UNIVERSITI PUTRA MALAYSIA

PADDY GROWTH MONITORING AND YIELD ESTIMATION USING TERRESTRIAL LASER SCANNER

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By

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

June 2016

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

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June 2016

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Rice (*Oryza Sativa L.*) is a primary food source for many countries especially in Malaysia. Sustainable rice production is really required to fulfill the needs. Appropriate amount of nitrogen (N) fertilizer is needed to ensure high production of rice. In this research, the growth of plant parameters at straw and leaf section and also yield such as above-ground biomass and grain has been monitored at seven different stages such as early tillering, tillering, early booting, panicle initiation, milk grain, dough grain and mature grain. Different amount of N such as 0 kg/ha, 85 kg/ha, 170 kg/ha and 250 kg/ha were applied to MR 219 and MR 220 paddy. The 2-way ANOVA results showed that different rate of N treatment affected plant parameters and yield of paddy. Plant heights, SPAD reading and above-ground biomass were significantly different at each N level while for the grain there was not much different between at 85 kg/ha, 170 kg/ha and 250 kg/ha. The highest plant height, SPAD reading, above-ground biomass and grain yield were achieved at 250 kg/ha of N level; 70.46 cm, 39.13, 65.48 g/pot and 59.00 g/pot respectively. Later, the Terrestrial Laser Scanner (TLS) was used to monitor the growth of paddy based on its height calculated using developed Crop Surface Model (CSM). The CSMs were developed from creating the DEM (Digital Elevation Model) and DSM (Digital Surface Model) surfaces first using the scan point cloud data with a resolution of 1 cm. Results have shown that the developed CSM maps can be used to monitor the spatial and temporal pattern of the growth. High coefficient of determination, (R^2 = 0.976) gave confirmation on the high compatibility of the method. The plant height from CSM was later used to estimate the above-ground biomass and grain yield of paddy. Results has shown that good correlations and regression were achieved for CSM plant height and above-ground biomass (R^2 = 0.809) but a bit smaller between CSM plant height and grain (R^2 = 0.582). Based on the result, above-ground biomass and yield were best estimated at 94 DAS (Days after sown). The above-ground biomass and grain yield estimation model was developed using linear equation. The estimated and measured above-ground biomass and grain yield were tested using a t-test analysis and the result showed that the significant values for both

parameters were 1 ($p \geq 0.05$) which indicates there was no significance difference between measured and estimated values. Therefore, it is concluded that above-ground biomass and grain yield can be estimated from CSM plant height.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuh keperluan untuk Ijazah Sarjana Sains

PEMANTAUAN PERTUMBUHAN DAN HASIL PADI MENGGUNAKAN PENGIMBASAN LASER TERESTRIAL

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Beras (*Oryza Sativa L.*) adalah sumber makanan utama bagi banyak negara terutamanya di Malaysia. Pengeluaran beras secara berterusan adalah sangat diperlukan untuk memenuhi keperluan penduduk. Jumlah baja nitrogen (N) yang sesuai diperlukan untuk memastikan pengeluaran beras yang tinggi. Dalam kajian ini, pertumbuhan parameter pokok di bahagian jerami dan bahagian daun dan juga hasil iaitu berat kering dan hasil padi telah dipantau pada tujuh peringkat iaitu awal beranak, beranak, awal bunting, keluar tangkai, padi susu, padi masak hijau dan padi matang. Jumlah N yang berbeza iaitu 0 kg/ha, 85 kg/ha, 170 kg/ha dan 250 kg/ha telah digunakan untuk padi jenis MR 219 dan MR 220. Keputusan 2 hala ANOVA menunjukkan bahawa kadar penggunaan N yang berbeza telah memberi kesan terhadap parameter tumbuhan dan hasil padi. Ketinggian tumbuhan, bacaan SPAD dan berat kering adalah jauh berbeza pada setiap peringkat N manakala bagi hasil padi, ia tidak menunjukkan banyak perbezaan antara 85 kg/ha, 170 kg/ha dan 250 kg/ha paras N. Ketinggian tumbuhan, bacaan SPAD, berat kering dan hasil padi merekodkan bacaan tertinggi pada tanaman yang diberikan 250 kg/ha N; iaitu 70.46 cm, 39.13, 65.84 g/bekas dan 59.00 g/bekas. Kemudian pengimbas laser telah digunakan untuk memantau pertumbuhan padi berdasarkan ketinggian yang dikira menggunakan model permukaan tanaman. Model ini telah dibangunkan hasil daripada peta model ketinggian digital dan model permukaan digital menggunakan data titik awan imbasan dari laser pengimbas dengan resolusi 1 cm. Keputusan telah menunjukkan bahawa peta model permukaan tanaman boleh digunakan untuk memantau corak ruang dan masa pertumbuhan. Pekali penentuan (R^2 = 0.976) memberikan pengesahan yang tinggi mengenai keserasian kaedah ini. Ketinggian tumbuhan daripada model permukaan tanaman kemudiannya digunakan untuk menganggar berat kering dan hasil padi. Keputusan menunjukkan bahawa hubung kait dan regresi yang baik telah dicapai untuk ketinggian tumbuhan daripada model permukaan tanaman dengan berat kering (R^2 = 0.809) tetapi agak kecil antara ketinggian tumbuhan daripada model permukaan tanaman dengan hasil padi (R^2 = 0.582). Berdasarkan hasil keputusan, berat kering dan hasil padi bagus dianggarkan pada hari ke-94 selepas ditanam. Model anggaran berat kering dan hasil padi telah dibangunkan dengan menggunakan persamaan linear. Anggaran dan

bacaan sebenar berat kering dan hasil padi telah diuji menggunakan analisis ujian-t dan hasilnya menunjukkan bahawa nilai signifikan bagi kedua-dua parameter adalah 1 ($p \geq 0.05$) yang menunjukkan tidak terdapat perbezaan yang signifikan antara nilai bacaan sebenar dan anggaran. Oleh itu, ia membuktikan bahawa berat kering dan hasil padi boleh dianggarkan daripada ketinggian tumbuhan yang dikira daripada model permukaan tanaman.

ACKNOWLEDGEMENTS

In the name Allah, the Most Gracious and Most Merciful. First of all, Alhamdulillah I am thankful to Allah Almighty for making all things possible and giving me strength to complete this study and thesis.

Secondly, I would like to express my deepest appreciation to my supervisor Assoc. Prof. Dr. Siti Khairunniza bt Bejo for the continuous support, guidance, patience and motivation towards me in order to complete this study. Her comments and ideas were really helpful all the time of research and writing this thesis. Besides my supervisor, I would like to thank my co-supervisor Dr. Farrah Melissa Bt Muharam for her insightful comments, encouragement and also guidance throughout this study.

My sincere thanks also go to all staff and technicians from the Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia and Institute of Tropical Agriculture, Universiti Putra Malaysia for their valuable assistance. In addition, I would like to thank my fellow lab mates from Spatial Laboratory for the discussion, guidance, help, and motivations and not to forget for all the fun we have had together during my study.

I also take this opportunity to record my sincere thanks to my family especially my mother who always stand behind me, supporting me and pray for my success continuously. To my siblings, other family members and friends, thank you for your understanding and encouragement which helps me a lot all this time.

Last but not least, I would like to acknowledge Kementerian Pengajian Tinggi Malaysia and Universiti Teknologi Mara (UiTM) for giving me a financial support for my study.

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LIST OF ABBREVIATIONS

ADC	Agriculture Digital Camera
ANOVA	Analysis Of Variance
AOI	Area of Interest
BERNAS	Padi Beras National Berhad
Chl_{ab}	Chlorophyll a and b
CSM	Crop Surface Model
DAS	Days After Sown
DEM	Digital Elevation Model
DMRT	Duncan Multiple Range Test
DOA	Department of Agriculture
DSM	Digital Surface Model
FAO	Food and Agriculture Organization
GNDVI	Green Normalized Difference Vegetation Index
GPS	Global Positioning System
IDW	Inversed Distance Weighed
LA	Leaf Area
LAN	Leaf Area Angle
LAS	Log ASCII Standard
LARS	Low Altitude Remote Sensing
LIDAR	Light Detection and Ranging
NIR	Near Infra-Red
NDVI	Normalized Difference Vegetation Index
PAD	Plant Area Density
PAI	Plant Area Index
r	Pearson Coefficient
R^2	Coefficient of Determination
RGB	Spectral value
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
TLS	Terrestrial Laser Scanner
XYZ	Spatial coordinates
3D	Three dimensional

CHAPTER 1

INTRODUCTION

1.1 Background of study

Paddy is a significant plant for a large part of the world's population especially in Malaysia. Rice is eaten routinely and constitutes a dominant portion of a standard diet for people, and supplied a large fraction of the needs for energy-rich materials. It is also important for other nutrients intake as well. Geographical location, temperature regime and suitable soil conditions in Malaysia are conducive and helpful for development and growth of the plant.

The production of rice in Malaysia was recorded as 2,520,409 tonnes from 2010 to 2011 and increased to 2,663,196 tonnes from 2011 to 2012 (FAO, 2015). This has showed a very high demand for rice in Malaysia as the average annual population growth was also increased at 2% in 10 years (2001-2010) as been reported by the Department of Statistic Malaysia (2010).

Paddy monitoring in the paddy field is essential as it is very important for optimizing food security, to sustain environmental issues, and to increase general economic prosperity (Asia-RiCE, 2016). This also can overcome food shortage due to a further growing population.

There are many possible measures of plant growth used in monitoring for examples leaf area index (LAI), vegetation index, plant height, and biomass. Among them, the most direct measurement for monitoring is plant height. Plant height can be used to identify the variety of rice, to estimate the yield and harvest planning, to manage the grain production, and handling of the grain and marketing (Sritarapipat & Rakwatin, 2012; Gao et al., 2013).

Terrestrial Laser Scanning (TLS) technology that provides accurate and dense 3D measurement of object has been introduced. Terrestrial Laser Scanning is easy to be used and gives high spatial resolution. It can measure several thousand or even more points per square meter depending on the distance between scanner and the object.

Bohler and Marbs (2002) have defined the basic principles of laser scanner which is using laser light to measure distance from the scanner to the object in a systematic pattern. The scanner will emit the laser light pulses towards the object and when it hits the object, it will reflected back to the scanner. The results were recorded in the form of 3D points cloud (XYZ) for each point of reflection.

Since TLS can capture and store highly accurate 3D measurement information for any object within its field of view, this has made the TLS become widely used in architectural, engineering and forestry application. For example, TLS was applied in forest industry for standing timber measurement and optimal harvest decision-making in a non-destructive manner (Keane, 2007). It was used to measure the tree height, stem diameter, stem volumes, trees density and even forest growth.

Nowadays, the application of TLS in agricultural field has become an interest. Just like application in forest, TLS was also used for acquisition of vegetation parameters.

Several crops were already investigated with TLS approaches for various purposes. For example, Zhang and Grift, (2012) have used TLS to measure the height of perennial grass while Keightley and Bawden, (2010) estimate biomass of grapevine.

In addition, Hosoi and Omasa (2009) has used TLS to estimate crop density, Eitel et al., (2011) used it to estimate nitrogen (N) status and Gebbers et al., (2011) have applied TLS for measuring LAI of wheat. Besides that, Lumme et al., (2008) has stated that TLS is a promising method for estimating the above-ground biomass of small grain cereals like barley, oat, and wheat.

1.2 Statements of problem and motivation

Conventionally, paddy monitoring is done based on ground survey data which includes plant height, rice leaf colour or leaf chlorophyll content, number of stems, LAI, vegetation coverage, biomass and etc. These data were collected in a destructive manner, often labour and time-consuming.

For example in the field, plant height was measured by using a meter stick. All plants in the hill were grabbed with a single hand and carefully raised up to determine the tallest plant. Normally in most countries, the farmers will plant two to three seedlings in one hill. Then, by placing a meter stick on the soil surface, the tallest plant in the hill was measured.

For above-ground biomass, the data was measured by cutting the plants from soil surface and separate the grains before leave it dried in an oven or under clear sky for few days until it reach constant weight. While leaf chlorophyll content measurement was done in laboratory and involved organic solvent to extract the pigment. Moreover, the data collected was often imperfect and deceptive due to errors during data collection (Prasad et al., 2009).

Hence, remote sensing technology has been introduced. This technology allows non-destructive data acquisition. It provides information about crop distribution, status of crop growth, area planted and potential production for decision makers (Jannoura et al., 2015; Satir and Berberoglu, 2016). Remote sensing technology has become an essential tool for paddy monitoring and mapping paddy growing over large areas (Son et al., 2012). This technology can be applied from space level to ground level using different equipment and sensors depend on the situations and needs.

Thus, since TLS offers high spatial resolution data, it gives an idea that the applications of TLS could also be used to monitor the paddy growth. There is not much study has been done to paddy currently and since the structure of paddy is similar to the previous investigated cereals like wheat and barley, which suggests that laser scanning can also be used to determine paddy crop properties especially in height measurement, above-ground biomass and grain yield estimation.

1.3 Aim and objectives

The aim of this study is to monitor the paddy growth and to estimate above-ground biomass and grain yield using TLS data.

Objectives:
1. To study the effect of N usage on paddy growth and grain yield.
2. To monitor paddy plant height at different growth stages using TLS data.
3. To estimate the above-ground biomass and grain yield of paddy using Crop Surface Model (CSM) derived from TLS data.

1.4 Scope and limitations

This study was conducted in a glasshouse located at Ladang 10, Universiti Putra Malaysia for a controlled environment. The varieties used in this study are the most planted varieties by farmers in Malaysia (MR 219 and MR 220). The treatment of N were categorized as zero N, less N, suggested N and excessed N (0kg/ha, 85kg/ha, 170kg/ha and 250kg/ha). While Phosphorus and Potassium were applied equally throughout the stages (P: 80kg/ha; K: 150kg/ha).

The used of different N were useful to capture different plant condition at different stages. The parameters involved were plant height, SPAD reading, above-ground biomass and grain yield as these were the most direct measurement could be done.

A Faro Laser Scanner Focus 3D was used for data acquisition as it provides simple method of 3D data capture. It also operates with a self-generated signal making the measurements independent from an external lights source. Moreover, the scanner was small and has light weight making it easier to be carried around.

1.5 Thesis outline

This thesis includes five chapters. Chapter One represents the background of this study, statements of problem and motivation, aim and objectives and scope and limitations. Chapter Two discussed the literature review about the whole study from general to more specific topics. It start with paddy, paddy in Malaysia, paddy growth phases, remote sensing for paddy monitoring, light detection and ranging (LIDAR), and application of LIDAR in agriculture. Next in Chapter Three, the proposed method of measuring the plant height using TLS was discussed. The whole process from data scanning, processing and analysing were explained. The results and discussion about this study was presented in Chapter Four. Lastly in the last chapter, Chapter Five concludes the whole study. Some suggestions for future work were also discussed.

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