Rice Monitoring Using ENVISAT ASAR Data:
Preliminary Results of a Case Study in the Mekong River Delta, Vietnam

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ABSTRACT: Vietnam is one of the world's largest rice exporting countries, and the fertile Mekong River Delta at the southern tip of Vietnam accounts for more than half of the country's rice production. Unfortunately, a large part of rice crop growing time coincides with a rainy season, resulting in a limited number of cloud-free optical remote sensing images for rice monitoring. Synthetic aperture radar (SAR) data allows for observations independent of weather conditions and solar illumination, and is potentially well suited for rice crop monitoring.
The aim of the study was to apply new generation Envisat ASAR data with dual polarization (HH and VV) to rice cropping system mapping and monitoring in An Giang province, Mekong River Delta. Several sample areas were established on the ground, where selected rice parameters (e.g. rice height and biomass) are periodically being measured over a period of 12 months. A correlation analysis of rice parameters and radar imagery values is then being conducted to determine the significance and magnitude of the relationships.
This paper describes a review of the previous research studies on rice monitoring using SAR data, the context of this on-going study, and some preliminary results that provide insights on how ASAR imagery could be useful for rice crop monitoring. More work is being done to develop algorithms for mapping and monitoring rice cropping systems, and to validate a rice yield prediction model for one year cycle using time-series SAR imagery.

1. INTRODUCTION

Rice is one of the world's major agricultural crops. It is the staple food of more than 50% of the Earth's population (FAO, 2002). In Asia, food security has become a key global issue due to the region's rapid population growth, extensive conversion of arable lands, and declining overall productivity in some areas. There is a need to develop spatio-temporal monitoring system that can accurately assess rice crop's vigour and health, area planted, and yield.

Vietnam is one of the world's largest rice exporter countries, second only to Thailand in rice exports (FAOSTAT, 2003). In 2003, 11% of the 13.8% of rice exported from Vietnam was harvested from the Mekong Delta.

In the past years, many research projects on rice crop monitoring have been done using remote sensing data. Among them, space-borne radar remote sensing imagery was used as main data source. Since the 1990s, new radar technology and increased image data availability has occurred with the launch of new systems in 2002 (Envisat), 2006 (ALOS) and 2007 (TerraSAR). New systems are scheduled in the near future e.g. Canada's Radarsat-2. Thus, space-borne radar remote sensing technological advances will continue to expand the range of data sources and new opportunities for research and applications on rice monitoring.

Rice crop monitoring, using satellite radar imagery, has been conducted in various countries including Indonesia (Le-Toan et al., 1997); Japan (Le-Toan et al., 1997); Vietnam (Lam-Dao et al., 2005); China (Bouvet et al., 2005); Sri Lanka (Frei et al., 1999); India (Choudhury and Chakraborty, 2006); and the Philippines (Chen and Mcnairn, 2006); etc. These studies reported results on various aspects including experimental SAR data analysis as a function of rice biophysical parameters and their temporal change, interpretation of the observations by theoretical modelling, determination of classifiers, development or application of classification methods, retrieval of biophysical parameters and interface with rice growth models for crop yield prediction.

With dual polarization capability, the recent ASAR data present an asset on the previous data sources. The objective of our study is to gain insights on how dual polarisation ASAR imagery could be useful for rice crop monitoring and mapping. This paper presents preliminary results in the Mekong delta.

2. METHODOLOGY

To monitor rice production, the methodology considered the rice growing stages and cropping systems, environmental and rice parameters data, and satellite systems and data.

2.1 Study Area

Figure 1: Location (left) and Administrative boundary map (right) of An Giang province

The study area (figure 1), An Giang province, Vietnam is located in the Mekong river plain, South of Vietnam and is surrounded by Kien Giang, Can Tho and Dong Thap provinces, and Cambodia. Located about 190km from Ho Chi Minh City, An Giang has an area of 3,406 square kilometres, with a population of about 2,170,100 people (2004 statistical data). Agricultural land covers the largest area (281,862 ha), of which 82% is dominated (264,284ha) by rice farms (An Giang Department of Agriculture and Rural Development, 2006).

2.2 Description of Rice Growing and Rice Cropping Systems

The temporal aspect of rice development is important for the understanding of the radar responses of rice fields at different growing stages. In wetland rice cultivation, three main periods can be distinguished: the sowing-transplanting period, the growing period (vegetative phase and reproductive phase), and the after-harvest period (Le-Toan et al., 1997).

Table 1: Main rice seasons in An Giang, Mekong River Delta

Rice crop	Local name	Planting	Harvesting
Winter-Spring	Dong Xuan (DX)	Nov./Dec.	Mar./Apr.
Summer-Autumn	He Thu (HT)	Apr./May	Jul./Aug.
Rainy season	Thu Dong (TD)	Jul./Sep.	Oct./Dec.
	Mua (M)	Jul./Sep.	Nov./Jan.

The combination of hydrology, rainfall pattern, and availability of irrigation constitutes the variety of rice-based cropping systems (table 1) practiced in the Mekong River Delta. The annual rainfall is 1600-2000 mm mainly falling between May and November.

2.3 Data Acquisition

2.3.1 Imagery Used for Analyzing the Winter-Spring Crop: Three Envisat ASAR APP (alternating polarization precision) data of HH/VV polarization, IS2 incidence angle, and ascending mode at 35-day repeat intervals acquired from January to March 2007.

2.3.2 Ground Data: Seven sample areas, in each of 5 fields over a large range of conditions, were selected on the basis of cropping systems and yield prediction criteria for both the double and triple crop rice. Field measurement included plant, leaf and panicle parameters based on the guidelines by Le-Toan (2002).

2.3.3 Maps: Existing land use / land cover map (1:50,000) of An Giang province, cadastral maps and 1:50,000 topographic maps were utilised.

2.3.4 SAR Data Pre-processing: The SAR data pre-processing consisted of a) image calibration or conversion to the radar backscattering coefficient sigma nought (σ^o); b) image registration; and c) image spatial filtering. Image calibration consists of correcting SAR images for incidence angle effect and for replica pulse power variations to derive physical values. This will transform SAR precision images into intensity images expressed in σ^o in dB (decibel).

Image registration is performed to register the calibrated images (dual polarizations and multidate) using correlation or control point methods. The image filtering is to reduce the speckle effect. In this work, enhanced Frost spatial filter has been applied to each image (Lopes et al., 1990 and Shi and Fung, 1994).

2.3.5 Rice Crop Mapping and Monitoring: Previous research results showed that rice fields present a large variation in their temporal radar response (Le-Toan et al., 1997). To identify rice fields, an alternative is to use the temporal change between any pair of data required during the crop cycle or between the end of one cycle and the beginning of the following cycle.

The current study used VV and HH/VV ratio at low incident angle IS2 as classifiers for rice/non rice mapping algorithm based on thresholding using Envisat ASAR APP data acquired at a

single date (Bouvet et al., 2005). At C band, the dominant scattering mechanism of HH and VV is the double bounce vegetation-water. The radar response of HH is higher than that of VV (figure 3) because of the stronger attenuation of VV by vertical stems. We have found that any pixels of the image taken in the middle of crop cycle (i.e. February 2007) are classified into rice class if their values satisfy two thresholds: *HH/VV > 3dB and σ^o of VV < -7dB*. The accuracy assessment of the classified rice pixels was produced based on the statistical data published by local Department of Agriculture and Rural Development.

3. PRELIMINARY RESULTS

3.1 Rice Growth Monitoring

Five sample fields at Long Dien B village of Cho Moi district, namely LDB1, LDB2, LDB3, LDB4, and LDB5, were selected for Winter-Spring rice crop monitoring analysis. These rice fields were planted during December 16-28, 2006 and harvested at March 28-30, 2007. The rice parameters were collected and measured on the ground on January 12, February 08, and March 23, 2007. The relationship of plant height and rice biomass was plotted in the figure 2.
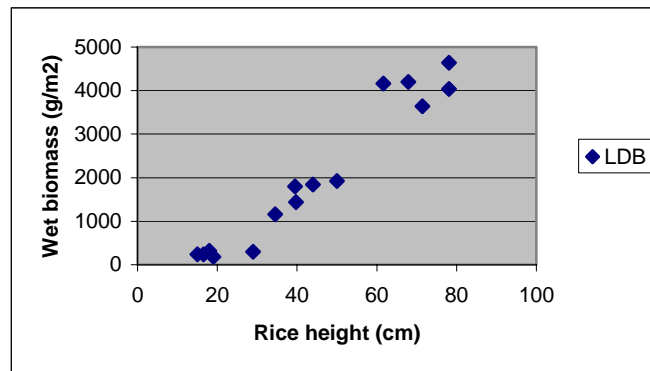

Figure 2: Relationship of plant height and rice biomass at LDB samples

The sigma nought of rice samples derived from the radar images determined the temporal change of rice field's radar backscattering during the growth cycle (figure 3). The strong temporal variation of the radar response is due to the wave-vegetation-water interaction. Note that HH backscatter is higher than VV.
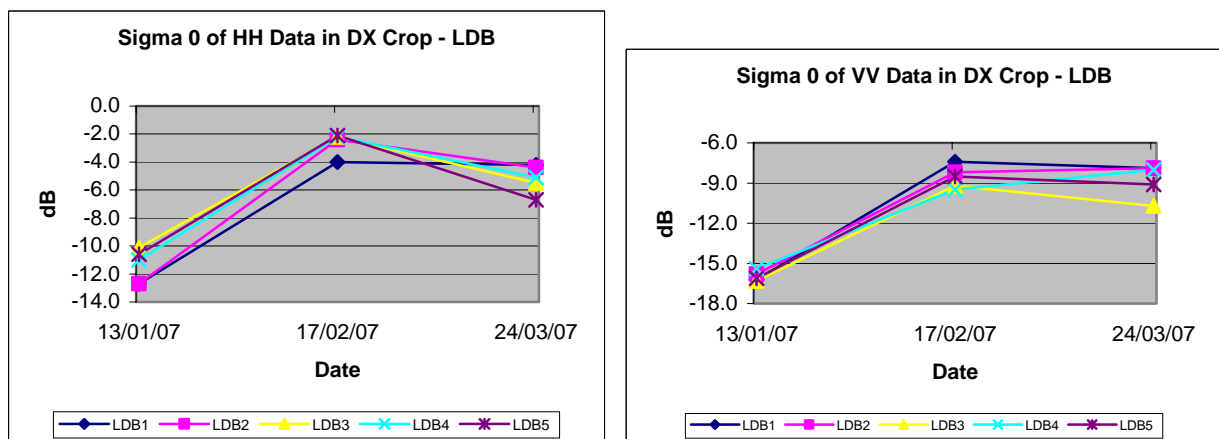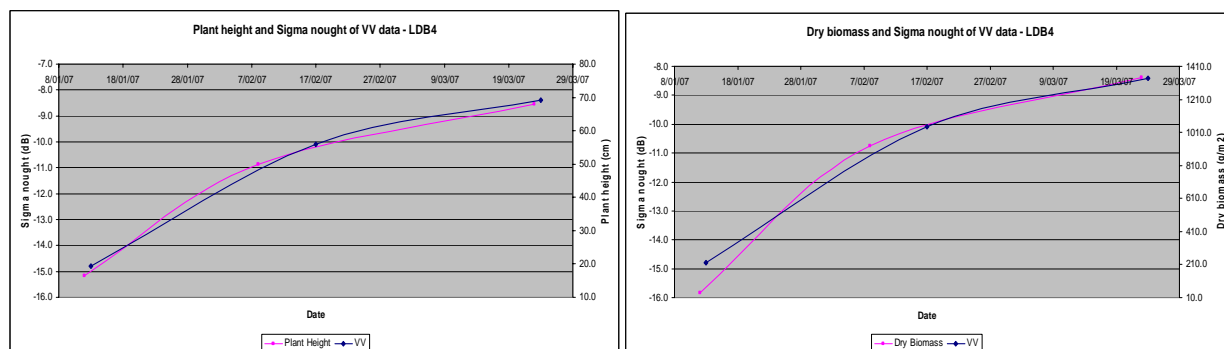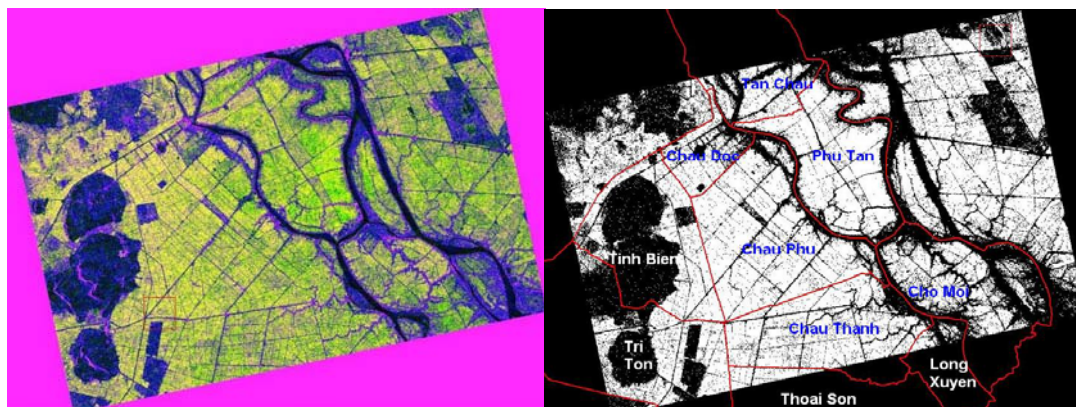

Figure 3: Temporal variation of σ^o of HH (left) and VV (right) polarization in DX crop

Figure 4: Temporal variation of σ° of VV and plant height (left), biomass (right)

Correlation analysis of rice parameters and radar imagery values depicts an increasing trend of backscattering coefficient of VV polarization as a function of rice parameters, i.e. plant height and rice biomass (figure 4). Figure 5 shows the temporal variation of HH/VV. While rice backscatter increases with the plant biomass, the other classes of land cover, urban areas, annual crop, forest, rural areas and river show the relatively stable backscatter ratio. HH/VV appears to be a simple and robust classifier.

Figure 5: Temporal variation of HH/VV of rice (left) and other land use classes (right)

3.2 Rice/Non Rice Mapping

Using single-date SAR data with dual polarizations and their ratio, a colour composite image was produced (figure 6). In the image, pixels were interpreted as rice in green and non rice in blue colour, which could be rivers, dikes, roads, forest, annual crops, etc. Magenta colour pixels show residential areas. Different crop calendars can be interpreted from this image composite.

Figure 6: Colour composite (HH-HH/VV-VV) image (left) and rice/non rice image (right)

A classified image of rice in white (figure 6) was produced using single-date mapping algorithm for dual polarization ASAR data with thresholding values referred to in 2.3.5 (figure 3 & 5). Fine line structures such as dikes, canals, small roads are well apparent. Figure 7 shows details of the classification results compared to an existing land use map.
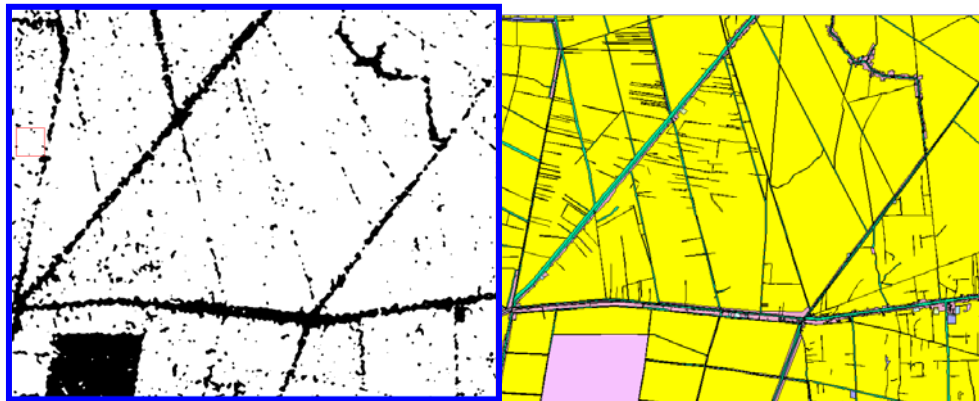

Figure 7: Subset of rice/non rice image (left) and GIS land use map (right)

The accuracy assessment was done using the statistical data on planted rice acreage in Winter-Spring crop by district as published by An Giang Department of Agriculture and Rural Development. Three districts, namely Phu Tan, Chau Doc and Chau Phu fully covered by the image were selected for assessment. The difference between rice area mapped from classified image and the statistics ranged from -1.7 to 6.7% (table 2).

Table 2: Difference of rice acreages produced by ASAR data and statistical data

District Name	Area_GIS (Ha)	Rice (Pixel)	Rice (Ha)	Statistical rice (Ha)*	Difference (%)
Phu Tan	32753.1	1573742	24589.7	23041.0	6.7
Chau Phu	45044.5	2338374	36537.1	34382.5	6.3
Chau Doc	10451.7	446286	6973.2	7094.3	-1.7

* Source: http://sonongnghiep.angiang.gov.vn

4. CONCLUSIONS AND FURTHER WORKS

The use of dual polarization Envisat ASAR data can be used for rice monitoring and mapping with the complicated cropping systems in the Mekong River Delta. It was demonstrated that: a. there was an increasing trend of backscattering coefficient during the Winter-Spring crop as a function of rice parameters, i.e. plant height and rice biomass; b. the polarization ratio appears to be a good classifier of rice; and c. the classified image, using a single-date mapping algorithm for dual polarization ASAR data acquired in the middle of crop cycle, showed only a maximum of 7% difference when compared to the estimates from the agency statistical data.

Further research will be conducted to determine the correlation of rice parameters and sigma nought derived from ASAR imagery for other crops throughout the full year. From this we will derive algorithms for mapping rice cropping systems, and to validate the rice yield prediction model for Mekong Delta using time-series dual polarization ASAR data.

Acknowledgement

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