RELATIONSHIPS BETWEEN RICE GROWTH PARAMETERS AND REMOTE SENSING DATA

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Abstract

Rice is an agricullure planis thai has the specific characlerislic in the life stage due to the growth stage having different proportion of vegetation, water, and soil. Vegetation index is one of the satellite remote sensing parameter that is widely used to monitor the global vegetation cover. The objective of the study is to know the spectral characteristic of rice plant in the life stage and find the relationship between the rice growth parameters and the remote sensing data by the Landsat ETM* data using the correlation and regression analysis. The result of study shows that the spectral characteristic of the rice before one month of age is different comparing after one inonlh. All of the examined vegetation index has close linear relationship with rice coverage. Difference Vegetation Index (DVI) is the best vegetation index which estimates rice coverage with equation y = 1.762x + 2.558 and R^2 value was 0.946. Rice age has a high quadratic relationship with all of evaluated vegetation index. Transformed Vegetation Index (TV1) is the best vegetation to predict the age of the rice. Formula y = O.OI3x^z - 1.625x + 145.8 is the relationship form between the rice age and the TV1 with R$^;$ = 0.939. Peak of the vegetation index of rice is in the rice age of 2 months. This period is the transition of vegetative and generative stages.

Key\vords: Vegetation index. Rice growth. Spectral characteristic. Landsat ET\f

I. Introduction

Monitoring and forecasting agricultural production arc very important for the management of world'regional or local food demand and supply balance for social security (Bingfang and Qiangzi, 2005). The rice plant is one of the most important agriculture plants in Indonesia because rice is the main food of the Indonesian people. Food security has long been an important political goal in Indonesia. This goal commonly associated with the rice self-sufficiency. In the mid-1980s, Indonesia has once achieved 100% self-sufficiency *For rice. However, ihe* growth of rice production got slow down in the 1990s, leading to increase of imports and a lower self-sufficiency ratio. Over the past two years the rice self-sufficiency ratio has remained around 95%, but dropped down 90% during the El Nino drought of 1998 (Bappenas, 2002).

Remote sensing satellite has been widely applied and been recognized as a powerful and effective tool in detecting the land use and the land cover change (Ehlers *et a/.*, 1990; Meaille and Wald, 1990). The remote sensing satellite provides cost-effective, multi-spectral and multitemporal data (Paine, 1981). The satellite imagery has been used to monitor spreading land cover types by spectral classification or to estimate the utilization of biophysical *characteristics of the land surfaces via the* relationships with spectral reflectance or indices (Steininger, 1996; Nuarsa *et at,* 2005a).

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Vegetation reflectance is known to be a function of tissue optical properties, canopy biophysical attributes, viewing geometry, illumination conditions, and background effects (Asner, 1998; Barrett and Curtis, 1992). In the rice field irrigation, the reflectance from the rice is actually a combination of *the* rice plant, water,' and soil. In the beginning of the plantation, the rice coverage is dominated by water and soil. By increasing the rice age, the proportion of the rice coverage is rising as well (Nuarsa *et a.*, 2005b).

Vegetation index is one of parameters of the remote sensing satellite that can be used to distinguish an object on the earth surface. Vegetative index is a value that is calculated from sets of remotely-sensed data that is used to quantify the vegetative cover on the Earth's surface (NASA Earth Observatory, 2003).

The objectives of study are to know the spectral characteristic of the rice plant in the life stage and find out relationship between rice growth parameters and remote sensing data using the Landsat ETM+ data by mean of correlation and regression analysis.

II. Method

a. Study Area **and** Sample Description

The period and the area used in this study were from May to November 2005 in Tabanan Regency, Bali Province, centered at latitude 8°29'46" S and longitude 115°29'48" E. The real time observation was performed in this study. It means the ground truth data were taken when the Landsat satellite was passing over the study area. Parameters of the rice growth were obtained in every 16 days, starting from the plantation time to harvest period. The parameters used to measure the rice growth parameters were rice height, total of the young plant, percentage of rice coverage, water condition of the field, and rice age. There were 9 observation stations in the study area as shown in Fig. 1.

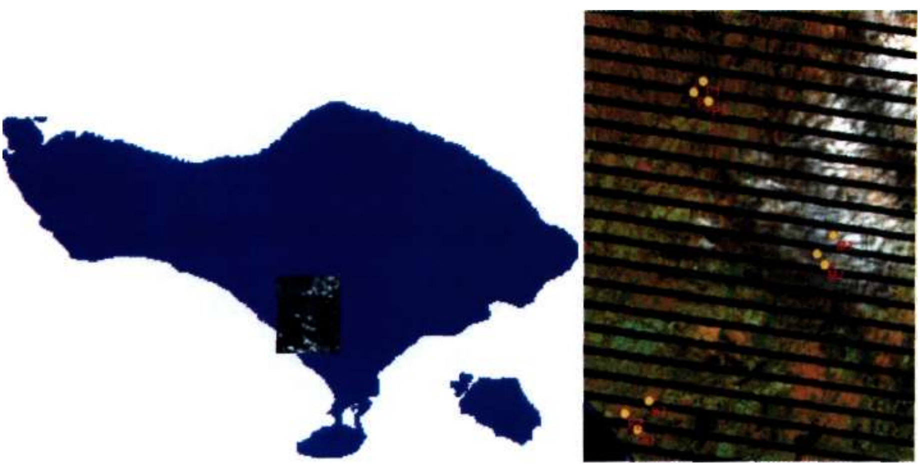


Fig. 1. Study Area and Points of the Observation

b. Data Used

The specification of Landsat ETM+ images was used in this study describes in Table 1. Digital number (DN) of Landsat ETM+ was converted to radian values (RV) before performed image analysis. The equation used to convert DN to RV is shown below:

$$L_\lambda = L_{\min\lambda} + \left(\frac{L_{\max\lambda} - L_{\min\lambda}}{255}\right) * DN$$

where L_λ, $L_{\min\lambda}$, $L_{\max\lambda}$, and DN are radiance value in Wm^{-2} sr^{-1}, minimum radiance value, maximum radiance value, and digital number of the original image respectively. $L_{\min\lambda}$, $L_{\max\lambda}$ was taken from the image header of Landsat data.

Table 1 Landsat ETM+ Images used in this Study

No	Path/Row	Acquisition Date	Spatial Resolution (m)	Band Used
1	116/066	Aug 1st 2005	30	1,2,3,4,5,7
2	117/066	Aug 24th 2005	30	1,2,3,4,5,7
3	116/066	Oct 4th 2005	30	1,2,3,4,5,7

c. Data Analysis

The first step of this study is to find out the spectral characteristic of the rice plant in all life stages by creating the relationship curve between the wave length and radian value of the rice for all measurement ages. The next step is calculating the vegetation Index (VI) to learn the relationship between the VI and the growth parameters, measured in this study. Several vegetation indices used in this study are explained in Table 2.

Table 2. Some Vegetation Index Applied in this Study

No	Vegetation Index	Formula
1	Ratio Vegetation Index (RVI)	$RVI = \frac{nir}{r}$
2	Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{nir - r}{r + r}$
3	Infrared Percentage Vegetation Index (IPVI)	$IPVI = \frac{nir}{r + r}$
4	Difference Vegetation Index (DVI)	$DVI = nir - r$
5	Transformed Vegetation Index (TVI)	$TVI = \frac{100}{\sqrt{\frac{nir - r}{nir + r}} + 0.5}$
6	Soil Adjusted Vegetation Index (SAVI)	$SAVI = \frac{(1 + L)(nir - r)}{nir + r + L}$

Where nir, r, and L are near infrared band, red band, and canopy background brightness correction factor respectively

The correlation analysis is then performed to all of the growth parameters, measured in this study using and remote sensing data to find out the relationship between the growth parameters and the vegetation using the correlation analysis. The estimation curve was created to determine rice coverage and rice age parameters. The best estimated curve model was selected to create a formula of relation between vegetation index and rice growth parameter.

III. Result and Discussion

a. Rice Growth Parameter

Based on the in situ data and the statistical analysis, we found a quadratic relation between the rice growth parameter and the age of the rice. The rice height has the closest relation with the determination coefficient (R^2), 0.92, and the rice coverage and the total of young plant with the R^2 values of 0.861 and 0.799 respectively. Form of the quadratic equation for height, coverage, and total of the young plant of the rice were $y = -0.007x^2 + 1.650x + 3.801$, $y = -0.01 lx^2 + 2.406x - 18.88$, and $y - -0.005x^2 + 0.802x - 0.992$ correspondingly (Fig.2a, Fig. 2b, and Fig. 2c).

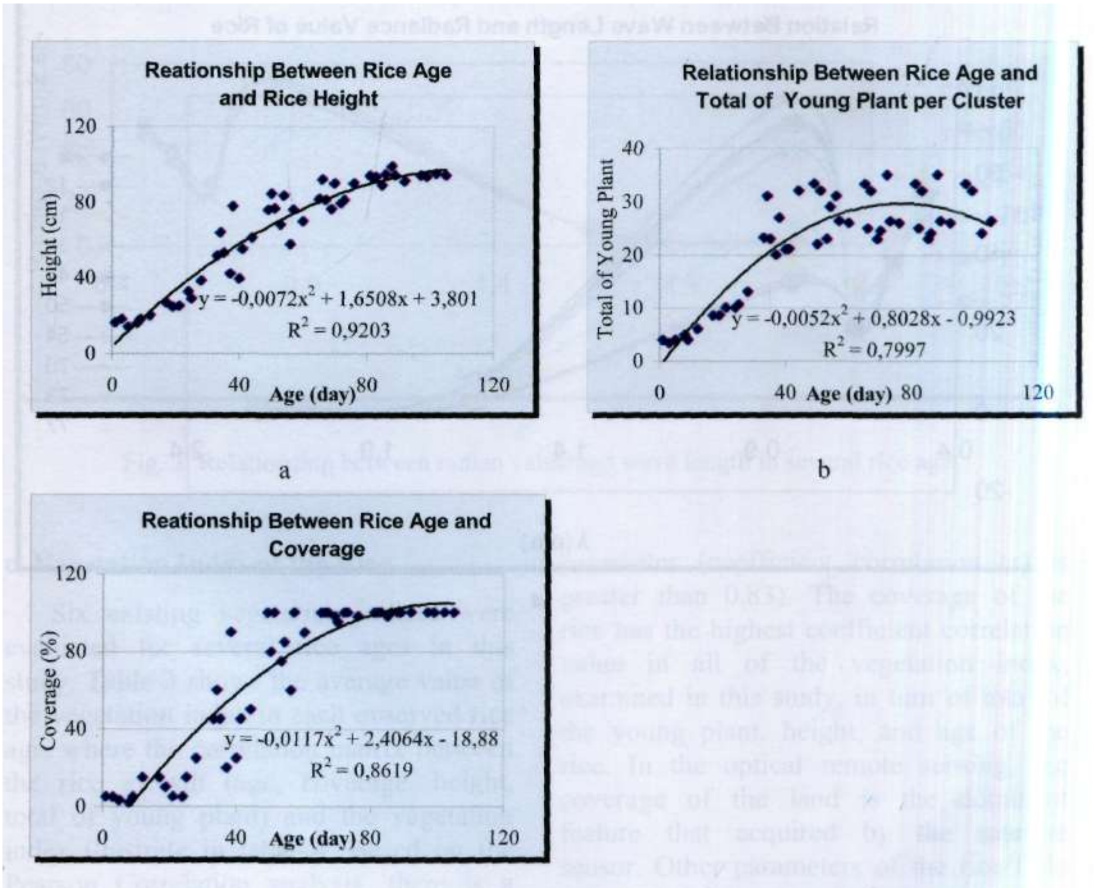
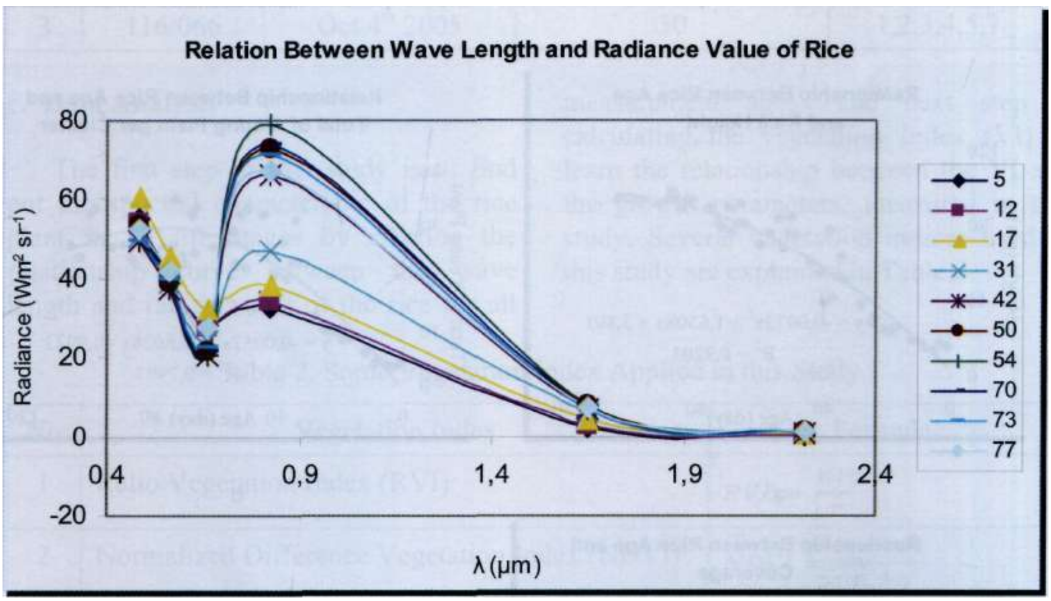


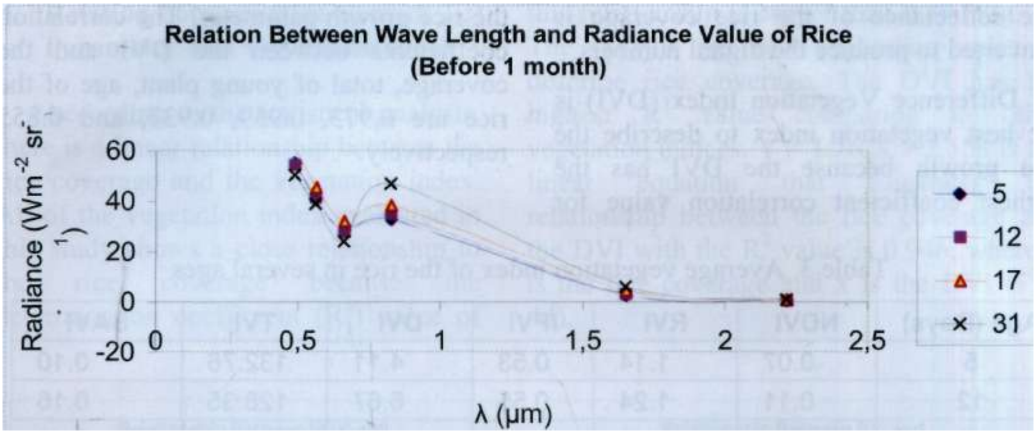
Fig. 2. Relationship between rice growth parameters and age of the rice

b. Spectral Characteristics of the Rice

The relationship between the radian value in several age of the rice and the wave length is shown in Fig. 3a. Based on this figure, the radian values of the rice in almost of their life are quite high in blue band and decrease in green and red bands. The highest peak of the reflectance is found in the near infrared band and decreases gradually in the middle infrared. This pattern of the rice reflectance is similar to the vegetation in general except in the blue band. In the irrigated rice plant, water coverage contributes a significant effect to the rice reflectance especially in the young rice plant.

The radian values of the rice one month before has different characteristic comparing to the one month later (Fig. 3b and Fig. 3c). In the young rice plant, the coverage of the rice is still dominated by the water. The reflectance of the rice has low tendency, especially in the near infrared region. On the other hand, the coverage of the rice one month later is controlled by the rice plant than the water, so their reflectance becomes higher in all of the spectrum region.





Relation Between Wave Length and Radiance Value of Rice (After 1 month)

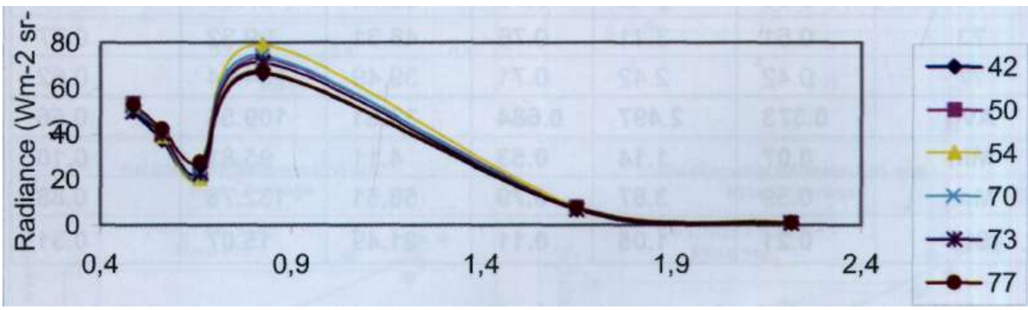


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Fig. 3. Relationship between radian value and wave length in several rice age

c. Vegetation Index of the Rice

Six existing vegetation indices were evaluated for several rice ages in this study. Table 3 shows the average value of the vegetation index in each observed rice age, where the correlation matrix between the rice growth (age, coverage, height, total of young plant) and the vegetation index illustrate in table 4. Based on the Pearson Correlation analysis, there is a high significant correlation between the vegetation index and the rice growth parameter (coefficient correlation (r) is greater than 0.83). The coverage of the rice has the highest coefficient correlation value in all of the vegetation index, examined in this study, in turn of total of the young plant, height, and age of the rice. In the optical remote sensing, the coverage of the land is the dominant feature that acquired by the satellite sensor. Other parameters of the rice field such as height and total of the young plant are actually represented by the coverage.

The reflectance of the rice coverage is converted to produce the digital numbers.

Difference Vegetation Index (DVI) is the best vegetation index to describe the rice growth because the DVI has the highest coefficient correlation value for the rice growth parameter. The correlation coefficients between the DVI and the coverage, total of young plant, age of the rice are 0.973, 0.959, 0.937, and 0.855 respectively.

Table 3. Average vegetation index of the rice in several ages

Age (Days)	NDVI	RVI	IPVI	DVI	TVI	SAVI
5	0.07	1.14	0.53	4.11	132.76	0.10
12	0.11	1.24	0.55	6.67	128.35	0.16
17	0.09	1.19	0.54	6.2	130.42	0.13
31	0.32	1.95	0.66	22.94	110.27	0.48
42	0.53	3.25	0.76	45.96	98.54	0.79
50	0.54	3.38	0.77	51.47	97.9	0.81
54	0.59	3.87	0.79	58.51	95.81	0.88
70	0.55	3.42	0.77	52.44	97.68	0.82
73	0.51	3.11	0.76	48.31	99.32	0.77
77	0.42	2.42	0.71	39.49	104.54	0.62
Avg	**0.373**	**2.497**	**0.684**	**33.61**	**109.56**	**0.56**
Min	***0.07***	***1.14***	***0.53***	***4.11***	***95.81***	***0.10***
Max	**0.59**	**3.87**	**0.79**	**58.51**	**132.76**	**0.88**
Std	**0.21**	**1.05**	**0.11**	**21.49**	**15.07**	**0.31**

Table 4. Correlation between rice growth parameters and vegetation index

		NDVI	RVI	IPVI	DVI	TVI	SAVI
Age	Pearson Correlation	.840(**)	.778(**)	.848(**)	.855(**)	-.854(**)	.838(**)
	Sig. (2-tailed)	.002	.008	.002	.002	.002	.002
	N	10	10	10	10	10	10
Coverage	Pearson Correlation	.956(**)	.937(**)	.957(**)	.973(**)	-.949(**)	.954(**)
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	10	10	10	10	10	10
Height	Pearson Correlation	.919(**)	.882(**)	.923(**)	.937(**)	-.922(**)	.917(**)
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000
	N	10	10	10	10	10	10
Young Plant	Pearson Correlation	.943(**)	.919(**)	.945(**)	.959(**)	-.940(**)	.941(**)
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	10	10	10	10	10	10

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

d. Relation between Rice Growth Parameter and Vegetation Index

According to the statistical analysis, there is a linear relationship between the rice coverage and the vegetation index. All of the vegetation index evaluated in this study shows a close relationship to the rice coverage because the determination coefficient (R^2) value of this relationship is bigger than 0.87 (Fig. 4). The DVI is the best vegetation index to describe rice coverage. The DVI has the highest R^2 value comparing to other vegetation indices. Y = 1.762x + 2.558 is the linear equation that illustrates the relationship between the rice coverage and the DVI with the R^2 value is 0.946, where y is the rice coverage and x is the DVI (Fig. 4d).

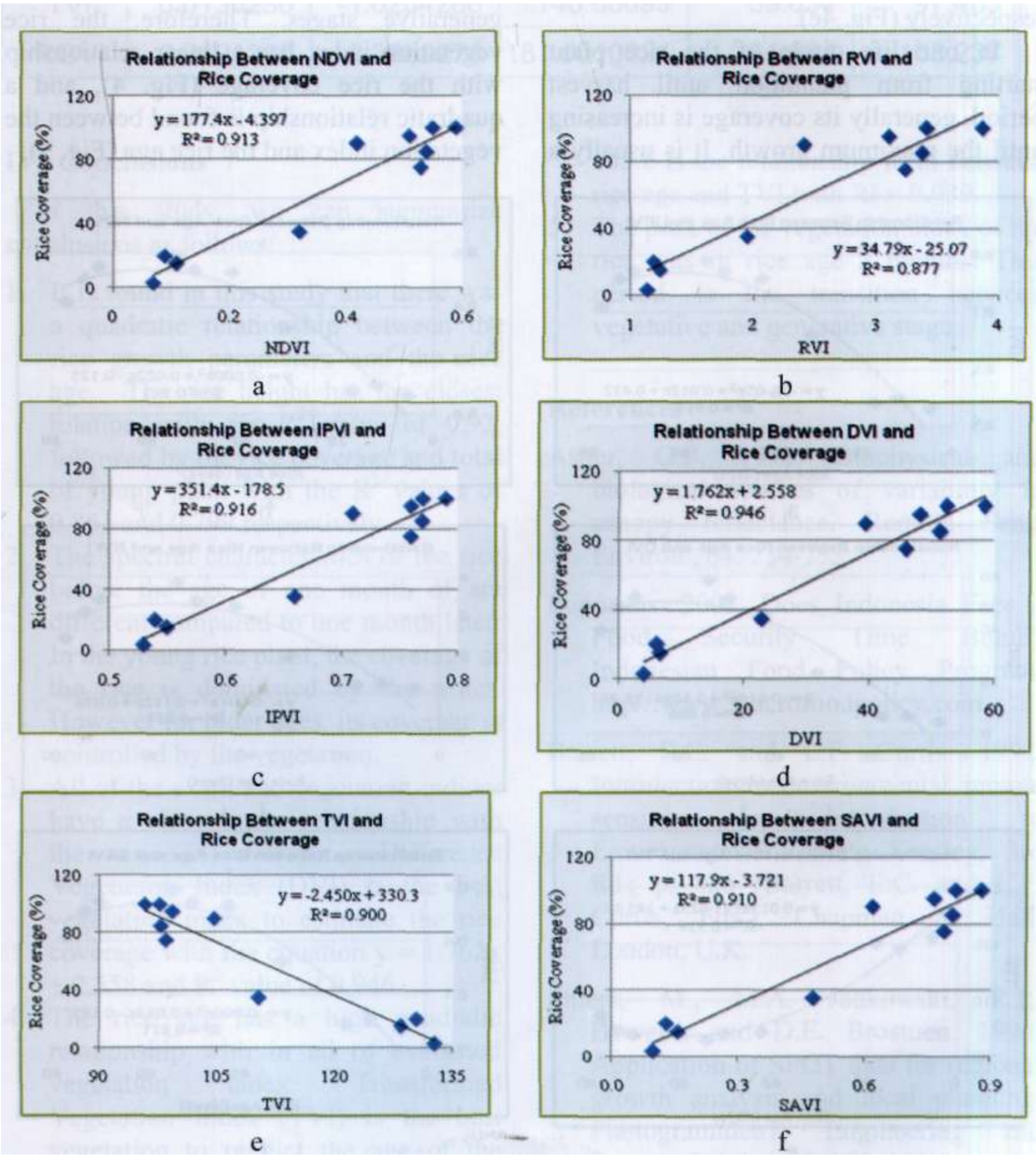

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Fig. 4 Linear relationship between vegetation index and rice coverage

On the other hand, the relationship between the rice age and the vegetation index show a quadratic form. Transformed Vegetation Index (TVI) is the best vegetation index to estimate the age of the rice, followed by IPVI, NDVI, SAVI, DVI, and RVI (Fig. 5). Formula $y = 0.013x^2 - 1.625x + 145.8$ is the relationship form between rice age and TVI with $R^2 = 0.939$, where x and y are rice age in days and DVI value respectively (Fig. 4e).

In one life circle of the rice plant starting from plantation until harvest period, generally its coverage is increasing until the maximum growth. It is usually a transition period between vegetative and generative stages. From the beginning of the generative stage to the harvest period, the rice coverage is usually decreasing (Shao *et al.*, 2001). The vegetation index has the same tendency with the rice coverage in its life stage (Fig. 5; Table 5). Based on Table 5, the average peak of the vegetation index is almost 2 month after plantation. This period is the changing period between the vegetative and generative stages. Therefore, the rice vegetation index has a linear relationship with the rice coverage (Fig. 4), and a quadratic relationship is found between the vegetation index and the rice age (Fig. 5).

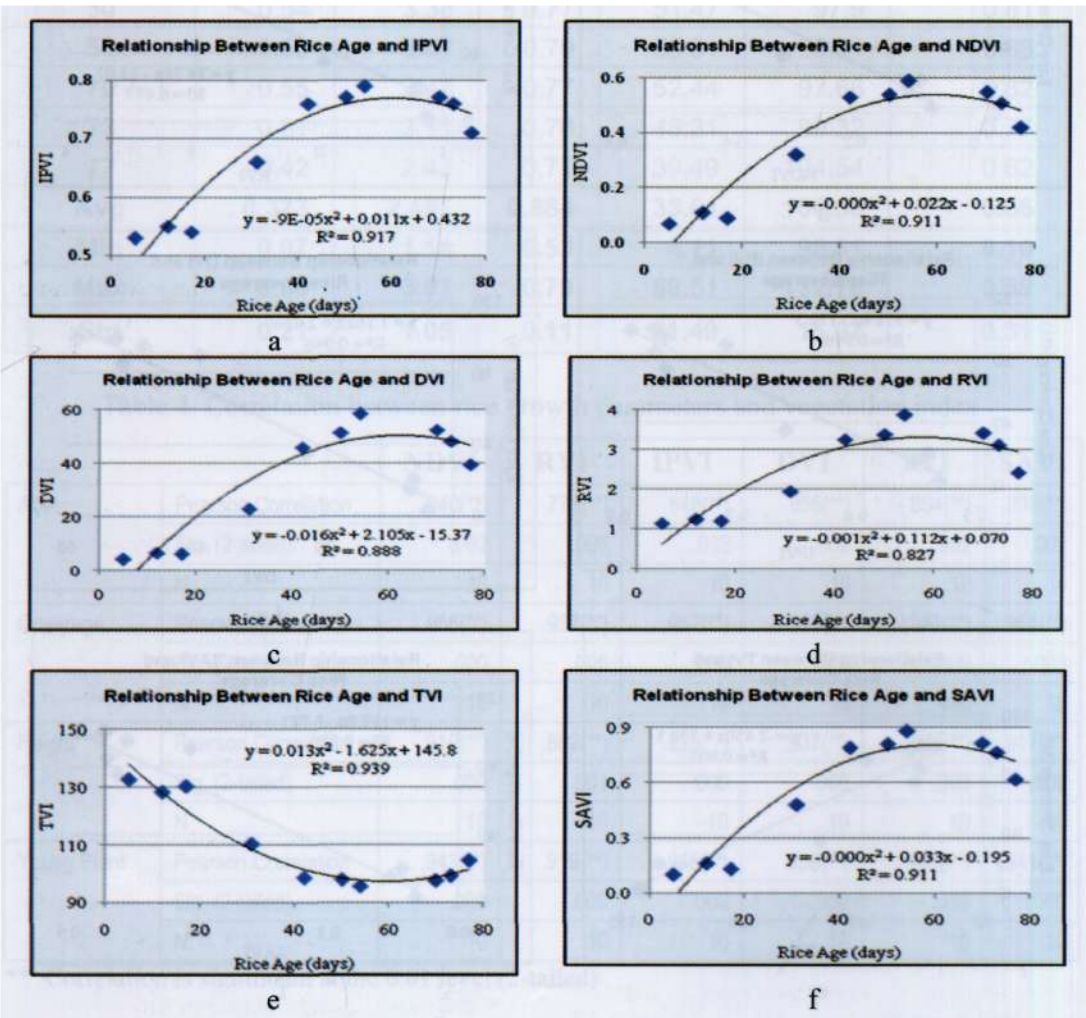

Fig. 5. Relationship between rice age and vegetation index for several vegetation indices

Table 5. Peak of the rice vegetation index value

VI	X2	X	C	Age	VI Value
RVI	-0.0009754	0.1123282	0.0705204	57.583	3.304
DVI	-0.0168659	2.1052742	-15.3723497	62.412	50.325
NDVI	-0.0001876	0.0223421	-0.1254922	59.547	0.540
SAVI	-0.0002846	0.0337604	-0.1950684	59.312	0.806
IP VI'	^0.0000932	0.0111885	0.4323916	60.024	0.768
TVI	0.0136236	-1.6254288	145.88699	59.654	97.405
RGVI	0.0191362	-2.3600274	181.0010824	61.664	108.237

IV. Conclusions

In this study, we can summarize conclusions as follows:

1. It is found in this study that there was a quadratic relationship between the rice growth parameters and the rice age. The rice height has the closest relation with the R^2 value of 0.92, followed by the rice coverage and total of young plant with the R^2 values of 0.861 and 0.799 respectively.
2. The spectral characteristics of the rice before the age of one month of are different compared to one month later. In the young rice plant, the coverage of the rice is dominated by the water. However for older ages, its coverage is controlled by the vegetation.
3. All of the examined vegetation indices have a close linear relationship with the rice coverage. Difference Vegetation Index (DVI) is the best vegetation index to estimate the rice coverage with the equation y = 1.762x + 2.558 and R^2 value of 0.946.
4. The rice age has a high quadratic relationship with in all of evaluated vegetation index. Transformed Vegetation Index (TVI) is the best vegetation to predict the age of the rice. Formula $y = 0.013x^2 - 1.625x + 145.8$ is the relationship form between rice age and TVI with $R^2 = 0.939$.
The peak of the vegetation index of the rice was in rice age 2 months. This period is the transition between vegetative and generative stage.

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