Relationship between RADARSAT backscatter coefficient and rice growth

HONG, Sukyoung*, Sanghoon HONG**, and Sangkyu RIM*
*National Institute of Agricultural Science and Technology (NIAST)
249 Seodun-dong, Kwonsun-gu, Suwon 441-707, KOREA
**Intersys Korea Inc., Doryong-dong, Yusung-gu, Taejoen 305-340, KOREA
Email : syhong@niast.go.kr, hongsh@intersys21.com, skrim@niast.go.kr

ABSTRACT

This study was carried out to assess the use of RADARSAT data which is C-band with HH polarization for the rice growth monitoring in Korea. Nine time-series data were taken by shallow incidence angle (standard beam mode 5 or 6) during rice growing season. And then, backscatter coefficient (σ°) were extracted by calibration process for comparing with rice growth parameters such as plant height, leaf area index(LAI), and fresh and dry biomass. Field experimental data concerned with rice growth were collected 8 times for the ground truth at the study area, Tangjin, Chungnam, Korea. At the maximum vegetative stage of rice, backscatter coefficients were the highest at the flooded rice field ranging from -4.4dB～-3.1dB. The temporal variation of backscatter coefficient(σ°) in rice field was significant in this study. Backscatter coefficient (σ°) of rice field was a little bit lower again after heading stage. This results show RADARSAT data is promising for rice monitoring.

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*).

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 σ° as 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 and rice growth.

STUDY AREA AND DATA USED

Study area for monitoring rice growth with RADARSAT data 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 ㎞ far away from our Institute(NIAST).

Nine sequential RADARSAT 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 seven times in order to compare with radar backscatter coefficient.

Each RADARSAT data was provided as a georeferenced 16-bit SGX product and a geocoded 16-bit SPG product from KEOC(Korean Earth Observation Center). However, SGX images appear

Table. RADARSAT acquisition and field data collection date

RADARSAT Acquisition		***Field data collection***
Date	***Mode***	
May 20, 1999	S6-A	
June 1, 1999	S5-D	
June 13, 1999	S6-A	June 9, 1999
June 25, 1999	S5-D	June 24, 1999
July 7, 1999	S6-A	July 12, 1999
July 26, 1999	S6-D	July 19, 1999
August 12, 1999	S5-D	August 11, 1999
August 31, 1999	S5-D	September 1, 1999
September 29, 1999	S5-D	September 15, 1999
		September 29, 1999

more relevant for extracting radar backscatter coefficient. RADARSAT data were taken by standard beam mode 5 and 6, which have shallow incidence angle(36～42 and 41～46, respectively). Because field variability of S1 is much higher than that of S7 data. That is, volume scattering is dominant in S7 and surface scattering is dominant in S1(Panigrahy *et al.*, ADRO project ID 349). Shallow angle data of more than 40 incidence angle is of particular interest for identification of agricultural crops.

TRANSFORMATION OF THE DIGITAL NUMBER INTO BACKSCATTER COEFFICIENT AND PREPROCESSING

The radar backscatter coefficient(σ°) 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, for the pixel given by;

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

- $A2_j$: the scaling gain value for the jth pixel
- A3 : the fixed offset

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

$$\sigma^\circ_j = \beta_j + 10*\log_{10}(\sin I_j) \quad dB$$

- I_j : the incidence angle at the jth range pixel

RADARSAT data were registered and projected with Transverse Mercator method(Bessel map system) and resampled by nearest neighborhood method with 8m x 8m for one pixel.

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.

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(Fig. 1). 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 rice and late August for mid-late rice. Harvest is done in around late September for early rice and mid-late October for mid-late rice.

The plant height of rice increases and reaches about 1 meter long until the maximum growth stage (Fig. 2). After reproductive stage, it grows no more in height. Figure 3 shows that the rice fresh weight per square meter was also increased until the reproductive stage and the rice dry weight per square

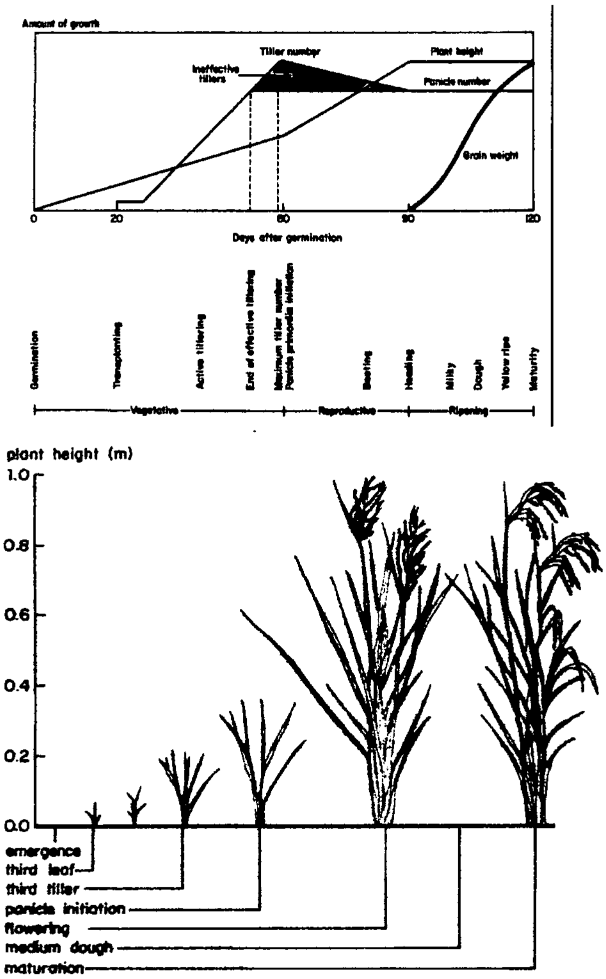

Figure 1. Development stages of a rice crop (Source: Stansel, 1975;Yoshida, 1981).

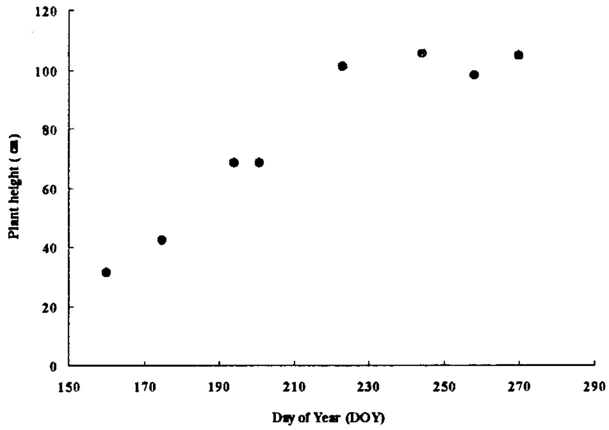

Figure 2. Temporal variation in rice plant height.

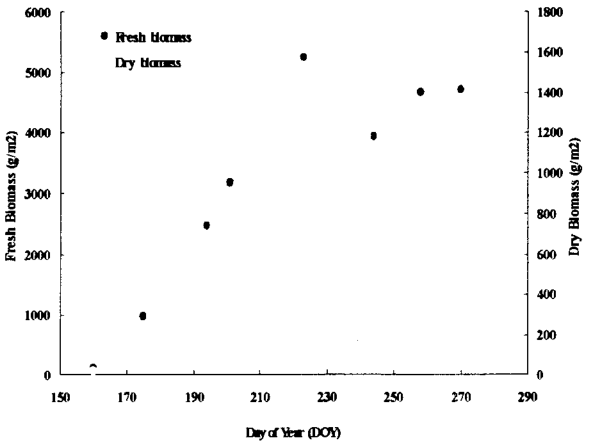

Figure 3. Temporal variation in rice fresh and dry biomass (g/m^2).

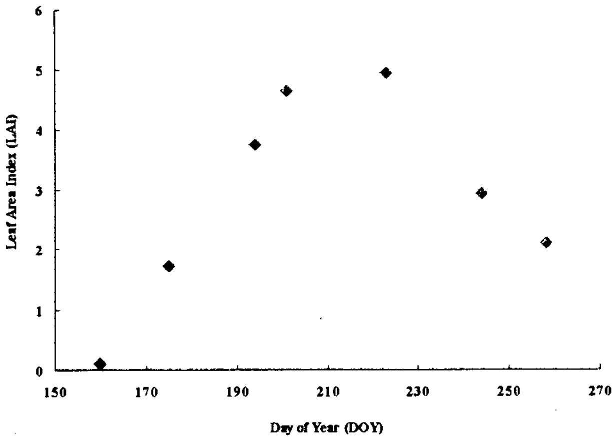

Figure 4. Leaf area index(LAI) of rice plant during growing season.

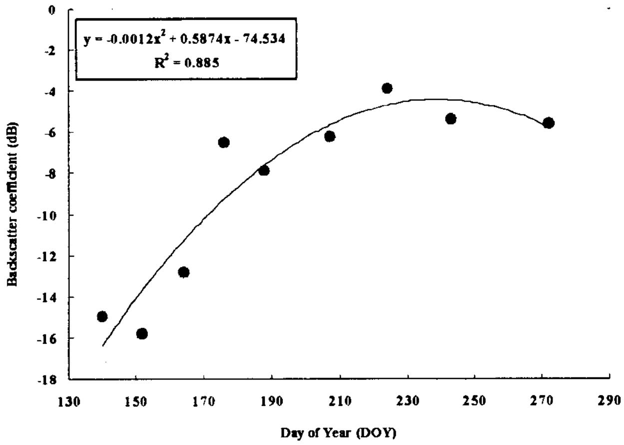

Figure 5. Radar backscatter coefficients of rice as a function of time.

meter 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 (Yoshida, 1981). Leaf area index is widely used in the research of crop photosynthesis and growth analysis. Leaf area index(LAI) is defined as:

$$LAI = \frac{\textit{sum of the leaf area of all leaves}}{\textit{ground area of field where the leaves have been collected}}$$

LAI increases as growth advances and reaches a maximum at around heading stage and declines as the lower leaves die after heading stage(Fig. 4). Leaf fresh weight per unit area appears the same trend as LAI although its absolute value is different.

BACKSCATTER BEHAVIOR AND RICE GROWTH

Radar backscatter coefficients of rice has been expressed as a function of time(Fig. 5). Backscatter coefficient(σ°) of time-series RADARSAT data shows the increasing trend as growth advances until reproductive stage in paddy field. At the rooting stage after transplanting, backscatter coefficients of paddy fields are ranged from -16dB to -13dB. Then at the end of reproductive stage, they reaches -4.4dB ~-3.1dB and shows plateau until the end of the ripening stage. The temporal variation(>8dB) of backscatter coefficient may be significant to interpret rice growth and to tell paddy fields from other land cover types in this study.

In comparison with previous studies, 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° 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㎓, VV polarization) and around 6dB(-13~-12 to -6dB) by Ogawa *et al.*(1998)'s report by using RADARSAT 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.

It was very difficult to meet the date of field experimental data collection and RADARSAT acquisition date. Due to the discrepancy between the dates of field data collection and RADARSAT

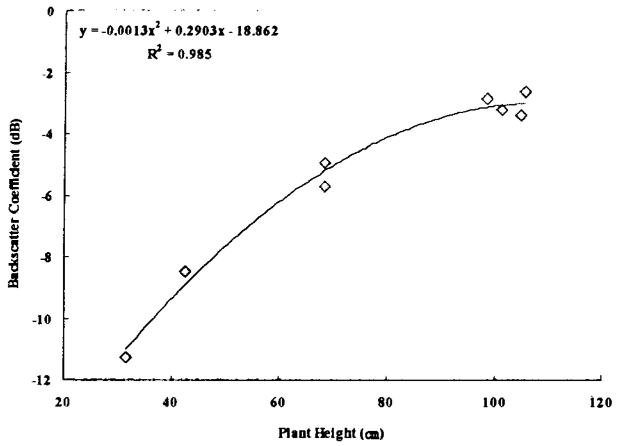

Figure 6. Radar backscatter coefficients of rice as a function of plant height(cm).

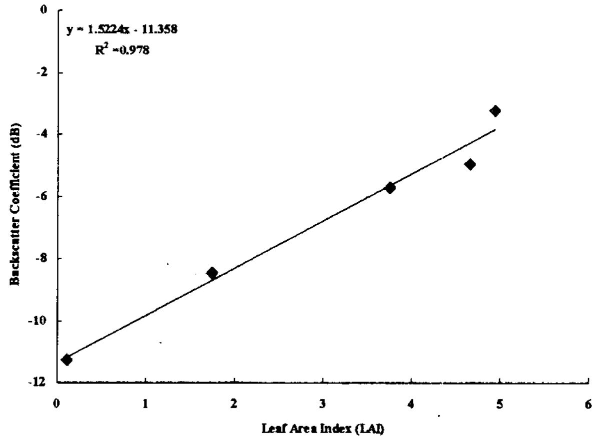

Figure 7. Radar backscatter coefficients of rice as a function of leaf area index before heading stage.

acquisition, backscatter coefficients were interpolated with the function of time ($y = -0.0012x^2 + 0.5874x - 74.534$: $R^2 = 0.885$), and then compared with the rice growth parameters, plant height(Fig. 6), leaf area index (Fig. 7), fresh biomass (Fig. 8), and dry biomass (Fig. 9). Interpolation made original values of σ° overestimating in their maximum and underestimating in their minimum.

The taller the rice plant in height, the higher the backscatter coefficient throughout the life history (Fig. 6). When backscatter coefficient was explained as a function of leaf area index(Fig. 7), linear relationship was observed between them before heading stage. This result is the same trend as Ogawa *et al.*(1998). Leaf area index(LAI) is very important parameter to estimate the final yields of rice in crop growth model.

In terms of biomass, backscatter coefficient was expressed as functions of fresh and dry weight(Fig. 8 and 9). Second order polynomial relationships were found between them with R^2>0.95 both in fresh and dry biomass. After rice reaches its maximum growth stage which is, in many case, at the end of reproductive stage, backscatter coefficients remain stable around -4～-6dB although fresh and dry biomass increase more and more.

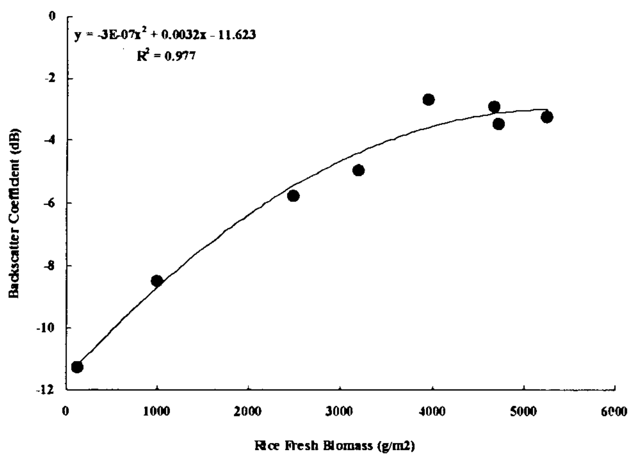

Figure 8. Radar backscatter coefficients of rice as a function of fresh biomass(g/m^2).

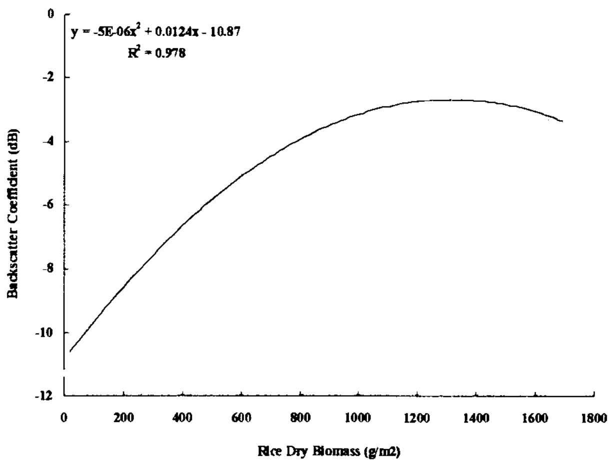

Figure 9. Radar backscatter coefficients of rice as a function of dry biomass(g/m^2)

CONCLUSIONS

The objective of this study was to evaluate the use of RADARSAT SAR data for rice growth analysis, furthermore paddy field mapping and yield monitoring for the next step. The characteristics of backscatter coefficient (σ°) in paddy field was 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 coefficient (σ°) of paddy fields was performed as a function of rice growth parameters, plant height, leaf area index(LAI), and fresh and dry biomass.

When radar backscatter coefficient (σ°) of rice has been expressed as a function of time, it showed the increasing trend as growth advances until reproductive stage ranged from -16～-13dB to -4.4～-3.1dB. The temporal variation of backscatter coefficient was significant to interpret rice growth. Backscatter coefficient could be explained as a function of time (DOY;day of year) with polynomial relationship. Linear relationship was observed between backscatter coefficient and leaf area index(LAI) until reproductive stage. Second order polynomial relationship were found between backscatter coefficient and rice fresh and dry biomass with R^2>0.95. And backscatter coefficient remain stable around -4～-6dB even after fresh and dry biomass increase more and more. This study also suggest to meet the date of field experimental data collection and RADARSAT acquisition date. 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, combining with optical remote sensing data and geographic information system, and retrieval of rice physiological parameters for crop growth model might be followed for the future work.

ACKNOWLEDGEMENT

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