Estimation of rice vegetation coverage from DVI of Landsat 7 and 8 data

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ABSTRACT

Monitoring of rice growth is a requirement for high quality rice production. In addtion to plant height, number stem and rice leaf color, vegetation coverage (VC) which represents for percentage of ground covered by rice plant is also considered as an important index to validate rice growth. Thus, the study is to estimate rice vegetation coverage from difference vegetation index (DVI) calculated from reflectance of near-infrared and red band of Landsat 7 and 8 images. The field observations of the reflectance and the VC were carried out in two paddy rice varieties in 2013. Paddy field reflectance was observed by spectrometer Ocean Optics SD2000. The photos of paddies were taken from the height of 1 m by a digital camera in order to calculate the VC. The reflectances of paddy field corresponding to red and near-infrared bands of Landsat 7 and 8 were calculated from the field observation data. Satellite reflectance was also converted from pixel value of Landsat images. According to the data analysis, VC rapidly increased in two fields and got saturation status (VC>90%) at 65 days after transplanting (DAT) in the early July. DVI was approximately 25% when VC saturated. Additionally, DVI had strong correlation with VC with high determination coefficient (r^2 =0.9) when VC was less than 90%. Thus, VC were computed from DVI, calculated from reflectances of Landsat images, using a regression model of VC and DVI. From the result of comparison between the estimated and computed VC, the possibility of estimating VC from DVI calculated from Landsat reflectance is confirmed.

***Keywords**: DVI, vegetation coverage, Landsat data, reflectance*

1. INTRODUCTION

Rice is the main food of many countries, especially in Asian countries. Nowadays, customers demand affordable and safe rice with high quality of taste. To satisfy such requirements, many researches have been performed for improving the quality of rice. Therefore, the information of rice development stages in paddy field has been observed because rice growth directly effects on rice quality. Physical parameters of rice (plant height, number of stem,…) change rapidly during rice growing season (Figure 1). They have been manual measured periodically to control the rice growth by deciding amount of adding fertilizer. Such directly measuring methods need a lot of time and working labor. Moreover, their accuracy depends on sample size and sampling position. Therefore, time- and labor-saving methods such as remote sensing techniques are considered a useful alternative and are widely utilized for monitoring rice crop [1].

Additionally physical parameters of rice plant, rice growth can be indicated from many parameters such as leaf color [2], leaf area index (LAI), leaf nitrogen content, fresh and dry weight,… In this study, vegetation coverage (VC) showing the percent cover of rice plant was focused. VC has been validated as a good predictor variable for plant growth parameters such as leaf area index [3], above ground biomass and nitrogen content [4]. Moreover, VC affects on plant self-shading, neighbour-plant competition and amount of solar energy that rice plant could be received. Due to the expectation of obtaining VC in large area of paddy fields, remote sensing technique is suggested. The purpose of this study is to estimate rice vegetation coverage from difference vegetation index (DVI) computed from Landsat surface reflectance. DVI, mentioned here, is the difference reflectance of of near-infrared and red band. This index is strongly sensitive to green vegetation.

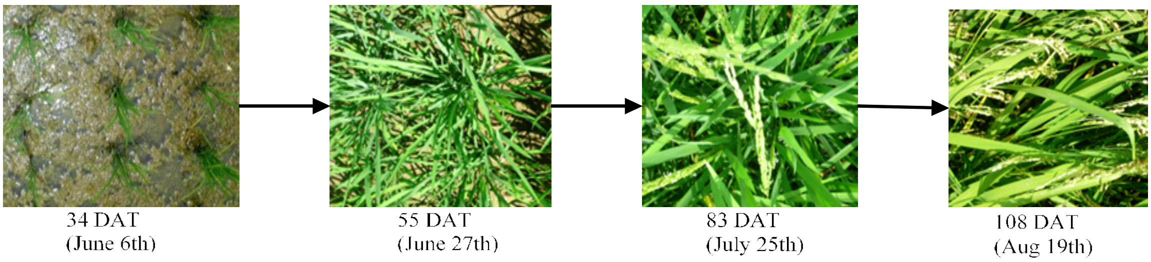


Figure 1. The change of rice canopy during rice development season

Table 1. Important date

Field	Rice variety	Transplanting date	Heading date	Harvesting date
A	Gohyakumangoku	May 03rd, 2013	July 21st, 2013	Aug 29th, 2013
B	Koshihikari	May 25th, 2013	Aug 10th, 2013	Sep 21st, 2013

Figure 2. Study area

2. STUDY AREA

The trial paddies are located in Niigata prefecture, known as rice capital of Japan. Because the weather is getting cool in Autum and snow appears during the winter, there is only one rice growing season from May to September. Paddy fields will be plowed in April, filled with water and prepared for planting. For this study, because of limited time and manpower, there was only two paddy rice varieties (Gohyakumankoku and Koshihikari) were chosen in Koshijinakazawa, Nagaoka City. In order to facilitate the equipment movement and data collection, two adjacent paddies were considered to select (Figure 2). Each paddy field had a standard width of 30 meters and 90 meters in length. They were planted with about 20 day old seedlings in May, 2013 (Table 1).

3. RESEARCH DIRECTION

The research direction is visually displayed in figure 3. To explain it in more details, the field observations were performed many times within study period by using spectrometer and digital camera. From spectral data the field reflectance was calculated. Then, the field reflectance corresponding to red and near – infrared band (NIR) of Landsat 7 and 8 were computed. Field DVI was computed as the difference of NIR and red band. Additionally, right after satellite reflectance was converted from pixel value of Landsat images [5], satellite DVI was also computed. In next step, the relationship between field reflectance and satellite reflectance was investiagted. Moreover, VC was calculated from the photos of paddy fields. The relationship between VC and spectral reflectance was constructed by checking their changes in value over time. Finally, the posibility of estimating VC from satellite reflectance was investigated.

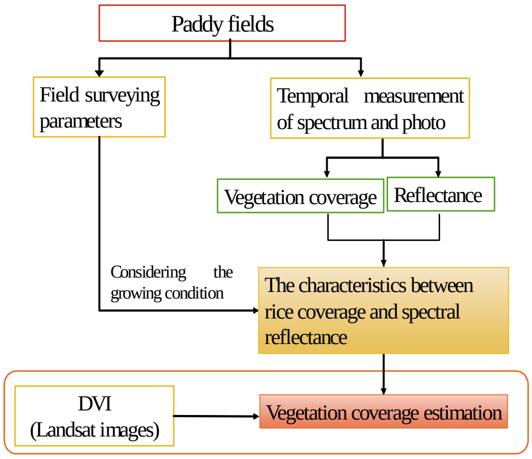


Figure 3. Research flow chart

4. FIELD OBSERVATION

For field observation, spectrometer Ocean Optics SD2000 in the range of visible light to infrared (340 nm ~1025 nm) was mounted on a steel bar placed on two tripods. The laptop in which the software was run to collect spectral data of paddy fields was connected to spectrometer using cable (Figure 4). All field observations were carried out in 2013. There were 12 observations for each paddy and 24 observations in total (Table 2). For each observation, there were two sizes of target area. Such target areas were observed for each trial field. The first one was wide area including rice plant and background (shadow, soil, water...) (Figure 4a). The second one was narrow area including rice plant only (Figure 4b). The radiation intensity of skylight and reflected radiation from the object surface were acquired at the same time by using two spectral cable assembling to two black tubes. For each target objects, these data were recorded 5 times. In case of wide target area, two tube receiving skylight and reflected light intensity were installed at the height of 1.25 m in field A and 1.34 m in field B with 46^0 field of view. Moreover, photos of paddy fields were taken every minute with spectral data by a digital camera in nadir direction. They were used to calculate rice coverage in paddy fields. Furthermore, there were five rice plants which were chosen to measure the physical parameters in each field. The average value calculated from that would be considered as representative value of whole paddy field.

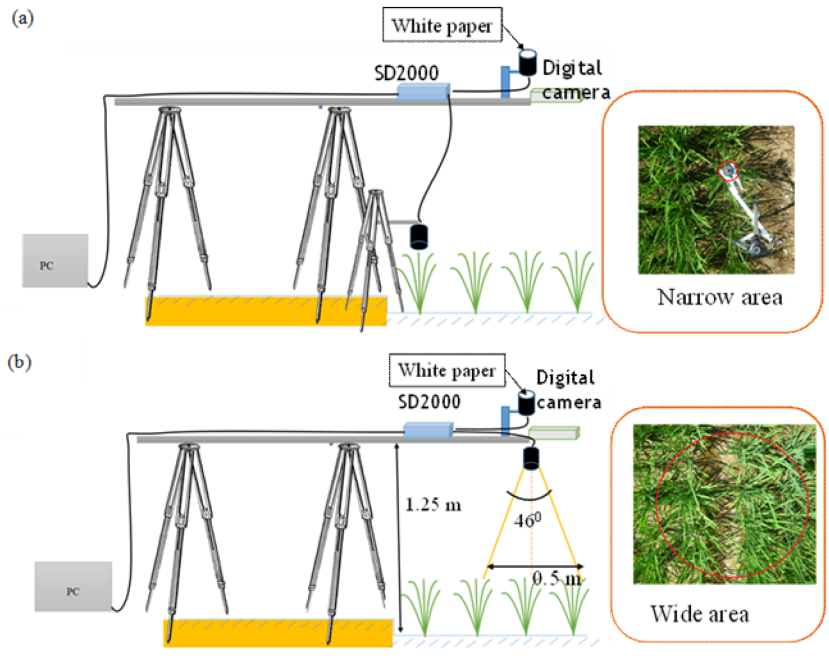


Figure 4. Field observations with (a) wide and (b) narrow area

Table 2. Field observation date

Date	Observed field	Date	Observed field	Date	Observed field
06/06/2013	A	16/07/2013	A and B	22/8/2013	A and B
12/06/2013	A	19/07/2013	A and B	26/8/2013	A and B
13/06/2013	A	22/07/2013	A and B	29/8/2013	A and B
20/06/2013	A and B	25/07/2013	A and B	2/9/2013	A and B
24/06/2013	A and B	30/07/2013	A and B	4/9/2013	A and B
27/06/2013	A and B	02/08/2013	A and B	10/9/2013	B
01/07/2013	A and B	06/08/2013	A and B	17/9/2013	B
04/07/2013	A and B	08/08/2013	A and B	20/9/2013	B
08/07/2013	A and B	15/08/2013	A and B		
11/07/2013	A and B	19/08/2013	A and B		

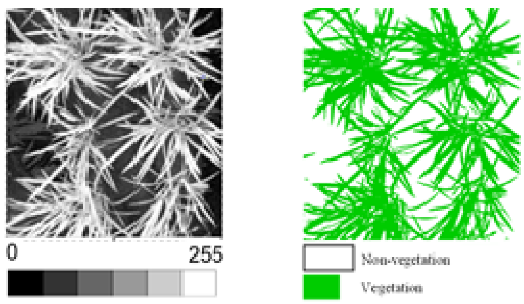
5. RESULTS

5.1 Rice coverage rate

Vegetation coverage (VC) shows the percentage of area covered by rice plant per one-unit area of paddy field. VC changes easily and corresponds the change of rice canopy. Moreover, its value is affected by the physical parameters of rice and depends on the transplanting density. To calculate VC, greenness index was calculation to enhance plant pixels from 8-bit color red, green, blue images using equation 1 (Figure 5). The threshold value of plant pixels was identified due to the useful of pseudo-color image. VC was computed by taking the ratio of plant pixels to total pixels of digital camera image of rice field (eq. 2). As a result, VC almost linearly increases from early growing season in both fields. VC in field B increases sooner than field A. Different cultivar and transplanting date could be mentioned as an explanation. At 65 days after transplanting (DAT) VC is 90%. The 90 % of VC is assumed as the saturation of rice canopy. After 65 DAT, VC did not significantly change and it decreased before harvesting time (Figure 6).

$$Greenness = 100 + \frac{2Green - (Blue + Red)}{510}100 \quad (1)$$

$$VC\,(\%) = \frac{The\ number\ of\ vegetation\ pixels}{Total\ pixel\ of\ the\ photo}100 \quad (2)$$



(a) Greenness image (b) Classified image

Figure 5. Plant pixels indentification

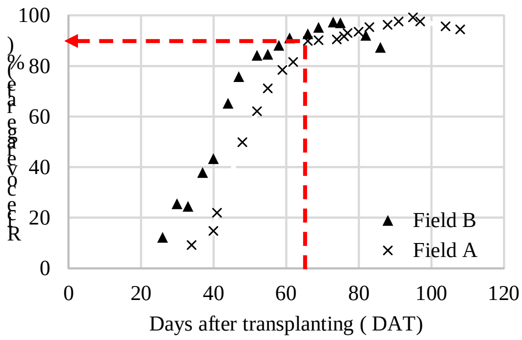


Figure 6. Rice coverage changes during development seasons

5.2 Field reflectance calculation

Regarding to the fundamentals, the reflectance has been calculated as the ratio between the intensity of light reflected from the object surface and the intensity of the incident light. However, in the process of data acquisition, there was a factor that affected data processing. To acquire the intensity of the skylight and reflected light from the object surface there were two spectral cables. One spectral cable end was attached to the spectrometer and another one was attached to a black hollow plastic tube with one end. Each tube was high 4.4 cm and its diameter was 3.8 cm. Because the intensity of skylight was many times as much as the intensity of the light reflected from ground objects surface it was difficult to collect them at the same time. When the field observation was performed, in case of the cable receiving energy from sunlight, the tube was covered by a white paper on the top to reduce the intensity of the skylight (Figure 4). Therefore, intensity of the skylight had to be adjusted by the transmittance coefficient (T_λ) of the white paper. Wavelength and intensity of experimental data were also calibrated [6] before calculating the reflectance (eq.3)

$$R_\lambda = \frac{I_1}{I_0}T_\lambda \quad (3)$$

Where

R_λ: reflectance

I_1 Intensity of reflected light from target object

I_0: Intensity of skylight

T_λ: Transmittance coefficient

The characteristic of reflectance in visible and near- infrared region in which healthy green vegetation had a characteristic interaction with energy was special focused. The field reflectance corresponding to visible and near-infrared bands of Landsat 7 and 8 were computed. As a result, the strongly development in vegetative phase leads to high reflection in near-infrared channel (NIR). The reflectance in NIR is many times as much as its value in visible band. To obtain rice growth, difference vegetation index (DVI) responding primarily to green vegetation was calculated as the difference reflectance of NIR and red band. Its value increased linearly prior to 65 DAT (Figure 7). This result confirmed the strong development of rice plant in vegetative phase with the rapid increase of rice foliage. Moreover, DVI was approximately equal 25% at 65 DAT. Before harvesting, green leaf area decrease and rice seed appearance caused reflectance non-increase in NIR band and reflectance advance in visible band. However, DVI did not have significant change because the reflectance in NIR band was many times as much as visible band.

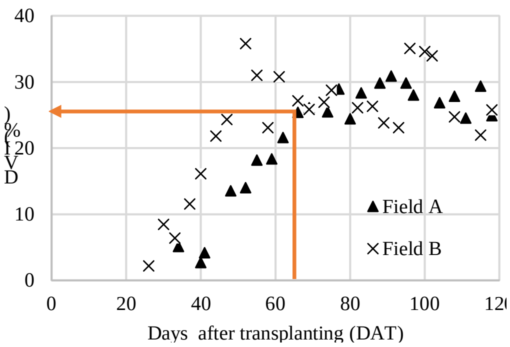


Figure 7. Change of field DVI

5.3 Estimation of vegetation coverage from satellite DVI .

There were 10 Landsat ETM+ and Landsat 8 images acquired from June to August of 2013. However, five of them had poor quality. The study area could not be observed from these images because of cloud cover. Finally, only 5 images collected on June 4, June 12, Jun 28, August 15 and August 31 were used in this study. Right after two pure pixels of paddy in which trial fields were located were extracted from satellite images, satellite DVI was calculated. The field DVI of such pixels was extended from field reflectance obtained in sample area without concerning extended errors. The field DVI corresponding to satellite observation date was estimated from field observation results. Satellite and field DVI were compared together. As a result, satellite DVI was almost smaller than field DVI. Linear regression attempts to model the relationship between satellite and field DVI was applied by fitting a linear equation to observed data. As a result, the high determination coefficient was determined (r^2=0.9).

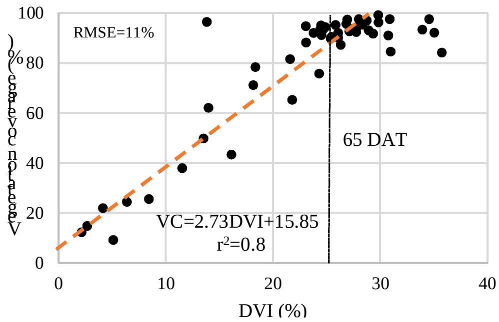


Figure 8. The relationship between DVI and vegetation coverage

Futhermore, the increase of field DVI corresponded to VC increase in the early period. With less than 90% of VC, the linear correlation of DVI and VC was determined with high determinetion coefficient (r^2=0.9). We expected that VC could be estimated from satellite DVI using empirical model (Figure 8). However, two rice varieties caused various respondent of spectral reflectance. After saturation of VC, the increases of reflectance did not depend on VC. Additionally, the satellite and field DVI differed in their values. Therefore, some values of estimated VC were over valid value. Although estimated VC with RMSE of 15 % did not as good as our expectation, the possibility of estimation of VC was considered.

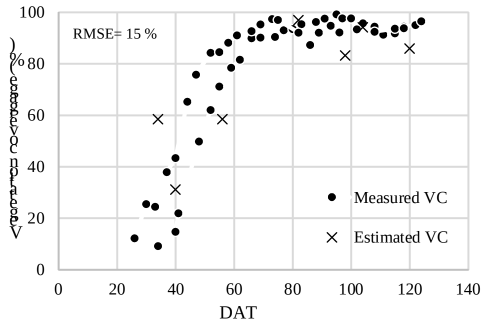


Figure 9. Estimated vegetation coverage

7. CONCLUSION

According to data analysis results, VC linearly increased in early period. It saturated (VC≥ 90%) in early July at 65 DAT. When VC saturated DVI was approximately 25%. The 25% of DVI has been considered as the threshold value to identify the paddy field from satellite images. The reflectance indicated the rice growth prior to saturation of VC. Moreover, VC correlated to field DVI with high coefficient of determination (r^2=0.9). With less than 90% of VC, the regression model of VC was determined with r^2=0.9. Satellite DVI was applied to the model in order to estimate VC. That estimated VC matched on VC calculated from paddies photos confirmed the posibility of estimating VC from satellite DVI (Figure 9). Although the result was not as good as our expectation, the possibility of estimation of VC was confirmed. The model could be used to calculate the VC with satellite DVI. However, the model was possible only if vegetation coverage was less than 90%. When VC saturated, some estimated VC was interpolated over valid value. At this time, instead of vegetation coverage as well as physical parameters, fertilizer and rice quantity contribute to the increase of field spectral reflectance.

Ước tính độ phủ thực vật của lúa từ chỉ số DVI được tính từ ảnh Landsat 7 và 8

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TÓM TẮT:

Theo dõi sự phát triển của cây lúa là yêu cầu cần thiết, phục vụ cho công tác sản xuất lúa gạo chất lượng cao. Bên cạnh chiều cao, số lượng nhánh, màu sắc lá lúa, độ phủ thực vật hay tỷ lệ che phủ mặt đất của cây lúa cũng là một chỉ số được dùng trong việc đánh giá sự tăng trưởng của cây lúa. Trong nghiên cứu hiện tại, độ phủ thực vật được ước tính từ giá trị DVI (Difference Vegetation Index). DVI được sử dụng trong nghiên cứu này là giá trị sai biệt độ phản xạ phổ của kênh gần hồng ngoại và kênh đỏ của các ảnh vệ tinh Landsat 7 và 8. Thực nghiệm được tiến hành trên hai ruộng lúa với hai giống lúa riêng biệt vào năm 2013. Giá trị phổ của ruộng lúa được ghi nhận bởi thiết bị đo quang phổ Ocean Optics SD2000. Bề mặt của ruộng lúa được chụp bằng máy ảnh kỹ thuật số gắn kèm trên thiết bị đo ở độ cao 1 mét so với mặt đất. Độ phủ thực vật thực tế của cây lúa được tính trực tiếp từ các hình ảnh này. Giá trị phản xạ trên mặt đất được tính toán và chuyển đổi thành giá trị phản xạ tương ứng với kênh đỏ và kênh gần hồng ngoại của ảnh vệ tinh Landsat 7 và 8 trong khi giá trị phản xạ của ảnh vệ tinh được chuyển đổi từ các giá trị pixel của ảnh. Theo kết quả phân tích số liệu, độ phủ của cây lúa gia tăng liên tục và đạt trạng thái bão hòa (độ phủ ≥ 90%) ở đầu tháng 7 vào thời điểm 65 ngày sau khi cấy. Tại thời điểm bão hòa của độ phủ DVI xấp xỉ đạt 25 %. Bên cạnh đó sự tương quan mật thiết giữa độ phủ và giá trị DVI cũng được xác định với hệ số xác định cao (r^2=0.9) khi độ phủ chưa đạt trạng thái bão hòa. Từ đó mô hình hồi quy được thành lập và sau đó giá trị DVI tính từ ảnh Landsat 7 và 8 được áp dụng vào trong mô hình nhằm ước tính giá trị độ phủ. Giá trị độ phủ ước tính phù hợp với giá trị độ phủ thực tế cho thấy khả năng sử dụng độ sai biệt phản xạ phổ của ảnh vệ tinh Landsat trong việc ước tính độ phủ thực vật của cây lúa.

Từ khóa: *DVI, độ phủ thực vật, ảnh Landsat, độ phản xạ.*

REFERENCES

[1]. Yoshirari Oguro, *Monitoring of rice field by Landsat 7 ETM+ and Landsat 5 TM data,* The 22nd Asian Conference on Remote sensing, 2001.

[2]. V. K. Choubey and Rani Choubey, Spectral Reflectance, *Growth and Chlorophyll Relationships for Rice Crop in a Semi-Arid Region of India,* Water Resources Management 13, pp 73–84, Kluwer Academic Publishers, 1999.

[3]. D. Nielsen, J.J.Miceli-Garcia, D.J.Lyon, *Canopy cover and leaf area index relationships for wheat, tritical and corn,* Agronomy Journal, Vol 104, Issue 6, 2012

[4]. S.Takemine, A. Rikimaru, K. Takahashi, Y. Higuchi, *Basic study for estimation of nitrogen content of rice plants from vegetation cover rate of rice obtained by a simple image measurement,* Photogrammetry and remote sensing confference, vol 46, No 4, 2007.

[5]. USGS, *Landsat & Users Handbook* – Chapter 11, http://landsathandbook.gsfc.nasa.gov/data_prod/prog_sect11_3.html

[6]. Ocean Optics, *Calibrating the Wavelength of the Spectrometer,* http://www.oceanoptics.com/Technical/wavelengthcalibration.pdf.