ESTIMATION OF PLANTING CONDITION OF PADDY FIELDS UTILIZING TERRASAR-X DATA

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ABSTRACT:

Estimation of planting condition of paddy fields is important for crop assessment, management and planning for food security. Paddy fields show variations at different planting periods for the wide expanse of paddy fields and therefore, it is necessary to have a better observation for paddy planting condition of fixed period and for the wide cropped areas. The Synthetic Aperture Radar (SAR) satellite can perform observations irrespective of all weather condition and highly suitable for fixed observation period of paddy fields. The planting estimation issue of the present study was to decide the observation technology utilizing TerraSAR-X (TSX) satellite data, high resolution SAR imaging day and night and regardless of atmospheric weather conditions, and covering widespread areas in early planting period. The objective of this study was to estimate planting condition of paddy fields by crop characteristics measured by the backscattering coefficients of SAR data. Paddy fields and other fields were prepared by different cultivation methods, and the backscattering coefficients had different values. Characteristics of the different value of time series of each fields had similarities for the distribution of backscattering coefficient. Identifications patterns of each field were designated by the ratio of similarities of the pattern distribution and paddy fields were classified based on the identification patterns of individual fields. The obtained results estimated by TSX data indicated a fair agreement with the field verification results.

1. INTRODUCTION

In recent years, the balance for food supply and demand has raised serious concerns considering global warming and population growth. Paddy is one of the most important cereal crops in Asia. In order to maintain the balance, it is necessary to have a better estimation of paddy production by planting condition of the wide expanse of paddy fields. Plantings periods are different in a certain local area but it is necessary to observe a fixed planting period. The fixed period observations has no influence of the weather condition observation technology due to the latest developments of high resolution spaceborne Synthetic Aperture Radar (SAR) and it has paved the way for observations and regardless of atmospheric conditions (A. Bouvet *et al*., 2009, Juan M. *et al.*, 2010, T. Kurosu *et al.*, 1995, T. Le Toan *et al.*, 1997, Y. Inoue *et al.*, 2002). The planting estimation issue of the present study was adopted the observation technology utilizing TerraSAR-X (TSX) satellite, high quality, high resolution SAR imaging day and night and fixed period observation regardless of atmospheric weather conditions, and covering widespread areas for assessing the paddy fields. The main objective of this study was to estimate planting conditions of paddy fields characteristics measured by backscattering coefficients of the SAR data.

2. STUDY SITE AND DATA UTILIZATION

The study site was located in the Osaki city of the Miyagi prefecture, Japan. The paddy planting period in this region ranges within late April to late May as shown in the crop-calendar in Figure 1. The usual planting date was 10th May and the earlier planting was 30th April and the later planting was 20th May in 2009.

The specification of the acquired TerraSAR-X data is shown in Table 1. Different polarization combinations were HH and VV, incident angle as 49.8 deg. with SpotLight imaging mode having ground spatial resolution of 2.2 m. The acquisition dates ranged from 20th April to 25th June in 2009 at 17:37:09 local time (8:37:09 UTC) once on the 11 days of revisit time of the satellite.

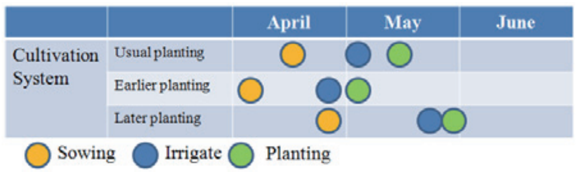

Figure 1. Crop calendar of the test site

Imaging mode	Polarization	Resolution (m)	Size (km)
High resolution Spot Light	HH , VV	2.2	10 × 5

	April	May	June
Acquisition date	20	1, 12, 23	3, 14, 25

Table 1. Specifications of TerraSAR-X, incident angle 49.8 and acquisition dates

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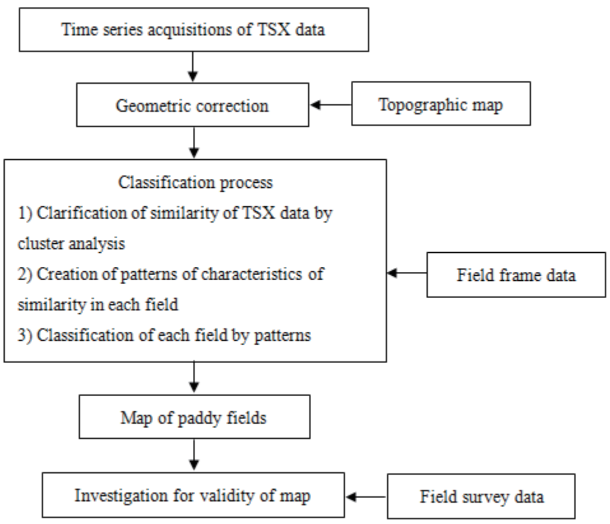

Figure 2. Study procedure

3. METHODOLOGY

The study procedure is depicted in Figure 2. The farmers irrigate the paddy fields during local planting period in Japan and the present study focused to start acquiring the TSX data during plowing, planting and growing periods of a single crop calendar. Analysis of the data followed three combinations, plowing-planting, planting-growing, and plowing-planting and growing terms, respectively. The adopted estimation methodology, considered the crop characteristics utilizing TSX data, is described as below:

1. Clarification of similarity followed the backscattering coefficients' distribution based on the classified scattering component by cluster analysis in all SAR images. The backscattering coefficients of paddy fields included mixed values according to the conditions of the paddy fields. The backscattering coefficients were glancing angle scattering, surface scattering, double-bounce scattering and so on. It is difficult to extract paddy fields directly by image classification in the SAR data mainly due to presence of speckle noise and mixed values.
2. Classification was based on to identify and discriminate paddy vs. non-paddy fields. Discriminant parameters were the characteristics volume value calculated by proportion of classified pixels of cluster analysis to the pixels of a single paddy field. The discriminant value pattern was set by variation in the calculated parameters.
3. Classification was carried out for the agricultural fields into paddy fields and non-paddy fields by the discriminant value pattern. The map of paddy fields was created by classifying agricultural fields. Additionally, in order to investigate validity of the practiced methodology, the estimation of planting conditions of agricultural fields were compared with the field verification campaigns conducted throughout the crop calendar. The field observations were performed for ninety-eight (98) fields.

4. RESULTS AND DISCUSSIONS

4.1 Relationship between backscattering coefficients and paddy fields

The time series of backscattering coefficients of HH and VV polarization combinations in paddy fields are shown in Figure 3 and 4. The changes between HH and VV polarization share many similarities. The curves of time series of backscattering coefficients in the usual planting, the earlier planting and the later planting are different to the peaks of the graphs indicated as bottom chord shape. Additionally, each curve values were similar on 20th April, 23rd May and 25th June of data acquisition dates. The TSX images of the fields and backscattering coefficients for the corresponding dates are shown in Figure 5, 6 and 7, respectively. Acquired images were for usual planting paddy field. In the field of 20th April, the backscattering coefficients were higher due to the influence of plowing. For the fields of 23rd May, the backscattering coefficients were lower due to irrigation. Again, on 26th June, the backscattering coefficients were higher due to crop growth stages. The orders of peaks of the graphs were for the stages of earlier, the usual, and the later plantings, respectively. This difference indicated irrigation scheduling.

The time series of backscattering coefficients of soybean fields and reservoirs are shown in Figure 8 and 9. The soybean curves trend to become between -11dB to -14dB. The reservoirs curves trend to become about -20dB. Paddy and soybean fields and reservoirs showed differences in the time series of backscattering coefficients. This led to classify the paddy fields and non-paddy fields according to the time series difference.

Classifying cropped fields at different time series is a expensive deal for acquiring the SAR satellite data. It is necessary to extract best period of the fields' characteristics considering total cost reduction. The best periods for extractions are shown in Figure 10. There are three periods indicating the similarity of time series according to values of backscattering coefficients in the different irrigated paddy fields. Each field can be divided into paddy fields and non-paddy fields by the three different TSX data acquisition periods.

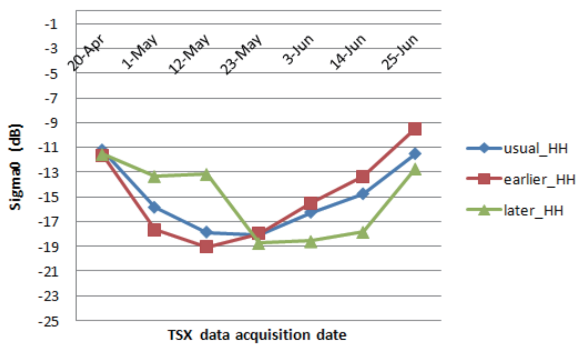

Figure 3. Time series of backscattering coefficients of HH polarization for paddy fields

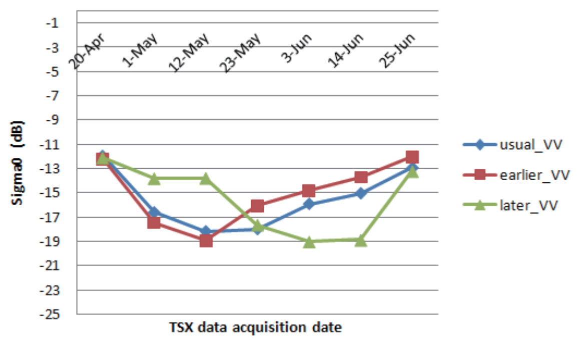

Figure 4. Time series of backscattering coefficients of VV polarization for paddy fields

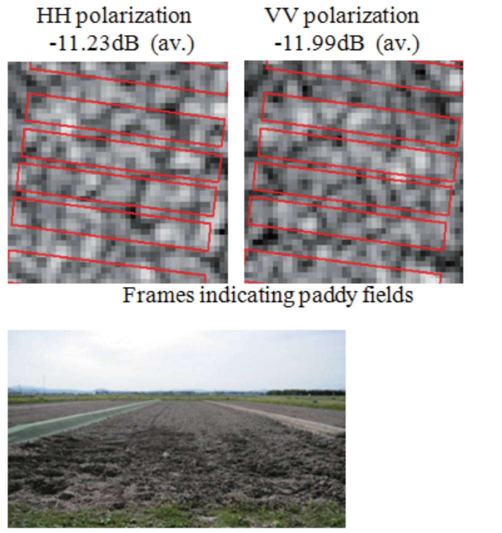

Figure 5. Polarization images (top) and photograph of paddy fields (bottom) on 20-April

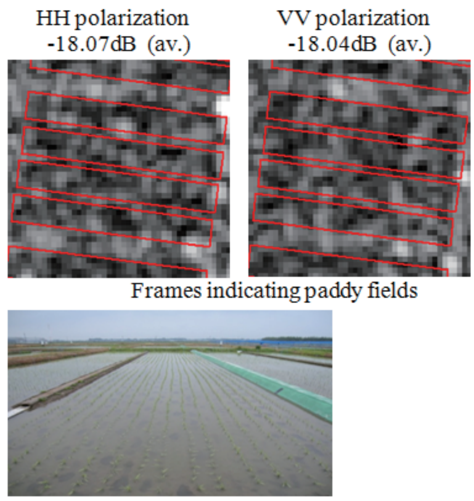

Figure 6. Polarization images (top) and photograph of paddy fields (bottom) on 23-May

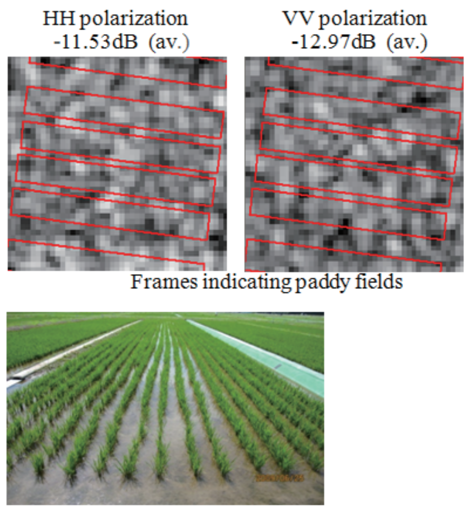

Figure 7. Polarization images (top) and photograph of paddy fields (bottom) on 25-June

4.2 Classification of paddy field and non-paddy field

The extracted distribution values of similarity of time series in each field by cluster analysis for the combinatorial periods are shown in Table 2. The distribution values of similarity of backscattering coefficients in paddy fields are shown in Figure 11. All combination periods show same tendency of the distributions in each field. The distributions of similarity of backscattering coefficient in soybean fields and reservoirs are shown in Figure 12. Each field differs significantly in ratio of the distribution. The ratio of the distribution estimated reflection elements of the scattered microwaves. For example, reservoirs always store water and reflection elements of microwaves have many specular reflections. On the other hand, the ratio of the distribution in paddy fields is due to fluctuations of the changes of plowing, planting and growing field conditions. Patterns were created by the ratio of the distribution in each field and classified for paddy fields and non-paddy fields. Classified fields were compared for the patterns by conducting field verifications (Table 3). The difference was apparent for the direct sowing fields which were not irrigated at planting period. The observed difference was attributed to the different cultivation practices. The findings were in accordance with the observed field verification data. Remarkable differences of the characteristics between the paddy fields and non-paddy fields indicated the possibility for the estimation of planting condition utilizing highest resolution TSX data. Additionally, the methodology could classify paddy fields and non-paddy fields at an early cultivation period.

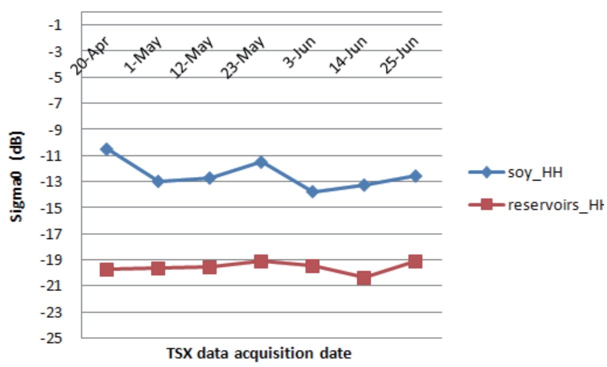

Figure 8. Time series of backscattering coefficients of HH polarization for soybeans fields and reservoirs

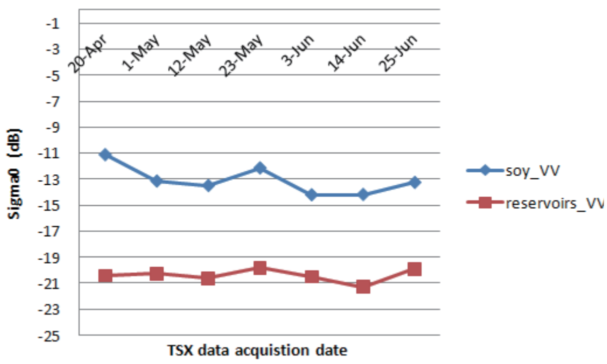

Figure 9. Time series of backscattering coefficients of VV polarization for soybeans fields and reservoirs

5. CONCLUSIONS

The characteristics of agricultural fields were extracted by the time series acquisitions of TSX data. Patterns of the characteristics were clarified for classifying agricultural fields as paddy fields and non-paddy fields. Identifications patterns of each field were designated by the ratio of similarities of the patter distribution. The following conclusions were drawn:

1. The time series of backscattering coefficients in paddy fields resulted bottom chord shape graphs characteristics. The peaks of bottom chord shape graph indicated the order of the earlier planting, usual planting and the later planting stages. This peak difference was affected by irrigation scheduling. Besides, the time series of backscattering coefficient in paddy fields did not differ between HH and VV polarizations.
2. The time series of backscattering coefficients were different between paddy fields and non-paddy fields. This characteristic was affected by the difference of the cultivation practices.
3. It was possible to estimate the planting condition utilizing TSX data due to a notable difference in the patterns of ratio of characteristics between the paddy fields and non-paddy fields. The observed results were substantially in accordance with the field verification data.

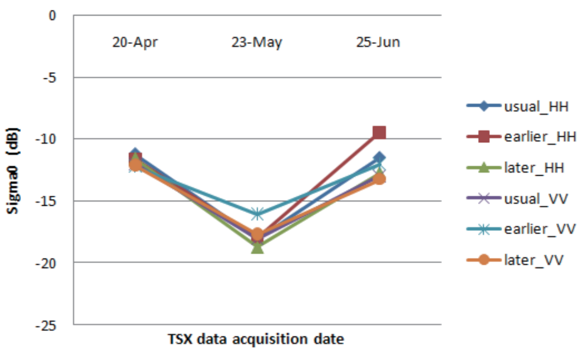

Figure 10. Optimized time series of backscatter coefficients of HH and VV polarizations

Earlier period	Later period	All period
20-April	23-May	20-April
23-May	25-June	23-May
		25-June

Table 2. Combination period for analysis

Field type		count	Match count		
			Earlier period	Later period	All period
Paddy	Usual planting	66	66	66	66
	Earlier planting	4	4	4	4
	Later planting	4	4	4	4
	Direct sowing	7	0	0	0
Non-paddy		17	17	17	17
Total		98	91	91	91

Table 3. Statistical values of estimations for classification

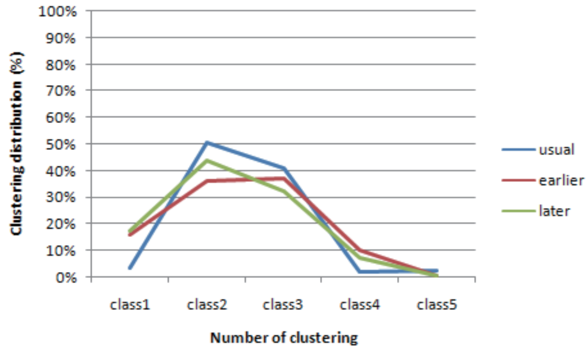

Figure 11. Distributions of similarity of TSX data for paddy fields on 20-April and 23-May

Figure 12. Distributions of similarity of TSX data for soybean fields and reservoirs on 20-April and 23-May

References

A. Bouvet, T. Le Toan, and N. Lam-Dao, Feb. 2009, "Monitoring of the rice cropping system in the Mekong delta using ENVISAT/ASAR dual polarization data," *IEEE Trans. Geosci. Remote Sens.*, vol. 47, pp. 517–526.

Juan M. Lopez-Sanchez, J. David Ballester-Berman, Irena Hajnsek, 2010, "First Results of Rice Monitoring Practices in Spain by Means of Time Series of TerraSAR-X Dual-Pol Images" *IEEE Juornal.* vol. PP Issue:99, pp. 1–11

T. Kurosu, M. Fujita, and K. Chiba, Jul. 1995, "Monitoring of rice crop growth from space using the ERS-1 C-band SAR," *IEEE Trans. Geosci. Remote Sens.*, vol. 33, pp. 1092–1096.

T. Le Toan, F. Ribbes, L.-F.Wang, N. Floury, K.-H. Ding, J. A. Kong,M. Fujita, and T. Kurosu, Jan. 1997, "Rice crop mapping and monitoring usingERS-1 data based on experiment and modeling results," *IEEE Trans. Geosci. Remote Sens.*, vol. 35, pp. 41–56.

Y. Inoue, T. Kurosu, H. Maeno, S. Uratsuka, T. Kozu., 2002, "Season-long daily measurements of multifrequency (Ka, Ku, X, C, and L) and full-polarization backscatter signatures over paddy rice field and their relationship with biological variables," *Remote Sens. Environ.*, vol. 81, pp. 194–204.

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