



## Biomass and Yield Estimation of MR219 and MR220 of Paddy Varieties using Terrestrial Laser Scanning Data

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**Abstract:** Rice (*Oryza Sativa L.*) is the main food source in Malaysia. Thus, to fulfill the needs, continuous rice production is required. Appropriate amount of nitrogen (N) fertilizer is needed to ensure high production of rice. In this research, the effect of N to plant height, SPAD reading, biomass and yield were firstly studied. It was later followed by the estimation of biomass and yield using Terrestrial Laser Scanning (TLS) data. Different amount of N i.e. 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 all parameters were significantly different at each N level. The highest reading was achieved at 250 kg/ha of N level; 70.46 cm (plant height), 39.13 (SPAD reading), 927.29 g/m<sup>2</sup> (biomass) and 830.99 g/m<sup>2</sup> (grain yield) respectively. Therefore, these parameters can be used to indicate the level of input nitrogen at the plant. Later, the plant height calculated using developed Crop Surface Model (CSM) of the Terrestrial Laser Scanning (TLS) data was used to evaluate the biomass and grain yield of paddy. Results has shown that high correlations and regression were accomplished for CSM plant height and biomass ( $R^2 = 0.809$ ). However, the results between CSM plant height and grain were lower ( $R^2 = 0.582$ ). In accordance with the outcome, biomass and yield were best estimated at 94 Day After Sowing (DAS). An estimation model for biomass and grain yield using linear equation was developed. Then a t-test was done to test the estimated and measured biomass and grain yield. The outcome showed that there was no significance difference between measured and estimated values. The values for both parameters were 1 ( $p \geq 0.05$ ). Thus, it can be said that CSM plant height can be used to estimate biomass and grain yield.

**Keywords:** Biomass, Yield, Height, Phase shift, Laser scanner.

## Introduction

Rice plant is an important plant for a significant portion of the world's residents especially in Malaysia. Rice is eaten routinely and forms a superior part 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.

Rice monitoring is essential for optimizing food security, to sustain environmental issues and to increase general economic prosperity. Some of the possible measures of plant growth used in monitoring are leaf area index (LAI), vegetation index, plant height and biomass. Plant height is the most direct measurement and can be used to identify the rice varieties, yield estimation and harvest planning, grain production management and grain handling and marketing (Sritarapipat & Rakwatin, 2012; Gao *et al.*, 2013) There are various researches has been done on the application of TLS in agricultural field. Lumme *et al.* (2008) investigated the utilization of laser scanners and laser point data in agriculture and precision farming. Faro laser scanner was used for growth height estimation and ear recognition for barley and wheat. The results showed that the TLS was a useful tool for growth height and grain yield estimation and could be used as precision farming tool in agriculture.

Lately, a Terrestrial Laser Scanning (TLS) technology has been introduced. This technology gives exact and dense 3D measurement of object. It was used in tree modelling to determine the canopy structure and leaf area using TLS technique by Riczu *et al.* (2011). A total of seven scans have been acquired using Leica Scan Station C10 laser scanner on two pear and one planted apple varieties. The tree parameters such as stem

diameter, height, surface and volume have been estimated successfully. They have concluded that the laser scanning technology could be used to determine some characteristics of studied trees with fast and non-destructive method. In addition, Keightley & Bawden (2010) in their research about grapevine biomass modelling using Tripod LIDAR have concluded that laser scanning technique gave encouraging results to be used correspondingly due to a highly linear relationship between vine volume and tissue mass.

In paddy-related studies, Tilly *et al.* (2014, 2015) used TLS based on a time of flight approach to monitor plant height on paddy fields by establishing crop surface models with 1 cm resolution. Subsequently the derived plant height was utilized to estimate paddy biomass. The technique used a Riegl VZ-1000 (Riegl, Austria) and gave strong coefficient of determination (0.91) between the TLS-derived and manually measured plant heights as well as the estimation of biomass based on the derived height, which illustrated an encouraging  $R^2$  value of 0.86. The measurement of TLS made by Tilly *et al.* (2014, 2015), nevertheless, only concentrated on the early stages of rice paddy cultivation, which were from the stages of leaf development to stem elongation. Meanwhile, Zulkifli & Khairunniza-Bejo (2015) used a phase shift TLS to monitor rice plant height at multiple growing stages. They reported that the monitoring of spatial and temporal pattern of the growth developed from CSM maps can be used. This has been supported by high coefficient of determination value, ( $R^2 = 0.96$ ). Therefore, the objective of this study was to analyse the effect of N to plant height,

SPAD reading, biomass and yield; and to determine the rice yield using Terrestrial Laser Scanning method.

## Materials & Methods

### Data Collection

The same plot of study area presented in Zulkifli & Khairunniza-Bejo (2015) was used in this study. In this research, data collection of plant height, SPAD, biomass and grain yield were done manually and using terrestrial laser scanner.

### Manual Data Collection

By using a measuring tape, three measurements of maximum plant heights were manually taken for each pot starting from soil surface in the pot to the tip of the tallest plant. Then, a SPAD-meter was used to measure N (leave greenness), as Gholizadeh *et al.* (2009; 2011) have reported that it is user friendly and provides data of the leaves' relative chlorophyll content. The measurements were taken from the youngest fully developed leaves at the centre top, middle and bottom. The average values were used to get the relative chlorophyll content. The measurement of rice plant height and SPAD reading was conducted at each stage.

Data of biomass and grain yield were collected during harvesting stage (109 DAS). The plants were put in sampling bag after been cut from the soil surface and any attached soil material were cleaned off. A total of 72 hours (2-3 days) were needed to dry the samples or until it reaches constant weight in the oven of 70°C. To obtain the oven-dried weight of aboveground biomass (g/m<sup>2</sup>), the final oven-dried weights were recorded instantly after taking them out from the oven.

As for the rice grain yield, the grains were threshed by hands after cutting all the panicles.

Then, the grains were leave sun-dried for 2 to 3 days or approximately 14% moisture content before being weighed (g.m<sup>-2</sup>).

### Terrestrial Laser Scanner Measurement

A faro laser scanner Focus 3D SX 130, version 6.1 (FARO Technologies, Inc., Florida, USA) was used during data acquisition to measure the height of the paddy as shown in fig. (1). The data collections were collected at every growth stage starting from 21 DAS until 94 DAS. Therefore, there were nine different dates of data acquisition. Table (1) shows the details on data acquisition. The plant height derived by the crop surface models with high spatial resolution of 1 cm as discussed in Zulkifli & Khairunniza-Bejo (2015) were used to approximate biomass and grain yield.



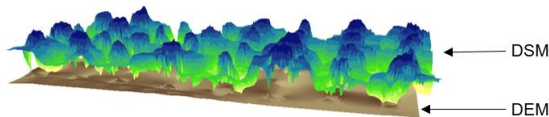
Fig. (1): Data acquisition using faro Laser Scanner.

Table (1): Details for data acquisition.

Date	DAS	Stage
24 June 2014	21	Early tillering
5 July 2014	32	Tillering
14 July 2014	41	Early booting
22 July 2014	49	Booting
1 August 2014	58	Panicle initiation
12 August 2014	69	Flowering
22 August 2014	80	Milk grain
29 August 2014	87	Dough grain

5 September 2014 94 Mature grain

Fig. (2) visualized an example of the developed Digital Surface Model (DSM) and Digital Elevation Model (DEM). So as to get the plants height derived from the Crop Surface Model (CSM), the DEM was subtracted from the DSM.



**Fig. (2): Example of DSM (top) and DEM (bottom).**

### Results & Discussion

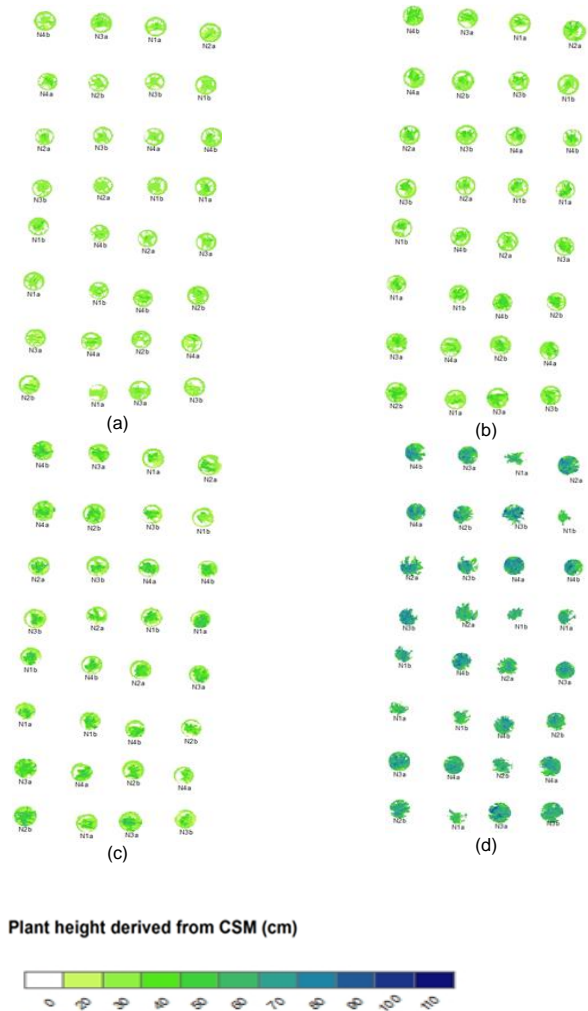
This section first presents results on the effect of Nitrogen to all mentioned parameters earlier taken from the statistical analysis. It is then followed by the results of biomass and grain yield estimation using TLS data.

#### Effect of Nitrogen to Plant Height, SPAD, Biomass and Grain Yield

For the purpose of determining the significantly difference between all parameters at different N level, a mean comparison using Duncan Multiple Range Test (DMRT) was executed and the result was presented in table (2). All parameters were significantly affected at each different levels of N but not for the grain yield. Plant height shows high increment along with the increasing N rates, and the highest was recorded as 70.46 cm at 250 kg/ha N while shortest was 60.07 cm in 0 kg/ha N. Manzoor *et al.* (2006) have reported that the increment in plant height was because N has improved the vegetative growth.

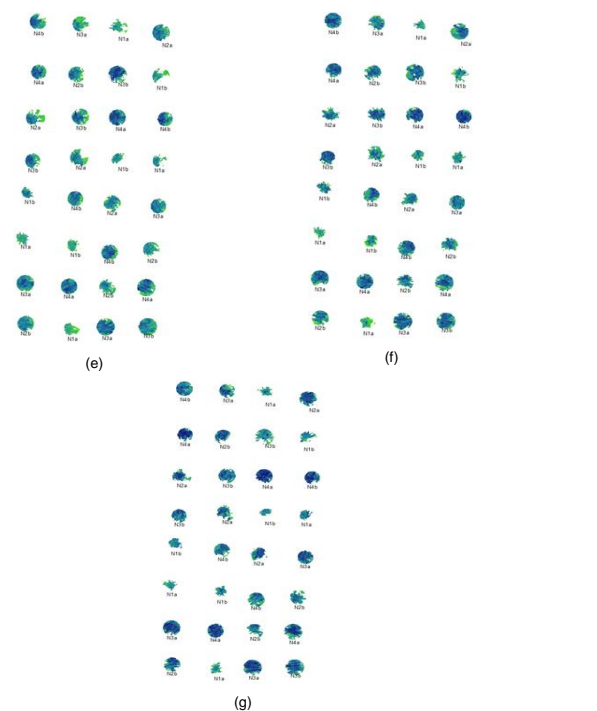
Fig. (3) visualized the spatial and temporal development of the plant height for each date. The diversity in color intensity in the map shows the spatial differences. As the color

becoming more intense, the plant heights were also increase. On the contrary, the changes in color from green to blue indicate the temporal development.



Note: N1\*= 0 kg ha<sup>-1</sup>, N2\*=85 kg ha<sup>-1</sup>, N3\*=170 kg ha<sup>-1</sup>, N4\*= 250 kg ha<sup>-1</sup>; where \* is the breed name i.e. a = MR219, b = MR220)

**Fig. (3): Maps of plant height (cm) derived from CSM for whole pots at each growth stages. (a) CSM at 21 DAS, (b) CSM at 32 DAS, (c) CSM at 41 DAS, (d) CSM at 58. DAS.**



Plant height derived from CSM (cm)



(Note: N1\*= 0 kg ha<sup>-1</sup>, N2\*=85 kg ha<sup>-1</sup>, N3\*=170 kg ha<sup>-1</sup>, N4\*= 250 kg ha<sup>-1</sup>; where \* is the breed name i.e. a = MR219, b = MR220)

**Fig. (3): (cont.) Maps of plant height (cm) derived from CSM for whole pots at each**

**growth stages. (e) CSM at 80 DAS, (f) CSM at 87 DAS, (g) CSM at 94 DAS.**

SPAD reading and biomass showed similar trend where the highest reading was recorded at 250 kg ha<sup>-1</sup> N with 39.13 and 927.29 g.m<sup>-2</sup> respectively. This has been supported by other studies done by Lampayan *et al.* (2010), Shibu *et al.* (2010) and Azarpour *et al.* (2014).

As for grain yield, the lowest was recorded at zero N level (360.92 g/m<sup>2</sup>) and it increased enormously at 85 kg/ha of N (651.41 g/m<sup>2</sup>), 170 kg/ha (772.89 g/m<sup>2</sup>) and 250 kg/ha (830.99 g/m<sup>2</sup>). Nevertheless, between 85 kg/ha, 170 kg/ha and 250 kg/ha of N level there was not much different of grain yield. Increment of N level have caused the increment in grain yield as well due to the better uptake of N which assists to higher dry matter build-up and its translocation to their sink (Dalal & Dixit, 1987). Marazi *et al.* (1993); Dixit & Patro (1994), Daniel & Wahab (1994), Bali *et al.* (1995) and Meena *et al.* (2003) have reported the same outputs.

**Table (2): Duncan analysis for plant height, SPAD, biomass and grain yield at different N level.**

N level	Plant Height (cm)	SPAD	Biomass (g/m <sup>2</sup> )	Grain Yield (g/m <sup>2</sup> )
0	60.07 <sup>a</sup>	31.71 <sup>a</sup>	307.04 <sup>a</sup>	360.92 <sup>a</sup>
85	65.27 <sup>b</sup>	36.76 <sup>b</sup>	560.92 <sup>b</sup>	651.41 <sup>b</sup>
170	68.23 <sup>c</sup>	37.60 <sup>c</sup>	703.35 <sup>c</sup>	772.89 <sup>b</sup>
250	70.46 <sup>d</sup>	39.13 <sup>d</sup>	927.29 <sup>d</sup>	830.99 <sup>b</sup>

Note: Mean values having same letter do not differ significantly at 5% level of probability

A correlation and regression analyses were done to quantify the association between all components and to identify the relationship between correlated components. The results for correlation were presented in table (3). Based on table (3), all components exhibited a positive and significant association between them. Plant height registered a positive and strong correlation to SPAD (R = 0.857) and a

bit lower compared to biomass (R = 0.794) and grain yield (R = 0.634).

**Estimating biomass and grain yield of paddy using TLS data**

Another statistical analysis was done by using plant height derived from CSM to discover whether TLS can be used to estimate the biomass and grain yield. Table (4) shows the



results of correlation analysis. Based on the table, all components showed positive and significant relationship ( $p \leq 0.01$ ). The coefficients were higher for CSM plant height with biomass ( $R = 0.843$ ) compared to CSM plant heights and grain yield ( $R = 0.718$ ). It also shows that grain yield was positively and strongly correlated to biomass ( $R = 0.798$ ) and this has been supported by Ntanos & Koutroubas (2002).

For details on their relationship, regression analysis was done at every stage. Table (5) shows the summary of regression analysis. Good coefficient of determination between CSM plant height with biomass ( $R^2 = 0.809$ ) and grain yield ( $R^2 = 0.582$ ) were achieved at 94 DAS. The result of biomass was almost similar to the result of Tilly *et al.* (2014) in their research about biomass estimation using TLS scanner in rice field ( $R^2 = 0.876$ ).

**Table (3): Correlation analysis between plant heights, SPAD reading, biomass and grain yield.**

	SPAD	Biomass (g/m <sup>2</sup> )	Grain yield (g/m <sup>2</sup> )
Plant Height (cm)	<b>.857**</b>	<b>.794**</b>	<b>.634**</b>
SPAD		<b>.748**</b>	<b>.630**</b>
Biomass (g/m <sup>2</sup> )			<b>.798**</b>
Grain Yield (g/m <sup>2</sup> )			

\*\* Correlation is significant at the 0.01 level (2-tailed).

**Table (4): Correlation analysis between CSM plant heights, biomass and grain yield.**

	Biomass (g/m <sup>2</sup> )	Grain yield (g/m <sup>2</sup> )
CSM Plant Height (cm)	<b>.843**</b>	<b>.718**</b>
Biomass (g/m <sup>2</sup> )		<b>.798**</b>
Grain Yield (g/m <sup>2</sup> )		

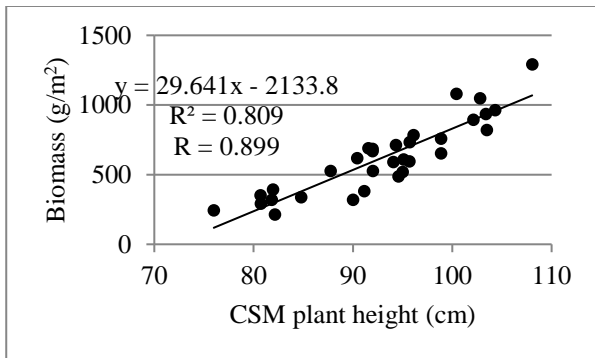
**Table (5): Summary of regression analysis between all parameters at different growth stage (R<sup>2</sup>).**

	21 DAS	32 DAS	41 DAS	58 DAS	80 DAS	87 DAS	94 DAS
CSM and Biomass	0.222	0.063	0.067	0.351	0.638	0.525	0.809
CSM and Grain Yield	0.101	0.083	0.058	0.254	0.407	0.469	0.582

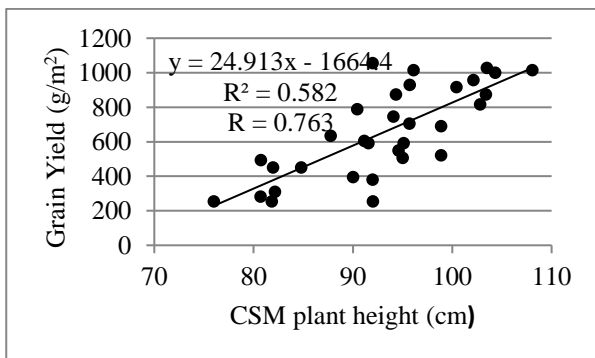
The best linear regression analysis for CSM plant height with biomass and yield was presented in fig. (4) and fig. (5), respectively. The R<sup>2</sup> values are increasing starting from 41 DAS which is early booting stage. During the

first two stages, the plants were too small to present the significant growth and thus not suitable for the biomass and yield prediction. When the plants are growing, the biomass are also keeps increasing even when it reaches the

heading stages where the height is remaining with no changes. More meaningful information comes from measurements taken from stem elongation to heading stage and this indicated that they are varies in the relationship between the CSM plant height with biomass and yield.



**Fig. (4): Regression analysis between CSM plant height and biomass.**



**Fig. (5): Regression analysis between CSM plant height and grain yield.**

Linear equation model produced from this analysis were then used to estimate the biomass and grain yield based on the CSM plant height. The equation models were as follows where (x) is CSM plant height:

$$\text{Biomass} = 29.641x - 2133.8 \quad \text{Equation 1}$$

$$\text{Grain yield} = 24.913x - 1664.4 \quad \text{Equation 2}$$

An independent t-test was carried out to assess if measured mean of biomass and grain yield were significantly different from estimated mean. Table (6) illustrates the result of t-test. No significant different between the two values,  $t(62) = 0, p = 1.0 \geq 0.05$  for both biomass and grain yield have been reported.

For that reason, it suggests that the linear equation model produced from regression analysis was good enough. In addition, biomass and grain yield can also be projected using CSM plant height. This has been supported by studies done by Confalonieri *et al.* (2011). They mentioned that plant height as one of the main factors to estimate grain yield.

**Table (6): t-test between measured and estimated biomass and grain yield.**

		N	Mean	SD	t	df	Sig (2-tailed)
Biomass	Measured	32	624.65	264.02	.00	62	1.0
	Estimated	32	624.62	237.41			
Grain Yield	Measured	32	654.05	261.55	.00	62	1.0
	Estimated	32	654.03	199.54			

## Conclusions

The increment of N level does affect all measured parameters which they were also increased. This was because N promote

exponential growth and increased the height which caused to increment in biomass and grain yield as well. The highest plant height (70.46 cm), SPAD reading (39.13), biomass (927.29 g.m<sup>-2</sup>) and grain yield (830.99 m<sup>-2</sup>)

were recorded at 250 kg.ha<sup>-1</sup> of N level. TLS also can be used to estimate biomass and grain yield. The CSM plant height was strongly correlated to biomass (R = 0.899, R<sup>2</sup> = 0.809) compared to grain yield (R = 0.763, R<sup>2</sup> = 0.582) at 94 DAS. Linear equations produced from regression analysis were used to estimate biomass and grain yield from CSM plant height. A t-test analysis was accomplished to distinguish the result between measured and estimated biomass and grain yield, and the result showed that there was no significant different. To sum up, TLS can be used to estimate plant height, biomass and grain yield. This method as well can avoid damaged to samples.

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