CHARACTERIZATION OF SPATIAL VARIABILITY OF SOIL NUTRIENTS AT USM ENGINEERING CAMPUS

By

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ABSTRACT

The general objective of this study is to examine the spatial variability of soil nutrients and pH in a flat region under subtropical climate using statistical and geostatistical methods. The soil samples were taken from 50 points in the Universiti Sains Malaysia, Engineering Campus, Nibong Tebal, Penang, Malaysia. Collection of the soil data were conducted by systematic sampling and the Global Positioning System (GPS) was used to determine the sample site locations. Semivariogram analysis was performed for the spatial soil nutrients to examine the autocorrelation among the data set using GS+ software. The results showed that the soil nutrients potassium (K), phosphorus (P) and nitrate have moderate spatial dependence, while there was a strong spatial dependence for pH with available lag distance of 0.18 km to 0.41 km. The SURFER software used to produce kriged maps for the spatial distribution and the results indicated the existing of significant spatial variability of the soil nutrients in the study area.

ABSTRAK

Secara amnya, objektif kajian ini dijalankan adalah untuk menentukan taburan kepelbagaian kandungan nutrien tanah dan nilai pH di dalam kawasan tanah rata beriklim tropika dengan menggunakan kaedah statistik biasa dan geostatistik. Sampel tanah telah diambil dari 50 tempat yang berbeza di kawasan Universiti Sains Malaysia, Kampus Kejuruteraan, Nibong Tebal, Malaysia. Proses pengambilan sampel telah dijalankan secara sistematik dengan menggunakan teknologi Sistem Penentuan Global (GPS) untuk menentukan titik lokasi pengambilan sampel tanah. Analisis semivariogram dilakukan terhadap maklumat sifat kandungan nutrien dengan menggunakan perisisin GS+ untuk mengkaji hubungkait antara set-set data. Hasil analisis menunjukkan bahawa kandungan nutrien kalium (K), fosforus (P) dan nitrat mempunyai kadar bergantungan yang sederhana antara satu sama lain manakala nilai pH mempunyai kadar bergantungan yang tinggi dengan jarak keseluruhan diantara 0.18 km hingga 0.41 km. Perisian SURFER digunakan untuk menghasilkan peta taburan mengikut kaedah kriging dan hasilnya membuktikan terdapatnya kadar kepelbagaian taburan kandungan nutrien dan nilai pH tanah yang signifikan di dalam kawasan kajian.

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CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Nutrients are known to be very important to life forms. In agricultural sense, there are about sixteen nutrients elements which are essential for the plant growth. Many of these elements are the same as those required by humans. In addition to carbon, hydrogen, and oxygen, which the plant gets from the air and water, another thirteen elements are required by plants, which they obtain from the soil. The nutrients required by plants usually can be divided into two major groups; major and micro nutrients. Among the major nutrients are related to this study which is Phosphorus (P), Potassium (K), and Nitrogen (N). However, for this particular study, the emphasis is more on determining the Nitrate (NO_3^-) rather than the total Nitrogen in soils.

These nutrients have different behaviors in soils. Nitrogen forms are mobile, the nitrate anion being more mobile than the ammonium ion, which can undergo cation exchange. There are many microbial interactions with nitrogen containing substances. Phosphorus is relatively immobile. It forms relatively insoluble compounds with calcium and magnesium and high pH's and iron and aluminum at low pH's. Only a very small percentage of the total phosphorus in the soil is soluble and available for plant uptake. (as HPO_3= and $H_2PO_3^-$, the hypophosphate anions). Potassium is a component of many soil minerals. As a result, many soils release potassium to the plant as they weather. However, potassium is utilized in fairly large amounts by plants, so its addition as fertilizer is often required. It is taken up by the plant as the ion K+. This ion can undergo cation exchange, and some of it can be leached by percolating soil water. There are some clay minerals that fix potassium ion almost irreversibly. The degree of mobility and availability of elements in the soil is a complex interaction of soil moisture content, pH, oxidation potential, electrical conductivity, organic matter content, and the chemical activities of all other soil constituents, and the biological activities of microorganisms.

The soil pH condition is also important and has been included in this study. pH content may influence the availability of nutrients in soils. The pH of the soil determines to a great extent the chemical forms in which many plant nutrients exist. Some of these forms are more or less soluble, depending on the nutrient. In cases of extreme pH ranges in either direction, some of the micronutrients are unavailable, while others are available in toxic quantities.

Geostatistical methods are useful in quantifying spatial variability of soil properties as soils are spatially heterogeneous at every scale. It also provides tools to facilitate the examination of spatial and temporal correlation in the data, thereby allowing the estimation of physical properties at close proximity (Cromer, 1996). Nevertheless, the variability in soils has unique spatial patterns. Understanding the patterns gives us more information about what caused them and what processes they might affect, and opens the possibility of using some statistical tools to account for them.

Despite the vast development of geostatistic methods, the geostatistical characterization of soil engineering properties from the humid tropics particularly, the south-east Asia are quite limited (Rezaur et al., 2004). It appears that no geostatiscal study reported on evaluation of spatial variability of soil engineering nutrients at small and regional scale. Due to that reason, the spatial variability of soil nutrients study is being conducted in Kampus Kejuruteraan Seberang Perai Selatan, Penang as the study area somehow represents the tropical climate area. The final outcome of the study is believed will assist future development, particularly in land management and agricultural production.

1.2. OBJECTIVES

The primary objectives of this study are as follows:

1) To characterize spatial structure of soil nutrients under tropical climate in terms of semivariogram parameters.

2) To map the variation of soil nutrients in the study area.

3) To evaluate the effect of land use changes on the variability of soil nutrients.

The soil nutrients parameters studied are Potassium (K), Phosphorus (P), Nitrate (NO_3^-) and pH.

1.3. SIGNIFICANCE OF THE STUDY

1) This study will allow understanding and characterization of small scale spatial variability nature of nutrient properties of tropical soil in the Nibong Tebal area, Malaysia. This will allow investigate land use practices and catchment characteristics in Nibong Tebal area.

2) By knowing the availability of nutrients of an area, the soil type and structure can be estimated. For example, sandy textured soils have much less than fine-textured clay soils (Oldham, 2003). In clay soils, the clay particles are usually aggregated together into complex granules, which enable it to hold more water and nutrients than sandy soils. Therefore the information of the nutrient contents undoubtedly useful for further studies and research.

3) Spatial variability of soil properties has been one of the major objectives in investigations related to agricultural and environmental sciences. Therefore, the evaluation of the spatial variability of major nutrients N, P, K and pH will be a good foundation for rational soil sampling as well as for site-specific management for any agricultural programs in this region.

4) Human activities on the land surface, has resulted in a significant modification of its biophysical properties. Changes in land cover have made changes in the land-atmosphere fluxes of heat, moisture, and momentum. These changes in turn impact weather and climate through influences on atmospheric dynamics, thermodynamics, convection, clouds, and rainfall. The finding on the spatial variability in soil nutrients can be used to predict the consequences of the human activities on the hydrological processes such as precipitation, surface water runoff, flood and etc.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Soil is a complex mixture of mineral particles, organic matter, fluids and gasses. The mineral particles come from the breakdown of two main types of rocks which are igneous rocks and sedimentary rocks. Organic matter will be broken down in the soil if conditions are suitable, to form humus, a black or brown jelly like substance which is a valuable soil constituent. Humus effectively has a very small particle size and carries a negative electrical charge, which will help to hold positively charge nutrients in the soil. These nutrients will include calcium, magnesium, potassium, and sodium. Organic matter also may make up only 5% to 10% of the volume of soil (less than 5% of the weight), but it is critical in holding soil particles together, storing nutrients, and feeding soil organisms.

Soils are produced as the parent rock weathers to various size particles. By convention, only particles less than 2mm are considered as soil, larger particles are classified as stones. Soil particles are categorized into particular texture, in descending order of size, sand, fine sand, silt and clay (Johnston, 1997). The soil texture depends on the proportion of particles from each of these groups as simplified in a soil texture triangle (see Figure 2.1). As soil will always be vulnerable to climatic condition or human activities, the soil properties may vary in character. The variation is basically influenced by both intrinsic factors such as soil formation process and soil organisms and extrinsic factors such as vegetation and fertilization (Rezaur et al., 2004).

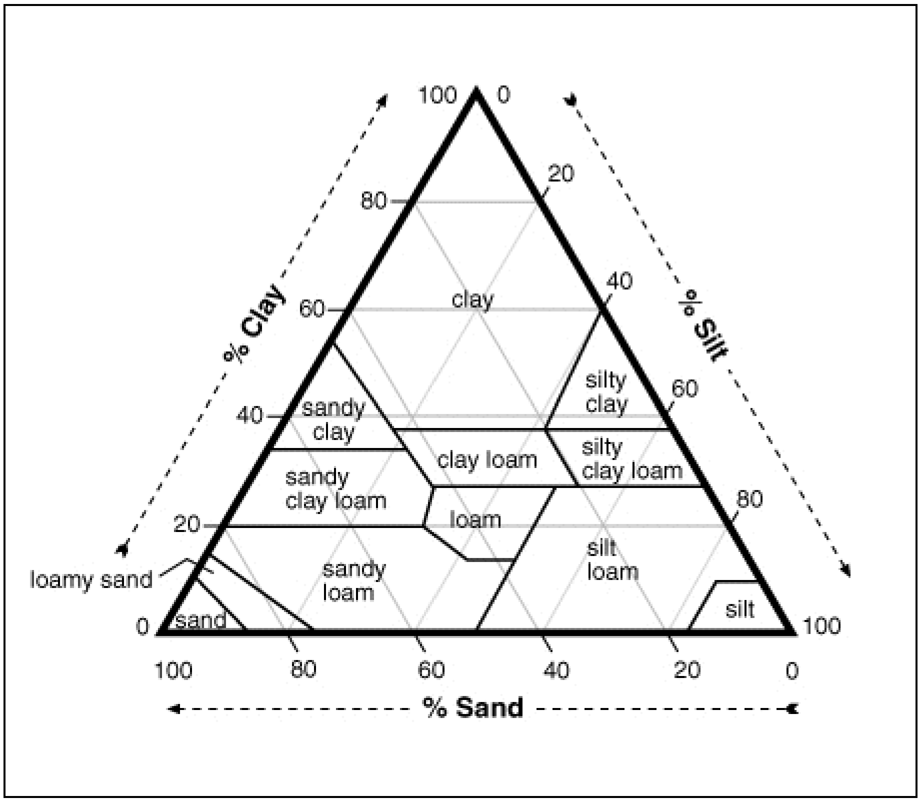

Figure 2.1: Soil Texture Triangle

The spatial variability of soil nutrients has been essential in any investigations and studies related to agricultural sciences. The evaluation of major nutrients status in soil will lead to enormous degree of research and land development. The study of three types of major nutrients which are Nitrogen (N) or for this particular study is Nitrate (NO_3^-), Phosphorus (P), and Potassium (K) in small portion of the tropical climate area, Kampus Kejuruteraan Nibong Tebal, Penang, will somehow catalyst the future development in agricultural in this region.

2.2. SOIL NUTRIENTS

Soil is the storehouse for the nutrients that plants need. It is a dynamic environment in which soil organisms, chemistry, and physics are continually acting to change the form of plant nutrients. Plant roots draw most of the nutrients they need from the soil solution and the nutrients cycle in soil can be summarized as in Figure 2.2 below.

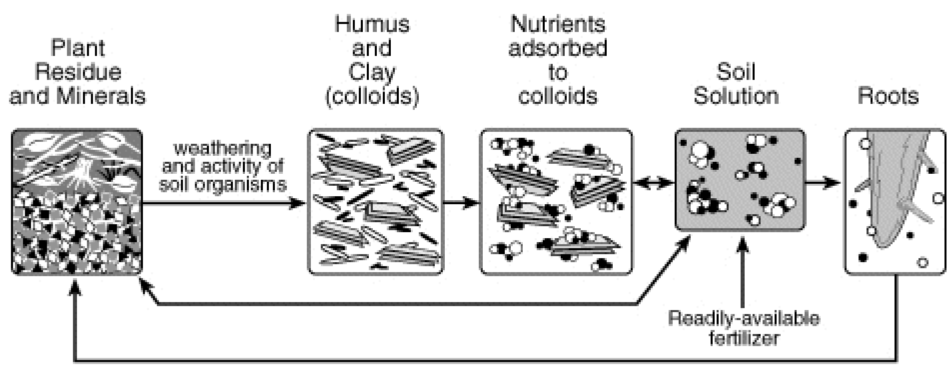

Figure 2.2: Nutrients cycle in soils

There are various kinds of nutrient exist with different sources and usage. In agricultural sense, the essential nutrients needed for plant growth can be divided into two major groups which are major nutrients and micronutrients. Table 2.1 shows the major nutrients for plant growth as well as the specific importance for the plants. Among them are the Phosphorus (P), Potassium (K) and Nitrogen (N) which are related to this study. The micronutrients and their importance are summarized in Table 2.2.

Table 2.1: The major nutrients

Nutrient	Chemical Symbol	Importance to Plants	Natural Source
Nitrogen	N	Synthesis of proteins, chlorophyll	Plant residues
Phosphorus	P	Synthesis of enzymes and the storage of energy.	Little natural reserves.
Potassium	K	Control of water by osmosis.	Much in soil, particularly where derived from igneous rocks, have a good reserve.
Calcium	Ca	Cell wall synthesis, enzyme activity.	Vast reserves in calcareous (chalk) soil.
Magnesium	Mg	Chlorophyll synthesis	Reserves in magnesium limestone.
Sulphur	S	Synthesis of some amino acids (the building blocks for proteins).	Rocks and organic material.

Table 2.2: The micronutrients

Nutrient	Chemical Symbol	Importance to Plants
Boron	Bo	Cell division
Manganese	Mn	Activation of some enzymes
Copper	Cu	Synthesis of some enzymes important in photosynthesis
Iron	Fe	Synthesis of chlorophyll, enzyme activity.
Molybdenum	Mo	Nitrate fixation
Zinc	Zn	Some enzymes
Chlorine	Cl	Photosynthesis

2.3. PHOSPHORUS

Phosphorus is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants (Busman et al, 1998). The phosphorus cycle is similar to several other mineral nutrient cycles in that phosphorus exists in soils and minerals, living organisms, and water. Although P is widely distributed in nature, it is not found by itself in elemental form. Elemental P is extremely reactive and will combine with oxygen when exposed to the air. In natural systems like soil and water, P will exist as phosphate, a chemical form in which each P atom is surrounded by 4 oxygen (O) atoms. Orthophosphate, the simplest phosphate, has the chemical formula PO_4^{-3}. In water, orthophosphate mostly exists as $H_2PO_4^-$ in acidic conditions or as HPO_4^{2-} in alkaline conditions.

The phosphorus plays vital part in plant growth. Like nitrogen, phosphorus (P) is an essential part of the process of photosynthesis. Plants use the energy of sunlight, and P must be present in the active portions of the plant for this energy transfer to be made and for photosynthesis to occur. The immediate source of P for plants is that which is dissolved in the soil solution. Plants absorb P primarily as the $H_2PO_4^-$ and HPO_4= ions which are predominant in most soils. The $H_2PO_4^-$ ion is more readily absorbed than the HPO_4= by most plants. A soil solution containing only a few parts per million of phosphate ions is usually considered adequate for plant growth. Concentrations of phosphate ions in the soil solution may be as low as 0.001 parts per million. Phosphate ions are absorbed from the soil solution and used by plants. The soil solution is replenished from soil minerals, soil organic matter decomposition or applied fertilizers.

In young plants, P is most abundant in tissue at the growing point. It is readily translocated (moved about) from older tissue to younger tissue, and as plants mature, most of the element moves into the seeds and/or fruits. P is responsible for such characteristics of plant growth as utilization of starch and sugar, cell nucleus formation, cell division and multiplication, fat and albumin formation, cell organization, and transfer of heredity.

In soils, it may exist in many forms but generally, there are three types of phosphorus classification in soils. The first category is known as **solution P**, which it is the pool from which plants take up P and is the only pool that has any measurable mobility. Secondly is the **active P pool** where the phosphorus is in the solid phase and relatively easily released to the soil solution. Soil fertility with respect to phosphate can be enhanced because this pool is able to replenish the soil solution P pool in a soil. The **fixed P pool** of phosphate, which is the third category, will contain inorganic phosphate compounds that are very insoluble and organic compounds that are resistant to mineralization by microorganisms in the soil.

2.4. POTASSIUM

Potassium (K), makes up about 2.4% of the weight of the Earth's crust and is the seventh most abundant element in it. Due to its insolubility, it is very difficult to obtain potassium from its minerals. However, other minerals, such as carnallite, langbeinite, polyhalite, and sylvite are found in ancient lake and sea beds. These minerals form extensive deposits in these environments, making extracting potassium and its salts more economical. The principle source of potassium, potash is mined in California, Germany, New Mexico, Utah, and in other places around the world. At 3000 ft below the surface of Saskatchewan are large deposits of potash which may become important sources of this element and its salts in the future. The oceans are another source of potassium but the quantity present in a given volume of seawater is relatively low compared to sodium. Potassium can be isolated through electrolysis of its hydroxide in a process that has changed little since Davy. Thermal methods also are employed in potassium production, using potassium chloride. Potassium is almost never found unbound in nature. However, in living organisms K+ ions are important in the physiology of excitable cells.

The behavior of the potassium in the soil is related to the type and amount of clay and soil organic matter. The type of clay depends on the parent rock, igneous or sedimentary, and the extent to which the mineral particles have undergone excessive weathering process over many years. Differ than the phosphorus, potassium in soil can be thought of as existing in four "pools" related to its availability to plants. These pools are the **soil solution**, where it is immediately available for uptake by roots, the **readily**

available pool, the **slowly available pool** and the **soil minerals**, where it is least available. Studies have shown that building up readily available potassium reserves in soil ensures the best opportunity for crops to achieve their optimum economic yield (Johnston, 1997). Adding large amounts of potassium fertilizer to soil with little readily available potassium will not always increase yields to equal those in enriched soil. Therefore, it is important that the availability of soil potassium in any particular area to be determined and studied so that the optimum mixture for crop fertilization can be done.

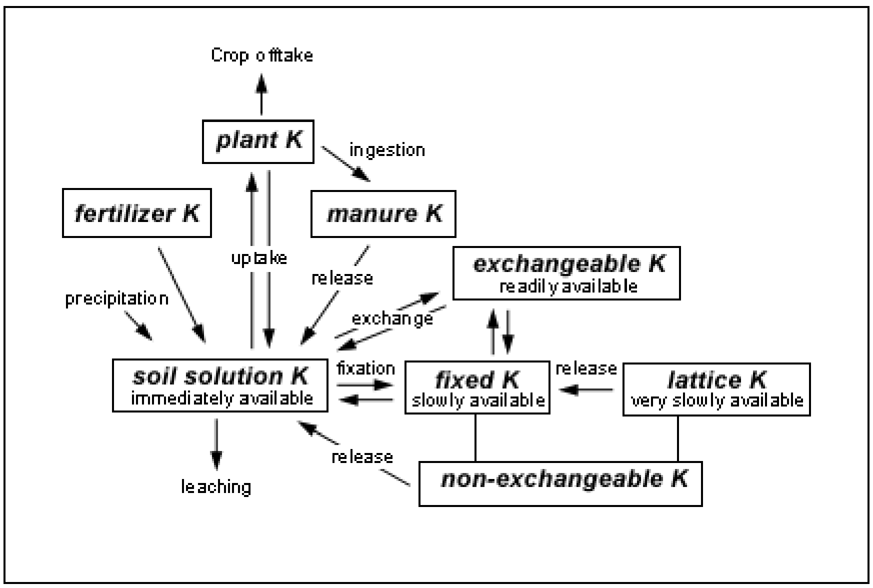

Figure 2.3: The Potassium cycle in the soil-plant-animal system

2.5. NITROGEN

Nitrogen in soil mostly is present in the form of complex organics molecules. Conversely there is little present in the immediately usable nitrate or ammonium forms. The organic forms are converted to ammonium and nitrate by soil microorganisms, a process called mineralization. Therefore the amount of nitrogen available to roots depends on the rate of mineralization and it in turn depends on all those environmental factors that affect the activity of the microorganisms; the amount of carbon, temperature, oxygen and so on. Lots of countries use the nitrogen to act as fertilizer for soil. Nitrogen inputs have increased with the growth in dairy farming, but it is becoming increasingly apparent that too much nitrogen can also lead to terrestrial and aquatic pollution (Manaaki Whenua, 2003). Another important behavior for the nitrogen is that it cannot accumulate in soil forever and the storage in soil may change from time to time. Nitrogen storage is affected by soil type, land use, and how much fertilization or nitrogen fixation occurs. Preliminary evidence suggests soils under dairy pasture are reaching saturation levels sooner than soils used for dry stock. Future work will examine the consequences of adding nitrogen to soils that are already saturated.

In warm, moist soils with a pH above 5.0, the majority of ammonium N is converted to nitrate N by soil organisms rather quickly (within days). Therefore, most N taken up by plants is in the NO_3^- form, although NH_4^+ is taken up when present in the soil solution. The nitrate ion (NO_3^-) carries a negative charge which prevents its retention by the negatively- charged soil colloids. Since it is soluble and mobile, the nitrate ion is readily and easily available to plants.

Nitrate moves in the soil solution and can be leached below the plant root zone when soil moisture is excessive. The loss of nitrate by leaching is a common problem on coarse-textured, sandy soils. Leaching losses of fertilizer N are minimal when rates of application conform to recommendations consistent with the yield potential for the crop and soil in question. Nitrate N is also subject to denitrification, a process in which the nitrate ion (NO_3^-) is reduced through several intermediate steps to a gaseous N oxide or to elemental N.

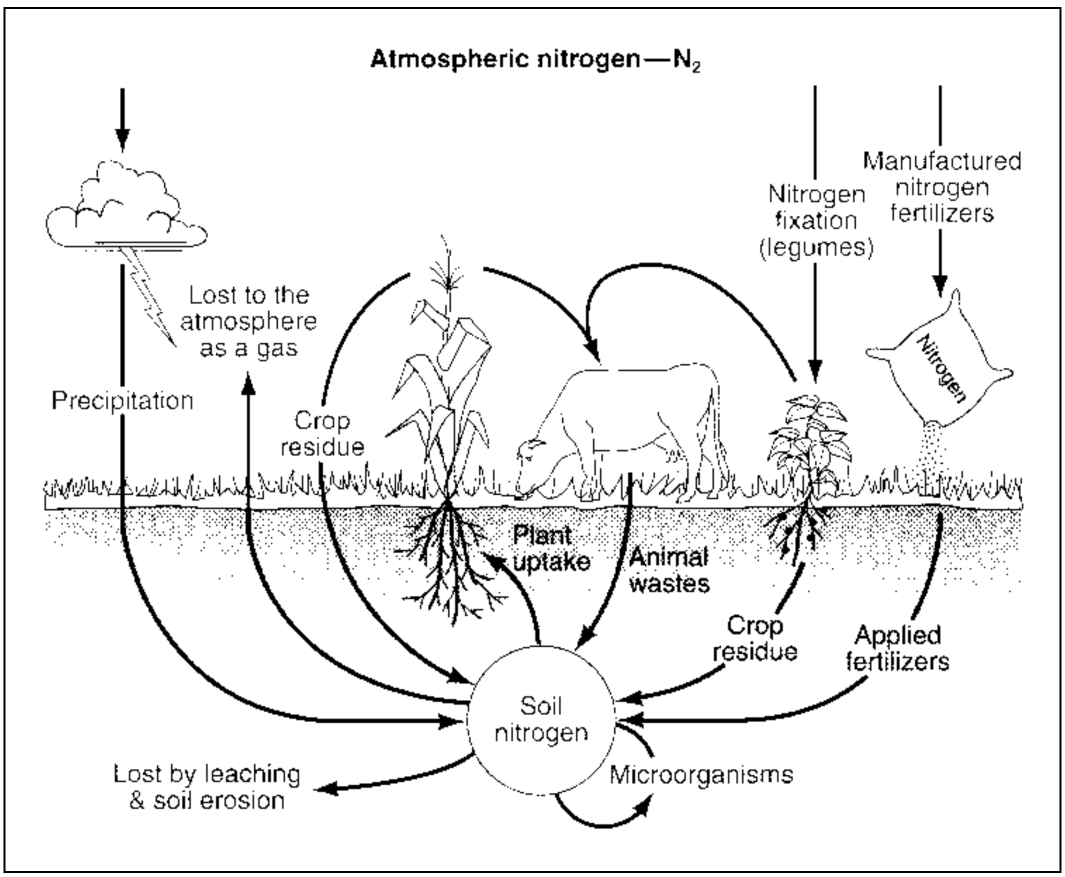

Figure 2.4: The nitrogen cycle in soils

2.6. SOIL PH

Another parameter that is equally important to be determined is the pH of the soil. By measuring the pH status, it will show whether the soil is alkaline or acidic, and that determines how easily the nutrients in the soil can be absorbed by the plant. Most plants do actually have specific requirements regarding their full potential growth and need to be suitable with the condition of the soil (Childs, 1999). The pH has also great effect in terms of solubility of nutrients and minerals. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils (Bickelhaupt, 1999). This eventually proves that the pH status is related with the soil nutrients and equally important to be determined for its variability in any particular area.

The availability of nutrients in soil does relate to the pH condition. The majority of food crops prefer a neutral or slightly acidic soil, because the solubility of most nutrients necessary for healthy plant growth is highest at pH 6.3-6.8. Some plants however prefer more acidic (e.g., potatoes, strawberries) or alkaline conditions. When the pH falls below 5.5, most major plant-nutrient minerals especially those needed in substantial quantities to promote healthy plant growth include nitrogen (N), phosphorus (P), potassium (K), sulfur (S), magnesium (Mg), and calcium (Ca) and some micronutrients become insoluble and hence unavailable for uptake by plant roots.

Many cationic (positively charged) nutrients such as zinc (Zn^{2+}), manganese (Mn^{2+}) aluminium (Al^{3+}), iron (Fe^{2+}), and copper (Cu^{2+}) are soluble and available for uptake by plants below pH 5.0, although their availability can be excessive and thus toxic in more acidic conditions. In more alkaline conditions they are less available, and symptoms of nutrient deficiency may result, including thin plant stems, yellowing (chlorosis) or mottling of leaves, and slow or stunted growth.

The pH levels also affect the complex interactions among soil chemicals. Phosphorus (P) for example requires a pH between 6.0 and 7.0 and becomes chemically immobile outside this range, forming insoluble compounds with iron (Fe) and aluminium (Al) in acid soils and with calcium (Ca) in calcareous soils. The following table indicates the availability of several nutrients at different pH values.

Table 2.3: The availability of nutrients at various pH values

<table>
<tr><th></th><th colspan="5">Acid</th><th colspan="3">Neutral</th><th colspan="5">Alkali</th></tr>
<tr><th></th><th>4</th><th>4.5</th><th>5</th><th>5.5</th><th>6</th><th>6.5</th><th>7</th><th>7.5</th><th>8</th><th>8.5</th><th>9</th><th>9.5</th><th>10</th></tr>
<tr><td>nitrogen, N</td><td colspan="5"></td><td colspan="4" style="background:blue"></td><td colspan="4"></td></tr>
<tr><td>phosphorus, P</td><td colspan="5"></td><td colspan="2" style="background:blue"></td><td colspan="3"></td><td colspan="3" style="background:blue"></td></tr>
<tr><td>potassium, K</td><td colspan="4"></td><td colspan="3" style="background:blue"></td><td colspan="3"></td><td colspan="3" style="background:blue"></td></tr>
<tr><td>calcium, Ca</td><td colspan="4"></td><td colspan="5" style="background:blue"></td><td colspan="4"></td></tr>
<tr><td>magnesium, Mg</td><td colspan="4"></td><td colspan="5" style="background:blue"></td><td colspan="4"></td></tr>
<tr><td>sulphur, S</td><td colspan="4"></td><td colspan="9" style="background:blue"></td></tr>
<tr><td>iron, Fe</td><td colspan="4" style="background:blue"></td><td colspan="9"></td></tr>
<tr><td>manganese, Mn</td><td></td><td colspan="3" style="background:blue"></td><td colspan="9"></td></tr>
<tr><td>boron, B</td><td></td><td colspan="4" style="background:blue"></td><td colspan="8"></td></tr>
<tr><td>copper, Cu</td><td></td><td colspan="3" style="background:blue"></td><td colspan="9"></td></tr>
<tr><td>zinc, Zn</td><td></td><td colspan="2" style="background:blue"></td><td colspan="10"></td></tr>
<tr><td>molybdenum, Mo</td><td colspan="6"></td><td colspan="7" style="background:blue"></td></tr>
</table>

2.7. RELEVANT STUDIES

Having known the importance of the nutrients and pH in soil, the study on the spatial variability of soil nutrients will obviously help other related research and relevant studies. For instance, studies at the Purdue University Davis Research Center in east central Indiana are focusing on analysis of the spatial structure of soil nutrient availability and its relationship to plant nutrients status, nutrient export and on the spatial and temporal stability of yield and yield variability (Brouder et al., 2001). Therefore, the results of the nutrients' variability study can be a scientific basis for rational soil sampling as well as for site-specific management (Kamaruzaman, 2004). Site-specific management also 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 production settings is a fundamental first step toward determining the size of management zones and the inter-relationships between limiting factors, for the development of management strategies. In agricultural aspect, when experts can give the correct site-specific recommendations, different rate of nutrient application can be possible (Eltaib et al., 2003). This will eventually enhance the crop production and assist the study of soil fertility. Spatial variability of soil properties and nutrients is also important in order to understand interaction between soil formation and agronomic process and to asses the effect of long term condition on general soil properties (Paz Gonzalez et al., 2000).

By monitoring and quantifying the nutrient elements in soils, crop production and other agricultural related products can be increased from time to time. The inputs can be used for fertilization research and help to make changes such as changes in cultivars, use of nematicides and increase the plant populations (Hochmuth et al., 2000). Besides that, knowledge of the variability in space and time of soil fertility such as the total N and available P is important in making decision for field management practices (Eltaib et al., 2003).

In the past, lot of studies on spatial variability being conducted by various statistic method and techniques. Geostatistical procedures provide tools to facilitate the examination of spatial and temporal correlation in the data. Among the widely tools used are the semivariogram and kriging which allow estimation of spatially correlated data and are superior to other commonly used interpolation techniques (Rezaur et al., 2004). Kriging requires the calculation of an experimental semivariogram to which a theoretical model is filled and will provide a description of the spatial structure of the attribute (Grunwald et al., 2001). As the method is widely used and well known, the geostastic method will be practiced for this study.

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

The initial procedure before further the study is to plan and establish the sampling location. In this case, the Universiti Sains Malaysia (USM), Engineering Campus map has been chosen as the base map. The base map then was digitalized and regenerated with geo-grid references coordinates. On the generated map, the USM Campus area was subdivided by a number of regular geo-grids. The intersection of the grid lines marked the locations for soil sample collection. Figure 3.1 shows the campus map and soil sampling locations. Soil samples were collected at these locations to determine the Phosphorus (P), Potassium (K), Nitrate and pH contents in the area.

However, the determination of the nutrients contents cannot be done by using solid soil samples. The soil samples have to be digested in liquid state and then analyzed by using the Direct Spectrometer Reader (DR 2000). The method of digestion and further laboratory test procedures shall be explained in the later sections.

3.2. SITE DESCRIPTION

The study was conducted in the Universiti Sains Malaysia (USM), Engineering Campus area located in Nibong Tebal, Pulau Pinang. It lies at about latitudes $100^{0}29.5'$ South and $100^{0}30.3'$ North and between longitudes $05^{0}09.4'$ East and $05^{0}08.5'$ West. The campus with area of 137ha (320acres), is uniquely situated near the border of three states which are, Pulau Pinang, 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. Daily temperature ranges from 26^{0}C to 32^{0}C and annual rainfall varies between 2000mm to 4000mm.

The campus area formally is used to be an oil palm plantation area. Therefore, the original topography of the area consisted of swamps and marshy areas which were unsuitable for any development. Foreign soils are dumped to the existing surface to built up the area and make it suitable for construction. The buildings mainly are resting on the piles and it is because of the quality of soil. At present, there is about 80% of the land area is open space while the remaining 20% is occupied by buildings and infrastructures. By conducting a study of the spatial variability of soil nutrients at the engineering campus, the results can be simplified in a particular map distribution and we may see whether human activities and development do affect the variability of the nutrients. It is hoped that the results and data obtained will be useful for the future studies.

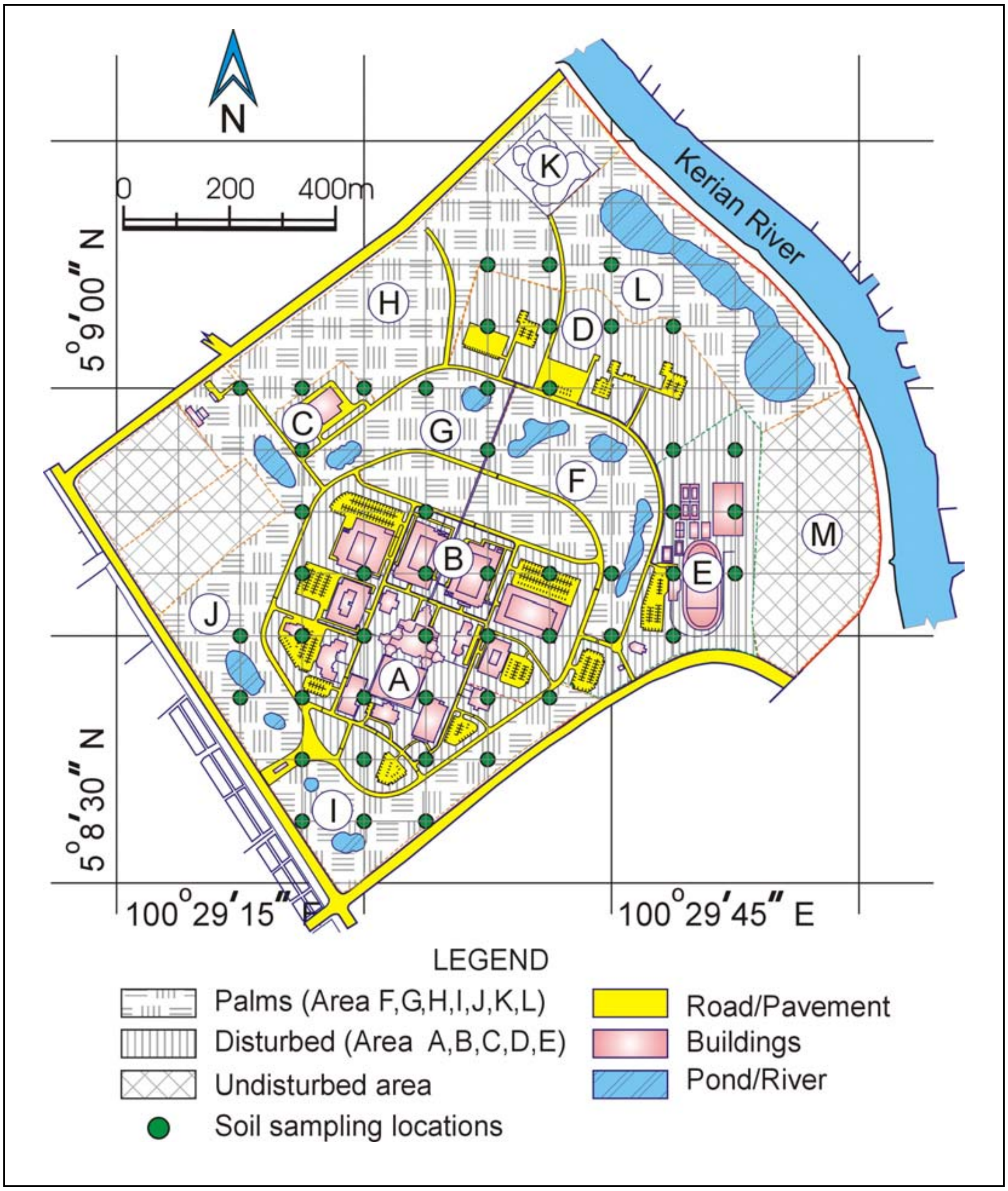

Figure 3.1: Map of the study area, reference grids and soil sampling location

3.3. SAMPLE PREPARATION

As mentioned earlier, the soil samples need to be digested into liquid state before they can be analyzed in the laboratory. The following sections will explain the procedures for soil sampling on the study area as well as the procedures for sample digestion.

3.3.1. Soil Sampling

A core sampler was used for collecting soil samples at the predetermined gird location (see Figure 3.1). The core sampler was made of iron, and was 230mm in length and 38.15mm in diameter. Grease can be 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. However, for this particular purpose of study, any changes in the bulk density is not closely related with nutrients properties and the effects can be considered as very minimal. Nevertheless, the lubrication of the sampler inner surface with grease may help 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.