IOP Conf. Series: Earth and Environmental Science **17** (2014) 012056 doi:10.1088/1755-1315/17/1/012056

The Potential of Polarimetric and Compact SAR Data in Rice Identification

Y Shao[1], K Li[1,3], B Brisco[2], L Liu[1] and Z Yang[1]
[1]State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing Applications, Chinese Academy of Sciences, #3 Datun Road, Chaoyang District, Beijing 100101, China
[2]Canada Centre for Remote Sensing, Earth Sciences Sector, Natural Resources Canada, 588 Booth Street, Ottawa, ON K1A 0Y7, Canada.

Abstract. Rice is a major food staple in the world, and provides food for more than one-third of the global population. The monitoring and mapping of paddy rice in a timely and efficient manner is very important for governments and decision makers. Synthetic Aperture Radar (SAR) has been proved to be a significant data source in rice monitoring. In this study, RADARSAT-2 polarimetric data were used to simulate compact polarimetry data. The simulated compact data and polarimetric data were then used to evaluate the information content for rice identification. The results indicate that polarimetric SAR can be used for rice identification based on the scattering mechanisms. The compact polarization RH and the RH/RL ratio are very promising for the discrimination of transplanted rice and direct-sown rice. These results require verification in further research.

1. Introduction

Rice is a major food staple in the world, and provides food for more than one-third of the global population. The major rice-producing countries of Asia account for more than half of the global population and rice provides nearly 30% of their daily caloric intake [1]. The monitoring and mapping of paddy rice in a timely and efficient manner is very important for governments and decision makers. However, rice is a crop that loves a humid and warm environment and mainly grows in cloudy and rainy regions, which leads to difficulty in optical remote sensing data acquisition. With its advantages of all-weather imaging, independent of illumination, and high repeat coverage, Synthetic Aperture Radar (SAR) has been proved to be a significant data source in rice monitoring.

Rice mapping with SAR is operational now in most countries in southeast Asia. Many successful studies on rice mapping with multi-temporal SAR data have been completed because of the unique temporal backscatter signature of rice, which changes abruptly as the rice grows above the flooded soil [2-4]. Bouvet and Le Toan developed an operational method for timely rice mapping using ENVISAT/ASAR wide-swath data by exploiting the outstanding temporal behaviour of rice backscatter [5]. On the other hand, owing to the great difference between horizontal (HH) and vertical (VV) polarizations caused by the vertical structure of rice, Chen and Li [6] and Bouvet et al. [7] developed rice mapping methods using the polarization ratio (HH/VV) at the C band.

[3] Corresponding author: kunli@irsa.ac.cn

These approaches allow accurate rice identification; however, all these methods for rice mapping use multi-temporal single or multi-polarization data, which can be described generically as 'images', as they do not include the relative phase between the two received channels. Consequently, the previous analysis options are restricted essentially to ratios or differences of their respective images. When the relative phase is retained between the two received polarizations, polarimetric SAR data are obtained, which are sufficient to calculate the covariance matrix that corresponds to the polarimetric degrees of freedom for each type of SAR. In contrast to elemental imagery, such matrices are an entirely different class of data product. They embrace a quantitative measurement of the (relative) phase and amplitudes of the backscattered data, in marked contrast to simple radar brightness [8]. Recently, compact polarimetry (CP) has been suggested as an alternative SAR configuration to maintain swath coverage while require that the relative phase between the two received polarizations be retained [9], in contrast to conventional 'dual-polarized' SARs in which the relative phase is not available. Many investigations have confirmed that CP data are promising for various applications [8]. The objective of this study was to explore the potential of polarimetric and compact SAR data in rice identification.

2. Test site and data source

2.1. Test site

The test site was located in Jinhu (33°15'22.33"N～32°58'35.00"N，118°49'39.97"～119° 6'51.67"), Jiangsu Province, east of China, with an area of 600 km^2 (Figure 1). The terrain is flat, with the average altitude being about 10 m. The size of rice field parcels was about 1700 m^2. The climate belongs to the transition region between the subtropical and the temperate zones, with four distinct seasons. The daylight hours can be up to 2400 every year and the annual average temperature is about 13 to 16^{o}C. The precipitation is about 800 to 1200 mm every year, and more than half of the precipitation occurs from June to September. The soil type of this region is yellow brown clay, which is favourable for the development of rice plants. There is one rice crop a year, with the growth cycle being about 150 days, from early May to late October. There are two rice planting methods, transplanting and direct sowing, which produce two different rice field structures (Figure 2) and have a certain impact on rice yields.

2.2. Data source

During the rice growing season in 2012, multi-temporal RADARSAT-2 polarimetric data were acquired. The details of SAR data are displayed in Table 1.

Table 1. Technical parameters of RADARSAT-2 data acquired in 2012.

Dates	Mode	Product	Resolution (m)		Image Size (km^2)	Incidence angle (°)	Look	Polarization
			Range	Azimuth				
6/27/2012	FQ20W	SLC	5.2	7.6	565	38.89	1	HH/HV/VH/VV
7/21/2012	FQ20W	SLC	5.2	7.6	565	38.89	1	HH/HV/VH/VV
8/14/2012	FQ20W	SLC	5.2	7.6	565	38.89	1	HH/HV/VH/VV
9/7/2012	FQ20W	SLC	5.2	7.6	565	38.89	1	HH/HV/VH/VV
10/25/2012	FQ20W	SLC	5.2	7.6	565	38.89	1	HH/HV/VH/VV

FQW: Fine Quad-pol Wide; SLC: Single Look Complex

The polarimetric SAR data were then used to simulate CP data, transmitting right circular polarization (R) and receiving horizontal (H) and vertical (V) polarizations in order to explore the potential of compact SAR in rice identification. The noise floor of the simulated CP data was -25dB and the resolution was 30 m.

A ground campaign was also conducted in the growing season. Forty-one sample plots were selected, covering 29 transplanted rice fields and 12 direct-sown rice fields. The distribution of the sample plots is shown in Figure 1. Field data were collected from three representative rice plants in each sample plot, including the variety, crop calendar, phenological stage, plantation geometry, plant structural information (plant height, number of leaves, leaf length and width, and number of stems and ears), and plant biomass (dry and wet weight).

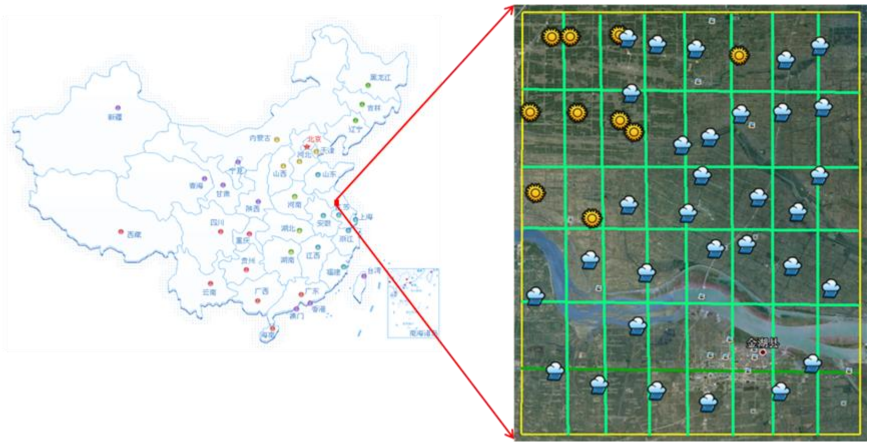


Figure 1. Location of the test site and the distribution of sample plots, cloud and sun symbols indicate transplanted and direct-sown rice fields, respectively.

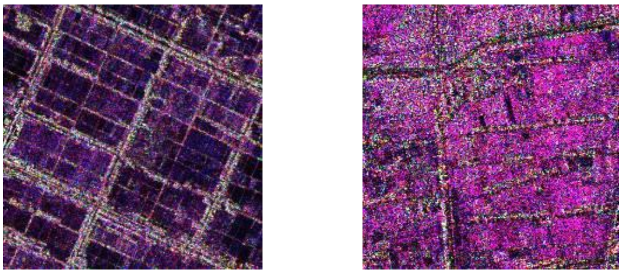
Transplanted Direct-sown

Figure 2. Rice fields in the Jiangsu test site.

3. Results

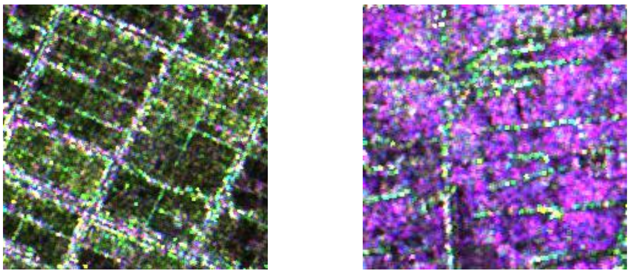
3.1. Backscatter behaviour

In the image acquired on June 27, 2012(seedling stage), transplanted and direct-sown rice showed the largest difference than at the other four dates. Figure 3 shows transplanted and direct-sown rice fields in the polarimetric SAR image acquired on June 27, 2012, and Figure 4 presents the corresponding simulated CP image. It can be seen that the two kinds of rice fields showed some difference in the polarimetric SAR image. Transplanted rice was much darker than direct-sown rice, because there was some water in the transplanted rice fields, but only soil in direct-sown rice fields. In the simulated compact SAR image, the two kinds of rice fields showed a great difference. Transplanted rice fields had great backscatter in RL polarisation, in a green colour, while direct-sown rice fields had great backscatter in RR, in a pink colour. The results indicated that CP data were better for the discrimination of the two kinds of rice fields. Figure 5 provides the backscattering coefficients in linear polarizations (HH, HV, VH, and VV) and compact polarizations (RH, RV, RR, and RL). Urban area and water can be discriminated from other features because of the large difference (≥3 dB) in backscattering coefficients [2]. Forest and lotus root could be identified by their differences in various polarizations. The HH/HV and VV/VH ratios were promising for forest and lotus root identification, respectively. The differences between transplanted and direct-sown rice fields in linear polarisations were no more than 3 dB, so the two kinds of rice fields could not be discriminated. However, they showed a great difference in RH polarization, about 5 dB. In addition, the RH/RL ratio was helpful for the discrimination of the two kinds of rice fields.



Transplanted rice Direct-sown rice

Figure 3. Rice fields in polarimetric SAR image (R: HH, G: HV, B: VV; 6/27/2012).



Transplanted rice Direct-sown rice

Figure 4. Rice fields in the simulated compact SAR image (R: RR, G: RL, B: RH; 6/27/2012).

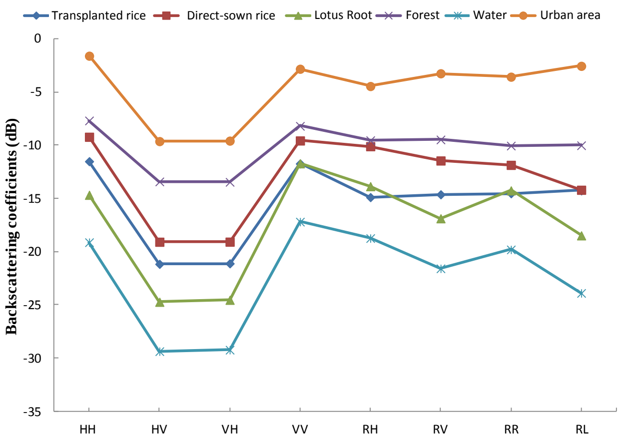
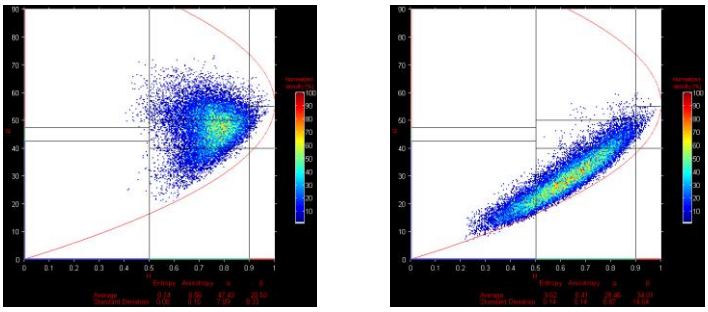


Figure 5. Backscattering coefficients of rice and other features, extracted from polarimetric SAR data acquired on 6/27/2012 and the corresponding simulated CP data.

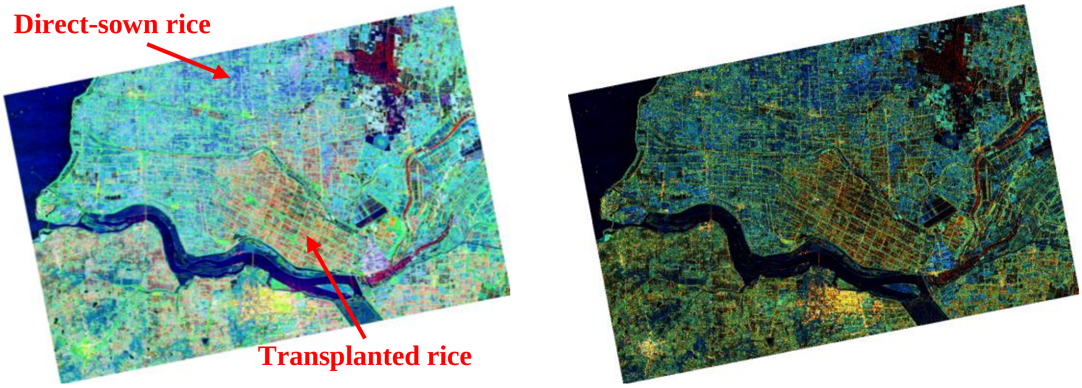
3.2. Scattering mechanisms

Polarimetric decomposition [10-11] was applied for scattering mechanism analysis. Figure 6 shows the distributions of the two kinds of rice fields in a Cloude H-α plot [10]. Transplanted rice fields were mainly in the medium-entropy volume scattering and double bounce region, while direct-sown rice fields were mainly in the low- and medium-entropy surface scattering region. The two kinds of rice fields showed a great difference in scattering mechanisms. Figure 7(a) gives the result of Freeman-Durden decomposition [11] based on polarimetric SAR data of June 27, 2012. Due to the great difference in scattering mechanisms, transplanted rice and direct-sown rice showed a great difference in the image of Freeman-Durden decomposition. The m-delta decomposition for CP data was very similar to the Freeman-Durden decomposition [8]. The m-delta decomposition could also be used to discriminate between transplanted and direct-sown rice (Figure 7[b]), but the result was not as good as the Freeman-Durden decomposition.



Transplanted rice Direct-sown rice

Figure 6. H-α plot (6/27/2012)



(a) Freeman-Durden RGB (R: double bounce, G: volume, B: surface) (b) m-delta RGB (R: double bounce, G: volume, B: surface)

Figure 7. H-α plot (6/27/2012)

4. Conclusion

RADARSAT-2 polarimetric data of a rice-growing region in China were used to simulate CP mode data. The potential of polarimetric and compact SAR data in rice identification were then evaluated. The results indicate that polarimetric SAR can be used for rice identification based on the scattering mechanisms. The compact polarization RH and the RH/RL ratio are very promising for the discrimination of transplanted and direct-sown rice. These initial results emphasise the value of polarimetric data and compact polarimetry data for rice identification. These results require verification and improvement in further research.

5. Acknowledgements
This work was supported by the CAS Knowledge Innovation Program (KZCX2-EW-320). The authors would like to take this opportunity to express their sincere appreciation to the Canada Centre for Remote Sensing for providing help in the CP data simulation.

References

[1] FAOSTAT (Food and Agriculture Organization of the United Nation). 2007. Food Balance sheets. Available from http://faostat.fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor.

[2] Le Toan, T, Ribbes, F, Wang, L F, Floury, N, Ding, K H, Kong, J A, Fujita, M and Kurosu, T. 1997. Rice crop mapping and monitoring using ERS-1 data based on experiment and modeling results. *IEEE Transactions on Geoscience and Remote Sensing*, **35**(1), 41-56.

[3] Ribbes, F, and Le Toan, T. 1999. Rice field mapping and monitoring with RADARSAT data. *International Journal of Remote Sensing*, **20**(4), 745-765.

[4] Choudhury, I, and Chakraborty, M. 2006. SAR signature investigation of rice crop using RADARSAT data. *International Journal of Remote Sensing*, **27**(3), 519-534.

[5] Bouvet, A, and Le Toan, T. 2011. Use of ENVISAT/ASAR wide-swath data for timely rice fields mapping in the Mekong River Delta. *Remote Sensing of Environment*, **114**(4), 1090-1101.

[6] Chen, H L, and Li, H G. 2008. Rice recognition using multi-temporal and dual polarized synthetic aperture radar images. In *Proceedings of the ISECS International Colloquium on Computing, Communication, Control, and Management 2008*, 3–4 August 2008, Guangzhou, China. Yu, F, Chen, Y J and Zhou, Q H (eds), IEEE Computer Society, Piscataway, N J. pp. 96-100.

[7] Bouvet, A, Le Toan, T, and Lam-Dao, N. 2009. Monitoring of the rice cropping system in the Mekong Delta using ENVISAT/ASAR dual polarization data. *IEEE Transactions on Geoscience and Remote Sensing*, **47**(2), 517-526.

[8] Charbonneau, F J, Brisco, B, Raney, R K, McNairn, H, Liu, C, Vachon, P W, Shang, J, De Abreu, R, Champagne, C, Merzouki, A, and Geldsetzer, T. 2010. Compact polarimetry overview and applications assessment. *Canadian Journal of Remote Sensing*, **36**(S2), S298-S315.

[9] Raney, R K. 2007. Hybrid-Polarity SAR Architecture. *IEEE Transactions on Geoscience and Remote Sensing*, **45**, 3397-3404.

[10] Cloude, S R, and Pottier, E. 1996. A review of target decomposition theorems in radar polarimetry. *IEEE Transactions on Geoscience and Remote Sensing*, **34**(2), 498-518.

[11] Freeman, A, and Durden, S L. 1998. A three-component scattering model for polarimetric SAR data. *IEEE Transactions on Geoscience and Remote Sensing*, **36**(3), 963-973.