UNIVERSITI PUTRA MALAYSIA

NUTRIENT AND YIELD SPATIAL VARIABILITY IN A COMMERCIAL MALAYSIAN PADDY FIELD

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Thesis Submitted in Fulfilment of the Requirement for the Degree of Doctor of Philosophy in the Institute of Bioscience Universiti Putra Malaysia

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DEDICATED TO MY BELOVED PARENTS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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In recent times, one of the major challenges in paddy plantation is the lack of proper interpretation of yield maps for site-specific management, and the identification and understanding of the causal factors influencing the variability of paddy yields. The ability to find and comprehend the soil factors influencing yield variability of paddy will enable to manage them more efficiently. A study was conducted in a commercial paddy farm at Kahang, Johor, southern part of Peninsular Malaysia with the objectives (i) to quantify and characterize the nature of spatial soil N, P and K variation, (ii) to quantify and characterize the spatial yield and grain moisture variation, and (iii) to establish the inter-relationship between paddy yields and soil N, P and K, so as to identify the ranges of soil nutrients for maximum paddy growth and production for the proposed management zone based on paddy yield variability. Soil samples (within 0-15 cm depth) were collected at 20 m x 20 m grid pattern at the beginning of paddy (MR211 variety) planting and analyzed for total N, available P and exchangeable K in the study plots. A GeoExplorer II was used to record the soil sampling points and boundary of the plots to help interpret the spatial maps in GIS platform with proper coordinates. Paddy yields and grain moistures were recorded for harvested paddy sample on a grid pattern of 55 m x 30 m during the harvesting period. Relationship between paddy yields and soil N, P and K were examined using regression analysis. Geostatistical analysis was used to characterize the spatial variation of soil N, P and K, and paddy yields. The coefficient of variation of soil nutrients (N, P and K) for the study area was more than 50% where soil P indicated very high (130%). Significant positive correlationships were found between each pair of soil nutrients (N, P and K). Semivariance analysis showed that the spatial dependence for soil N, P and K was reached at 350 m to 450 m (2 samples ha^{-1} where plot width was 70 m). The kriged soil N, P and K maps showed that a large portion of area (> 80%) in each plot was with soil N lower than 3 g kg^{-1}, soil P lower than 10 mg kg^{-1}, and soil K more than 0.45 cmol(+) kg^{-1}. The paddy yield variation was more than 47% and was significant within and between plots. The semivariance for paddy yield was attained at 380 m, suggesting that the spatial correlation existed within 2.6 ha (70 m x 380 m) where 70 m is width of the plot. The paddy grain moisture showed randomly distributed after a separation distance of 30 m and it has no significant variation within the plots. The yield kriged map illustrated that the middle portion (> 50% of the area) of each plot has lower yield (< 3.5 t ha^{-1}) compared to both ends in lengthwise. Significant positive correlations were obtained between each soil nutrient (N, P and K) and yield. In the combined effect of soil N, P and K on yields, soil N and P together could explain 41% of yield variations where P accounted for 36% and N accounted for 5% of the total yield variation ($Y = 2.41 + 0.39 X_N + 0.20 X_P$; $R^2 = 0.41^{**}$, n = 159). Based on this inter-relationship, a management zone was suggested in yield maps where soil N and P need to be improved in moderate and low ranges, respectively, for obtaining maximum yield (5 t ha^{-1}). Some selected soil properties were measured at different locations and the variations were found to be 4.25 to 4.54 in pH, 0.77 to 0.92 g cm^{-3} in bulk density, and the soil texture was clay with 75-83% of clay content. The yield difference between estimated yield from spatial maps and actual yield from the combine harvester was ±10%. To characterize the combine harvester, average machine operation grain loss was determined which was about 2% of total grain yield, and the average machine field

capacity was 1.01 ha h^{-1} with 72% of field efficiency. The results exhibit the potential of interpreting the spatial yield maps to develop management zone for site-specific fertilizer application. Therefore, GPS, GIS and geostatistical technique are useful for assessing patterns of soil nutrients (N, P and K) and yield variation, and their interpretation. This integrated technique is a useful prognostics management tool for site-specific fertilizer management for single crop cultivation.

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

VARIASI RUANG NUTRIEN DAN HASIL TUAIAN DI SAWAH PADI KOMERSIL DI MALAYSIA

Oleh

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Pada masa kini cabaran utama dalam penanaman padi adalah interpretasi peta hasil yang sesuai untuk pengurusan tapak spesifik, dan identifikasi serta pemahaman faktor-faktor yang mempengaruhi variasi hasil padi. Kemampuan untuk menemui dan memahami faktor-faktor tanah yang mempengaruhi variasi hasil tuaian padi akan membolehkan pengurusan secara lebih efisien. Satu kajian telah dilaksanakan di ladang padi komersil di Kahang, Johor, di bahagian selatan Semenanjung Malaysia dengan objektif (i) untuk mengira dan mencirikan tabiat variasi ruang nutrien N, P dan K tanah (ii) untuk mengira dan mencirikan variasi ruang hasil dan kelembapan bijirin, dan (iii) untuk mengenalpasti hubungkait antara hasil tuaian padi dan nutrien N, P dan K tanah, agar julat nutrien tanah diperolehi untuk mencapai tumbesaran dan pengeluaran yang maksima berdasarkan variasi ruang hasil tuaian padi. Sampel tanah atas (0-15 cm) telah diambil menggunakan corak grid 20 m x 20 m sejurus sebelum padi (MR211) ditanam dan dianalisis untuk menyukat N jumlah, ketersediaan P dan K tukarganti di petak sawah tersebut. Alat GPS Geoexplorer II telah digunakan untuk merekod koordinat titik-titik sampel tanah dan sempadan plot bagi membantu interpretasi peta ruang dalam GIS dengan sistem unjuran yang sesuai. Hasil padi dan kelembapan bijirin padi direkodkan untuk sampel tuaian padi pada setiap ukuran grid 55 m x 30 m semasa proses menuai. Hubungkait antara hasil tuaian padi dan nutrien tanah (N, P dan K) dilakukan dengan

menggunakan analisis regresi. Analisis geostatistik digunakan untuk mencirikan variasi ruang nutrien tanah dan hasil tuaian padi. Pekali variasi nutrien (N, P dan K) tanah di kawasan kajian didapati melebihi 50% di mana variasi P tanah adalah sangat tinggi (130%). Terdapat hubungkait yang positif di antara setiap pasang nutrien tanah (N, P dan K). Analisis semivarian menunjukan bahawa pergantungan ruang adalah di antara 350 hingga 450 m (2 sampel ha^{-1}). Peta nutrien tanah (N, P dan K) menunjukkan bahawa lebih 80% daripada luas kawasan setiap plot mengandungi kurang daripada 3 g kg^{-1} N tanah, kurang daripada 10 mg kg^{-1} P, manakala K adalah lebih daripada 0.45 cmol(+) kg^{-1}. Variasi hasil tuai padi adalah melebihi 47% dan menunjukkan perbezaan yang nyata di dalam dan antara kawasan. Semivarian hasil tuaian padi mencapai pada jarak 380 m, dan ini menunjukkan bahawa korelasi ruang adalah dalam lengkungan 2.6 ha (70 m x 380 m) di mana 70 m adalah lebar dalam setiap plot. Kelembapan bijirin padi mempunyai sebaran secara rawak pada jarak melebihi 30 m dan tidak menunjukkan variasi yang nyata di dalam setiap petak sawah. Peta hasil tuaian padi menunjukkan bahawa di bahagian tengah setiap plot (> 50% daripada luas kawasan) menghasilkan padi yang lebih rendah (< 3.5 t ha^{-1}) berbanding di bahagian kedua-dua tepinya. Kajian ini juga mendapati korelasi yang positif di antara setiap nutrien tanah (N, P dan K) dengan hasil tuaian padi. Pengaruh gabungan N, P dan K tanah terhadap hasil menunjukkan bahawa N dan P tanah dapat menerangkan 41% daripada variasi hasil, di mana P tanah adalah 36% dan N tanah 5% ($Y = 2.41 + 0.39 X_N + 0.20 X_P$; $R^2 = 0.41^{**}$, n = 159). Berasaskan kepada hubungkait tersebut, zon pengurusan khas disyorkan. Untuk mencapai hasil 5 tan ha^{-1}, N dan P perlu ditambah pada kawasan yang mengandungi N dan P yang serderhana dan rendah. Beberapa sifat tanah terpilih telah diukur pada beberapa lokasi dan didapati julat pH di antara 4.25 - 4.54, ketumpatan pukal 0.77-0.92 g cm^{-3}, dan tekstur tanah adalah lempung (75-83% lempung). Perbezaan hasil yang dianggarkan daripada peta ruang dan tuaian sebenar daripada jentera penuai ialah ±10%.

Untuk mencirikan jentera penuai padi, purata kadar kehilangan bijirin adalah 2% bagi jumlah hasil tuaian bijirin dan purata kapasiti jentera adalah 1.01 ha $(jam)^{-1}$ dengan kecekapan 72% dalam kapasiti ladang. Hasil penyelidikan menunjukkan interpretasi peta ruang berpotensi untuk menentukan zon pengurusan yang spesifik bagi tujuan pembajaan. GPS, GIS dan geostatistik adalah berguna untuk menilai nutrient tanah (N, P dan K), variasi ruang hasil dan interpretasinya. Penggabungan teknik ini merupakan satu kaedah yang bermanfaat bagi pengurusan baja secara spesifik untuk tanaman sejenis.

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$\gamma(h)$	semivariance, $(unit)^2$
Ao	range, m
Co	nugget variance, $(unit)^2$
Co+C	sill, $(unit)^2$
EFC	effective field capacity, ha h^{-1}
FE	field efficiency, %
h	lag distance, m
n	number of observations or pairs
s	time in second
t	ton
TFC	theoretical field capacity, ha h^{-1}
T	total time, s
T_o	time loss for other activities, s
T_{rful}	time loss for refueling, s
T_{rm}	time loss for repairs, s
T_t	net harvesting time, s
T_{turn}	time loss for turning, s
T_{uld}	time loss for unloading, s
z_i, z_{i+h}	pairs of sample of observation separated by h, unit

CHAPTER 1

INTRODUCTION

Precision farming (PF), alias prescription farming, site-specific farming, or variable-rate application, is currently the focus for many research and technology activities. The goal for PF is to optimize inputs to produce the highest possible net return on investment and be environmental friendly. Microprocessor control systems for adjusting fertilizer, spraying, irrigation, and seeding rates; Global Positioning System (GPS) for determining field location; and yield monitors for measuring the results as a function of position have advanced rapidly. If the inputs (such as seed, fertilizer and spray) can be to right amount, then money could save without wasting valuable materials. On the other hand, we could get higher yields because the recommended application rate is also in optimal rate, and thereby, we can avoid environmental problems. There are two distinct parts to 'precision farming'. One is the technical aspect, whereby farmers are enabled to apply exactly the right amount of inputs at the right place using modern electronics. The other vital aspect is quality of management in which a farmer integrates the high technology into the farm business to increase efficiency, yields and profits.

Over the last 10 years, precision agriculture has gained an increasing profile in the agricultural community. Although considerable research effort has been expanded, it is still only a minority of farmers who practice any part of this new concept. In the context of Malaysia, the practice of precision agriculture is in primitive stage compared to U.S. and Western Europe. The basis of precision agriculture – the