Characterization of Spatial Variability of Soil Nutrients at Seberang Perai , Malaysia

By

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Dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

as a partial fulfillment for the requirement of the
Degree of Bachelor in Engineering

BACHELOR OF ENGINEERING (CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

April 2005

ABSTRACT

This study addressed the characterization of spatial variability of soil nutrients at Seberang Perai, Malaysia using Geostatistical methods. Accurate information from this study on the spatial variability of soil chemical properties is very important in understanding and characterization of small scale spatial variability nature of nutrient properties of tropical soil, and thus allows in investigation of the catchment's characteristics in Seberang Perai area in Malaysia. Two significant aspects of spatial variability of soil chemical properties were examined in this study. First, spatial distribution patterns of soil chemical properties (pH, total Nitrogen (N), available Phosphorus (P) and exchangeable Potassium (K)) were investigated and secondly the spatial autocorrelation for these properties were investigated. The study area was divided by a number of geo-grid reference points. Soil samples (n=70) were collected at these points and were analyzed in the laboratory for soil chemical soil properties. Differential global positioning system (DGPS) was used to locate the sample position. These soil properties along with their geo-grid reference location were analyzed to produce soil properties map over the entire area using the software SURFER. Semivariogram analysis was performed for the spatial soil properties to examine the autocorrelation among the data set using GS+ software. Results indicate that significant spatial variability exist in the soil chemical properties. The nugget to sill ratio indicates a moderate dependency for soil pH and available Phosphorus, while a strong dependency for Potassium and total Nitrogen.

ABSTRAK

Kajian ini tumpu kepada aspek perbezaan permukaan sifat kimia tanah di kawasan Seberang Perai, Malaysia dengan menggunakan kaedah "Geostatistical". Maklumat yang tepat daripada kajian dalam aspek perbezaaan dalam sifat kimia tanah di iklim tropika adalah penting kerana ia akan membantu membuat penyiasatan dalam ciri-ciri saliran dan permodelan reaksi tanah dan hidrologi di kawasan sekitar Seberang Perai di Malaysia. Dua kesan yang ketara bagi aspek perbezaan permukaan telah dikaji dalam kajian ini. Pertama, corak taburan sifat-sifat kimia tanah seperti pH, kandungan Nitrogen (N), kandungan Phosphorus (P) dan kandungan Potassium (K) dalam tanah telah dikaji dan kedua hubungkaitan antara sifat-sifat ini dikaji. Kawasan kajian ini dibahagikan kepada beberapa nombor rujukan grid-geo (n=70). Sampel tanah kemudian diambil pada titik ini dan dikaji dimakmal untuk menentukan sifat kimianya. Sifat tanah ini dengan rujukan lokasi grid-geo dianalisis untuk membuat peta sifat kejuruteraan pada kawasan kajian dengan menggunakan perisian SURFER. Kemudian analisis semivariogram dibuat untuk sifat kejuruteraan dengan menggunakan perisisin GS+ untuk menkaji hubungkait antara set-set data. Keputusan menunjukan bahawa terdapat perbezaan yang ketara didalam sifat kimia tanah di sekitar kawasan kajian. Nisbah "nugget to sill" daripada analisa GS+ menunjukan bahawa pH dan kandungan fosforus bersifat separa bebas. Manakala kandungan Pottasium dan jumlah Nitrogen bersifat bebas.

ACKNOWLEDGEMENT

I am deeply indebted to my supervisor Dr. Rezaur Rahman Bhuiyan. He has devoted so much time and effort in teaching me both the research methods and in writing up this report. Besides, he also has devoted so much afford in teaching me all the software which is a new thing for me. If I ever become a lecturer, I wish I could be like him. Though I have not troubled him, I know he had troubled himself helping me indirectly, to the extent of which I am not even certain. The thoughts he has offered have enriched my thesis.

Special thanks to Research Officer Mr. Azhari for insightful and helpful comments and for making clear to me various issues. My sincerest appreciation also goes to technical staffs Mr. Mohd Fauzi, Mr. Mohd Taib, Mr. Rasidi Razak, Mr. Zulhairi Ariffin, Mr. Junaidi Ramli, Mrs. Nurul Akma and Mrs. Samsiah for helping me so that my lab work can be carried out successfully in safely environment. Without the help from them I might not be able to complete my lab work successfully within the limited time.

I am also grateful to my classmate, Mr. Lim Boon Chiang, battles fought in class, forcing me to see where my analysis might be inadequate. Mr. Lim Boon Chiang sympathetic ear deserves special mention, without which writing this report would take a longer time.

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CHAPTER 1: INTRODUCTION

1.1 Background

Soil is a complex heterogeneous mixture of organic and inorganic mineral compounds formed by weathering of rocks. Soil nutrients are influenced by both intrinsic (e.g. soil formation process, composition of parent rocks, soil organisms) and extrinsic factors (e.g. regional climate, vegetation, soil management practices, fertilization, etc). Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristic and precludes characterization of soil hydrological response. One of the major issues in distributed parameter hydrological modeling is how to estimate attributes of spatially varying soil nutrients.

Soil quality is defined as the capacity of a soil to sustain biological production within ecosystem boundaries, to maintain environmental quality, and to promote plant and animal health (Doran et al., 1994). Common nutrient properties of soil include Nitrogen (N), Phosphorus (P) and Potassium (K). Semivariance analysis is a geostatistical analysis method used to estimate the distance or range over which samples of a regionalized variable have related variances. The geostatistical methods consider the spatial-temporal variation of soil properties as random process depending on both the time and space (Goovaerts., 1999).

Recently, there has been increasing concern about how to estimate attributes of spatially varying soil nutrient properties (Bo Sun et al., 2003). Characterizations of spatial structure of soil nutrients are important for several form of analysis: (i) evaluation of conventional statistical characteristics of soil nutrient properties, (ii) spatial dependence of soil nutrient properties, (iii) estimating point or spatially averaged values of soil properties using kriging technique (e.g. Bardossy and Lehmann, 1998), (iv) in designing sampling networks and improving their efficiency (e.g. Prakash and Singh, 2000). Thus, spatial variability of soil nutrient properties should be monitored and quantified for a better understanding of such factors as management and pollution, and finally leading to more efficient farming practices (Bo Sun et al., 2003).

In the past, conventional statistics have been widely used to assess the variability of various properties of soil (e.g. Brejda et al., 2000). Statistical characterization of spatial variability involves parameter estimation such as the variance (Var), standard deviation (SD) and Coefficient of variation (CV). Conventional statistics assumes that observations in the field are random processes, regardless of their location. However, there is a significant volume of literature in various disciplines such as hydrology (Ali et al., 2000; Rezaur et al., 2002), geology (Davis, 1986), mining (Isaaks and Srivastava, 1989), environmental science (Vereeckern et al., 2000) and soil science (Dasselaar et al., 1998) which shows that variation in earth science data tends to be correlated across space. Therefore, conventional statistical methods may be inadequate for interpolation of spatially dependant variables, because they assume random variation and do not consider spatial correlation and relative location of samples (Vauclin et al., 1983, Goderya et al., 1996).

Geostatistical procedures recognize these difficulties and provide tools to facilitate the examination of spatial and temporal correlation in the data, thereby allowing the estimation of a physical property using measurements of that property made at close physical proximity (Cromer, 1996). One of the most efficient tools is the semivariogram, which measures the temporal or spatial behavior of a variable of interest. Geostatistical tools such as kriging allow estimation of spatially correlated data and are superior to the commonly used interpolation techniques such as, Inverse Distance Weighting (IDW) and Normal Distance Weighting (NDW) (Rouhani, 1996). Because of this, the geostatistical approach has received increasing attention in science and engineering during the last decade (Western et al., 1998; Bardossy and Lemann, 1998; Ali et al., 2000; Rezaur et al., 2002).

Soil quality index is the main method to assess soil quality. Some approaches, e.g. multiple variable indicator kriging (MVIK), are used as an integrated index of soil quality (Doran et al., 1994; Doran and Jones, 1996). So far, studies of the effect of land use alteration on the spatial variability of soil nutrients are very limited (B.Sun, 1997) and no geostatistical case study has been reported on evaluation of spatial and temporal changes of soil quality, especially at farm and regional scale.

1.2 Objective of the study

This proposed project will allow understanding and characterization of small scale spatial variability nature of nutrient properties of tropical soil in Seberang Perai area in Penang state, Malaysia.

The primary objectives of this study were:

(I) To characterize spatial structure of soil nutrients under tropical climate in term of semivariogram parameter,

(II) To map the variation in soil nutrients in the study area, and

While the secondary objective of this study is to investigate agriculture practices and catchments characteristic in Seberang Perai area in Penang state, Malaysia and provide ample data to another IRPA project, "GIS based Watershed Management System for Non Point Source (NPS) Pollution Modeling.

CHAPTER 2: LITERATURE REVIEW

2.1 Importance of soil properties

Nutrients are the available nitrogen, phosphorus, potassium, and other minerals. Soil nutrients (N, P, K) and pH values vary spatially and temporally from a field to a bigger region scale, the results from the developed countries show that soil variability can occur on any scale including area, field, regions within the field and even between some millimeter spaces. Bouma and Finke (1993) divided the variability of soil properties into several categories. The first is the static variability, such as soil texture and organic matter. The second is the dynamic variability, such as soil moisture and temperature. The variability of these properties has a direct relationship with the specific condition in the field, but the variability of physical–chemical properties is more important for researchers because it is the main reason for the variability of crop yield.

Soil nutrients are influenced by both intrinsic (e.g. soil formation process, composition of parent rocks, soil organisms) and extrinsic factors (e.g. regional climate, vegetation, soil management practices, fertilization, etc). Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristic and precludes characterization of soil hydrological response. One of the major issues in distributed parameter hydrological modeling is how to estimate attributes of spatially varying soil nutrients.

The heterogeneity and variation of soil properties should be monitored and quantified for a better understanding in order to provide potentially useful information in improving agriculture site specific management to yield aggressive crops productivity, catchments characteristic and preventing environmental risks within ecosystem boundaries.

A key requirement for precision agriculture development is to understand comprehensively the spatial variability of soil nutrients (Jin, 1998). Soil fertility for plants in reality is a very simple affair but difficult to explain. There are no miracle fertilizers, only plain and simple chemical nutrients that are absolutely essential for plant growth. In moist sand loams plant nutrients are generally more accessible than in silt or clay soils although clay soils contain higher fertility resources. Nutrients became restricted or unavailable; in very wet or very dry soils for obvious physical reasons such as a lack of root absorption by most crop species.

Plant nutrients, divided into macronutrients and micronutrients are indistinguishable, whether they are from organic or chemical sources. All must be water soluble in order to enter plant root systems. Macronutrients are nitrogen (N), phosphate (P), potash (K), sulphur (S), calcium (Ca) and magnesium (Mg). The oxygen (O), hydrogen (H) and carbon (C) come from air and water and make up 95 to 99% of a plant's weight. Naturally phosphate is expressed as P_20_5 (43% actual P) and potash as K_20. (83% actual K) in soil so that can absorb by the plant. Micronutrients are needed in only very small quantities but they are every bit as essential as macronutrients to normal plant growth. Plant essential micronutrients are boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn).

Erosion and runoff are both detrimental to nutrient management. Nutrients contain in the top soil, along with the soil organic matter, can be carried away by erosion or washed out with runoff water. The organic matter is the first to transport by the water or wind because of it lower specific gravity. Additional nutrients are required to maintain productivity lost when top soil is carried away by erosion.

Sediment additions in the field can be good or bad. Some sediment, especially the finer clay particles and organic matter, bring in nutrients. The coarser sediment, like sands does not have high nutrient content and tend to cover the top soil that is in place. Coarser texture soil also lack moisture holding and pesticide retention capacity.

The understanding of the variability of soil chemical properties especially Nitrogen (N), available Phosphorus (P), and exchangeable Potassium are important for refining agriculture management practices and for reducing the impact of agriculture on pollution. Plants require different nutrient levels and a proper nutrients level is important to plants growth. That's why some plants, such as those blueberries, grow well in acid soil. The pH they prefer releases the nutrients that make them grow to their full potential. But that same acid soil couldn't dissolve the right nutrients for alkaline-loving peas to thrive. If the pH is adjusted to a more alkaline level, using limestone blueberries grow profoundly.

pH in soil indicate how alkaline or acidic a soil is, and it determines how easily the nutrients in the soil can be absorbed by the plant and also what type of nutrients suitable for the plants. But soil pH can vary from place to place. And different plants require different pH levels. The availability of nutrients, especially micronutrients, is dependent on soil pH. It generally registers on a scale from 0 to 14. Most soil pH levels fall between 4 and 8. Generally, a reading of 6.5 to 7 is considered neutral, and most garden plants will grow well in this range. Thankfully, plants are usually forgiving and will be happy as long as the reading is close. But some plants do have more specific requirements.

Soil pH is referred to as the "acidity" of the soil and is measured by the number of Hydrogen ions present in the soil solution. Ammonium fertilizers also have an acidifying effect on the soil. When the soil pH is too "acid" (low pH) or "alkaline" (high pH), nutrients present in the soil become locked-up or unavailable. Correcting the pH has the same effect as applying fertilizer since it "unlocks" plant nutrients already present.

Highly acid soils are also characterized by chemical soil changes detrimental to plants (with the exception of acid lovers). Phosphorous, calcium, and magnesium become less available to plants in acid soils. Other elements such as aluminum and manganese, become available in quantities toxic to plants. Because soil organisms are less active in acid soils, the decomposition of organic matter is slowed, and nitrogen is reduced. Most soils in the Midwest test alkaline, and need to be acidified. Acid soil develops naturally in areas where soil is leached by high rainfall. You can correct overly acid soil by adding lime or organic manure.

Nitrogen (N) normally exists in the form of $N0_3^-$ (Nitrate) and NH_4^+ (Ammonia) in soil. Nitrogen is macronutrients required by plants in large amounts. Green, leafy growth and proteins, including the food proteins found in corn, beans and other vegetables are made possible by nitrogen. It’s one of the main components of chlorophyll. Nitrogen comes from many organic sources, such as urea, or it can be man-made. Nitrogen limits the growth on most boreal forest. Anthropogenic input of N has resulted in increased forest productivity, which may lead to depletion of other nutrients (Mohren et al,1986; Dralle and Larsen, 1995; Thelin et al, 1994).

Phosphorus (P) normally exists in the form of PO_4 in soil. This nutrient promotes root growth and the development of flowers and fruit. It strengthens stems and improves disease resistance. Two common sources of phosphorus are bone meal and rock phosphate. All forms release into the soil slowly. Phosphorous is essential to all living cells, being utilized in the formation of nucleic acids e.g. Dioxiribo Nucleic Acid (DNA) and Ribo Nucleic Acid (RNA). It is also used in the storage and transfer of energy. Most of the Phosphorous in soils is tied-up chemically with compounds of limited solubility. The application of complexes Phosphates will help release this bond and make more Phosphorous available to the plant. Many other essential elemental nutrients are governed by similar conditions involving compatibility with each other, and the soil/plant environment.

Potassium/Potash (K) normally exists in the form of K^+ in soil. The flow of water in plant cells is regulated by potassium. It's necessary for flowering, fruiting and disease resistance. It also plays an important role in the formation of chlorophyll. Wood ash, crushed granite or sulfate of potash, a synthetic ash, are all good sources. Potassium also takes part in activation of enzymes, Photosynthesis, transport of Sugars, protein synthesis, water and nutrient transport and maintaining water-solute balance and thus affecting osmosis.

Soil nutrients need to be applied according to the crop and soil requirements. Soil analysis is a good way to determine the amount of nutrients needed in order to become healthy soil. Over application of nutrients can be lead to plant toxicity, poor pH respond, and excess nutrients susceptible to runoff, leaching and volatilization. A deficiency in nutrients will not sustain optimum crops growth.

Accurate information on the spatial variability of soil chemical properties is very important in developing site fertility management for agriculture practice. The pattern of the spatial variability in the form of kriging map can help to improve the decision for fertilizer recommendation. Different rate of soil nutrient application is possible only if experts can give correct site specific recommendation and the potentially effective advises could only be gave when the spatial variation in nutrient status across a field is quantified. The quantitative information obtains from this study could be used to facilitate site specific management as it is able to creates high expectations with higher financial returns, increased crops quality, and decreased environmental risks.

Recently, precision farming or known as site specific crops management are highly encouraging in Asian countries for the reasons include: (i) Social concern regarding to environment problems and ground water contamination due to over feeding of agriculture chemicals with the purpose to increase yield to support rapid increasing population on a limited space of land, (ii) Pressure to strengthen the value of crops product in order to survive in competitive market, (iii) Public demand for higher environmental safety agriculture product and, (iv) Shortage of labor due to decreasing and aging rural population (Srinivasan, 1999). Therefore, interest among agro-business, traders, farmers, and researchers is increasing because of the potential and highly expectation benefits of the precision farming.

Site specific crops management can be viewed as a cyclical process of within field data collection, data analysis and optimum decision making, variable rate application and evaluation. Yield, crop growth status and soil properties are necessary data inputs to the system. Describing spatial variability of within field properties in typical Malaysia production setting is a fundamental first step toward determining the management zones and the inter-relationship between limiting factors, for the development of management strategies.

The effect of land use alteration on the spatial variability of soil properties are seldom in consideration. There is various type of land use pattern changes include: keeping the original land use pattern for wasteland and paddy field, change from wasteland to woodland, arable upland and paddy field.

Changing the land use pattern may affect the pH, ranges, and the variability of soil nutrients across the field particularly for available Nitrogen (N), Phosphorus (P) and exchangeable Potassium (K), but the impact could be different for different soil properties. "By keeping the original land use patterns of wasteland and paddy field had no significant effect on soil pH, available P and K, but decreased significantly soil organic matter. Soil available P and K increased with fertilization in arable upland, but decreased in forest restoration without fertilization. Changing wasteland into paddy filed led to an increase in the mean value of all soil properties." (B.Sun et al., 2003)

2.2 Problems associated with variability of soil nutrient properties

Previously, changes in soil properties have been monitored through long term field experiments, like Rothamsted Classical Experiments (Johnson et al, 1986) and the long term Ecological Research Program (Risser,1991). However, this method is time consuming and in many cases too expensive to be affordable. Moreover, the greater spatial variation makes it difficulty to evaluate the temporal changes of soil properties in very limited period. Recently, scientist starts to concern about how to estimate spatial and temporal changes of spatial varying soil attributes (Papritz and Webster, 1995; Heuvelink et al, 1997). Papritz and Webster used a co-kriging method with the pseudo-cross variogram to estimate temporal changes of spatial auto correlated soil properties by focusing on the methodology of geostatistical analysis on some grid point or other pattern.

The variability of soil nutrient properties across field is often described by classical method, which assumes that variation of the soil nutrient properties is randomly distributed within mapping units. Soil variability is the outcome of many processes acting and interacting across continuum of spatial and temporal scales and is inherently scale dependent (Parkin, 1993). The geostatistical methods consider the spatio-temporal variation of soil nutrient properties as a random process depending on both the time and the space (Goovaerts, 1999).

Previous study shows that application of concepts on spatial dependence could help in understanding and deal more effectively with variability in soil characteristic (ScienceAsia 29, 2003). Therefore, parametric statistics are inadequate for analysis of spatial dependent variables as they assume that measure observations are independent in spite of their distribution in space (Hamlett et al. 1986). Besides, soil nutrient properties frequently exhibit spatial dependent in which they tend to be more similar in samples that are aggressively close to each other. Thus, we might assume that soil nutrient properties measure at a grid point is practically and theoretically able to represent the unsampled neighborhood across a mapping unit. Most of the researches were focused on the methodology of geostatistics at plot scale, while the effect of the undulating topography on the geostatistical analysis is seldom taken into consideration.

Nowadays, scientist started to apply geostatistical and interpolation kriging method as a potential analysis tool for monitoring and quantifying the changes of soil nutrients over small to large spatial scale. Soil nutrient properties are usually studied by taking samples on some grid or other pattern with the assumption that properties measure at a grid point is able to represent the unsampled neighborhood. Differential global positioning system (DGPS) was used to locate the sample position. The soil samples collected from the field are then airdried and ground to pass through a 2mm sieve before bringing to laboratory to carry out further analysis. The study indicated geostatistical analysis in conjunction with conventional statistical analysis could reveal spatial variability nature of soil properties and causes behind the variability. Of significant importance to land management practices is the finding that the variability of the soil properties are largely due to topographic features and land disturbances.

Previous study has been done by Zhou et al., (1996) to investigate the spatial variability by a small grid of 50x50m over a 200x200m field in the hill region of subtropical China. Soil nutrient properties were measured: soil pH was measure with glass electrode in a 1:2.5 soil/water suspension. Total nitrogen (N) by sulfuric-salicylic acid digestion method, available phosphorus (P) were determined by NH_4F-HCl extraction method otherwise were extracted with $NaHCO_3$ at pH 8.3 using the method of Olsen et al. (1954), and exchangeable potassium (K) were extracted with NH_4AC and then measured by an atomic absorption spectrometer. Next, the data obtained from the laboratory will compute and display in the form of semivariogram using geostatistical method (GS+, Gamma Design Software, St Plainwell, MI, version 5.0.3 Beta) to transform the data into various useful information. Besides, interpolation using Kriging method can show a spatial similarity among soil nutrient properties.

2.3 Relevant study in Malaysia

Many studies have been conducted in Malaysia with the purpose to investigate the soil nutrients variability within a small to large spatial region. One of the studies was conducted at the Sawah Sempadan rice plantation area. This study is a part of University Putra Malaysia (UPM) – Malaysian Center for Remote Sensing (MACRES) precision farming project funded by the Malaysian government. The location of the study is on a flat coastal plain in Northwest Selangor, Sabak Bernam at latitude 3º 35′ and longitude 101º 05′. The area of study is 2300 hectare and including five major soil series, Jawa, Teluk, Karang, and Sedu dominate the soil.

According to the author, the primary objective of their study was to determine the structure of spatial dependence of soil chemical properties selected over relatively long distances and to examine and interpret semivariogram of Nitrogen (N), available Phosphorus (P), and exchangeable Potassium (K) across the large rice field. The study analyzed the spatial variability in soil chemical properties, particularly the total Nitrogen (N) and available Phosphorus (P) on 2300 ha rice field.

The soil samples (n=240) were taken from 120 points; two points in each plot were taken in each depth: top soil (0-20cm) and sub soil (20-30cm). Collection of the soil samples has been done in order to cover all types of the soil series dominant in the study area. Differential global positioning system (DGPS) was used to locate the sample position, and variability of soil chemical properties was analyzed by geostatistical techniques. Total N and available P varied greatly for both depths as indicated by variogram analysis. The range of total N varied between 0.434 and 0.475 km for top and sub soil depth respectively, and available P between 0.597 and 0.610 km for top and sub soil depth respectively. The kriging maps showed the spatial variation for soil chemical properties measured. The results suggest that soil chemical properties measured maybe useful in the field management zones that could maximize application benefits.

The outcome of the quantitative information obtained in the study could be used to facilitate site-specific management in Sawah Sempadan, Malaysia and finally for leading to more efficient farming practices.

CHAPTER 3: METHODOLOGY

3.1 Introduction

A study map was chosen and was used as a base map. The geo–reference (Latitude, Longitude) for two locations on the base map was established by a Differential Global Positioning System (DGPS) survey. The base map was then digitalized with DigXY software to obtain map boundary data in digital form and in geo-grid reference system. From the digitalized data, the map was regenerated with geo-grid reference co-ordinates using surfer software.

On the generated map, the study area was subdivided by a number of regular geo-grids. The intersection of the grid lines marked the locations for soil sample collection. Figure 3.2 shows the map and soil sampling locations. Soil samples were collected at these locations for pH test and also test for variability of total Nitrogen (N), available Phosphorus (P) and exchangeable Potassium (K) in the laboratory.

When information of the soil chemical properties were available from laboratory tests, the sampling locations on the map provided two information; The soil properties at this location and the geo-grid reference locations for this property. The sample location with geo-grid locations and sample properties at the grid locations provided a spatial data set. The spatial data were then evaluated to investigate on:-

(i) Spatial distribution pattern of soil nutrients

(ii) Spatial autocorrection among the data.

3.2 Site Description

In this section, a brief review on the climate of Malaysia is made to enhance the readers understanding regarding the condition of the land and environment where the research has been done. The research was conducted at the Seberang Perai area in Penang state, Malaysia.

3.2.1 The Climate of Malaysia

Malaysia can be divided into three main regions: Peninsular Malaysia, Sabah and Sarawak. Approximate location of these three regions is given below (see figure 3.1). (UNEP Environment Assessment Programme-Asia Pacific, 1997)

Peninsular : 6^0 45’ and 1 ^{0}20’ N latitudes and 99^0 40’and 104^0 20’ E longitudes

Sabah : 4^0 00’ to $7^0$00’ N latitudes and 115^0 20’ and 119^0 20’ E longitudes

Sarawak : 0^0 50’ and 5^0 00’ N latitudes and 109^0 35’ and 115^0 40’ E longitudes

Figure 3.1 Map of Malaysia (from, http://www.lib.utexas.edu)

The total area of Malaysia is 328,600 km^2 of which Peninsular Malaysia is 131,600 km^2, Sabah is 73700 km^2 and Sarawak is 123,300 km^2. Geographically Peninsular Malaysia is separated from Sabah and Sarawak by 720 kilometers. Peninsular Malaysia accounts for 40% of the country's landmass. (UNEP Environment Assessment Programme-Asia Pacific, 1997)

The climate of Malaysia is typical of the humid tropics and is characterized by year-round high temperature and seasonal heavy rain. Temperature ranges from 26^0 C to 32^0 C and rainfall ranges from 2000 mm to 4000 mm per annum (UNEP Environment Assessment Programme-Asia Pacific, 1997). The climate of Sabah is characterized as marine equatorial. The rainfall is very high due to the influence of both north-east monsoon and the south-west monsoon. This make the soils in Malaysia to be dry and wet thought out the year.

3.2.2 The study area

The study was conducted at the Seberang Perai area in Penang state, Malaysia.

3.2.3 Description of the study area

A brief of site description is described in this section; varies type of land used and the climate of the study area has been carried out to enhance the readers understanding regarding to the environmental condition of the land.

The study area is in the state of Penang mainland and lies between latitude $100^{o}25.616^{'}$ to $100^{o}31.575^{'}$ and longtitude $05^{o}09.452^{'}$ to $05^{o}18.660^{'}$ (see figure 3.2). Seberang Perai is divided into three major regions namely Seberang Perai Utara, Seberang Perai Tengah and Seberang Perai Selatan. As can see from the map, Penang is among the thirteen states in Malaysia and just located beside state of Kedah and Perak.

The climate at the study area is typical of the humid tropics and is characterized by year-round high temperature and seasonal heavy rain with the total rainfall of year 2003 is 3457mm from station of Pintu Air Bagan Itam (No. Station 5302002). While the average of rainfall of the year 2003 is about 288.1mm. Daily temperature ranges from 26 Celsius to 32 Celsius.

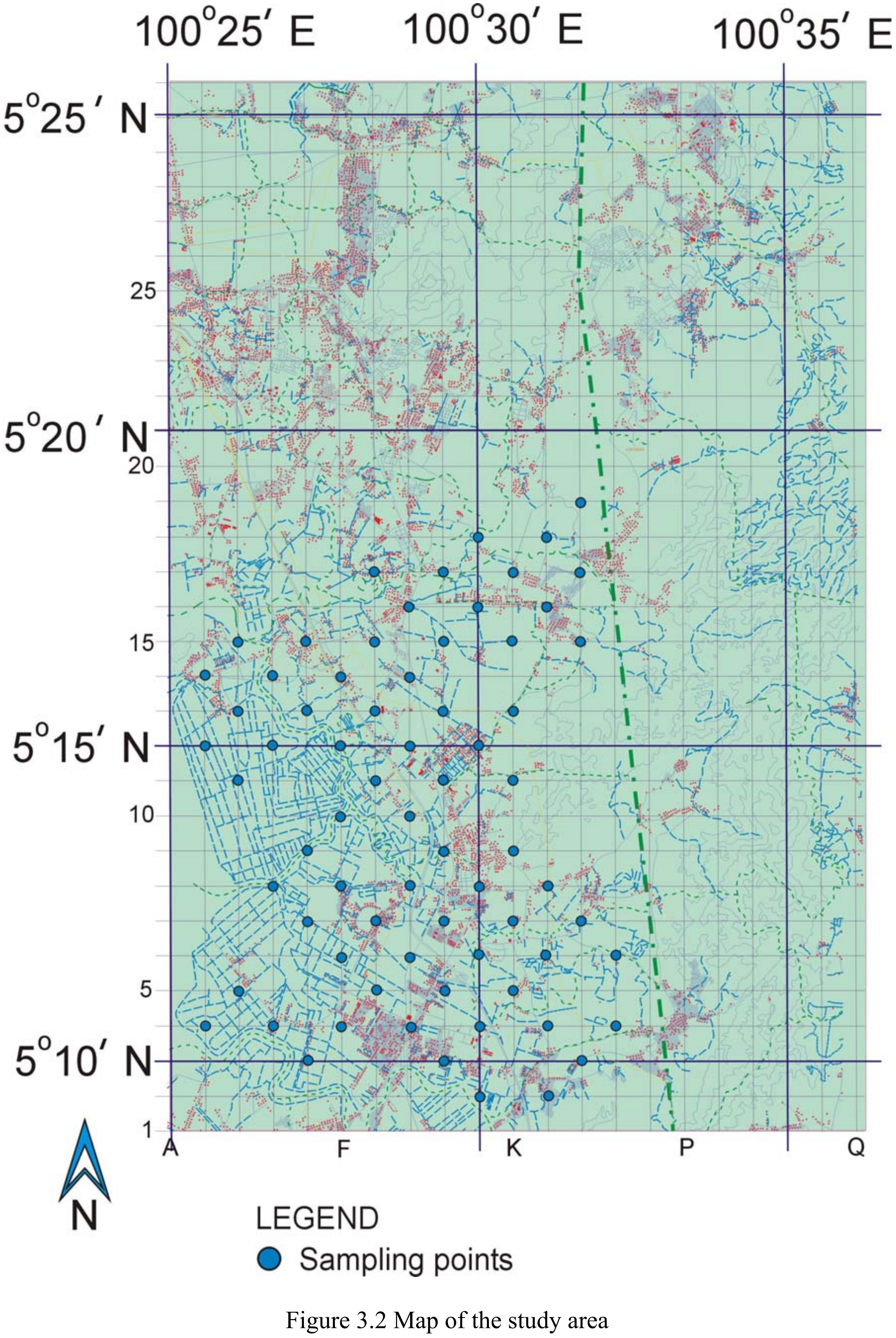

Figure 3.2 Map of the study area

3.3 Soil Collection

A core sampler was used for collecting seventy soil samples at the predetermined gird location (see Figure 3.2). The soil samples were collected between month of November and December 2004. The core sampler was made of iron, and was 230mm in length and 38.15mm in diameter (see figure 3.3). Grease was applied to the inner part of the sampler as a lubricant. The function of the lubricant is to minimize the friction between the inner surface of the sampler and the soil. When the core sampler was pushed inside the soil, the friction would cause the soil to compact. This can cause changes in the bulk density of the collected sample. The lubrication of the sampler inner surface with grease also enhanced the sample extrusion.

The following steps were followed while collecting the soil samples

1. The sampling location was cleared from grass. The presence of grass makes it harder for the sampler penetration into the soil and it may also affect the density of the sample. The cleaning of the grass ensured easy penetration of the sampler and eliminated possibilities of the sample disturbances.
2. The core sampler was pushed around 200 mm into the soil. Then the core sampler was extruded from the soil. This brings the core sampler together with the soil sample.
3. The core sampler together with the sample was then tied inside a plastic bag and brought back to the lab for testing. This is done to avoid any moisture content loss from the sample. Loss of moisture content due to wind and sun is very fast, so the samples were preserved in sealed plastic bag to avoid any loss in soil moisture.

4. To extrude the sample from the sampler the core sampler was hit on a wood surface slowly. Strong hitting was avoided to prevent changes in density. Depending on the soil condition, sometimes it was possible to extrude the sample from the sampler just by shaking.
5. Extruded samples were then used for finding the pH, total nitrogen (N), available Phosphorus (P) and exchangeable Potassium (K).

Figure 3.3. Photograph showing core sampler used in soil sampling

3.4 Laboratory Tests

3.4.1 Samples Preparation

50g air-dried and ground to pass through a 2mm sieve. The fine soil samples are shaken for one hour with 250 ml water using orbital shaker with adjusting to 250 rpm (see Figure 3.4). After that the samples were filtered by using vacuum pump (see Figure 3.5), with this the solid soil samples were transform into water samples and thus this solution can be used for the further determinations.

Figure 3.4 Photograph showing orbital shaker

Figure 3.5 Photograph showing vacuum pump