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Abstract **:** This study investigates the applicability of high resolution satellite-SAR sensors to timely acquisition of crop and management information on a regional scale. X-band SAR images were obtained frequently by COSMO-SkyMed® during the rice-transplanting season. The "water-point method" proved useful for normalization of σ^0 values from SAR images with different configurations. The response of σ^0 to the changes in paddy surface-conditions were elucidated. The chrono-sequential mapping of transplanting-date at individual fields would be realized at regional scale by using X-band SAR images.
Keywords **:** backscattering coefficient, COSMO-SkyMed®, microwave, rice paddy, synthetic aperture radar, water-point method.

1. Introduction

Timely assessment of crop and field conditions is critical for diagnosis and decision making for precision crop management as well as for food security [5)]. Many studies have shown that the synthetic aperture radar (SAR) sensors have great potential for a wide range of agricultural applications due to their superior ability in timely observation of land surfaces [1-5)]. Rice (*Oryza sativa* L.) is the most important staple crop in Asia. Under the cloudy weather conditions in monsoon Asia, SAR sensors are particularly useful for timely monitoring of the rice cropping conditions [1-4)]. The transplanting date in individual paddies is the critical information for accurate diagnosis or prediction of rice growth and yield.

The objective of this study is to investigate the potential of satellite-SAR sensors for such applications. Here, we present the analytical results of the characteristics of hyper-temporal images acquired by the constellation of COSMO-SkyMed® (CSK®) sensors during the transplanting season. The dynamic change of σ^0 values was analyzed in relation to the chrono-sequential change of paddy surface conditions.

2. Data and methods

2.1. Study site and ground-based surveillance

A study site was selected in one of the major rice-growing regions in northeast Japan (Tsugaru Plain, Aomori Prefecture; center: 40º 36' 20.74" N, 140º 33' 36.02" E). The plain is flat and relatively uniform in its rice varieties grown and crop management practices. In general, rice is grown once a year during the summer season (May–September) in this region. The surface conditions of paddy fields in the plain (10 km x 10 km) were observed on the ground periodically throughout the transplanting season.

2.2. Acquisition and processing of SAR images

Eighteen X-band SAR images were acquired in spotlight mode by CSK sensors (9.65 GHz) during the major transplanting period, i.e., from May 10th (DOY130) to June 10th (DOY161) in 2014. Accordingly, the paddy fields were observed by the CSK sensors at an interval of nearly two days. The sensor configurations (spatial resolution, mode, polarization, incidence angle) were selected based on our previous examinations [1,2,4)]. Majority of the images were obtained in VV polarization and a few were in HH for comparison. The range of incidence angle was from 43.1º to 51.5º. A vector file of polygons for the paddy fields in the plain (around 20,000 fields) was used to extract the average and variability of σ^0 values for individual paddy fields from all 18 images. Similarly, σ^0 values were extracted for stable surfaces such as still-water, asphalt and urban areas by assuming that the still-water surfaces, asphalt surfaces and urban areas would be most suitable as reference targets in image-to-image comparison. In each image, more than 20 polygons for each stable-surface category were generated based on the field-surveillance and optical satellite images.

3. Results and discussion

3.1. Characteristics of hyper-temporal images

Fig.1 shows the chrono-sequential change of σ^0 values in stable land surfaces (water, asphalt, urban). The overall range of σ^0 for each of the three types of surfaces during the season was within 4.77 dB. The majority of the variability may be attributable to the difference of sensor configurations such as polarization, incidence angle, and viewing direction. The difference between HH and VV polarizations was minor.

To reduce the variability of σ^0 due to the difference sin SAR configurations, we applied the "water-point method" (i.e., normalization of each image data by subtracting the σ^0 values for water surfaces: this differential σ^0 is designated as $\delta\sigma^0$) [2-4)]. The basis for the method was confirmed by the consistent linear relationship between the σ^0 values for stable surfaces (Fig.2). The consistency was further supported by the additional data points in Fig.2 that were obtained from the images acquired in 2009 and 2010 for the same region (but different season; September). Fig.3 depicts the effects of "water-point method" for improving the consistency of σ^0 values from images at different incidence angles. The temporal mean of $\delta\sigma^0$ in 2014 was

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3.6 dB for asphalt and 10.4 dB for urbans areas.

3.2. Chrono-sequential change of surface conditions and its relation with σ^0

Fig.4 shows the chrono-sequential changes of $\delta\sigma^0$ values in several groups of paddy fields as well as in the stable surfaces. In general, before starting cropping preparations (initial plowing or cultivation), the $\delta\sigma^0$ values for paddy surfaces were around 10 dB, and never reached lower than 5 dB. In normal cases, the $\delta\sigma^0$ tended to increase slightly after starting such preparatory practices, and then drastically decrease with inundation, and reached near 0-1 dB at flooding and puddling stages. These low values are usually found a day before transplanting practice. Just after transplanting, the $\delta\sigma^0$ value usually slightly increases (~3 dB) in response to rice seedlings, but also fluctuates to some extent depending on the water level. Around two weeks after transplanting, the increasing trend of $\delta\sigma^0$ became consistent. In case that paddy fields were used for upland crops (e.g., soybean), $\delta\sigma^0$ kept high values (8-12 dB) with some fluctuations due to cultivation practices.

Accordingly, the transplanted paddies can be discriminated by the low $\delta\sigma^0$ (within a few dB) in each image, and newly transplanted fields are detected by comparing the two consecutive images. Some systematic procedures would be needed for precision mapping since the temporal resolution basically depends on the frequency of SAR observations.

4. Conclusions

The "water-point method" is useful for consistent use of SAR images acquired in different sensor configurations. The chrono-sequential mapping of transplanting-date at individual fields would be realized at regional scale by constellation of X-band SAR sensors. Even a few images during a transplanting season will be useful to improve the crop diagnosis, capability of crop growth models, and assessment of rice yield and quality.

5. References

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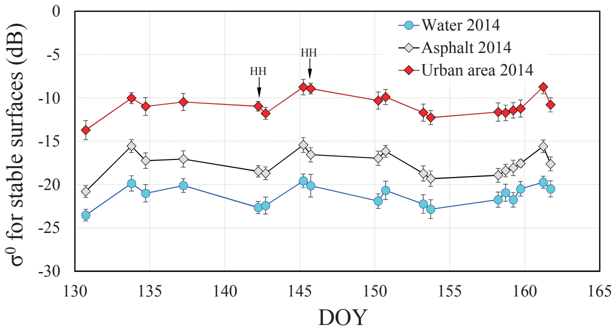

Fig.1. Chrono-sequential change of σ^0 for stable land surfaces.

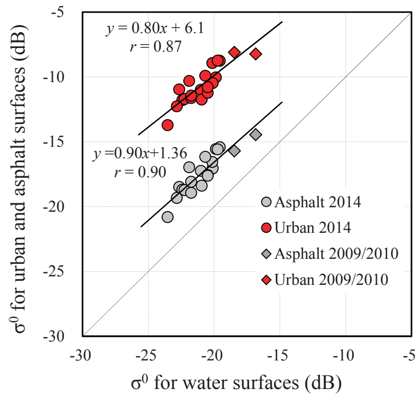

Fig.2. Relationship of σ^0 for asphalt and urban areas against σ^0 for water surfaces within each SAR images.

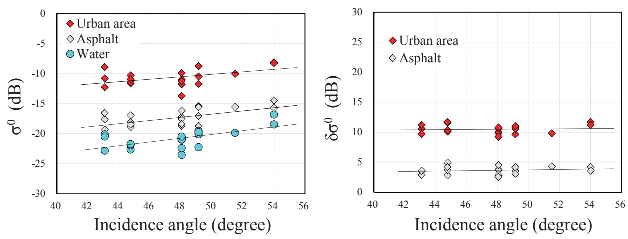

Fig.3. Effects of incidence angle on σ^0 and $\delta\sigma^0$ values for stable land surfaces.

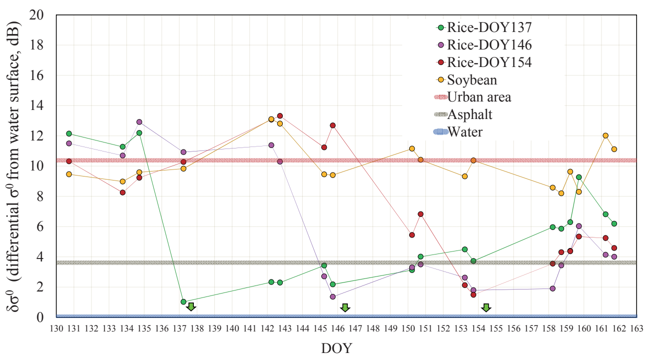

Fig.4. Chrono-sequential change of $\delta\sigma^0$ for typical paddy fields with different transplanting dates and soybean fields.

Acknowledgment: This study was supported in part by CSTI-SIP, Japan.