MONITORING OF RICE FIELD BY LANDSAT-7 ETM+ AND LANDSAT-5 TM DATA

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ABSTRACT: By using the time series data of Landsat-7 ETM+ and Landsat-5 TM which were observed during the period from the rice planting to harvest in 2000 over a rice field under the control of Agriculture Research Center of Hiroshima Prefecture in Higashi-Hiroshima City in Japan, the relation between typical vegetation indices NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) computed from satellite data and the physical parameters for rice growth (plant height of a rice, the spread of blade, LAI, vegetation coverage, etc.) obtained by the field survey was investigated. In this analysis, in order to use Landsat-5 TM (Thematic Mapper) data launched in 1984 together with Landsat-7 ETM+ (Enhanced Thematic Mapper Plus) data launched in 1999, the digital count values were converted into the spectral radiance values with the calibration parameter file recorded on satellite data, and the vegetation indices were computed using those values. The proportion ratio of the components (water, soil, blade of a rice, ear of a rice) of the rice field that exists in fixed acreage was computed using the pictures taken just above the rice filed by a digital camera. And the spectral reflectance of each object collected by a spectrometer (MSR-7000) was mixed using this proportion. Then the temporal changes of the vegetation indices of the rice field were simulated based on the simulated spectral reflectance and proportion ratio of rice vegetation. The result of this study suggests that the temporal changes of the vegetation indices of the rice field by satellite data are primarily correlated to the changes of the proportion ratio of rice vegetation within the rice field.

1. INTRODUCTION

Landsat-7 was launched on 15 April in 1999 and has been observed the same areas every 16 days. Hiroshima Institute of Technology in Japan has established Landsat-7 Ground Station for receiving and processing the ETM+ data on 15 March in 2000. Landsat-5 TM and Landsat-7 ETM+ have three visible bands, one near-infrared band, two short-wave infrared bands and one thermal band, and it is useful for a vegetation monitoring. As the vegetation indices computed from some visible and near-infrared bands, NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index, Huete, 2000) are known widely. On the other hand, as vegetation indices by using the short-wave infrared band, NDVI_SWIR (Imamoto, 2001) and EVI_SWIR (Extended Vegetation Index, Iino, 1999) were reported. The authors have been investigated the rice growth conditions by using these vegetation indices obtained from satellite data. From the compassion of vegetation indices computed from satellite data and field survey data, it was found that the features of satellite data are different to the field survey data especially in the period when the vegetation indices are increasing. In this paper, the difference between the vegetation indices obtained from field survey data and those of satellite data will be investigate by using a mixture model of rice field.

2. TEST SITE AND TEST DATA

In this study, the time series satellite data (Path-Row: 112-036) over a rice field under the controlled of Agriculture Research Center of Hiroshima Prefecture in Higashi-Hiroshima City in Japan listed in Table 1 were analyzed. And the field surveys were performed in the same area on the days listed in Table 2. In each field survey, some physical parameters (plant height of rice, plant width of rice, vegetation coverage and LAI of rice) relevant to rice growth conditions were measured and some photgraphs were taken just above the rice filed by a digital camera. Also the spectral reflectance of each object (water, soil, blade of a rice, ear of a rice) in the rice field were collected by multi-purpose spectrometer (MSR-7000 made in Optreasarch Co. made in Japan, wavelength: 280 – 2500 nm) were corected. In this area, the rice was planted on 8 May 2000 and that was flowed on 1 August 2000.

Table 1. Analyzed Satellite Data

Satellite	Observation Date	Days from Rice Planting
L-5 TM	04 May	-4
L-7 ETM+	20 Jun.	43
L-7 ETM+	06 Jul.	59
L-5 TM	07 Jul.	60
L-7 ETM+	22 Jul.	75
L-5 TM	15 Aug.	99
L-5 TM	24 Aug.	108
L-7 ETM+	24 Sep.	139

Table 2. Analyzed Field Survey Data

Observation	Days from	Conditions of Rice Field	
		Background	Rice Plant
25 May	17	Water	Blade
02 Jun.	25	Water	Blade
15 Jun.	38	Water, Soil	Blade
30 Jun.	53	Soil	Blade
04 Aug.	88	Soil	Blade, Ear
11 Aug.	95	Water	Blade, Ear
16 Aug.	100	Soil	Blade, Ear
24 Aug.	108	Water	Blade, Ear
30 Aug.	114	Soil	Blade, Ear

3. ANALYZING METHOD

3.1 Conversion from Digital Numbers to Radiance of Satellite Data

The Digital Numbers (DN) of image data of Landsat-5 TM are converted into spectral radiance values (L) based on Eq.(1).

$$L = \{ (Lmax - Lmin) / 255 * DN + Lmin \} / BW \quad [W / m^2 / Sr / micro\ meter] \quad (1)$$

where BW is the bandwidth in micrometer, L_{min} and L_{max} are the total radiances for each band at the minimum and the maximum digital numbers 0 and 255 respectively. Similarly the DN's of Landsat-7 ETM+ are converted into spectral radiance values based on Eq. (2).

$$L = (Lmax - Lmin) / 254 * (DN - 1) + Lmin \quad [W / m^2 / Sr / micro\ meter] \quad (2)$$

where L_{min} and L_{max} are the total radiances for each band at the minimum and the maximum digital numbers 1 and 255 respectively. These total radiance values for Landsat-7 ETM+, however, are changed with the observation area (Path/Row) of the data and the gain setting are different for the surface cover types of the Earth (Land, Desert, Ice/Snow, Water, Sea Ice, and Volcano/Night Path). In addition, the gains for bands 1-3 are changed together as are the gains for bands 5 and 7. Therefore, it is important to check the calibration parameter file recorded on each satellite data when the DN's convert into the spectral radiance values.

3.2 Vegetation Indices

NDVI (Normalized Difference Vegetation Index) is computed by Eq.(3) from the spectral radiance in red band (R) and near-infrared band (NIR).

$$NDVI = (NIR - R) / (NIR + R) \quad (3)$$

Similarly, NDVI_SWIR is computed by Eq.(4) from the spectral radiance in near-infrared, and short-wave infrared band (SWIR, wavelength: 1.5-1.7 micro meter, band 5 of Landsat-5 TM and that of Landsat-7 ETM+).

$$NDVI\_SWIR = (NIR - SWIR) / (NIR + SWIR) \quad (4)$$

On the other hand, EVI (Enhanced Vegetation Index) is computed by Eq.(5) from the spectral radiance in red, near-infrared, and blue band (B, wavelength: 0.4-0.5 micro meter, band 1 of Landsat-5 TM and that of Landsat-7 ETM+).

$$EVI = 2.5 * (NIR - R) / (NIR + 6.0 * R - 7.5 * B +1) \quad (5)$$

Also, EVI_SWIR (Extended Vegetation Index) is computed by Eq.(6) using NDVI and NDVI_SWIR.

$$EVI\_SWIR = (NDVI + 1) * NDVI\_SWIR \quad (6)$$

3.3 Mixture Model for a Rice Filed

The spatial resolutions of Landsat-5 TM and Landsat-7 ETM+ are approximately 30 meter except for band 6 of both satellites and for band 8 of Landsat-7 ETM+. Therefore, the data of each ground target obtained from satellite images affects by the reflectance's from the several targets within one pixel data. On the other hand, a rice field is consists of four comportments (blade of a rice, ear of a rice, background water and background soil). In this analysis, the proportion ratio of the components of a rice field that exists in fixed acreage was used for mixture model. The reflectance of a rice field is computed by Eq.(7) from the spectral reflectance of each comportment collected by a spectrometer.

$$R = (A * R\_rb + B * R\_re) * VC + (C * R\_bw + D * R\_bs) * (VC - 1) \quad (7)$$

A=1, B=0	(before a rice flowing)
A=0.5, B=0.5	(after a rice flowing)
C=1, D=0	(background is covered with water)
C=0, D=1	(background is dry soil)
C=0.5, D=0.5	(background is a moisture soil).

where R_rb, R_re, R_bw and R_bs are the spectral reflectance's for blade of rice, ear of rice, background water and background soil, respectively. Moreover, VC is vegetation cover ratio of a rice field and this value was estimated using the pictures taken just above the rice filed by a digital camera.

4. EXPERIMENTAL RESULTS

4.1 Physical Parameters Relevant to Rice Growth Condition

Ths time serise photgraphs from the rice planting to harvest in 2000 that indicate the growth condition of rice plants taken just above rice filed by a digital camera are shown in Figure 1. From the figure it is confirmed that a rice field is consists of four comportments (blade of a rice, ear of a rice, background water and background soil). Figure 2 shows the physical parameters (plant height of rice, plant width of rice, vegetation coverage and LAI of rice) relevant to rice growth condition obtained from field survey listed in Table 2. The growthing speed of rice by the days 45 – 90 is significantly different from that until the 45 days after rice planting. Moreover, the speed is reduced after 90 day and plant height and plant width appoximately were satulated since the rice was flowed.

(a) 19 May (11 Days) (b) 14 June (37 Days) (c) 06 July (59 Days)

(d) 03 August (87 Days) (e) 12 August (96 Days) (f) 30 August (114 Days)

Figure 1. The growth condition of the rice plants seen from right above with a digital camera.

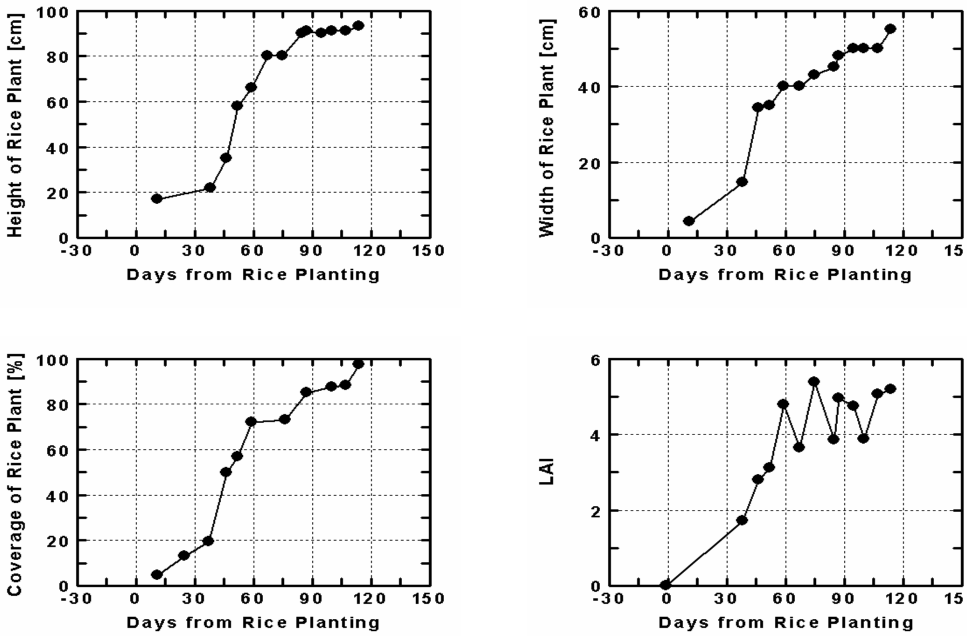
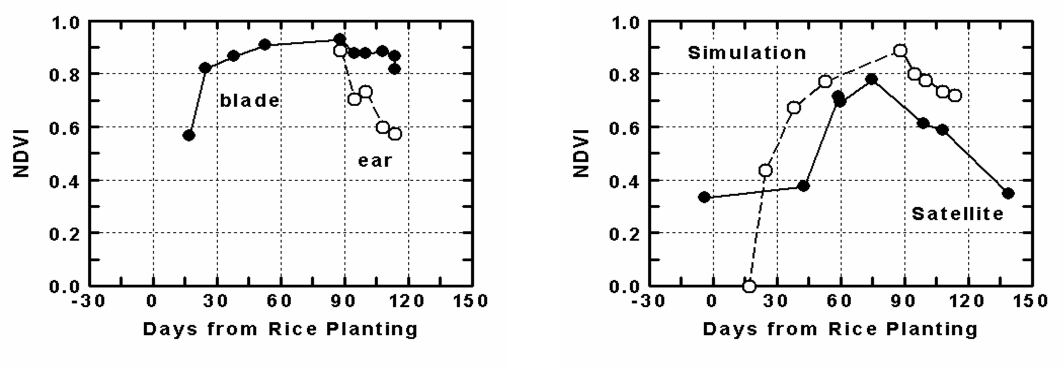
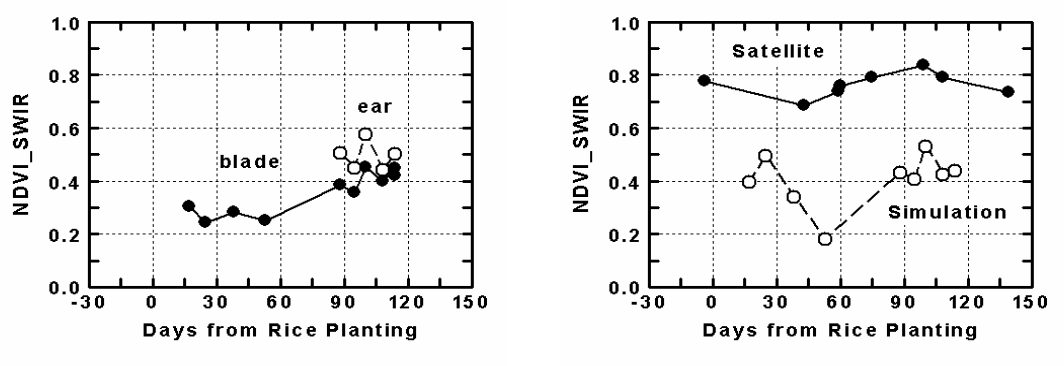


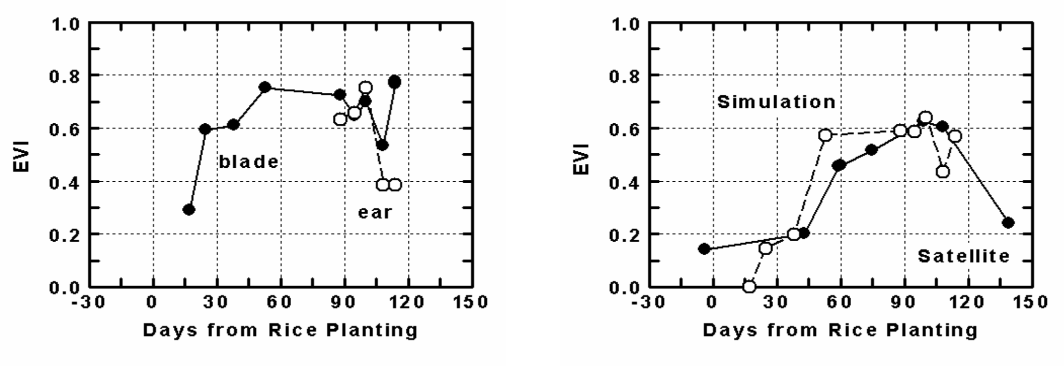
Figure 2. Physical paramets relevant to rice growth condition obtained from field survey.



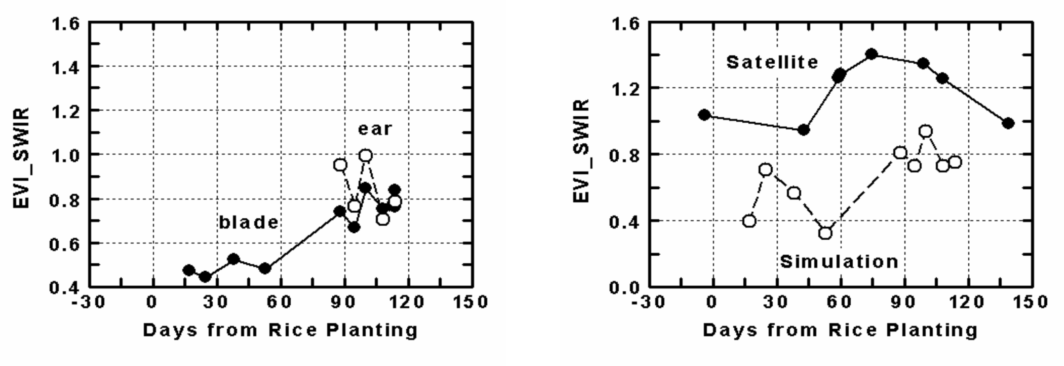
(a) NDVIs



(b) NDVI_SWIRs



(c) EVIs



(d) EVI_SWIRs

Figure 3. Results of vegetation indices obtained from field survey with spectrometer (left), those of obtained from satellite data (right: satellite) and those of mixture model of rice field obtained from field survey (right: simulation).

4.2 Vegetation Indices Computed from Field Survey Data and Satellite Data

The results of for vegetation indices (NDVI, NDVI_SWIR, EVI and EVI_SWIR) computed from the spectral reflectance of rice by field survey and those from the spectral radiance of satellite data are shown in Figure 3. In this figure, the results of field survey for a blade of rice and ear of rice are shown in the left side figures and the results of satellite data (indicates as Satellite in the figure) and those of mixture model for field survey data (indicates as Simulation in the figure) shown in right side figures. For the spectral reflectance data by field survey, NDVI has the similar feature to EVI and NDVI_SWIR has the similar feature to EVI_SWIR, although individual values and the ranges are a little different. The difference between the features for NDVI and EVI and those for NDVI_SWIR and EVI_SWIR are considered due to the differences of using spectral bands in each formula. For the satellite data, NDVI, EVI and EVI_SWIR are almost same feature except NDVI_SWIR. From the compassion of vegetation indices computed from field survey and satellite data, it is found that the features of satellite data are different to the field survey data especially in the period when the vegetation indices are increasing. On the other hand, vegetation indices for satellite data have similar features the indices computed from the simulated spectral reflectance by field survey using a mixture model of Eq.(7). NDVI and EVI obtained from the simulated spectral reflectance by mixture mode are much similar to those obtained from satellite data, although individual values are a little different. The day around 90 is the maximum growing period of rice plant, and after this period, the rice condition varies due to flowering and fructification. It can be seen that the difference between NDVI and EVI is useful to discriminate rice planted field from flowering, thus it can be concluded that the combination of NDVI and EVI is effective for monitoring of rice planted area.

5. CONCLUSION

In this study, the temporal changes of the vegetation indices of the rice field obtained from field survey data and satellite data were compared. From the analyses, it is found that the features of satellite data are different to the field survey data especially in the period when the vegetation indices are increasing. Moreover, a mixture model is applied for the field survey data and that compared with satellite data. The results of the mixture model suggests that the temporal changes of the vegetation indices of the rice field by satellite data are primarily correlated to the changes of the proportion ratio of rice vegetation within the rice field.

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