L-band SAR Monitoring of Rice Crop Growth

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Abstract

Rice crop has relatively short growing season during the summer in Korea and, therefore, it is often difficult to acquire cloud-free imagery on time. This study was attempt to define the temporal characteristics of radar backscattering observed from satellite L-band SAR data on different growing stages of rice crop. Six scenes of multi-temporal JERS SAR data were obtained from the transplanting season to the harvesting month of October. Six layers of multi-temporal SAR data were registered on a common geographic coordinate system. Using topographic maps, field collected data, and Landsat TM data, several sample rice fields were delineated from the imagery and their relative radar backscatters were calculated by using a set of reference targets. The temporal pattern of radar backscattering was very distinctive by the growing stage of rice crop. It was also separable between two types of rice fields having different cultivation practices. Considering the temporal characteristics of radar backscattering observed from the study, it is obvious that a certain date of the growing season can be more effective to delineate the exact area of the cultivated rice crop field.

Introduction

Crop monitoring and yield estimation over large geographic areas have been primary concerns to many remote sensing scientists since the early Landsat program in 1970s. Although rice is a single major crop type used for primary food grain for human, it has been rare to find remote sensing studies related to rice crop. Rice has relatively short growing season during the summer in which the weather conditions are relatively poor for obtaining necessary image data by optical sensors. In Korea as well as in many other countries in Asia where the rice paddy is the most prevailing agriculture land, it is very important to monitor the growth of rice crop not only for the planning of food supply but also for assessing the environmental capacity of rice paddy.

With recent development of active microwave remote sensor data, the weather conditions are is no longer prohibitive factor for acquiring image data over rice fields during the growing season. Synthetic aperture radar (SAR) sensor is capable to penetrate canopy layer of vegetation, which provides unique information related to the internal structure of standing crop. Furthermore, the reflected signal of imaging radar has something to do with the moisture content of the target. Such characteristics of SAR data has a great potential to be used for monitoring rice crop. Recently, C-band imaging radar data have shown interesting relationship with the growth status of rice (Panigrahy et al., 1997) and of wetland vegetation that shows very similar backscattering behavior to rice paddy (Kasischke and Chavez, 1997). Spaceborne L-band SAR data have a relatively long history from the SEASAT and the Shuttle Imaging Radar (SIR) programs and utilized for characterizing the forest vegetation primarily due to the high canopy penetration capacity by longer wavelength. The objectives of this study are to define the temporal characteristics of L-band radar backscatters by different growing stages of rice crop and to recommend proper season of data acquisition for obtaining the most information related to the rice crop conditions.

Study Area and Data Used

The study area covers approximately 36 km x 42 km and is located near the Chinju in southern part of Korean Peninsular. The study area is mostly covered by forest over highly undulated terrain and relatively small size of agricultural crop lands are distributed along the streams. This area has relatively warmer temperature with more precipitation compared to the other parts of Korea and, therefore, double cropping is common at certain rice fields. Rice fields have often been used for growing winter barley that is planted in early winter and harvested before the transplantation of rice.

Six scenes of multi-temporal JERS L-band SAR data were acquired from the pre-transplanting time of April to the harvesting season in October. Although it would be ideal to have the multitemporal data set collected within a single growing sequence, the 44 days of revisit cycle of the JERS satellite can provide only two or three scenes during the rice growing period. To minimize the time interval between growing stages, the data set was collected during two growing periods in 1997 and 1998. Table 1 shows detailed characteristics of JERS L-band SAR data used for this study. In addition, Landsat TM data of June, 1994 were used to verify the location of field study sites. Along with the image data, extensive field data were collected for crops, land cover, and weather conditions during the days of orbit pass.

Table 1. Characteristics of L-band satellite SAR data used for this study.

Acquisition date	Apr. 8, 1998 May 22, 1998 July 18, 1997 Aug. 18, 1998 Oct. 1, 1998 Oct. 14, 1997
Frequency	1.275GHz (L-band)
Polarization	HH
Looks	3 looks
Flight Direction	Descending
Incidence Angle	35°
Coverage	75km x 75km
Nominal Resolution	20m
Pixel Spacing	12.5m ~ 18m

Procedures

To compare the temporal pattern of L-band radar backscattering on rice crop, the six scenes of JERS SAR data were processed by the sequences shown in Figure 1. Once necessary data sets were prepared, the initial process was to combine the multitemporal SAR data as well as Landsat TM data on a plane rectangular coordinate system. The registration of multiple image layers was performed by a set of ground control points that could be identified on both image and topographic map. The geometric distortion of SAR image is quite severe due to the slant looking behavior of imaging radar, in particular for the undulated terrain, and digital elevation model (DEM) data are needed for precise geocoding of SAR data (Guindon and Adair, 1993). However, the primary target of interest in this study was rice fields that are mostly found on relatively flat terrain and it was believed that the precise geocoding of the SAR data was not necessary. Speckle noise is one of the most distinct characteristics observed on SAR imagery and can be a major obstacle for analyzing the data. Since the rice fields to be selected were relatively small in size having a few pixels, it would be wise to reduce the variability caused by speckles. Before extracting the sample pixels from the image data the SAR data were filtered by using a filter reported by Lopes et al. (1990), which has been known to effectively reduce speckle while maintaining the image sharpness.

Sample rice fields of known characteristics were selected on the display monitor and their boundaries were delineated using topographic maps, field survey results, and Landsat TM image overlaid with the SAR data. The sample fields were delineated so as to include relatively homogeneous pixels and had only a few pixels per each field.

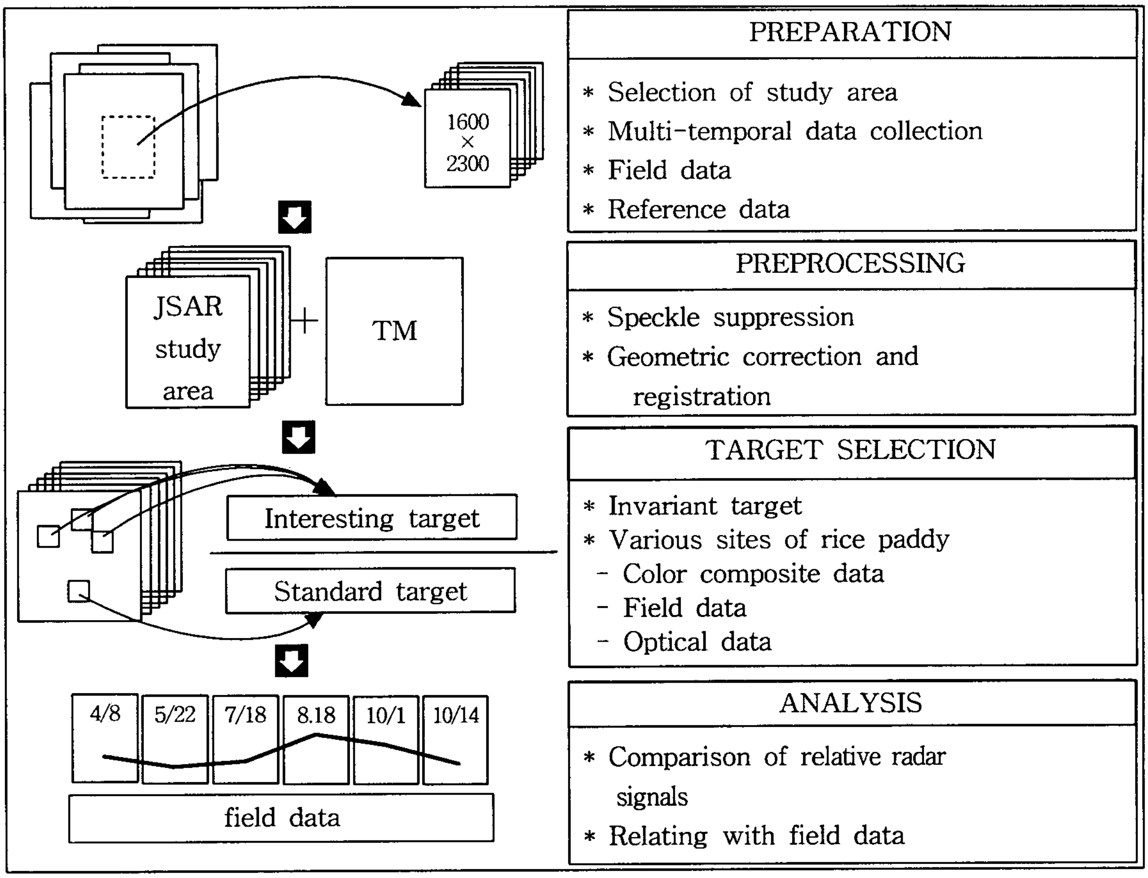

Figure 1. Data analysis procedure to define the temporal pattern of radar backscattering.

Mean digital number (DN) values within the boundary of each selected field were converted to relative radar backscatters for the comparison of temporal pattern. Ideally, the measure of radar backscattering should be a value of backscattering coefficients (σ^o) in dB, after appropriate calibration. However, due to inherent system problems of the JERS-1 SAR system, it was impossible to achieve absolute calibration for this data. As an alternative, relative radar backscatters values ($\sigma^o{}_i$) at a date of i were obtained from mean DN values by using a ratio technique which gave relative values to a reference target:

$$\sigma^o{}_i = DN_i \ / \ DN_{ref\ i} \quad .... (1)$$

Since the DN values of pixels are linearly related to the amplitude of received radar signals, the ratio value between the DN of rice field and the DN of reference target is approximately the same as the ratio of true radar backscatter of the same target against radar backscatter of the reference target (Cimino et al., 1986). As a reference target for the relative calibration, a set of inland water was selected for each data set. Inland water seems to be the most invariant regardless of the time of data acquisition.

Results and Discussions

Relative radar backscatters obtained from the sample fields of rice paddy were compared along the time sequence of rice growing from April to October. In overall, the radar backscatters did not

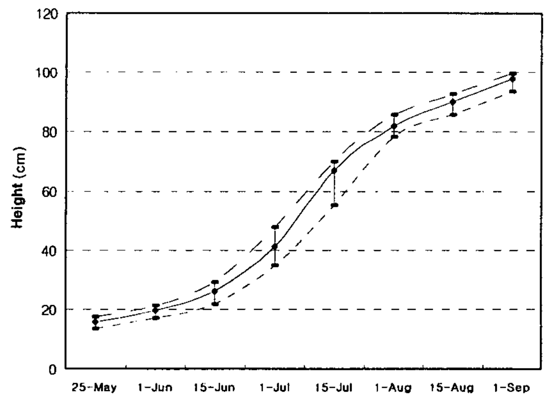

Figure 2. Height growth of normal rice crop in the study area.

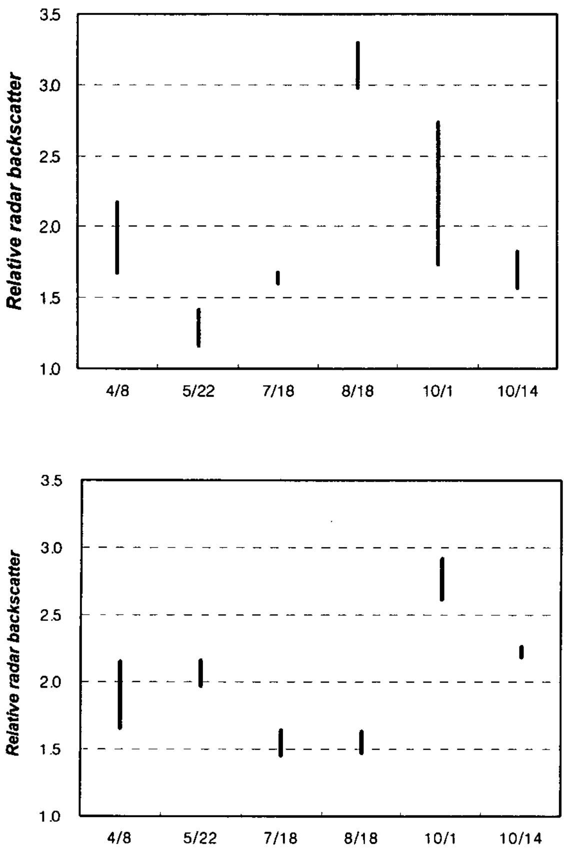

Figure 3. Temporal pattern of L-band radar backscatters from two types of rice fields (Above: normal single cropping, bottom: double cropping)

show the substantial increase proportional to the height growth of rice crop as expected. Figure 2 shows the normal growth pattern of rice crop in this area, which had been measured by the local agricultural agency. After transplanting of rice crop in May, rice shows constant height growth until it reaches the maximum growth in early September. If the amount of radar interaction with standing stem and leaves increased by the growth rate of rice, the reflected radar signals should have shown about the same proportion of increase.

However, the relative radar backscatters of May and July were not much different each other although the rice height in July was much higher than the one in May (Figure 3). Once it reaches near the maximum height in late August, the radar backscatters increase significantly. It has been reported that the transplanting stage of rice fields, in which the ground is covered by plentiful of water, did not show not much difference from water surface in L-band backscattering (Lee et al., 1998). Even if the height of rice crop can reach up to 50cm in middle of July, it does not seem to be any significant influences on radar backscattering. The L-band radar, having a longer wavelength than any other imaging radar system, has been well known for better penetration of plant canopy and backscattered signals are closely related to the structure between standing stems and ground surface. Rice crop is basically herbaceous plant and its stem size may have minimal effects for producing the corner reflections between stem and ground at early growing stage. Probably, shorter wavelength C-band radar could generate stronger signals in July with more interactions with standing crop. The radar backscatters rapidly increased when the rice height reached about 80cm and the ground is almost fully covered by leaves of rice crop. When the rice fields were drained for the preparation of harvest, the radar backscattering decreased. Such decrease may have something to do with the moisture contents of rice crop, in which the rice crop turns to yellow by losing water content in leaf organism after it attains the maximum height growth.

From the interpretation of color composite of the multitemporal SAR data as well as the changing pattern of relative radar backscatters, it was obvious that there were two different types of rice paddy in the study area. As mentioned before, the double cropping is possible in this area due to the favorable climate condition of warm temperature and high precipitation. Although much of the rice fields were used only for a single cultivation of rice crop, there were the rice fields used for the double cropping. The double cropping rice fields were used for growing winter barley and other vegetables in green house. The transplanting time of the rice field used for double cropping is about one month later than the normal rice fields due to the harvest of winter crops and the preparation plowing for subsequent cultivation of rice. Figure 3-b shows the change of radar backscatters observed on the rice fields that were used for double cropping. Unlike in the normally transplanted rice field in Figure 3-a, the radar backscatters in August is very low and not much different from the one in July. Since the transplanting date was a month behind the normally planted rice fields, the stem and height growth did not close to the full canopy stage. The highest radar backscatters was found in early October when the growth of rice crop would be the greatest at this time.

Subtle differences in growth condition produced interesting pattern of radar backscatters, which imply that the use of multitemporal data sets is essential to monitor rice crop. The temporal change of the radar backscatters can be utilized to many applications of the exact classification of rice crop fields, the monitoring growth conditions, yields estimation, and the discrimination of rice fields from similar target such as water or bare soils.

Conclusions

Due to the weather problem of obtaining necessary data during the growing season, it has been difficult to conduct detailed studies of rice crop monitoring by satellite remote sensing. First of all, this study using satellite based SAR data demonstrates the flexibility of data problem by using six sets of sequential data during the growing season of rice crop. With increasing number of satellite based imaging radar systems, the data acquisition would be no longer obstacle for certain application like rice crop monitoring, in particular for the areas where the weather conditions are not favorable for the optical remote sensor data.

Based upon the analysis of the multitemporal SAR data along with the field collected data, the L-band radar backscatter shows unique pattern of temporal change. The radar backscatters did not show any significant changes until the height and stem growth reached to the nearly full canopy stage. When the height of rice crop is approximately 70 to 80cm, the L-band radar backscatters rapidly increased. Such abrupt increase of radar signal might be related to the degree of radar interactions with standing stems. Radar interactions with standing stems would be very minimal until it reaches certain level of size and density, primarily due to the high penetration effects of L-band radar. The temporal changes of radar backscatters also allow us to distinguish two different types of rice fields.

Since the current satellite SAR systems provide only a single wavelength band of data, it should be more common practice to use multitemporal data sets for many applications. For the identification and classification of rice fields from other similar targets, it would be wise to choose the data set obtained when rice crop is in fully growth stage. The results obtained from this study can be more expanded to other applications, such as yield estimation and flood monitoring, and assessing growth conditions, which can be influenced by several factors of natural disasters and insect/disease infestations. Since the C-band SAR data are also available nowadays, further study is planned to define the characteristics of temporal patterns of C-band radar backscattering and to find the synergic effects of using both L-band and C-band data.

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