UNIVERSITI PUTRA MALAYSIA

EVALUATION OF SPATIAL VARIABILITY OF SOIL AND LEAF TISSUE NUTRIENT STATUS AND YIELD (FRESH FRUIT BUNCH) IN AN OIL PALM PLANTATION

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By

TAMALUDDIN SYAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to:

My beloved parents,
my wife, my daughter, my families

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia
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Chairman: Major Professor Dr. Kamaruzaman Jusoff

Faculty: Faculty of Forestry

The study was carried out at Dusun Durian Estate, Golden Hope Plantations Berhad Banting, Selangor, in a 50 ha plot which represents a coastal oil palm plantation. The general objective of this study was to obtain accurate and timely information about the spatial distribution and status of nutrients in the soil and leaf tissue using Geographic Information System (GIS) and remote sensing technology for precision farming of oil palm plantation. Collection of soil and leaf tissue data were conducted by using systematic sampling and an Omni Star DGPS was used to precisely determine the sample sites location. Geostatistics (GS+) software and classical statistics were used for data analysis. A SPOT image of K-J.299344 acquired on March 2000 from the Malaysian Centre for Remote Sensing (MACRES) was analysed using a PCI software version 7.0. Descriptive statistical analysis classed the status of total N as low, whereas available P and exchangeable K varied from moderate to high. Soil exchangeable Ca and Mg ranged from low to moderate. Soil nutrients variability of available P, exchangeable K, Ca and Mg status were classified as high and moderate for total N. Semivariance analysis showed that the total N, available P and exchangeable K in the soil have a moderately spatial dependence and while strongly spatial dependence for exchangeable Ca and Mg with available lag distance of 52 to 117 m. Leaf nutrient analysis illustrated that the leaf nutrient variability of N, P, and K could be classified as low (CV values of 7, 8 and 12) and moderate variability for Ca and Mg (CV values of 19 and 22). Based on the semivariance analysis, all the leaf nutrients have a moderately spatial dependence with the lag distances of 75, 75, 51, 63 and 117 m for N, P, K, Ca and Mg, respectively. There was no strong relationship between nutrient content in the soil and nutrient content in leaf tissue; therefore nutrient content analysis in leaf tissue was not able to predict nutrient content in the soil. Yield of fresh fruit bunches (FFB) has a high variability and moderately spatial dependence within the lag distance of 84 m. Both the soil nutrient and nutrient content in leaf tissue were not able to predict FFB, because the statistical analysis indicated that there were no strong relationships between yield FFB and nutrients in soil and leaf tissue. SPOT image analysis using Digital Numbers (DN), unsupervised and supervised classifications methods could not be used to predict nutrient content in leaf tissue.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN VARIASI RUANG KANDUNGAN NUTRIEN TANAH DAN DAUN SERTA HASIL (BUAH TANDAN SEGAR) PADA LADANG KELAPA SAWIT

Oleh

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Satu kajian telah di jalankan di kawasan pesisiran pantai Ladang Dusun Durian, Golden Hope Plantations Berhad, di Banting, Selangor dengan keluasan 50 ha. Secara amnya tujuan penyelidikan ialah untuk memperolehi data yang pasti dan tepat masa hal pergantungan ruang dan kadar nutrien di dalam tanah dan di dalam daun menggunakan sistem maklumat sejagat (GIS) dan penderiaan jauh untuk pertanian tepat pada kelapa sawit. Pengumpulan sampel tanah dan daun dikerjakan secara beraturan dengan bantuan Omni Star DGPS untuk penetapan kedudukan pasti daripada sample. Perisian geostatistics (GS+) dan statistik biasa telahpun digunakan untuk analisis data. Satu imej SPOT bernombor K-J. 299344 liputan Mac 2000 yang diperolehi daripada Pusat Remote Sensing Malaysia (MACRES) telahpun dianalisis menggunakan perisian PCI versi 7.0. Uraian analisis statistik menunjukkan bahawa status total N di dalam tanah telahpun dikelaskan ke dalam tingkatan rendah, sedangkan P boleh di dapati dan K boleh dipertukarkan berbagai-bagai daripada sederhana hingga tinggi. Sementara itu, Ca dan Mg boleh dipertukarkan berbagai-

bagai antara tingkatan rendah hingga tinggi. Variasi nutrien tanah P boleh di dapati, K, Ca dan Mg boleh ditukar telah dikelaskan kepada variasi yang besar, sedangkan untuk total N mempunyai variasi sederhana. Semivarian analisis juga menunjukkan bahawa total N, P boleh didapati dan K boleh ditukar di dalam tanah mempunyai pergantungan ruang sederhana, sedangkan untuk Ca dan Mg boleh ditukar mempunyai pergantungan ruang yang kuat dengan jarak berbagai-bagai daripada 50 m sehingga 117 m. Analisis nutrien di dalam daun menunjukkan bahawa nutrien di dalam daun daripada N, P and K boleh di kelaskan kepada variasi kecil (CV= 7, 8 dan 12), manakala untuk nutrien Ca dan Mg dikelaskan kepada variasi sederhana (CV= 19 dan 22). Didasarkan kepada semivarian analisis menunjukkan bahawa semua nutrien di dalam daun mempunyai pergantungan ruang sederhana dengan jarak 75, 75, 51, 63 dan 117 m, berturut-turut untuk N, P, K, Ca dan Mg. Tiada hubung kait yang kuat antara nutrien di dalam tanah dengan nutrien di dalam daun, hal ini menyifatkan bahawa kandungan nutrien di dalam daun tidak boleh digunakan untuk meramalkan nutrien yang ada di dalam tanah. Hasil buah tandan segar (FFB) mempunyai variasi yang besar dan kebergantungan ruang yang sederhana dengan jarak 84 m. Kadar nutrien di dalam tanah mahupun nutrien di dalam daun tidak boleh digunakan untuk meramalkan hasil FFB kerana tiada hubungan yang bermakna antara FFB dengan nutrien di dalam tanah ataupun nutrien di dalam daun. Analisis imej SPOT menggunakan kaedah angka digital (DN), pengkelasan terselia dan tanpa selia tidak boleh digunakan untuk meramalkan kadar nutrien di dalam daun.

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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CHAPTER I

INTRODUCTION

Background of the Study

The history of oil palm in Malaysia began from the time when oil palm was first introduced into this country in 1890 through the Botanical Gardens, Singapore. However, the first commercial planting was not initiated until 1917 at Tennamaram Estate in Kuala Selangor. Long before its introduction into Malaysia, the oil palm (*Elaeis guineensis* Jacq) was abundantly found in tropical Africa under natural conditions and its kernel and pericarp oil were widely used by the natives (Tang, 1966). In 1968, the area under oil palm was 204,000 ha and increased significantly 10 years later to 850,000 ha (Mielke, 1987). A recent data in 2000 showed that the area under oil palm in Malaysia was 3,463,000 ha (Ministry of Finance Malaysia, 2000), covering about 57.7% of the total area under selected crop plantations in Malaysia (Ministry of Primary Industries Malaysia, 2000).

Production of crude palm oil in Malaysia in 2000 was about 10.7 million tonnes, an increase of 0.9% over the previous year, which made Malaysia the leading producer and exporter country in the world. The latest data showed that during the first eight months in 2000, Malaysian palm oil export was about 5.39 million tonnes compared to 5.48 million tones in 1999 for the same period. The total income of these periods were RM6,576 million and RM9,736 million, respectively (Ministry of Finance Malaysia, 2000; Oil World, 2001). Oil palm plantation is generally managed conventionally. The conventional technology considered that the whole plantation is homogenous, therefore one set of practice applies to the entire plantation. Such management is inadequate because of the tendency of over treating and under-treating some portions of a field. This may increase input costs, decreased net economic return, and contribute to surface and ground water pollution and waste of energy.

Precision farming (PF) or Precision Agriculture (PA) is a technology available for sustainable agricultural production, which enables farm management based on the small-scale spatial variability of soil and crop variables in the field (Stafford *et al*., 1996; Haneklaus *et al*., 1997). The PA aims to achieve a better usage of resources and control mechanism so as to improve production efficiency, reduce input costs and reduce negative environmental impact (Costopoulu and Anagnostou, 1997; Voltz, 1997). Soil, an important component of land should be assessed in terms of their abilities to supply plants need of nutrients. In specifying such plant requirements, it is essential to state them quantitatively and precisely (Tinker and Leigh, 1985). Using precision farming technologies requires better understanding of soil variability in physical and chemical properties. Some of that variations are inherent, but others are the result of the management history of the field (Bocchi *et al*., 2000). Fundamental question of the concept of precision farming for the farmer is the assessment and appropriate treatment of substantial heterogeneity for site-specific management decision at a reasonable cost (Grenzdorffer, 1997; Van Groenigen *et al*., 2000). Proper land management leading to sustainable agriculture production system, which are in balance with nature and the environment, is being guided by farmer's assessment of variation in space and time of soil and crop conditions (Bouma, 1997a).

Problem Statement

In general, oil palm plantations are managed based on conventional technology on large-scale extensive agricultural practices. It appears inevitable to intensify and improve the planting practices by developing new techniques to increase efficiency and productivity to keep ahead of competitors and maintain its reputation as a responsible "green industry". The conventional technology manages the fields as if they were a homogenous unit, whereas the real condition indicated that land characteristics are very heterogeneous. Conventional crop production methods developed within the last 30-50 years have been linked to the negative effects on the environment, human health and safety, and long term effects on soil fertility (Poudel *et al*., 2001). Lawrence and William (1990) reported that agricultural production processes generate residuals such as manure, fertilizer, pesticides, and soil particles, which can contaminate both ground and surface water. Numerous health and environmental quality problems have been associated with these contaminants. Spatial variability can occur on a variety of scales, between regions, between fields, or within fields, especially variation in soil properties (Burrough, 1993). Soil chemical properties that vary spatially include nutrients, pH, salinity and organic matter. Soil nutrients are essential for crop growth and the advent of fertilizer technology had made them easily manageable (McBratney and Pringle, 1997). The nutrient balances and the dosage of fertilizers needed to secure the level of production required and ensure that soil fertility is maintained and preferably improved. Local balances that has sound scientific and economic basis are also required for cropping systems to provide good advice to farmers (Cooke, 1986).

For years, agronomist and soil scientists have encouraged farmers to regularly sample and analyze the soil of their fields. Regular soil sampling is important for developing a successful fertility management program. However, in the past, soil sampling was often overlooked and fertilizer was frequently over-applied in order to guarantee that nutrients levels were adequate. Foliar analysis is carried out to quantify the deficiency of individual nutrients so that fertilizer adjustments can be calculated. Optimum leaf nutrient levels correspond to maximum yield (Foster *et al*., 1987).

In precision farming, information on soil and plant nutrient status of oil palm is very important and useful for fertilizer recommendation. A PF system matches resource availability to crop capability and then knowledge of soil spatial variability (McBratney and Pringle, 1997). This requires proper information on specific soil conditions, especially soil characteristics and soil behavior. However, soil-specific management will be relevant only if the agronomist is able to deliver accurate site-specific advice (Voltz, 1997). The major problem remains with knowledge of the critical factors and their effects on growth and yield as well as knowledge of important nutrient budget requirements in the oil palm systems. Using global positioning system (GPS) and geographic information system (GIS) technology would have a quick result in improved availability of information for planning, organization, monitoring and supervision of work. The most useful application will be the integration of agronomic and management information in the establishment of a decision support system (DSS) for oil palm management to assist in site specific decision making for particular blocks (Chew, 1998).

The question is where precision farming can be implemented and how these new technologies for precision planting practices (PPP) can help achieve the purpose for which the plantations were established. Remote sensing image and techniques have to be cost effective, problem oriented, geo-referred and relatively quick, available for a broad range of applications in site-specific management (Grenzdorver, 1997). Remote sensing technology combined with GIS/GPS could be used to obtain information about healthy vegetation and nutrient content in leaf of oil palm plantation. Satellite data such as SPOT can be differentiated in contrast between high and low content of nutrients in plant tissue of oil palm plantation for nitrogen, phosphorous, potassium, calcium and magnesium (Nguyen *et al*., 1993). Lukman Fadli and Siahaan (1993) reported a good relationship between near infrared (NIR) reflectance with macro nutrient (N, P, K, Ca, Mg, S) status in leaf tissue using SPOT image.

Objective of Study

The general objective of this study is to obtain accurate and proper time information about soil and leaf nutrient variability using GIS and remote sensing