UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF A MOBILE SOIL PROFILE DIGITIZER

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DEDICATED TO

HIS PARENTS, BROTHERS AND SISTER

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

DESIGN AND DEVELOPMENT OF A MOBILE-TYPE 2 AXIS LASER SURFACE SOIL PROFILE DIGITIZER

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This study describes the design and development of an automated, mobile-type 2-axis laser soil surface profile digitizer for 3D mapping of soil surface. The construction of the digitizer consists of 2 main parts, the measurement apparatus and a special design trailer. The measurement apparatus provides the non-contact soil surface digitizing and the special design hydraulically powered open-base trailer is used for transporting, uplifting or releasing the measurement apparatus during field operation. The digitizer was pulled by a Massey Ferguson 3060 Instrumented agricultural tractor. Three PLC controlled stepper motors and 3 sets of precision ball screw carriage mechanism were used to drive the sensor in 2-axis of digitizing direction. Dewe-2010 PC Instrument was employed to perform the data acquisition and user control task for the digitizer. The simplified method of the user control interface integrates the concept of touch-screen virtual control panel built on DasyLab® V5.5 programming platform. The Digitizer was capable to digitize a maximum area of 1.05m x 1.8m with an adjustable digitizing speed, digitizing interval and digitizing area to suit with the required operation time and output resolution. Field tests were

conducted to determine adequate digitizing speed and digitizing interval for the digitizer, and also to evaluate the significant of tillage operations, tractor travel speeds and rotary tiller's speeds with respect to average elevation height, Degree of Tilth, and Random Roughness Index of the soil surface profile, and sensing error of the digitizer. Result from field test showed that implement types, tractor travel speed, and rotary tiller speed had significant effects on random roughness index of the soil surface profile. Implement types had only significant effect on the sensing error of the digitizer and rotary tiller speed had only significant effect the Degree of Tilth of the soil surface profile.

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

MEREKABENTUK DAN MEMBINA SEBUAH ALAT PENDIGITALAN PROFIL PERMUKAAN TANAH LASER 2-PAKSI DAN MUDAH-ALIH

Oleh

WEE BENG SUI

Mac 2004

Pengerusi : Profesor Madya Azmi Hj. Yahya, Ph.D.

Faculty : Kejuruteraan

Kajian ini melibatkan rekabentuk dan pembangunan sebuah alat pendigitalan profil permukaan tanah laser 2-paksi jenis automatik dan mudah-alih untuk pemetaan 3-dimensi permukaan tanah. Pembinaan alat pendigitalan ini terdiri daripada 2 bahagian utama, iaitu alat pengukuran dan sebuah treler yang direkabentuk khas. Alat pengukuran tersebut memainkan peranan sebagai alat pendigitalan permukaan tanah tanpa-sentuh, manakala treler khas dengan kuasa hidraul serta permukaan bawah terbuka pula memainkan peranan untuk mengangkut, menaikan, dan menurunkan alat pengukuran tersebut semasa pengendalian di ladang. Alat pendigitalan ini ditarik oleh sebuah traktor pertanian Massey Ferguson 3060 yang dilengkapi dengan sistem instrumentasi. Tiga motor lelangkah yang dikawal oleh PLC dan 3 set mekanisme pembawa jenis skrew bebola persis diguna untuk memacu penderia dalam 2 arah paksi pendigitalan. Perkakas PC Dewe-2010 digunakan untuk perolehan data serta kawalan untuk alat pendigitalan. Kaedah kawalan-mudah tersebut menggunakan konsep skrin-sentuh maya yang berasaskan pengaturcaraan DasyLab® V5.5. Alat pendigitalan ini berupaya untuk mendigitalkan keluasan maximum bersaiz 1.05m x 1.80m dengan keupayaan mengubah kelajuan pendigitalan, julat pendigitalan serta keluasan pendigitalan

untuk disesuaikan dengan masa pengendalian dan resolusi keluaran. Ujian ladang dijalankan untuk menentukan laju serta julat pendigitalan yang sesuai bagi alat pendigitalan tersebut, dan juga untuk menilai kesan operasi pembajakan, kelajuan traktor, dan kelajuan alat bajak putar ke atas purata ketinggian, Darjah Kegemburan, dan Index Kekasaran Rawak bagi profile permukaan tanah, serta juga ralat penderiaan bagi alat pendigitalan. Keputusan ujian ladang menunjukan jenis pembajak, kelajuan traktor, dan kelajuan alat bajak putar memberikan kesan yang nyata hanya kepada Index Kekasaran Rawak bagi profil permukaan tanah. Manakala hanya jenis pembajak memberikan kesan yang nyata kepada ralat penderiaan bagi alat pendigitalan dan hanya kelajuan alat bajak putar memberikan kesan yang nyata kepada Darjah Kegemburan.

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CHAPTER I

INTRODUCTION

1.1 Justification

Soil as one of the most important natural resources, has been damaged by erosion and agricultural practices. Tillage as one of the important and delicate phases in seedbed preparation, has contributed a significant effect to the soil physical properties. Excessive tillage, which is an unfortunate habit of Malaysian farmers, causes considerable damage to the soil structure. To sustain a productive and profitable agriculture, the present conventional soil management system need to be re-evaluated, and a precise and scientifically proven method has to be applied in modern soil management system. Therefore, it is important to identify an optimal tillage conditions in accordance to the crop growth requirements, soil conservation's level, and the machine operation economics. To achieve the above objective, it is necessary to identify one or more precise parameters describing the degree of roughness, that can be utilized not only within experimental boundaries, but also to check with the work quality and correctly regulated implements in the field (Sandry et al.,1998).

Various concepts of quantifying soil surface roughness has been proposed and tested by the agricultural researchers all around the world in the efforts of searching the most appropriate, precise, consistent, reliable, time saving, and user friendly measurement methodology. Various roughness indexes have also been proposed for the study of soil surface roughness. Romkens and Wang (1986) describe four categories of soil roughness. The first category is the roughness due to individual particles or aggregates in the order of 0 to 2mm in magnitude. The second category is the roughness due to the clod size in the surface variation in the order of 100mm in the magnitude. The third category is the roughness due to plowing effect of the tillage implements on the terrain surface, which is in the order of 100mm to 300mm in magnitude. The forth category is the higher order roughness due to field topography in the order of more than 300-mm in the magnitude. The second and third category of roughness is are those, which change most rapidly due to weathering and tillage and are the importance-measured parameters in this study.

Even though various soil surface roughness indexes have been used and proposed, all these parameters are based on the common principal of measuring soil surface elevations at selected intervals to form a Digital Elevation Model (DEM). DEM is a computer representation of a surface morphology. Basically, this is a grid of points where each point has an altitude. Two types of commonly used DEM is a macro DEM where each point size is greater than 1m, and micro DEM where each point size is less than 100mm. This study will concentrate only on the micro DEM since micro DEM gives a significant effect to soil surface roughness and erosion due to tillage implement.

However, the recent designed and developed measurement apparatus for measuring soil surface roughness are still not perfect and needs some modifications. The sensing device of the recent instrumentation system uses a dedicated pair of laser beam emitter and beam receiver, which is quite complicated to be aligned and need field calibration for each operation. These measurement apparatus also need to be in-field assembly, which can be a time consuming process. The control and data acquisition system of these measurement apparatus also utilizes a dedicated personal computer (PC), power generator, and signal analyser, which can be quite messy and time consuming cabling process during operation. A large-scale measurement apparatus of this kind also faces transportation problem, which is due to its size and weight.

Thus, there is a need of having a user friendly and reliable measurement apparatus that can be used to measure the soil surface roughness that is mobile, utilize integrated instrumentation system, and faster field setup. The develop measurement apparatus should be able to generate a DEM of soil surface profile and at the same time could be used to quantify soil surface roughness.

1.2 Objectives

The main objective of this study is to design, develop, and test a laser soil surface profile digitizer for the purpose of quantifying soil surface roughness for seedbed preparations.

The specific objectives of this study are as follows:

1. To design and develop an automated measurement apparatus that is able to digitize soil surface elevations in 2-axis directions.

2. To design a special trailer for supporting and carrying the measurement apparatus with a built-in mechanism for uplifting and releasing the measurement apparatus during its operation in the field.
3. To design a computer program that can control, calculate, visualize, and perform a real time display of the surface elevations data obtained from the measurement apparatus.
4. To calibrate the laser displacement sensor of the measurement apparatus for its output variations due to the color variety of the target surfaces and its output resolutions in accordance to the selected predefined digitizing intervals.
5. To quantify and evaluate soil surface profile of seedbeds prepared after a disk plow, a moldboard plow, a disk harrow, and a rotary tiller using the developed digitizer.

CHAPTER II

LITERATURE REVIEW

2.1 Soil Surface Roughness

Various types of soil surface roughness quantification techniques and parameters have been proposed by past researchers in the study of soil science. Among the commonly used parameters include the Random Roughness Index, Micro-relief index, Degree of Tilth Index, Tilth Index, Regionalized Soil Roughness Index, and Coefficient of Manning's Roughness Index. However, Random Roughness Index (RR) has been widely used to describe surface roughness for a range of soils and tillage implements (Chi-hua Huang et al., 1992). It represents a scale equivalent to the standard deviation of soil surface elevations heights (Kuipers, 1957; Allmaras et al., 1966; Currence and Lovely, 1970). The employed technique implicitly assumed that soil surfaces have a Random Roughness with no spatial correlation. Various equations have been proposed and used to describe the Random Roughness index. Gupta et al., (1991) describes the measurement of Random Roughness index in the following equation:

$$RR = \left(\sum(Z_i - Z)^2 / (n - 1)\right)^{1/2} \qquad (2.1)$$

where RR is a Random Roughness index, Z_i is the standard deviation of the elevation heights, Z is a mean value of elevation heights after slope and tillage Oriented Roughness in both directions has been removed, and n is a number of measured points. The schematic representation of Random Roughness measurement is illustrated in Figure 2.1.

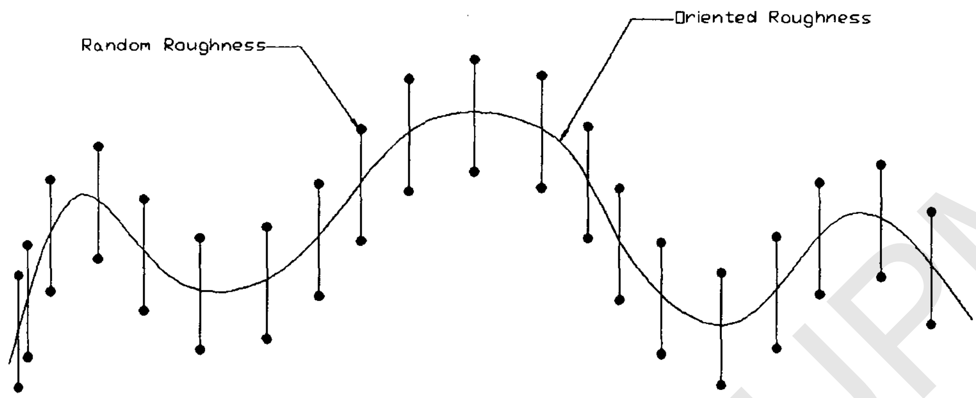

Figure 2.1: Random Roughness Measurement

Allmaras et al., (1967) suggested that since the elevation heights in logarithm values were normally distributed, the Random Roughness index could be defined as the natural logarithm of standard deviation for the correlated elevation heights after multiplication with a constant value of 100 as in equation 2.1.

$$RR = 100 \times \text{Log}\ \sigma \qquad (2.2)$$

where RR is the Random Roughness index and σ is the standard deviation of the elevation heights. The computation for σ were to be made based on the elevation heights after corrected from slope and tillage orientation in both directions with the exclusion of 10% upper and lower extreme values of the elevation heights data set.