MONITORING OF RICE-PLANTED AREAS USING SPACE-BORNE SAR DATA

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ABSTRACT
The authors attempted to estimate rice-planted areas using multi-temporal RADARSAT fine-mode and ERS-1/SAR data in an early period of rice-planting season. The eastern part of Hiroshima City, Higashi-Hiroshima City, was selected as the test field, and three multi-temporal RADARSAT fine-mode images and ERS-1/SAR images, taken before and after rice-planting were used as the test data. From the first two temporal data in RADARSAT and ERS-1/SAR data sets, SAR backscatter intensity in rice-planted fields was found to decrease significantly. From the last two temporal data, SAR backscatter intensity increased significantly due to the growth of planted rice. We evaluated the actual performance for rice area estimation by RADARSAT and ERS-1/SAR data by comparing with the estimated area by SPOT data and also with the results by the statistical report.

1 INTRODUCTION

Rice is the most important agricultural product in Japan and a lot of man-power is still necessary to monitor rice-growth and to estimate rice planted areas in whole areas of Japan every year. Satellite remote sensing images, such as Landsat TM or SPOT HRV, have been expected to be used to monitor rice-growth and estimate rice-planted areas. However, these optical sensors hardly have been able to get necessary data at a suitable timing due to cloud cover problem during rice planting season in Japan. Therefore currently only space-borne synthetic aperture radar (SAR) images might be practical data sources to realize rice area estimation by remote sensing in Japan.

According to high sensitivity of C-band radar image to surface roughness conditions, the backscatter intensity of RADARSAT or ERS-1,2/SAR images changes greatly from non-cultivated bare soil condition before rice planting to inundated condition just after rice planting (Suga *et al*, 1999). In addition, C-band SAR images are rather sensitive to the change of rice biomass in a growing period of rice (Ribbes *et al*, 1999 and Liew *et al*, 1999). Therefore, rice area estimation is expected to be realized in an early stage, namely only after rice planting or earlier than one month after rice planting.

In this study, first the authors investigated the temporal changes of SAR backscatter of RADARSAT fine-mode and ERS-1/SAR data in rice-planted fields. Then we attempted to estimate rice-planted areas by RADARSAT and ERS-1/SAR images in an early stage after rice planting and evaluated the actual performance for rice area estimation by comparing with the estimated area by SPOT multi-spectral data and also with the statistical reports.

2 TEST SITE AND TEST DATA

The eastern part of Hiroshima City, Higashi-Hiroshima City, was selected as the test field. A total of seven multi-temporal RADARSAT fine-mode images, taken from Apr. 8 to Sep. 4 in 1999, were used as the test data. SPOT/HRV multi spectral data taken on June 21, 1999 were used to generate a reference image for rice-planted area extraction in 1999. A total of five multi-temporal ERS-1/SAR images, taken from Mar. 27 to Nov. 27 in 1993, were used to be compared with the results by above RADARSAT data. In addition, the statistical data for rice-planted areas in whole of Higashi-Hiroshima City in 1999 and 1993 were referred for the comparison with the area estimates by SAR images.

An example of multi-temporal RADARSAT images and a SPOT image in a part of the test site are shown in Figure 1. The rice fields are mainly distributed in the middle-right and bottom-left portions in the images. The land surface condition in the rice fields of Apr. 8 is a non-cultivated bare soil before rice planting with rather rough soil surface. The surface condition of May 26 is almost smooth water surface just after rice planting, and that of June 19 is a mixed condition of growing rice and water surface. It is easily found that the rice fields are shown in a dark tone in the RADARSAT image on May 26 , while they are shown in a brighter tone in the RADARSAT images on Apr. 8 and June 19.

3 DATA PROCESSING

3.1 Processing of SAR Data

The RADARSAT and ERS-1/SAR data were processed from Level-0 by Vexcel SAR Processor (VSARP) and single-look power images with 6.25 meters (for RADARSAT) or 12.5 meters (for ERS-1) ground resolution were generated. Then the power images were filtered using mean filter with 7 by 7 moving window and finally converted into 8-bits image data in which power level is represented in dB. All RADARSAT, ERS-1/SAR and SPOT images were overlaid onto the topographic map with 1:25,000 scale. As the SAR images are much distorted by foreshortening due to topography, the digital elevation model (DEM) with 50 meters spatial resolution issued by Geographical Survey Institute (GSI) of Japan was used to correct foreshortening of the SAR images.

3.2 Extraction of Temporal Changes of SAR Backscatter in Rice Fields

Figure 2 and 3 show the temporal changing patterns of SAR backscatter by RADARSAT and ERS-1/SAR respectively in several rice-planted sample areas together lawn of a golf course and water surface. In Figure 2 and Figure 3, rice shows a significant change of backscatter in an early period, namely from the end of March or the beginning of April to the beginning or middle of June. These backscatter changes are considered due to the change of its surface condition described in the previous section. The results of Figure 2 and 3 suggest that rice-planted areas are possible to be extracted using backscatter changes in an early period of rice planting season using multi-temporal SAR images.

3.2 Extraction of Rice-Planted Areas

Rice-planted areas were extracted using two methods from RADARSAT images. One was thresholding and the other was supervised classification by maximum likelihood (ML) classifier. The thresholding is a simple one, that is, a pixel is extracted as rice if the backscatter change of that pixel is larger than a certain threshold value. The data combinations for thresholding were three, the first one was Apr.8 - May 26, the second May 26 - June 19 and the third the combination of the first and the second. For the third case, rice-planted areas are extracted by AND operation of the areas by two data combinations (Apr.8-May 26 and May 26-June 19).

The second method, ML classifier, conducted land cover classification including rice category using the merged images of three or two temporal RADARSAT images, namely three or two channel images in which each channel indicates each temporal image. The three channel means to use all three temporal images and the two channel means to use only Apr.8 and May 26 because the backscatter decreases significantly between the two date. For SPOT/HRV, the same method, ML classifier, was used to classify several land cover types including rice.

4 EXPERIMENTAL RESULT

4.1 Evaluation of Rice-Planted Areas from RADARSAT by Those from SPOT

First we evaluated the rice-planted areas extracted from RADARSAT images by comparing with those from SPOT data taken in the same year. We defined two indices, true production rate (TPR) and false production rate (FPR) for rice areas by RADARSAT. TPR is the coincidence rate of rice areas by RADARSAT within those by SPOT and FPR is the rate of non-rice areas by SPOT within rice areas by RADARSAT. As the rice area images extracted by RADARSAT are still contaminated by speckle noises, the majority filter with 7 by 7 window was applied once or twice to the rice extracted images by RADARSAT before evaluation. The rice extracted image by SPOT was also filtered once by the same majority operation as RADARSAT to make the ground resolution compatible each other.

Table 1 shows the result of TPR and FPR by the thresholding method for the data pair Apr. 8 and May 26. As the threshold value, -2dB, -3dB and -4dB were set. Table 1 shows almost equal rate for TPR and FPR in all cases, in which the case with -3 dB threshold and filtering twice is the best for the value of TPR-FPR. No other data combination (namely (May 26 - June 19) and (Apr.8-May 26) AND (May 26-June 19)) could obtain the better result for TPR-FPR. Table 2 shows the result by ML classifier of multi date RADARSAT data. The results are slightly better than those in Table 1. The best result for TPR-FPR was obtained by using all three dates and filtering twice, although there are only small differences between two dates and three dates.

In general, the rice area extraction by RADARSAT did not give much high coincidence rate as that by SPOT in the quantitative evaluation. Over 50 percent of rice areas by SPOT were not extracted by RADARSAT and about 30 percent of the areas by RADARSAT were outside areas of rice by SPOT. However, this result doe not always mean that the performance for rice-planted area estimation by RADARSAT is poor because the rice areas by SPOT also may not be so reliable because of only one time observation by SPOT. The fact is only that the rice areas extracted by RADARSAT and SPOT do not coincide well each other. In addition, concerning to the method, ML classifier seems to be slightly better than thresholding because the result of evaluation by SPOT is slightly better for ML classifier.

4.2 Evaluation by Statistical Report

According to the previous result, we adopted ML classifier to multi-temporal RADARSAT and ERS-1/SAR data in the whole areas of Higashi-Hiroshima City and the total area estimate in the city was compared with that by statistical report. Table 3 and 4 show the result by RADARSAT and ERS-1/SAR respectively. As the year of observation is different each other, the rice areas are not the same each other because of yearly change for rice-planting. For both of RADARSAT and ERS-1/SAR, the results of area estimate are quite closed to those by the statistical report in the same year, although the estimate value changes with the filter size. From Table 3 and 4 it is also pointed out that only two times observation before and after rice-planting is almost sufficient for estimating rice-planted areas by both of two SAR sensors.

Figure 4 and 5 show the estimated patterns of rice-planted areas by RADARSAT and ERS-1/SAR respectively. The estimated patterns in both images coincide well each other, although the patterns by ERS-1/SAR look larger than those by RADARSAT. This difference is considered to come from the difference of resolution. However, the result by the statistical report also supports this difference because it reports that the rice areas in 1999 reduced significantly from those in 1993.

5 CONCLUSIONS

Rice-planted area extraction was attempted using multi-temporal RADARSAT and ERS-1/SAR data taken in an early stage of rice growing season. The overall rice distribution patterns extracted by RADARSAT showed a fairly good coincidence with those by SPOT/HRV data taken in the same year of RADARSAT observation. However, by a quantitative evaluation, the rice areas by RADARSAT and SPOT resulted in poor coincidence. On the other hand, the total rice areas estimated by RADARSAT and ERS-1/SAR in Higashi-Hiroshima City resulted in a fairly good coincidence with those by the statistical report. These results suggest that there may still exist some limitation for precise area estimation by SAR data, but at the same time a possibility to obtain a statistical estimation for rice-planted areas of wide areas by SAR data. Therefore, the further study on the practical method for rice area estimation by remote sensing should be continued.

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