RELATIONSHIP BETWEEN SOIL APPARENT ELECTRICAL CONDUCTIVITY AND SELECTED SOIL PROPERTIES, AND OIL PALM YIELD

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The ultimate goal of precision farming is to manage the farm on a site specific basis. In realizing this goal, knowledge of the soil and crop characteristics on a practical fine grid basis is necessary. However, to obtain soil and crop parameters on a greater intensity in oil palm plantation using the traditional soil and crop sampling and analysis methods are very expensive, tedious, and time consuming. This problem could be addressed using sensors that can gather information on-the-go. A sensor that is currently available with the above feature is Veris® 3100 soil EC sensor (Electrical Conductivity sensor), a product of Technologies and Probe Systems, Kansas, USA. An evaluation of the sensor was conducted in a mature oil palm plantation at Dusun Durian Estate, Banting, Selangor with the following objectives : (i) To determine the relationships between Veris soil EC and selected soil chemical and physical properties, and oil palm yield, (ii) To investigate the spatial variability of soil EC, selected soil chemical and physical properties, and oil palm yield, and (iii) To define spatial classes of the variables based on interpretation of geostatistical parameters.

The evaluation conducted proved that EC sensor can be used to develop spatially dense datasets desirable for describing within-field spatial soil variability for precision agriculture. The data obtained using this sensor were very intensive and can rapidly determine soil EC *in-situ*. The electrical conductivity mapping is a fast means of characterizing spatial patterns in soil profiles. Mapping with an EC sensor provides information at two levels of soil profile, i.e. shallow (<30 cm) and deep profiles (<90 cm) which allow calibration of soil parameters at different depths. It was also noted that the patterns of soil EC within a field tend to remain the same from season to season. Therefore, once a map is generated it could be used for several years. The results showed that significant positive relationship ($p<0.01$) existed between shallow EC and pH, K, Ca, Mg but there was negative relationship with fine sand content of the soil. A significant correlation at $p<0.05$ was also observed between shallow EC and total P, CEC, silt, clay and percentage of coarse sand content in the soil. The relationships observed between EC and certain nutrient concentrations were also influenced by the relationship between EC and other soil properties, and it was not really a direct measure of the nutrient itself. Electrical conductivity measured at the experimental site was significantly explained by the soil Potassium, sand content, and Nitrogen levels. This relationship was linear, i.e EC shallow = 9.1212 + 1.0271 Potassium – 0.0308 fine sand – 4.669 Nitrogen. The use of EC in measuring nutrient concentrations depends on the relationship between EC and key soil properties (i.e. K, fine sand and N).

There were also significant correlations between the soil physical properties and measured EC. However, the coefficients of determination were weak (i.e. less than 25%). Kriged map produced based on soil physical properties showed relatively uniform silt, clay, and fine sand distribution. The pattern was attributed to the homogeneous soil type and flat topography of the study area.

The overall results showed that EC data did not correlate with FFB yield despite significant correlation between EC shallow and FFB yield in 2000/01 and EC deep and FFB yield in 1999/00 at P=0.05 level. Thus it can be concluded that Soil EC cannot directly predict crop growth or yield. Kriging analysis of yield data from 1999 to 2003 showed that the Q-value varied from 0.53 to 0.72 indicating a relatively spatial structure. However, the range of spatial dependence varied between 3243 m and 7681 m. This long spatial dependence is reflective of the uniform soil type and relatively flat topography of the study area that resulted in low variation of FFB yields production.

Principal Component Analysis (PCA) analysis using these latent variables revealed that the yield variability could be explained by principal components such as available P, and CEC although their influence was not always consistent. It appears that soil management zones cannot be strictly determined using any one soil parameter across the field. Management zones represent the integration of detailed information regarding soil types, depth, texture, moisture, conductivity and crop type found in the field. Consequently, a database of soil characteristics becomes fundamental for the identification of the soil management zones. For the study area, available P and CEC are the factors that

influence soil EC and thus, these parameters can be used to delineate the management zone. Thus, PCA is a useful statistical tool in delineating management zones.

From the experience and results obtained, it is strongly believed that soil EC map can provide information for precision agriculture. It can be used to guide soil sampling, conduct crop yield map analysis, and help to decide whether or not to vary the amounts of agricultural inputs such as fertilizers across the field. Soil EC is one of the simplest and least expensive soil measurements available for precision farming at the moment. Veris EC sensor is useful in assessing the spatial variation that affects productivity of oil palm field but site specific calibration is required because several characteristics of soils can influence EC simultaneously. It has also the potential to provide estimates of within-field variations of some soil properties. However, care must be taken to understand the effects of the other, non-estimated properties on the conductivity measurement.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PERTALIAN ANTARA KEKONDUKSIAN ELEKTRIK TANAH DAN KANDUNGAN UNSUR TANAH TERPILIH, DAN HASIL KELAPA SAWIT

Oleh

JAMALUDDIN NASIR

Ogos 2006

Pengerusi: **Profesor Madya Anuar Abd Rahim, PhD**

Fakulti: **Pertanian**

Matlamat perladangan presis adalah untuk menguruskan ladang berdasarkan perincian kawasan. Menyedari hasrat ini, pengetahuan tentang ciri-ciri tanah dan hasil tanaman berasaskan grid koordinat yang jitu adalah perlu. Walau bagaimanapun untuk mendapat maklumat yang terperinci di ladang kelapa sawit dengan kaedah penyampelan tanah dan daun mengikut kaedah tradisi dan analisis di makmal adalah melibatkan belanja yang mahal, dan mengambil masa yang panjang. Masalah ini mungkin dapat diatasi dengan menggunakan alat penderia yang boleh mengumpulkan semua maklumat pada waktu yang singkat. Buat masa kini alat yang terdapat di pasaran adalah penderia Veris ® 3100 iaitu alat penderia kekonduksian elektrik (EC), produk buatan Technogies and Probe Systems, Kansas, USA. Satu penilaian ke atas alat tersebut telah

dilakukan di kawasan kelapa sawit matang di ladang Dusun Durian, Banting, Selangor dengan objektif seperti berikut: (i) Untuk menentukan hubungan di antara kadar EC Veris dengan kandungan kimia dan fizikal tanah, dan hasil kelapa sawit, (ii) Untuk menyelidiki kebolehubahan spatial EC tanah, sifat kimia dan fizikal tanah tertentu dan hasil kelapa sawit, (iii) Untuk mendefinisi kelas spatial pembolehubah berdasarkan kepada tafsiran yang dibuat oleh parameter geostatistik.

Melalui kajian yang dijalankan membuktikan bahawa penderia EC boleh digunakan untuk mencerap data pada kepadatan tinggi yang diperlukan untuk menghuraikan kebolehubahan tanah di ladang bagi tujuan amalan perladangan presis. Data yang diperolehi menggunakan alat penderia EC adalah amat intensif dan boleh mengukur bacaan EC tanah dengan kadar yang cepat. Pemetaan kekonduksian elektrik adalah alat yang dapat memperlihatkan corak ruangan di dalam profil tanah. Pemetaan menggunakan alat penderia EC memberikan maklumat pada dua kedalaman profil tanah, iaitu profil cetek (<30 cm) dan profil dalam (<90 cm) yang membolehkan tentukuran parameter tanah pada kedalaman yang berbeza. Juga diperhatikan corak taburan EC tanah di ladang hampir tetap sama dari musim ke musim. Adalah dijangka peta EC yang dihasilkan boleh digunakan untuk beberapa tahun. Keputusan itu menunjukkan bahawa korelasi positif yang ketara ($p<0.01$) wujud di antara EC cetek dengan pH, K, Ca, Mg tetapi kaitan yang negatif dengan kandungan pasir halus di dalam tanah. Hubungkait yang ketara ($p<0.05$) di perolehi di antara EC cetek and jumlah P, CEC, lanar, lempung, dan peratus kandungan pasir kasar di dalam tanah. Pertalian yang diperolehi di antara EC dan kandungan nutrien

juga dipengaruhi oleh paras EC dan sifat tanah yang lain. Ianya adalah bukan ukuran sebenar kandungan nutrien. Kekonduksian elektrik yang diukur di tempat kajian ditentukan dengan ketara oleh paras Kalium, kandungan pasir, and paras Nitrogen yang terdapat di dalam tanah. Kaitan ini adalah dalam bentuk linear, iaitu EC cetek = 9.1212 + 1.0271 Kalium – 0.0308 pasir halus – 4.669 Nitrogen. Kegunaan EC di dalam mengukur kandungan nutrien bergantung kepada kaitan di antara EC dan ciri-ciri utama tanah (iaitu K, pasir halus dan N).

Terdapat juga hubungkait yang nyata di antara sifat fizikal tanah dan EC yang dicerap. Walau bagaimanapun 'pekali penentuan' adalah lemah (iaitu kurang dari 25%). Peta kriged yang dibentuk berdasarkan kepada sifat fizikal menunjukkan lanar, lempung and taburan pasir halus yang agak sekata. Corak ini disebabkan oleh tempat kajian yang mempunyai tanah dan topografi yang seragam.

Keputusan keseluruhan menunjukkan bahawa data EC tidak mempunyai hubungkait dengan hasil FFB walaupun sedikit korelasi yang ketara di antara EC cetek dan hasil FFB dalam tahun 2000/01 dan korelasi EC dalam dan hasil FFB pada tahun 1999/00 pada paras $p = 0.05$. Oleh itu ia boleh disimpulkan bahawa EC tanah tidak dapat menganggarkan kadar hasil tanaman. Analisis 'kriging' mengenai data hasil dari tahun 1999 hingga 2003 menunjukkan bahawa nilai-Q berubah dari 0.53 kepada 0.72 menunjukkan struktur yang berubah mengikut ruangan. Walau bagaimanapun lingkungan pergantungan ruangan berkisar di antara 3243 m dan 7681 m. Pergantungan ruangan yang

jauh menggambarkan jenis tanah yang seragam and topografi yang seragam di lokasi kajian memberikan keputusan hasil pengeluaran FFB yang rendah perbezaan.

Analisis komponen prinsipal (PCA) menggunakan data sedia ada menunjukkan bahawa perubahan hasil dapat dijelaskan oleh prinsipal komponen yang diwakili oleh P, dan CEC walaupun pengaruhnya tidak konsisten. Ia menunjukkan zon pengurusan tanah tidak dapat diukur dengan hanya menggunakan mana-mana parameter tanah di ladang. Zon pengurusan perlu merangkumi integrasi maklumat tentang jenis tanah, kedalaman, tekstur, kelembapan, kekonduksian dan jenis tanaman yang terdapat di ladang. Data sifat tanah adalah asas untuk mengenal pasti zon pengurusan tanah. Bagi lokasi kajian, kandungan P dan CEC adalah faktor yang mempengaruhi EC tanah, oleh itu parameter ini boleh digunakan sebagai asas persempadanan zon pengurusan. PCA boleh membantu dan merupakan pakej statistik yang berguna untuk pembahagian zon pengurusan tanah.

Pengalaman dan keputusan yang diperolehi menunjukkan bahawa peta EC tanah dapat memberikan maklumat untuk pertanian presis. Peta ini boleh digunakan sebagai panduan mengambil sampel tanah, mengendalikan peta analisis hasil tanaman, dan membantu membuat keputusan untuk pengagihan kadar baja yang spesifik di kawasan ladang. Penderia EC tanah adalah alat pengukuran tanah yang paling mudah dan murah dapat diperolehi untuk perladangan presis buat masa kini. Penderia Veris EC adalah berguna untuk menaksirkan perubahan ruangan yang memberikan kesan keluaran di ladang

kelapa sawit tetapi tentukuran tertentu mengikut kawasan adalah diperlukan kerana beberapa faktor kandungan tanah boleh mempengaruhi EC secara serentak. Ia berpotensi untuk menganggarkan perubahan sifat tanah dalam ladang. Walau bagaimanapun pertimbangan perlu mengambil kira kesan faktor lain yang tidak dianggarkan untuk cerapan EC.

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I certify that an Examination Committee has met on 8th August 2006 to conduct the final examination of Jamaluddin Nasir on his Master of Science thesis entitled "Relationship between Soil Apparent Electrical Conductivity and Selected Soil Properties, and Oil Palm Yield" 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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DECLARATION

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 of concurrently submitted for any other degree at UPM or other institutions.

JAMALUDDIN NASIR

Date: 16 Oct 2006

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LIST OF ABBREVIATIONS

AA	Auto Analyser
AAS	Atomic Absorption Spectrophotometer
CEC	Cation Exchange Capacity
CV	Coefficient of Variation
DGPS	Differential Global Positioning System
EC	Electrical Conductivity

FFB	**Fresh Fruit Bunches**
GIS	**Geographical Information System**
GPS	**Global Positioning System**
GS	**Geostatic Software**
PA	**Precision Agriculture**
PC	**Principal Components**
PCA	**Principal Component Analysis**
SAS	**Statistical Analysis System**
VRA	**Variable Rate Applicator**