UNIVERSITI PUTRA MALAYSIA

DETERMINATION OF ENERGY REQUIREMENTS FOR DRY LAND TILLAGE USING SPATIAL VARIABILITY TECHNIQUE

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By

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Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATED TO

My wife, daughter and family members

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

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Faculty : Engineering

This study describes the utilization of spatial variability technique in obtaining the tillage energy requirements of disk plowing operation, first rotary tilling after disk plowing operations and second rotary tilling after first rotary tilling and disk plowing operations. Spatial variability of soil terrain characteristics, tractor-implement performances and tillage qualities were measured across two field plots using the mapping system that consists of a Massey Ferguson 3060 instrumented tractor with built-in data acquisition system, differential global positioning system (DGPS) and transducers, mounted-type soil penetrometer-shearometer unit and trailed-type soil surface profile digitizer, respectively. The collected soil terrain characteristic and tractor-implement performance data sets were transferred to ArcView GIS software to produce spatial interpolated surface maps for further statistical analyses. SAS statistical software was used to perform univariate, correlation and stepwise multiple regression analyses to generate mathematical models for tillage energy requirements. Models for tractor travel speed, draft and fuel consumption with respect to the soil terrain characteristic and tractor-implement performance variables were successfully developed for disk plowing operations and

models for tractor travel speed, PTO power and fuel consumption with respect to the soil terrain characteristic and tractor-implement performance variables were successfully developed for first rotary tilling after disk plowing operations and second rotary tilling after first rotary tilling and disk plowing operations. Mean values of soil moisture content, average elevation height, degree of tilth, random roughness index of the soil surface profile, sensing error, PTO power and fuel consumption data sets resulting from first rotary tilling after disk plowing operations and second rotary tilling after first rotary tilling and disk plowing operations at rated and reduced engine speed were also documented for comparison purposes. Evidence trends were shown on soil random roughness index, PTO power, and fuel consumption when subjected to different tillage operations and engine speeds.

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

PENENTUAN KEPERLUAN TENAGA UNTUK PEMBAJAKAN TANAH KERING DENGAN KAEDAH PERUBAHAN RUANGAN

Oleh

NG ENG BOON

Mac 2006

Pengerusi : Profesor Madya Azmi Hj. Yahya, PhD

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Kajian ini menerangkan penggunaan kaedah perubahan ruangan dalam mendapatkan keperluan tenaga pembajakan bagi operasi-operasi pembajakan bajak piring, operasi-operasi pembajakan bajak putar pertama selepas bajak piring serta operasi-operasi pembajakan bajak putar kedua selepas bajak putar pertama dan bajak piring. Perubahan ruangan bagi sifat-sifat permukaan tanah, kecekapan traktor dan jentera bajak, dan kualiti pembajakan diukur dengan menggunakan sistem pemetaan yang mengandungi sebuah traktor Massey Ferguson 3060 yang dilengkapi dengan sistem instrumentasi, sistem perolehan data, 'differential global positioning system (DGPS)' dan alat-alat penderia, serta satu unit alat penusuk dan pericih tanah jenis sangkut penuh, dan sebuah alat pendigitalan profil permukaan tanah jenis treler bagi dua plot ladang. Set-set data bagi sifat-sifat permukaan tanah dan kecekapan traktor dan jentera bajak yang telah dikumpulkan dan dipindahkan ke perisian "ArcView GIS" untuk menghasilkan peta-peta permukaan daripada interpolasi ruangan bagi analisis-analisis statistik yang seterusnya, Perisian statistik "SAS" digunakan untuk menghasilkan analisis-analisis "univariate", "correlation" dan "stepwise multiple regression" bagi membentukkan model-model matematik keperluan tenaga

pembajakan. Model-model kelajuan traktor, rintangan daya tarikan bajak dan kadar gunaan minyak dari segi pertimbangan kepada parameter-parameter sifat permukaan tanah dan kecekapan traktor dan jentera bajak telah berjaya dibentukkan bagi operasi-operasi pembajakan bajak piring dan model-model kelajuan traktor, kuasa PTO dan kadar gunaan minyak dari segi pertimbangan kepada parameter-parameter sifat permukaan tanah dan kecekapan traktor dan jentera bajak telah berjaya dibentukkan bagi operasi-operasi pembajakan bajak putar pertama selepas bajak piring serta operasi-operasi pembajakan bajak putar kedua selepas bajak putar pertama dan bajak piring. Purata bacaan set-set data bagi kandungan air tanah, purata ketinggian aras tanah, darjah kegemburan, index kekasaran rawak bagi profil permukaan tanah, ralat penderiaan, kuasa PTO dan kadar gunaan minyak yang didapatkan daripada operasi-operasi pembajakan bajak putar pertama selepas bajak piring serta operasi-operasi pembajakan bajak putar kedua selepas bajak putar pertama dan bajak piring juga didokumentasikan untuk tujuan perbandingan. Kesan-kesan yang jelas telah ditunjukkan pada index kekasaran rawak, kuasa PTO dan kadar gunaan minyak jika diperhatikan dalam operasi-operasi pembajakan dan kelajuan enjin yang berlainan.

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INTRODUCTION

1.1 Justification

Soil information such as soil quality, soil strength, soil property and so on is an important element in daily agricultural activities. For instance, farmers always check the soil quality of an agricultural field by means of visual inspection of the field or feeling the soil in the hand before any tillage operation is carried out. This technique may result in considerable error in determining the extent of tillage operation need to be conducted based on the known soil quality. Excessive tillage could cause damage in the soil structure and high energy expenses in the operation. On the other hand, inadequate tillage may results with regions of poor soil quality within the field plot. The existence of uneven soil quality distribution within an area could affect the growth of the germinated seeds and ultimately affects its total crop yield.

Much progress has been made in soil and tillage studies, particularly in tillage energy requirements, to understand the relationships between soil physical parameters and tractor-implement performances for different tillage implements and operations, soil conditions and seedbed preparations. For example, researchers had successfully developed an agricultural machinery management data in ASAE standard D497 which could provide mathematical expressions for draft and power requirements for tillage implements in several soil types (ASAE, 2003b). However,

the draft equation provided by ASAE standard D497 only involve two parameters namely tractor travel speed and tillage depth and neglect other possible important soil parameters such as soil penetration resistance and soil moisture content and also other possible machine parameters such as drive wheel torques, drive wheel slippages, and pitch and roll angles. Currently, attempt had been made by researchers to quantify spatial variability of both soil and machine parameters using global positioning system (GPS), data logging system and sensors on board an agricultural tractor. This new technology and technique allows high density of spatial variability of field parameters to be collected within a considerable time period and the collected field parameters are able to be illustrated and analyzed in spatial maps basis. McLaughlin and Burtt (2000) carried out a study in spatial mapping of tillage energy and reported that draft, fuel consumption, engine speed and forward speed were closely related and maps of these four tractor-implement performance parameters showed similar patterns. Similar study was also done by Sirjacobs *et al.* (2001) to map the spatial variability of draft force, vertical force and moment and correlate them with penetrometry index, gravimetric water content, bulk density, cohesion and internal friction angle, simple compression resistance, Atterberg limits, granulometry and pF curves. They stated that significant relationships were established between a global penetrometry index and the draft force and moment solicitations measured by the sensor, and between gravimetric water content and the vertical force. Therefore, it is hope that with the recent available technology, a study in spatial variability of the field attributes for a particular tillage operation using both geographical information system (GIS) and statistical analysis methods could be carried out to produce a better soil-tillage relationship in a quantitative manner.

Generally, dry land in Malaysia is defined as a typical agricultural field used for vegetable cultivation. Average moisture content in dry basis and annual precipitation in this agricultural land are about 20% and 3000mm, respectively. Conventional tillage operation practices in preparing a crop seedbed in a Malaysian dry land involve disk plowing and rotary tilling operations. Nevertheless, farmers run the tillage operation using traditional practices (i e. rotary tillage after disk plowing or double rotary tillage after disk plowing) without realizing that excessive tillage energy had been applied resulting in the increased of cost and duration of operation. Determination of energy requirements of rotary tillage after disk plowing and double rotary tillage after disk plowing taking into account the correlation between soil physical parameters, tractor-implement performance and tillage quality in a scientifically proven study is therefore an interest to researchers. Traditional methods under controlled field experiment with the involved tractor-implements were time consuming, labourious and could be almost impossible because it involves a lot of parameters. Thus to overcome this problem, a precise system that is equipped on a tractor, capable of measuring the spatial variability of soil physical parameters, tractor-implement performance and tillage quality, and could be used practically in field condition is required to quantify the energy requirements for tillage operations.

The Department of Biological and Agricultural Engineering, Universiti Putra Malaysia has developed a mapping system that consists of a data acquisition system and differential global positioning system (DGPS) on board a Massey Ferguson 3060 tractor for mapping soil terrain characteristics, tractor-implement performances

and tillage qualities, allowing analyses to be done on a spatial basis. However, the mapping system is not equipped with the terrain slope and tillage depth transducers. The measurements of terrain slope and tillage depth were highlighted in the past researcher works as the important variables that contribute to the correlation relationship among the tractor-implement performance and soil terrain parameters. Thus, it is essential to develop these two transducers to the mapping system. This research work is conducted to quantify the energy requirements for dry land tillage using spatial variability technique.

1.2 Objectives

The objectives of the study are as follows:

1. To determine the energy requirements of disk plowing operation, single rotary tillage after disk plowing operations and double rotary tillage after disk plowing operations using spatial variability technique

2. To evaluate spatial relationships between tillage energy requirements and soil terrain characteristics

3. To determine the tillage quality of a single rotary tillage after disk plowing operation and a double rotary tillage after disk plowing operation