EFFECTS OF CHANGING RICE CULTURAL PRACTICES ON C-BAND SAR BACKSCATTER USING ENVISAT ASAR DATA IN THE MEKONG DELTA

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ABSTRACT

Rice cultivation systems in various countries of the world have been changing in recent years. The change has been observed in the Mekong Delta in Vietnam, where new cultural practices have been gradually adopted in the last 10 years. Some of these practices include the use of short cycle rice varieties instead of long cycle ones and direct sowing on wet soil instead of transplantation on flooded fields, with a much higher plant seedling than before, etc. These changes in cultural practices have impacts on remote sensing methods developed for rice monitoring, in particular, methods using radar data, which are based on the temporal change of C-band backscattering intensity of flooded vegetation canopy to identify rice fields and to retrieve rice biomass. The impact on other more recent methods using two polarisations (HH, VV) also needs to be evaluated. This study showed that the radar backscattering behaviour is much different from that of the traditional rice previously reported, due to changes brought by modern cultural practices. HH, VV and HH/VV of ENVISAT ASAR APP data are not strongly related to biomass as in the reported traditional rice results. This is explained by the effect of water management, plant density and structure. However, the polarization ratio of rice fields during a long period of the rice cycle could be used to derive the rice/non-rice mapping algorithm with a high accuracy of planted rice areas.

1. INTRODUCTION

Food security has become a key global issue due to the Asian region's rapid population growth, extensive conversion of arable lands, and declining overall productivity in some areas. For this reason, there is a need to develop spatio-temporal monitoring system that can accurately assess rice area planted, crop vigour and health, and to predict crop yield.

Research on rice crop monitoring using satellite radar data has been conducted in various countries. Theoretical modelling has indicated that, at C band, the dominant scattering mechanism of HH and VV is the double bounce vegetation-water scattering (Le-Toan et al., 1997). Experimental results confirmed that a) the radar backscattering coefficients of rice fields have a characteristic increasing temporal behaviour resulting from the increase of double bounce scattering with plant biomass, b) similar variations of the backscattering coefficients were observed in different areas when expressed as a function of rice biomass, and c) the backscattering intensity at C-band VV (ERS) or HH (RADARSAT) increases with increasing biomass during the vegetative phase (Le-Toan et al., 1997).

The rice growing areas of the Mekong Delta are a good example to study the changes from traditional to modern rice cultivation system. These changes can have a significant impact on radar backscattering behaviour that may have an influence on remote sensing methods. The study site is located in the An Giang province, where SAR data and ground data were acquired over a period of 12 months in the year 2007. The objectives of the study were a) to determine relationships between radar backscatter coefficients and selected parameters (height and biomass) of rice crops over an entire growth cycle and b) to develop algorithms for mapping and monitoring rice cropping systems using multi-date SAR imagery.

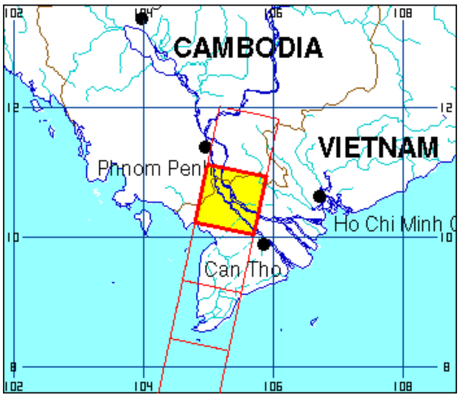
2. TEST SITE AND DATA

2.1 Test site

The Delta has a monsoon tropical semi-equatorial climate. Two seasons are distinguishable: the rainy season that lasts from May to November and constitutes approximately 90 percent of the total rainfall of 1600-2000 mm, and the dry season that lasts from December to April. The combination of hydrology, rainfall pattern, and availability of irrigation constitutes the variety of rice-based cropping systems practiced in the area. The major rice cropping systems are listed in table 1.

Table 1. Main rice-based cropping systems in the Mekong Delta

Rice cropping system	Rice season
Single rice crop	Traditional rice (rain-fed)
Double rice crop	Summer Autumn (SA) – Autumn Winter (AW) (rain-fed)
	Winter Spring (WS) – Summer Autumn (irrigated)
Triple rice crop	Winter Spring – Summer Autumn - Autumn Winter



a)

b)

Figure 1. Location of the frame of ASAR APP scene on the study site (a) and Administrative boundary map of An Giang, with locations (red dots) of the samples (b).

The study area is the An Giang province (Figure 1), extending from 10^o 12’ to 10^o 57’ N latitude and 104^o 46’ to 105^o 35’ E longitude and is covered by the entire 100 x 100 km ENVISAT ASAR scene IS2 mode (Figure 1a). Located at the border of Cambodia, about 190km from Ho Chi Minh City, An Giang has an area of 3,536.8 square kilometres, with a population of about 2,210,400 people (GSO, 2006). In An Giang province, agricultural land covers the largest area (281,862 ha), of which 82% (264,284ha) is dominated by rice farms (An Giang DARD, 2005). The main rice seasons in the province are listed in table 2.

Table 2. Main rice seasons in An Giang, Mekong River Delta

Rice crop		Planting	Harvesting
English name	**Local name**		
Winter Spring	Dong Xuan	Nov./Dec.	Mar./Apr.
Summer Autumn	He Thu	Apr./May	Jul./Aug.
Rainy season	Thu Dong (AW)	Jul./Sep.	Oct./Dec.
	Mua (Traditional rice)	Jul./Sep.	Nov./Jan.

2.2 SAR data

This study used the ENVISAT ASAR APP data of HH and VV polarization, IS2 incidence angle (19.2^O – 26.7^O) at 35-day repeat interval. The APP images have a nominal spatial resolution of 30m x 30m and pixel size of 12.5m x 12.5m. The data under study have been acquired at 10 dates in 2007 covering three rice crops: WS (13 Jan., 17 Feb., 24 Mar.); SA (28 Apr., 02 Jun., 07 Jul.) and rainy season (15 Sep., 20 Oct., 24 Nov., 29 Dec.).

2.3 Ground and survey data

Seven sampling areas which are located in Chau Phu, Chau Thanh, Thoai Son and Cho Moi district were selected to meet the research objectives (Figure 1b). The measurements were done on five rice fields in each of the seven sampling areas. The parameters measured for each field include general parameters, plant parameters, leaf parameters and panicle parameters. All field works were accomplished during or near the time of the satellite pass.

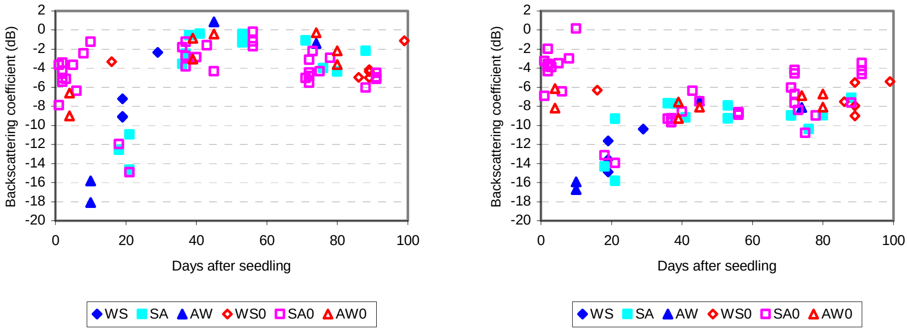
For WS, SA and AW crops, the farmers use various seed varieties of short cycle (80 to 105 days). Direct seedling method was dominant at about 80% of the selected fields. In each sampling area, the sowing/transplanting dates differ between the sampling fields from 0 to a maximum of 9 days. The plant densities of sampling fields measured at the middle of the season have average values of 928, 850, 750 stems per square meter in WS, SA and AW crops, respectively, whereas plant density of 200 stems per square meter was observed in traditional practiced rice fields at the same stage as reported by Le-Toan et al. (1997).

3. ANALYSIS OF THE RADAR BACKSCATTER

3.1. Effect of water/no water in the field

With the present technique of direct sowing, at the early stage of the rice crop cycle, the fields in the test area were wet soil. After 10-20 days, the fields were filled with water.

Backscatter temporal variations of HH and VV polarization data for the three rice crops WS, SA, and AW in the year 2007 were presented in figure 2 and described as follows: 1) At the beginning of the rice season (<20 days after sowing), flooded and non-flooded rice fields have low and high backscatter, respectively; 2) During the period of 20-70 days, flooded and non flooded fields have similar high backscatter response; 3) After the age of 70 days, almost backscattering coefficient values of the rice fields without water are slightly lower in HH and higher in VV compared to that of fields with standing water (Figure 2); 4) The polarisation ratio (HH/VV) was presented in figure 3. In general, the ratio increases until the period 30-60 days, then decreases until harvest. The most striking observation is the high value of the ratio (4.6 to 7.8 dB for flooded fields). However, fields without water at the SAR overpass have large dispersion of the ratio values, varying from -1.4 to 6.5 dB.



a) HH b) VV

Figure 2. Backscatter temporal variation of HH (a) and VV (b) in WS, SA and AW crops, 2007 of the fields with water and without water.

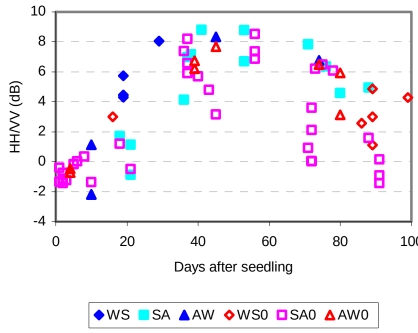
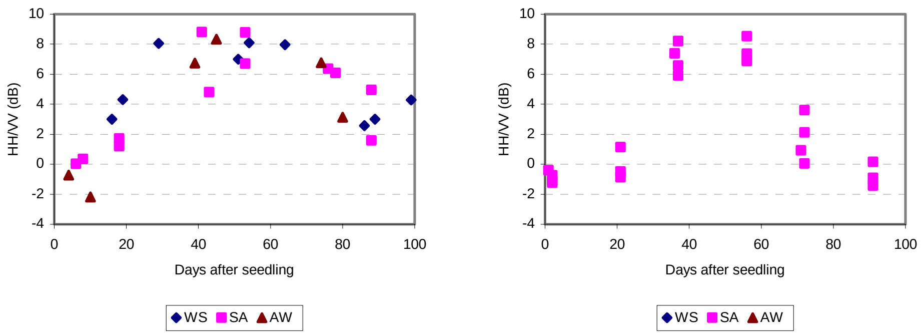


Figure 3. Temporal variation of HH/VV ratio in WS, SA and AW crops, 2007 of the fields with water and without water.

3.2. Effect of plant structure and seed varieties

Plant structure and different rice varieties can have impact on radar response. HH/VV can have lower values when the plant structure deviates from vertical. The differences in plant structure are also related to rice varieties. As plotted in figure 4b, most of IR 50404 rice variety is characterized by a very low HH/VV (i.e. below 1 dB at the end of the rice crop), whereas Jasmine species with a quasi-vertical structure has higher ratio (Figure 4a) at the same stage of the rice season.



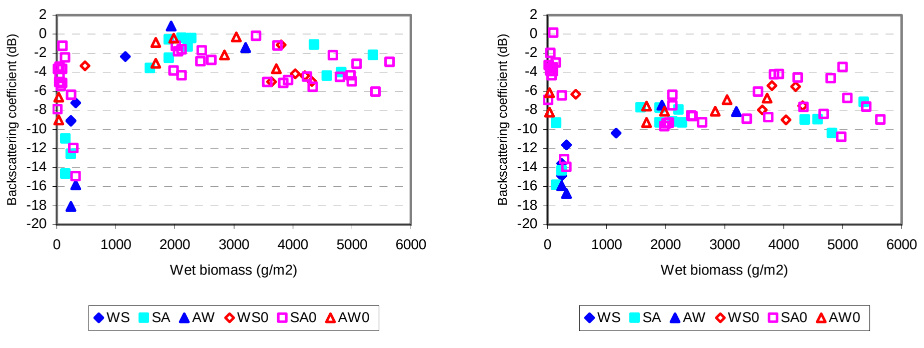
a) b)

Figure 4. Temporal variation of HH/VV ratio of Jasmine (a) and IR 50404 varieties (b) in WS, SA and AW crops, 2007.

3.3. Radar backscatter and rice biomass

In traditional rice cultivation system, radar backscatter was found to be strongly correlated to rice parameters i.e. plant height and biomass (Le-Toan et al., 1997). Backscatter of rice fields increases steadily during the growing stage and then reaches a saturation level. Radar backscatter can increase by more than 10 dB from the beginning of the crop (flooded fields) to the saturation level (Le-Toan et al., 1997).

An analysis of the relationship between radar backscatter and rice biomass in the study site of An Giang was carried out. Figure 5 shows the HH and VV data as a function of biomass. HH and VV polarization data increases strongly until the plant fresh biomass reaches 1000 g/m^2 (at 30 days after sowing). However, for unflooded fields, the increase in HH is smaller and VV even decreases. A saturation level of backscatter is reached at around 2000 g/m^2 at the middle of crop cycle. After saturation level, radar backscatter remains stable and slightly reduces for HH and rises for VV until biomass gets to maximum values.



a) HH b) VV

Figure 5. Radar backscattering of HH (a) and VV (b) versus plant wet biomass in WS, SA and AW crops, 2007.

Figure 6 shows the polarization ratio (HH/VV) as a function of rice biomass. Only the increase of HH/VV at the beginning of the season is clearly observed. However, this increase is restricted to the first month or a limit of 1000g/m^2. After this date, the backscatter of non flooded fields has a large dispersion with respect to biomass. Figures 5 and 6 show that retrieving rice biomass using HH, VV or HH/VV is not applicable to modern rice practices.

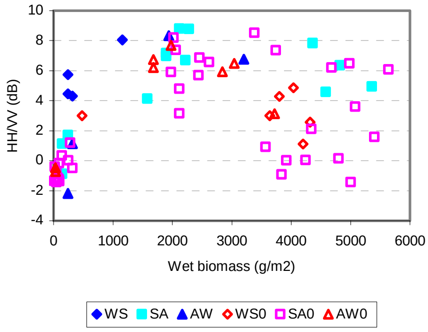


Figure 6. Polarization ratio versus plant wet biomass in WS, SA and AW crops, 2007.

4. RICE MAPPING

The previous analysis results have shown that the ratio HH/VV is a good classifier during the period of 30 days to 60 days after seedling. Classification method based on HH/VV ratio was tested on the image taken in the middle of Winter Spring crop cycle (i.e. February) to map rice and non-rice. A threshold of HH/VV (Ra) value = 3dB is used to segment rice and non-rice area. In order to reduce the confusion with other non-rice areas having high HH/VV ratio (e.g. reed or marshland with vertical structure of the plants), an additional criteria was added: VV < -7 dB. Then, the ENVISAT ASAR images taken in the middle of crop cycle of Summer Autumn and rainy season, i.e. June and October respectively were used for mapping the rice/non-rice of the various crop seasons during the year 2007. Figure 7 shows the pixel based mapping results.

a) b) c)

Figure 7. Rice maps (green pixels) of WS (a), SA (b) and rainy season crop (c)

The accuracy assessment of the classified rice pixels in the WS (Table 3) and SA crops has been produced based on the statistical data published by An Giang DARD, 2007 for the WS crop and provided by An Giang Statistics Office (for SA crop).

Table 3. Difference of rice acreages in WS crop produced by ASAR data and statistical data

District name	Agency data (Ha) (**)	Rice from SAR (Ha)	Difference in WS crop (%)
Phu Tan	23041.0	24560.8	6.6

Chau Phu	34382.5	36533.3	6.3
Tri Ton (*)			
Tinh Bien	14797.0	15065.5	1.8
Chau Doc	7094.3	6973.9	-1.7
Long Xuyen	5590.8	5303.7	-5.1
Thoai Son	36714.0	38992.1	6.2
Tan Chau	11420.0	10095.8	-11.6
An Phu	13982.5	12421.5	-11.2
Cho Moi	17886.0	17344.3	-3.0
Chau Thanh	27685.5	28804.1	4.0
Province	192593.6	196094.9	1.8

(*) Outside of the SAR image coverage; (**) Source: An Giang DARD, 2007

The difference between rice area by district from the classified image and the statistics ranged from -11.6 to 6.6% (Table 3) for WS and -11.1 to 4.0% for SA crops. The differences of provincial rice grown acreages, however, are of 1.8% in WS crop and -1.3% in SA crop. The rice cropping system map has been produced by combining three rice/non-rice maps of Winter Spring, Summer Autumn and rainy season crops.

5. CONCLUSIONS

As a consequence of changes brought by modern cultural practices, the radar backscattering behaviour is much different from that of the traditional rice plant previously reported in scientific literature. At the early stage of the season, direct sowing on fields with rough and wet soil surface provided very high backscattered values for both HH and VV data (about -7 to -2 dB). Around 10 – 20 days after sowing, rice plants attained approximately 20 cm high and field flooding decreases dramatically the backscatter to -18 to - 12 dB. The backscatter then increases and reaches a saturation level (-2 to 1 and -9 to -7 for HH and VV, respectively) at the middle of crop cycle. The very high value of HH and the similar response of flooded and unflooded fields are explained by the high plant density. HH, VV and HH/VV are not strongly related to plant biomass as in the reported traditional rice results. This is explained by the effect of water management, plant density and structure. As a result, retrieving rice biomass using HH, VV or HH/VV is not applicable to modern rice growing practices that prevailed in the study area. However, the polarization ratio of rice fields during a long period of the rice cycle could be used to derive the rice/non-rice mapping algorithm. The results using ASAR APP data acquired at a single date provided a high accuracy for mapping rice area planted.

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