**UNIVERSITI PUTRA MALAYSIA**

# SPATIAL VARIABILITY OF SOIL ELECTRICAL CONDUCTIVITY IN RELATION TO RICE YIELD FOR SITE-SPECIFIC FERTILIZER MANAGEMENT

**ELTAIB SAEED MOHAMED GANAWA**

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By

ELTAIB SAEED MOHAMED GANAWA

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

May 2003

***Dedicated to***

***'The estimable nucleolus in my life who championed my struggle'***

***My beloved Mother, Wife, Daughter and Family***

Abstract of thesis submitted to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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**Chairman: Professor Ir Dr. Mohd Amin Mohd Soom**

**Faculty: Faculty of Engineering**

Describing the variability of nutrients status and electrical conductivity (EC) in the paddy soil is essential in developing a variable application rate of fertilizers. The main idea of precision agriculture understands spatial variability of soil properties, crop status and yield within a field; identifying the reasons for yield variability; making farming prescription and crop production management decisions based on variability and local knowledge. Field variability study was carried out in the Tanjung Karang rice irrigation scheme, northwest of Selangor, Malaysia. The general objective of this study was to obtain information about the distribution of soil electrical conductivity, soil nutrients in relation to rice yield to enable site-specific N, P and K fertilizers management in the paddy field. Collection of the soil samples was done at two depths (0-20 and 20-30 cm) using two different schemes from: (i) the small field (a typical 1.2 ha paddy plot), and (ii) a large irrigation compartment (2300 ha). Differential global positioning system (DGPS) was used to locate the sample position. The soil samples were collected before seeding (BS), 15 days after seeding (15 DAS) and at tillering stage (TS). The rice yields were manually measured for two seasons at harvest. Variability of soil electrical conductivity (EC), soil nutrients and rice yield were determined using geostatistical method and classical statistics. Site-specific fertilizer recommendation maps of N, P and K were obtained using geographical information system (GIS) software. Accurate amount of N, P, and K fertilizer was investigated to replenish nutrient removal from the previous season. Descriptive statistical analysis showed variations between soils EC collected at different times. The spatial dependence level of the EC for all soil collection was moderate and the range was 118.39 m. The EC measurements can be used to estimate the soil nutrients and yield variations. High rice yield corresponds to high EC and soil nutrient values in the irrigation compartment. Yield is best related to EC and Nitrogen by the equation $y=1.190+0.323EC+1.967N$ with $r^2=0.732^{**}$. In the small field, the spatial dependence of soil nutrients varied between moderate and weak for all soil collections. Based on the results of the study, the numbers of soil samples recommended to be taken from a small field (1.2 ha) are two for N, K and OM, and four for P and Mg. Soil sampling with the lowest N was observed at 15 DAS and high P was at TS, while high N, K and OM were found at BS. The amount of N fertilizer need to be added to the middle part of the small study area was 13.70 kg urea based on sampling at BS, but 64 kg urea at 15 DAS, and 24.5 kg urea at TS. Hence, soil sampling at BS could not indicate the actual amount of fertilizer need to be added. From the geostatistical analysis, the recommended yield sampling distance should be within 12.30 m. Thus, recommended fertilizer maps should be created

based on soil data and chlorophyll content collected during the rice growing stage. This will indicate the actual status of nutrients in soil. Site-specific fertilizer management offers a new method to reduce the cost of fertilizer application and preventing excessive chemical pollution to the environment.

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

**VARIASI SPATIAL KONDUKTIVITI ELEKTRIK TANAH, DALAM HUBUNGKAIT DENGAN HASIL PADI UNTUK PENGURUSAN BAJA MENGIKUT KEPERLUAN TAPAK**

**Oleh**

**ELTAIB SAEED MOHAMED GANAWA**

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Penerangan mengenai bahawa variasi status nutrien bagi tanah sawah padi dan konductiviti elektrik adalah sangat penting dalam pembangunan aplikasi kadar variasi bagi baja. Pertanian Persis melibathan pemahaman pembahan spatial ciritanah, status tanaman dan hasil padi dalam sawah, mengenalpasti sebab perbezaan hasil, memuat rawatan perladangan dan keptusan pengerusan pengeluaran tanamam berasakan perbezaan tersbut dan pengetahuan tempatan. Kajian ini dijalankan di Barat Laut Selangor, di kawasan Rancangan Pengairan Padi Tanjung Karang. Objektif umum bagi kajian ini adalah untuk mendapatkan maklumat semasa tentang pengagihan konduktiviti elektrik tanah, nutrien tanah dan hasil padi serta menentukan tapak spesifik pengurusan baja N, P dan K di kawasan padi. Pengumpulan sampel tanah telah dijalankan dalam kawasan berasingan (i) kawasan kecil (sebidang tanah sawah seluas 1.2 ha) dan (ii) sebuah kawasan pengairan seluas 2300 ha dengan dua

kedalaman (0-20 dan 20-30 cm). Sistem Kedudukan Global (DGPS) digunakan untuk menentukan kedudukan kawasan kajian tanah. Contoh tanah dikumpulkan pada tiga keadaan berbeza, iaitu sebelum penanaman, 15 hari selepas penanaman dan pada peringkat pembajakan. Hasil padi dikumpulkan secara manual pada dua musim. Parameter bagi penuaian, konduktiviti elektrik (EC), nutrien tanah dan hasil padi di tentukan. Analisis geostatistikal dan statistik. Peta syor pembajaan tapak-mengikut keperluan tapak untuk N, P dan K diperolehi dengan menggunakan perisian sistem maklumat segajat (GIS). Jumlah kandungan yang baja N, P, dan K dikaji untuk menggantikan pengurangan nutrien yang berlaku pada musim yang lalu. Analisis gambaran statistikal menunjukan terdapat variasi diantara EC tanah yang dikumpulkan pada masa yang berbeza. Tahap EC bagi kesemua tanah yang dikumpul adalah sederhana dan berada di antara nilai 118.39m. Pengukuran EC dapat digunakan untuk menentukan nutrien tanah dan hasil variasi. Nilai EC dan nutrien tinggi tanah di kawasan pengairan yang berdekatan dengan laut. Di dalam kawasan yang kecil, nutrien tanah yang berubah di antara sederhana dan lemak pada semua tanah yang dikumpulkan. Hasil padi dapat dihbungkan dengan EC dan melaui persamaan $y=1.190+0.323EC+1.967N$ dengan $r^2=0.732^{**}$. Bilangan sampel tanah dicadangkan untuk diambil daripada kawasan kecil pada perbezaan pengumpulam tanah berubah diantara dua dan empat sampel untuk pengasingan N, K dan OM dan P dan Mg. N terendah didapati pada 15 selepas sampel tanah diampil (15 DAP) dan P tinggi pada pengumpulan tanah peringkat pembajakan (TS), sedangkan N, K dan OM yang tinggi didapati pada pengumpulan tanah selepas menabur (BP) disebabkan oleh baki tumbuhan yang ditinggalkan oleh jentera penuai. Jumlah kandungan baja N yang perlu ditambah kepada bahagian tengah kawasan kajian yang kecil adalah 13.70 kg urea berdasarkan kepada pengsampelan di BS, 64 kg urea di 15 DAS dan 24.5 kg urea di TS. Walaubagaimanapun pengumpulan tanah sebelum penanaman tidak memberikan status yang sebenar untuk jumlah baja yang perlu ditambah. Daripada analisis geostatsistical jarak mengambil sampel yang disyorkan adalah ditanah 12.30 m. Oleh sebab itu peta pembajaan sepatutnya dibina berdasrkan ketika peringkat pertumbuhan padi. Ini akan menentukan status sebenar bagi nutrien didalam tanah. Pengurusan baja mengikut keperluan tapak menawarkan kaedah baru untuk mengurangkan kos baja dan pencemaran alam sekitar.

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I certify that an Examination Committee met on 28th May 2003 to conduct the final examination of Eltaib Saeed Mohamed Ganawa on his Doctor of Philosophy thesis entitled "Spatial Variability of Soil Electrical Conductivity in Relation to Rice Yield for Site-specific Fertilizer Management" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**ELTAIB SAEED MOHAMED GANAWA**

Date: - 4 SEP 2003

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| | |
|---|---|
| PF | Precision Farming |
| EC | Electrical Conductivity |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| IPM | Integrated Pest Management |
| SSCM | Soil Specific Crop Management |
| IDW | Inverse Distance Weight |
| GNSS | Global Navigation Satellite Systems |
| VRT | Variable Rate Technology |
| DGPS | Differential Global Positioning System |
| DOA | Department of Agriculture |
| CIRP | Christmas Island Rock Phosphate |
| MOP | Muriate of Potash |
| mS/m | milliSiemens per meter |
| CEC | Cation Exchange Capacity |
| dS/m | decisiemens per meter |
| mg $kg^{-1}$ | milligram per kilogram |
| kg | kilogram |
| MARDI | Malaysian Agriculture and Development Institute |
| m | meter |
| ha | hectare |
| cm | centimeter |
| BS | Before Seeding |
| 15 DAS | 15 Days after Seeding |
| TS | Tillering Stage |
| OC | Organic Carbon |
| OM | Organic Matter |
| N | Nitrogen |
| P | Phosphorus |
| K | Potassium |
| Mg | Magnesium |
| AA | Auto Analyzer |
| AAS | Atomic Absorption Spectrophotometer |
| $\gamma(h)$ | semi-variance |
| $h$ | lag |
| $n$ | number of observation |
| $X(i)$ | value of the current point |
| $X(i=h)$ | value of the point at lag $h$ |
| $C+C_o$ | Sill |
| $C_o$ | Nugget |
| $a$ | Range |

# CHAPTER I

# INTRODUCTION

## 1.1 General Introduction

Precision farming (PF) is a new concept for sustainable utilization of agricultural resources defined as the management of arable variability to improve the economic benefit and reduce environmental impact (Blackmore, 2001). Precision farming sometimes called site-specific farming or variable rate technology. This definition serves a two-fold purpose. Firstly, it identifies management of variability as the essential factor and not a technology as many people seem to believe. Secondly, it identifies the drivers for changing the existing systems, improving the economic returns while reducing the impact of management practices on the environment. Both of these drivers work in the same way to improve the efficiency of the agricultural process. The manner in which these drivers are implemented will vary depending on different crops and countries concerned. Underlying these different implementations are the principles that applied universally.

The main ideas of precision agriculture are understanding spatial variability of soil properties, crop status and yield within a field; identifying the reasons for yield variability; making farming prescription and crop production management decisions based on variability and knowledge; implementing site-specific field management