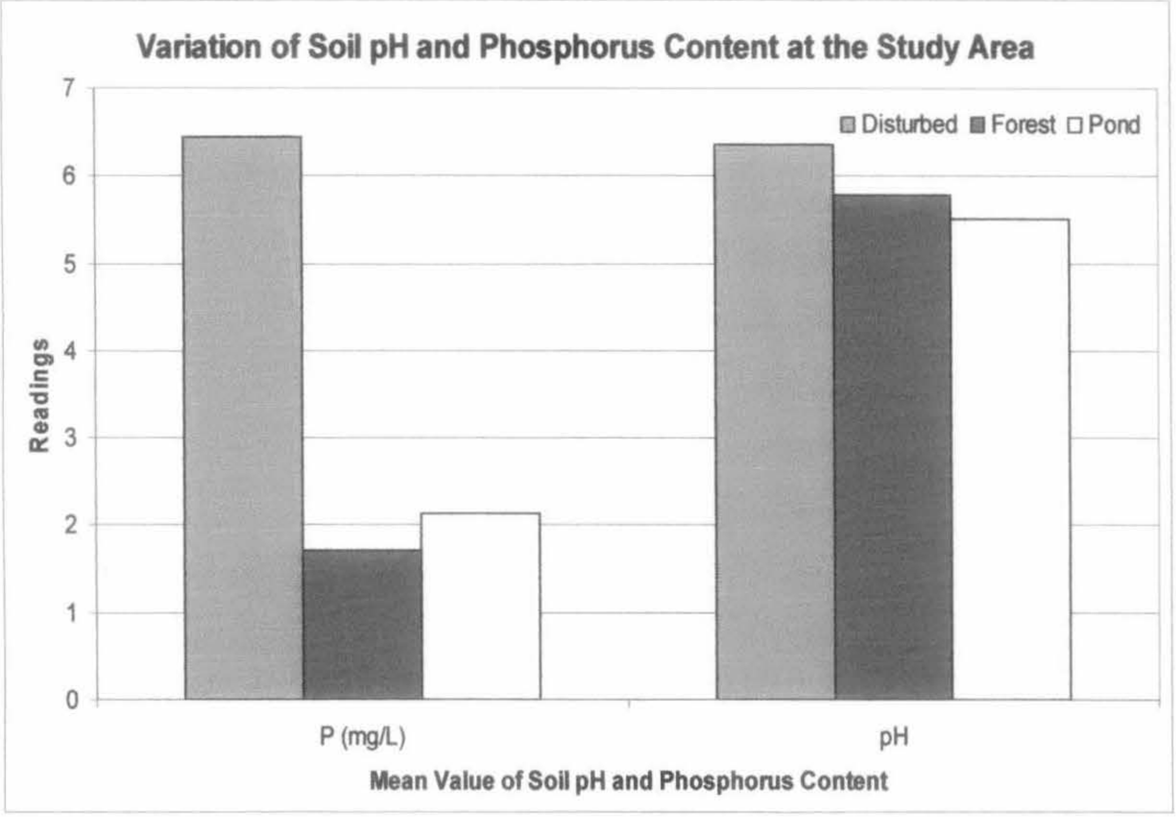

FIGURE 4.6: Variation of Soil pH and Phosphorus Content at Study Area.

From Figure 4.6, the soil pH is higher at the disturbed area. The lowest value is at forest area while at pond area, the value is medium. Figure 4.6 also shows the content of Phosphorus at disturbed area is the higher, followed by the forest area and pond area is the least. The higher soil pH and Phosphorus is caused by the land alteration done at the disturbed area due to construction of building and road. The land alteration has increased the pH and Phosphorus content. In pond area, the runoff has dissolved the Phosphorus and thus; reduced the Phosphorus content. The runoff process also decreases the pH of the soil at that area.

The land use pattern of UTP has caused a large variation of soil pH and Phosphorus content. The significance different between the disturbed, forest and pond area is due to disturbances caused by the construction activities taken place before. The activities are forest clearance and land alteration.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

The study of spatial variability of soil pH and Phosphorus content at University Technology PETRONAS (UTP) is very essential especially to characterize the soil behavior with environment practices. The soil pH and Phosphorus varies significantly across the study area. 50 samples were collected from the field points determined by using geogrid positioning method. The samples were analyzed statistically and geostatistically to reveal the nature of spatial variability. Geostatistical methods used are semivariogram and kriging.

Statistical analysis involving characterization of average value of soil properties (mean), the distribution of soil properties (median), the scatter around the mean (standard deviation) and the variability of soil properties (coefficient of variation). Larger coefficient of variation indicates irregular distribution of soil properties across the study area. From the statistical result, Table 4.1; Phosphorus has higher coefficient of variation thus, it has irregular distribution across UTP area.

Geostatistical analysis enables characterization of semivariogram parameters like the distances at which the semivariogram reaches maximum value and different soil properties are correlated (range), the variability of the soil properties in the study area (sill), the variability of unaccounted spatial variability at the smallest lag (nugget), and the ratio of spatial dependencies (nugget-to-sill ratio). Geostatistical analysis also enables contour mapping that indicates the spatial distribution of soil pH and Phosphorus across the study area, UTP. By applying geostatistical analysis, spatial variability of soil pH and Phosphorus content at UTP has been characterized. Semivariogram analysis showed that the variability of soil properties exists even within small range.

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APPENDIX

TABLE A-1: Global Positioning System (GPS) Results

Used GPS Observations					
Name	**dN (m)**	**dE (m)**	**dHt (m)**	**Horizontal Precision (m)**	**Vertical Precision (m)**
Chancellor-Heli Pad	-255.667	-541.969	1.992	0.001	0.002
Chancellor-Kantin	617.044	-293.195	3.349	0.002	0.003
Chancellor-MPH	198.234	13.470	2.518	0.001	0.002
Heli Pad-Kantin	872.710	248.775	1.353	0.003	0.004
Heli Pad-MPH	453.902	555.442	0.531	0.001	0.002
Kantin-MPH	-418.810	306.664	-0.830	0.002	0.003
GPS Observation Residuals					
Name	**dN (m)**	**dE (m)**	**dHt (m)**	**Horizontal Precision (m)**	**Vertical Precision (m)**
Chancellor-Heli Pad	-255.667	-541.969	1.992	0.001	0.002
Chancellor-Kantin	617.044	-293.195	3.349	0.002	0.003
Chancellor-MPH	198.234	13.470	2.518	0.001	0.002
Heli Pad-Kantin	872.710	248.775	1.353	0.003	0.004
Heli Pad-MPH	453.902	555.442	0.531	0.001	0.002
Kantin-MPH	-418.810	306.664	-0.830	0.002	0.003

Control Points				
Name	**Latitude**	**Longitude**	**Ell.Height (m)**	**Code**
Chancellor	4°22'56.60467N	100°58'14.85808E	23.096	
Adjusted Points				
Name	**Latitude**	**Longitude**	**Ell.Height (m)**	**Code**
Heli Pad	4°22'48.28137N	100°57'57.28015E	25.088	
Kantin	4°23'16.69270N	100°58'05.34877E	26.444	
MPH	4°23'03.05825N	100°58'15.29499E	25.616	

TABLE A-2: Summary of Lab Test Results

Point	Longitude	Latitude	pH	P (mg/L)
1	100° 58' 11.65555E	4° 23' 21.49137N	7.276	9.62
2	100° 58' 08.06170E	4° 23' 21.49137N	7.415	11.38
3	100° 58' 04.46785E	4° 23' 21.49137N	6.894	7.93
4	100° 58' 11.65555E	4° 23' 17.80137N	7.535	12.45
5	100° 58' 08.06170E	4° 23' 17.80137N	7.438	10.9
6	100° 58' 15.24940E	4° 23' 14.11137N	6.462	18.43
7	100° 58' 11.65555E	4° 23' 14.11137N	6.414	16.39
8	100° 58' 08.06170E	4° 23' 14.11137N	6.774	15.46
9	100° 58' 29.62480E	4° 23' 10.42137N	5.329	3.64
10	100° 58' 18.84325E	4° 23' 10.42137N	5.931	13.42
11	100° 58' 11.65555E	4° 23' 10.42137N	6.613	10.04
12	100° 58' 08.06170E	4° 23' 10.42137N	6.823	5.62
13	100° 58' 04.46785E	4° 23' 10.42137N	5.519	1.56
14	100° 58' 36.81250E	4° 23' 06.73137N	5.259	2.19
15	100° 58' 33.21865E	4° 23' 06.73137N	5.427	1.16
16	100° 58' 18.84325E	4° 23' 06.73137N	5.76	1.84
17	100° 58' 15.24940E	4° 23' 06.73137N	6.735	9.31
18	100° 58' 08.06170E	4° 23' 06.73137N	6.68	3.65
19	100° 57' 57.28015E	4° 23' 06.73137N	4.148	1.51
20	100° 57' 53.68630E	4° 23' 06.73137N	5.872	7.12
21	100° 58' 29.62480E	4° 23' 03.04137N	5.375	2.06
22	100° 58' 26.03095E	4° 23' 03.04137N	5.642	1.73
23	100° 58' 15.24940E	4° 23' 03.04137N	6.311	8.37
24	100° 58' 04.46785E	4° 23' 03.04137N	6.541	19.63
25	100° 57' 57.28015E	4° 23' 03.04137N	4.824	1.47
26	100° 57' 53.68630E	4° 23' 03.04137N	5.386	4.58
27	100° 58' 36.81250E	4° 22' 59.35137N	4.853	1.68
28	100° 58' 29.62480E	4° 22' 59.35137N	4.768	1.35