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Monitoring of Rice Growth by RADARSAT and Landsat TM data

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RADARSAT과 Landsat TM 자료를 이용한 벼 생육모니터링

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ABSTRACT

The objective of this study is to evaluate the use of RADARSAT and Landsat TM data for the monitoring of rice growth. The relationships between backscatter coefficients(σ^o) of RADARSAT data and digital numbers (DN) of Landsat TM and rice growth parameters were investigated. Radar backscatter coefficients were calculated by calibration process and then compared with rice growth parameters ; plant height, leaf area index (LAI), and fresh and dry biomass. When radar backscatter coefficient (σ^o) of rice was expressed as a function of time, it is shown that the increasing trend ranged from -22--20dB to -9--8dB as growth advances. The temporal variation of backscatter coefficient was significant to interpret rice growth. According to the relationship between leaf area index and backscatter coefficient, backscatter coefficient underestimated leaf area index at the beginning of life history and overestimated, at the reproductive stage. The same increasing trend between biomass and backscatter coefficient was shown. From these results, RADARSAT data appear positive to the monitoring of rice growth. Each band of time-series Landsat TM data had a significant trend as a rice crop grows during its life cycle. Spectral indices, NDVI[(TM4-TM3)/(TM4+TM3)] and RVI(TM4/TM2), derived from Landsat TM equivalent bands had the same trend as leaf area index.

Key words **: RADARSAT, rice growth, Backscatter coefficient, Landsat TM, Spectral index**

I. INTRODUCTION

Rice is the most important food grain for Koreans. Field area of paddy rice covers 1,157,306 ha according to the government statistics of 1998, which constitutes about 60.6% of the total farm land in Korea. It is essential to monitor rice growth status and to estimate paddy field area for accurate and prompt yield estimation and decision-making on well-timed food policy.

The government spends a lot of efforts to estimate the paddy field area and yields by field survey and to produce statistical data. Considering the time and budget required for the field survey, remote sensing techniques can be an attractive alternative to produce spatial distribution of rice plantation.

There has been many studies on rice monitoring as to acreage and yields, so far, by optical remote sensing technique. But we may say it is impossible to acquire optical remote sensing data during rice growing period because Korea is located in monsoon area.

Radar remote sensing has a number of advantages over conventional, optical remote sensing systems in terms of all-weather imaging capability and day/night data acquisition. A radar image is a display of grey tones which are proportional to the amount of backscatter that is received from a target (*RDLP Guide*).

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Toan *et al*.(1997) assessed the use of ERS-1 SAR data to map rice growing areas and to retrieve rice parameters. According to the results, the strong temporal variation of the radar response of rice fields is due to the wave-vegetation-water interaction, which increases from the transplanting stage to reproductive stage. The backscatter coefficient of RADARSAT has been analyzed as a function of age, plant height and plant biomass. An increasing trend of so σ^o a function of rice growth parameters is observed for RADARSAT data, until the reproductive phase(Ribbes and Le Toan, 1999).

Ogawa *et al*.(1998) reported that although backscatter coefficients of paddy field were increased from May 17 to June 27 it remain almost unchanged from June 27 to July 28. And backscatter coefficient and LAI is observed to linear relationship. The understanding of the radar backscatter of rice fields as a function of rice growth is thought to be a key condition for the development of reliable and robust methods of rice monitoring.

The aim of this study is to examine the relationship between radar backscatter coefficient (σ^o) and digital number (DN) of Landsat TM and rice growth.

II. Study Area and Data Used

Study area for monitoring rice growth in this study was Yedang Plain, Tangjin-gun, Chungnam, Korea. Yedang Plain is located in the central western part of Korean Peninsular which is about 150 km away from our Institute (NIAST).

Three RADARSAT, six Landsat TM, and field data were obtained for this study during rice growing period (Table 1). Field experimental data for rice growth parameters such as plant height, leaf area index (LAI), fresh and dry biomass were collected eight times in order to compare with radar backscatter coefficients and digital numbers (DN) of Landsat TM.

Table 1. Dates for RADARSAT and Landsat TM acquisition, and field data collection used

RADARSAT acquisition	Field data collection	Landsat TM
Jun. 1, 1998 (F3-A) Jun. 18, 1998 (F5-A) Jly. 26, 1998 (S4-A)	Jun. 9, 1999 Jun. 24, 1999 Jly. 12, 1999 Jly. 19, 1999 Aug. 11, 1999 Sep. 1, 1999 Sep. 15, 1999 Sep. 29, 1999	May 31, 1991 Jun. 2, 1992 Aug. 19, 1991 Sep. 1, 1996 Sep. 12, 1994 Sep. 27, 1988

Each RADARSAT data was provided as a 16-bit SGF (path image) product from RSI (RADARSAT International Inc.), Canada.

III. Transformation of the Digital Number Into Backscatter Coefficient and Preprocessing

The radar backscatter coefficients(σ^o) have been calculated by using LUT in leader files with IDL program programmed by Mr. Hong, Intersys Korea Inc. as follows (Shepherd, 1997)

If DNj is the digital number which represents the magnitude of the jth pixel from the start of a range line in the detected image data, then the corresponding value of radar brightness, β^o, for the pixel given by;

$$\beta^o=10*\log_{10}[(DN_j^2+A3)/A2_j]dB$$

where $A2_j$=the scaling gain value for the jth pixel, and A3=the fixed offset.

And then, the radar brightness value could be converted to radar backscatter coefficient by following relationship;

$$\sigma^o_j=\beta^o_j+10*\log_{10}(\sin I_j)dB$$

where I_j=the incidence angle at the jth range pixel

RADARSAT and Landsat TM data were registered and projected with Transverse Mercator method (Bessel map system) and resampled by nearest neighborhood method with 8 m×8 m and 30 m×30 m for one pixel, respectively.

Paddy field features were sampled and extracted by GPS every field experimental data collection. Rice growth parameters ; plant height, leaf area index (LAI), fresh and dry biomass, planting density, stem number, were measured and then compared to radar backscatter coefficient.

IV. Rice Growth

The rice plant usually takes 130-160 days from germination to maturity, depending on the variety and the environment under which it is grown. Agronomically, it is convenient to regard the life history of rice in terms of three growth stages ; vegetative, reproductive, and ripening. The vegetative stages refers to a period from germination to the initiation of panicle primordia; the reproductive stage, from panicle primordia initiation to heading; and the ripening period, from heading to maturity.

In the central part of Korea, farmers transplant rice seedling to the paddy field in around May 25 of each year, in general. Heading and flowering stages are in around late July for early matured rice and late August for mid-late matured rice. Harvest is done in around late September for early matured rice and mid-late October for mid-late matured rice.

The rice plant grows to heights of up to 1 meter at the maximum growth stage and grows no longer after reproductive stage. The rice fresh weight per square meter was increased until the reproductive stage and dry weight was increased until harvest.

The leaf growth of a rice crop, as a whole, can be measured in terms of the whole leaves per unit of ground area, and of leaf area of whole leaves per unit of ground area. Leaf area index is widely used in the research of crop photosynthesis and growth analysis.

LAI increases as growth advances and reaches a maximum at around heading stage and declines as the lower leaves die after heading stage. Leaf fresh and dry weight per unit area appears the same trend as LAI although its absolute value is different (Fig. 1).

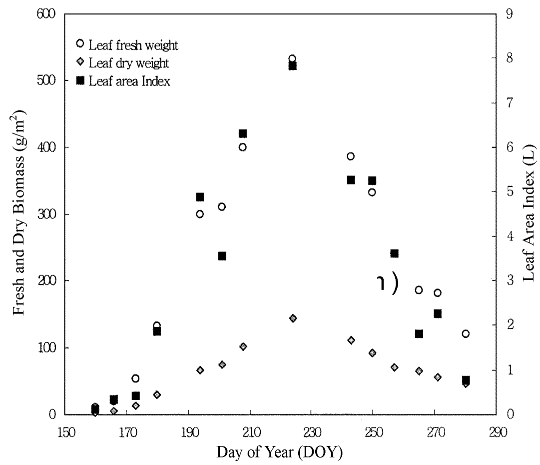

Fig. 1. Leaf fresh and dry weight and leaf area index (LAI) during rice growing period.

V. Spectral Behavior and Rice GROWTH

Spectral reflectances of paddy fields as to digital numbers (DN) of six-dates registered Landsat TM data were analyzed to compare with rice growth(Fig. 2 and 3). DNs of TM 1, 2, and 3 were the lowest in August 19 (231) and September 1 (244) when the canopy was at the maximum growth. TM 1, 2, and 3 are in the visible wavelength range which is closely related to light absorption by plant pigments such as chlorophylls. TM 5 and 7 in the middle infrared region was very sensitive to the flooded water in the paddy field. DNs of TM 5 and 7 were the lowest in May 31 (151) and June 2 (153) and they showed the same trend as total dry matter of rice plant. The more matured rice canopy, the higher the DN values of TM 5 and 7. DNs of TM 4 were the highest at the maximum growth of rice canopy since plants did not absorb near-infrared lights so much for their growth. DNs of TM 4 had a same trend as leaf biomass and leaf area index.

Radiance measurements, used to determine per cent reflectance of rice canopies, were acquired with a spectroradiometer (GER-SFOV, 0.35-2.50 μm) *in situ* weekly or biweekly during rice growing period. The spectroradiometer was elevated 50 cm above the crop canopies. Data were taken only when there were no clouds in the vicinity of the sun. Measurements of incident solar radiance with barium sulfate plate and reflective radiance from canopies were made after the instrument was leveled for a nadir view angle. Per cent spectral reflectance was calculated as the ratio of canopy radiance to the incident solar radiance via barium sulfate plate. Landsat TM equivalent band set was created by averaging measured spectral reflectance vlaues to the real TM band range. Spectral indicies, NDVI [(TM4-TM3)/(TM4+TM3)] and RVI (TM4/TM2), with TM equivalent bands were derived and then, compared with measured leaf area index (LAI) (Fig. 4).

Both of spectral indicies were the same trend as leaf area index. At the maximum of leaf area index, NDVI and RVI also appeared the highest value. VI was very promising to express leaf area index from these results.

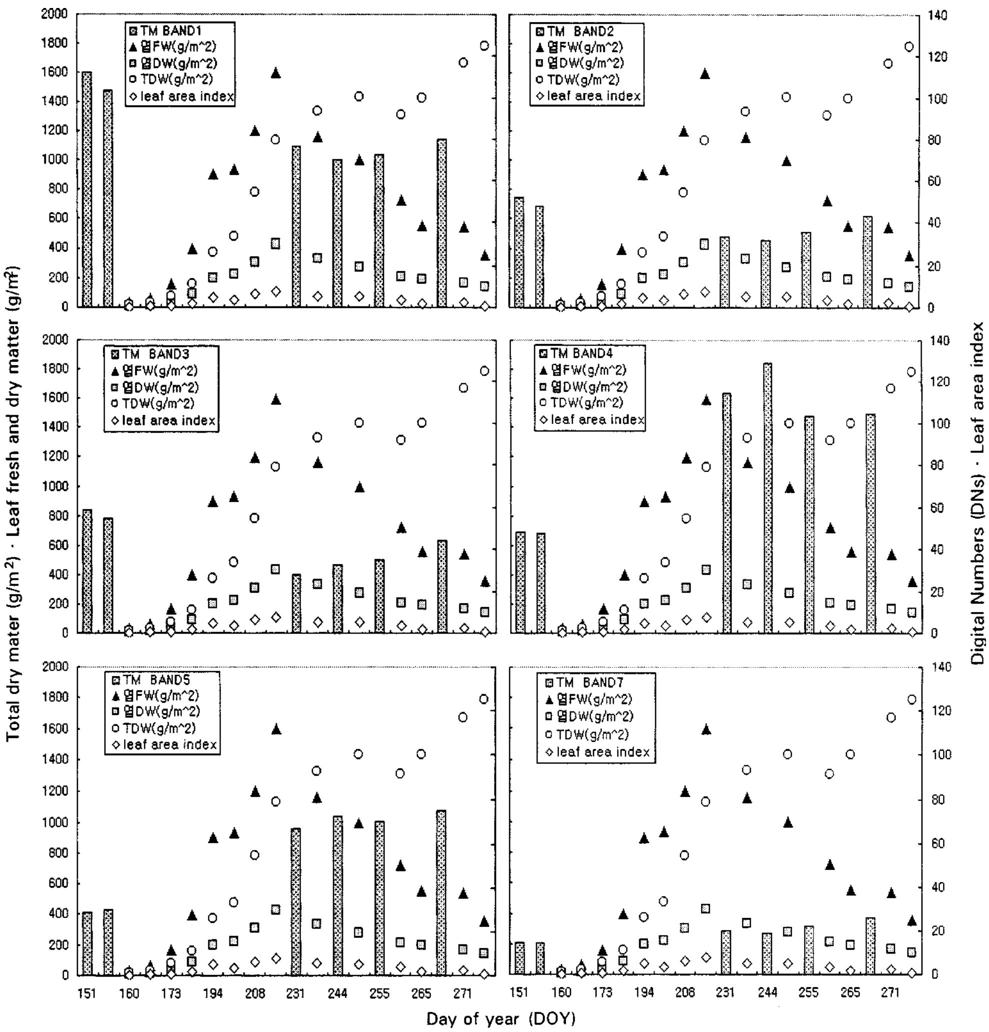

Fig. 2. Digital numbers of Landsat TM bands and rice growth.

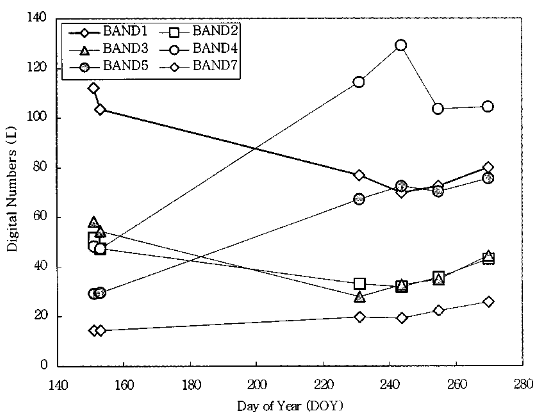

Fig. 3. Digital numbers of Landsat TM bands as a function of time.

VI. Backscatter Behavior and Rice Growth

Radar backscatter coefficients of rice has been expressed as a function of time (Fig. 5). Backscatter coefficient (σ^0) of time-series RADARSAT data shows the increasing trend as growth advances. At the rooting stage after transplanting, backscatter coefficients of paddy fields are ranged from -22dB to -20dB. Then at late reproductive stage, they reaches -9dB--8dB. The temporal variation (>11dB) of backscatter coefficient may be significant to interpret rice growth.

In comparison with previous studies, Hong *et al.* (1999) reported that backscatter coefficients of pa-

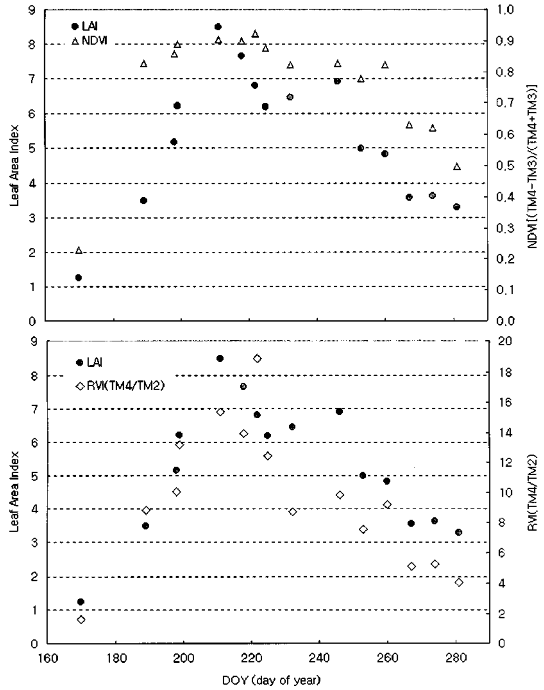

Fig. 4. Leaf area index (LAI) and spectral indices, NDVI [(TM4-TM3)/(TM4+TM3)] and RVI(TM4/TM2).

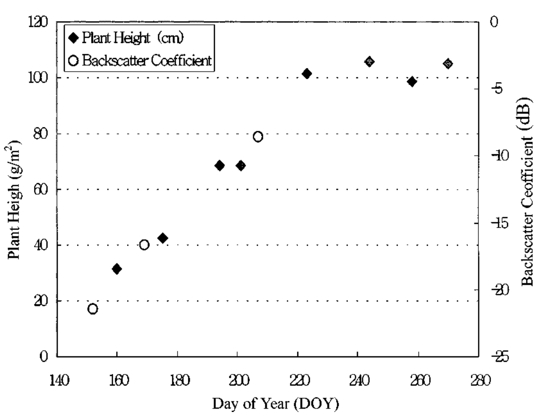

Fig. 5. Plant height and radar backscatter coefficient of rice as a function of time.

ddy fields were ranged from -16dB to -13dB at the rooting stage after transplanting and then they reaches -4.4dB--3.1dB at the end of reproductive stage and shows plateau until the end of the ripening stage, with RADARSAT standard beam mode 5 or 6. Ribbes and Le Toan(1999)'s report by using RADARSAT S1 mode showed that at the beginning of the cycle, flooded fields provide low backscatter (-14 to -12dB) and then at the end of the reproductive stage, σ^o values reach -6dB and remain stable until the end of the cycle. Temporal variation were more than 7dB(-15--20dB to -8--6dB) by Le Toan *et al.* (1997)'s report by using ERS-1 SAR(C band; 5.3 GHz, VV polarization) and around 6dB (-13--12 to -6dB) by Ogawa *et al.*(1998)'s report by using RA DARSAT data. Panigrahy *et al.*(ADRO Project ID 349) reported rice crop showed the largest dynamic range of backscatter of -18--8dB during the study period. Ribbes and Le Toan(1999) also revealed the dynamic range of RADARSAT data is found lower than that of ERS data due to a higher backscatter at HH than VV polarization at early stage of rice growth because the wave attenuation by the canopy is higher for VV than for HH, resulting in the higher values of RADARSAT data.

The taller the rice plant in height, the higher the backscatter coefficient (Fig. 5). Accoring to the relationship between leaf area index and backscatter coefficient (Fig. 6), backscatter coefficient may underestimate leaf area index at the beginning of life history and overestimate, at the reproductive stage. Ogawa *et al.* (1998) reported leaf area index and backscatter coefficient of RADARSAT has a linear relationship.

In terms of biomass, backscatter coefficients were compared with fresh and dry weight per unit area of rice plant as shown in Fig. 7 and 8. Even though three time data were not enough to explain the relations between biomass and backscatter coefficients, they showed the same trend.

Hong *et al.*(1999) reported that second order polynomial relationships were found between backscatter coefficient and fresh and dry biomass more than 0.95 in determination coefficient with nine sequential RADARSAT data (S5 or S6). After rice reaches its maximum growth stage which is, in many cases, at the end of reproductive stage, backscatter coefficients remain stable around -4--6dB although fresh and dry biomass increase more and more.

VII. CONCLUSIONS

This study was carried out to investigate the relationship between radar backscatter coefficient (σ^o) & digital number (DN) and rice growth, furthermore paddy field mapping and yield estimation for the next step. The characteristics of backscatter coeffi-

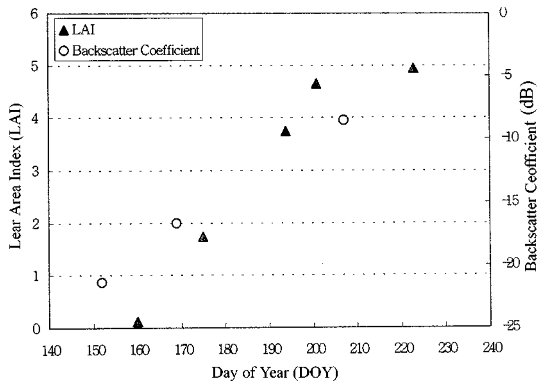

Fig. 6. Leaf area index and radar backscatter coefficients during rice growing period.

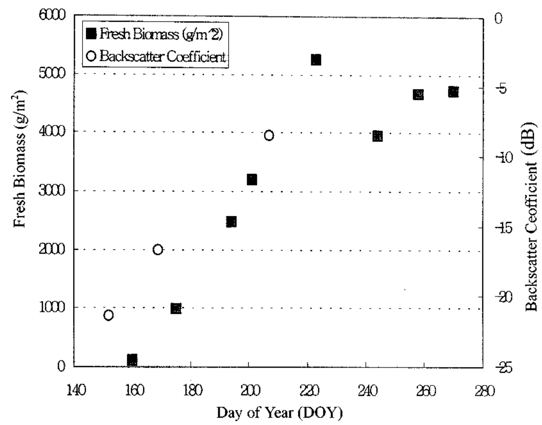

Fig. 7. Rice fresh biomass and radar backscatter coefficients during rice growing period.

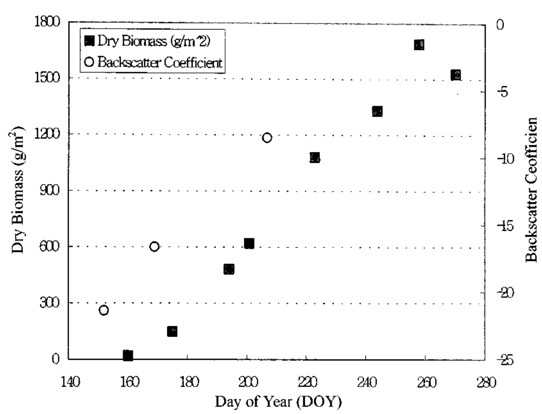

Fig. 8. Rice dry biomass and radar backscatter coefficients during rice growing period.

cient (σ^o) of RADARSAT data and digital number of Landsat TM in paddy field were examined and field experimental data were collected during the rice growing season over the study area, Yedang plain, Tangjin-gun, Chungnam, in Korea. The analysis of the radar backscatter coefficients (σ^o) and digital numbers in paddy fields was performed as to rice growth parameters, plant height, leaf area index (LAI), and fresh and dry biomass.

Each band of time-series Landsat TM data had a significant trend as a rice crop grows during its life cycle. But it is still impossible to get those time-series data in a year. Spectral indices, NDVI [(TM4-TM3)/(TM4+TM3)] and RVI(TM4/TM2), derived from Landsat TM equivalent bands had the same trend as leaf area index. At the maximum of leaf area index, NDVI and RVI also appeared the highest value. RVI was very promising to express leaf area index from these results.

When radar backscatter coefficient (σ^o) of rice has been expressed as a function of time, it showed the increasing trend as growth advances ranged from -22--20dB to -9--8dB. The temporal variation of backscatter coefficient was significant to interpret rice growth. The taller the rice plant in height, the higher the backscatter coefficient. According to the relationship between leaf area index and backscatter coefficient, backscatter coefficient may underestimate leaf area index at the beginning of life history and overestimate, at the reproductive stage. The same increasing trend between biomass and backscatter coefficient was shown. From these results, RADARSAT data appear positive to rice growth monitoring.

Filter and window size selection for speckle noise reduction, development of paddy field classification method, and retrieval of rice physiological parameters for crop growth model might be followed for the future work.

요 약

날씨 · 밤낮에 관계없이 자료를 취득할 수 있는 RADARSAT(C-밴드; 5.3GHz, HH 편광)의 후방산란계수와 태양광에 대한 반사값으로 데이터가 얻어지는 Landsat TM의 자료값(DN; Digital Numbers)을 이용하여 벼 생육과의 관계를 조사하였다. 벼 생육기간 동안 RADARSAT 3시기의 자료를 취득하여 보정 과정을 통하여 지표면의 특성이 잘 나타나는 후방산란계수 (backscatter coefficient)를 산출하였다. 연구지역에서 초장, 엽면적지수, 생체중, 건물중 등 벼의 생육변수를 조사하여 산출된

후방산란계수를 비교하였으며, Landsat TM은 논 지역의 6시기 자료값을 산출하여 벼 생육과의 관계를 살펴보았다. 벼의 생육초기 담수상태일 때 논의 후방산란계수 범위는 -22dB--20dB이었고, 벼의 영양생장이 최대에 달했을 때 논의 후방산란계수는 -9dB--8dB 범위로 생육단계별로 뚜렷한 차이를 보였고 생육변수, 초장, 엽면적지수, 생체중, 건물중 변화와 유사한 경향을 나타내었다. TM 밴드 1, 2, 3의 자료값은 생육후기로 갈수록 낮아졌다가 등숙기에 다시 높아졌고, TM 밴드 4의 자료값은 생육후기로 갈수록 높아졌다가 등숙기에 낮아지는 경향이었다. TM 밴드 5와 7의 자료값은 생육기간 동안 계속 증가하여 건물중의 변화추세와 유사하였다. 시계열 RADARSAT과 Landsat TM 자료를 이용한 벼 생육모니터링은 전망이 있는 것으로 보인다.

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