# RICE CROP MONITORING IN THE MEKONG DELTA, VIETNAM USING TERRASAR-X AND ENVISAT-ASAR RADAR DATA

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## ABSTRACT

*The relationship between radar backscattering coefficient with the growth of rice plants was analyzed in previous studies. The backscattering coefficient of HH and VV polarization changes according to different growth stages of rice plants. In particular, the polarization ratio HH/VV of radar data is highest at mid-crop; this is the basis for threshold approach. This research study used dual-polarization radar data HH and VV of TerraSAR-X and ENVISAT ASAR for monitoring and mapping the distribution of rice-growing areas in Cho Moi district and An Giang province. The threshold method was applied to produce rice maps in detail at district and provincial levels using TerraSAR-X SM and ASAR APP data respectively. However, because of different rice sowing dates, it should cause many difficulties for mapping rice with a single-date image in a crop season. The research used radar remote sensing data with dual-polarization, multi-resolution and multi-temporal to monitor and map rice crop for better results in the study area.*

## 1. INTRODUCTION

Various methods have been developed for rice/non-rice mapping. For single polarization SAR data at C-band, such as ERS and RADARSAT, the main classifier is the temporal variation of the radar backscattering intensity [Le Toan et al., 1997; Ribbes and Le Toan, 1999]. The ratio of two polarizations HH and VV of Envisat ASAR appears to be a good classifier of rice [Bouvet et al., 2005; Lam Dao et al, 2007]. With dual polarization capability, the ASAR data can be used for mapping rice crops. In the study of Lam Dao (2009) showed that rice crops can be monitored by the single-date ASAR APP image with dual-polarization.

Recently, the TerraSAR-X (TSX) satellite for X-band has provided a better temporal resolution with a 11-day cycle (C-band satellites from 25 to 35 days) and higher spatial resolution radar imagery for rice monitoring. There are studies on the responses of rice fields for the polarization HH, VV of TSX [Lopez-Sanchez et al., 2011; Lam Dao. et al 2012], investigation of the coherent co-polarized behavior of rice during growing stages. Lam Dao (2012) used the threshold method for monitoring rice crops by using HH/VV ratio data of single-date image, which gave good results for identifying rice-growing areas that their sowing dates are a minor difference. This paper presents the use of multi-temporal images of TSX SM and ASAR APP for rice crop monitoring with better results for the study areas having much difference of crop calendar, and comparison with single-date image used.

## 2. DATA AND METHODS

### 2.1. Study area

The study area is An Giang province (Figure 1). An Giang is located in the Mekong river plain, South of Vietnam, extending from 10° 12' to 10° 57' latitude and 104° 46' to 105° 35' longitude. Cho Moi is a district of An Giang and it is an island surrounded by two branches of Mekong River (Tien and Hau rivers). Located about 190 km from Ho Chi Minh City, Cho Moi has an area of 369.26 square kilometers, with a population of about 345,506 people [AGSO, 2012]. The crop calendar varies each year, depending on the beginning of the rainy season at the start of the Summer Autumn crop.

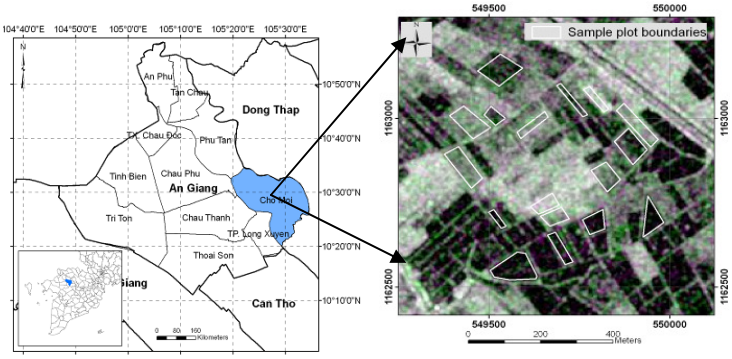



**Figure 1. Study area of An Giang province and sample locations in Cho Moi district.**

## 2.2. Data used

**Table 1. List of Envisat ASAR APP and TerraSAR-X SM data used.**

| No. | Sensor-Mode | Date of image | No. | Sensor-Mode | Date of image | No. | Sensor-Mode | Date of image |
|---|---|---|---|---|---|---|---|---|
| 1 | ASAR APP | 13-Jan-07 | 11 | ASAR APP | 22-Feb-08 | 21 | TSX SM | 31-Jan-11 |
| 2 | ASAR APP | 17-Feb-07 | 12 | TSX SM | 19-Aug-10 | 22 | TSX SM | 11-Feb-11 |
| 3 | ASAR APP | 24-Mar-07 | 13 | TSX SM | 30-Aug-10 | 23 | TSX SM | 22-Feb-11 |
| 4 | ASAR APP | 28-Apr-07 | 14 | TSX SM | 10-Sep-10 | 24 | TSX SM | 16-Mar-11 |
| 5 | ASAR APP | 2-Jun-07 | 15 | TSX SM | 24-Oct-10 | 25 | TSX SM | 27-Mar-11 |
| 6 | ASAR APP | 7-Jul-07 | 16 | TSX SM | 4-Nov-10 | 26 | TSX SM | 7-Apr-11 |
| 7 | ASAR APP | 15-Sep-07 | 17 | TSX SM | 15-Nov-10 | 27 | TSX SM | 29-Apr-11 |
| 8 | ASAR APP | 20-Oct-07 | 18 | TSX SM | 26-Nov-10 | 28 | TSX SM | 10-May-11 |
| 9 | ASAR APP | 24-Nov-07 | 19 | TSX SM | 18-Dec-10 | 29 | TSX SM | 1-Jun-11 |
| 10 | ASAR APP | 29-Dec-07 | 20 | TSX SM | 29-Dec-10 | | | |

The TSX data of X-band is used in the research with StripMap (SM) mode, HH&VV polarization, and incidence angle of 34.9° – 36.5°, with spatial resolution of 3 m, swath width of about 30 km, and a revisit interval of 11 days. This data is used for district level (Cho Moi).

The ASAR APP products with resolution of 30 m and swath of IS2 are used for provincial level (An Giang) (Table 1).

Ground truth data were sampled at 17 plots in Cho Moi (Figure 1). Rice parameters were measured and collected at the fields including of date of sowing/transplanting, plant height, biomass and leaf area index. Locations of the sample fields were determined from the GPS receiver with accuracy of about 10 m and from the cadastral maps.

### 2.3. Methods

Rice mapping was carried out through the image pre-processing steps; analyzing changes over time of radar backscattering coefficient in the growing stages of rice; applying a threshold method to each of polarization ratio data to produce rice maps; and then combining rice maps to produce a final map of rice crop season (Figure 2).

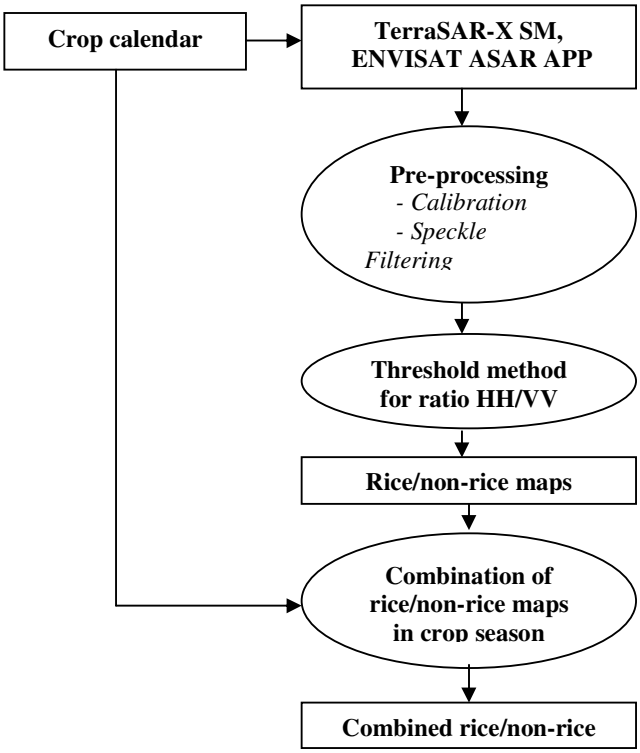
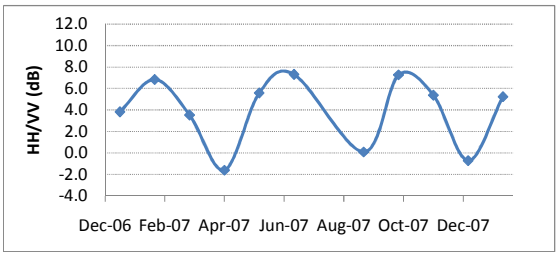



**Figure 2. Methods used for rice/non-rice mapping using multi-temporal radar images.**

## 3. RESULTS AND DISCUSSION

### 3.1. Temporal variation of the radar polarization ratio HH/VV



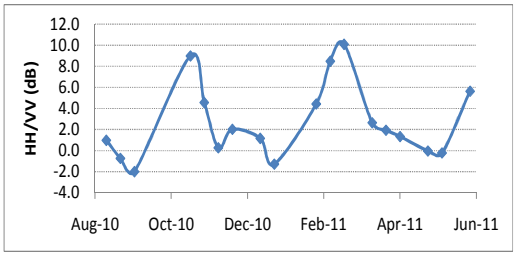
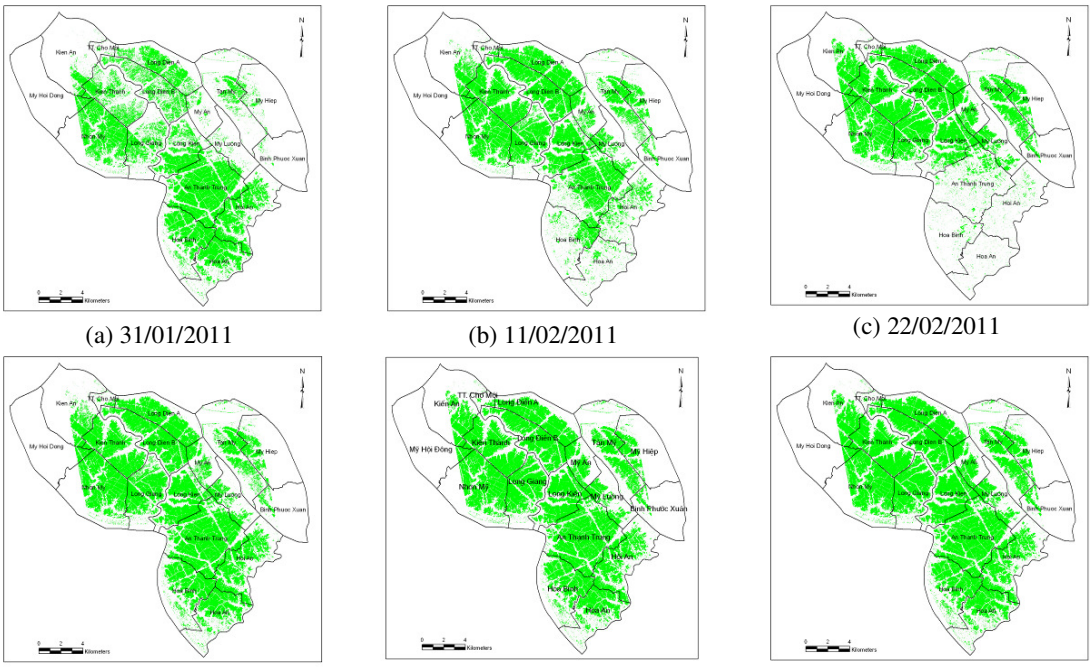



**Figure 3. Temporal variation of average polarization ratio HH/VV of ASAR APP (left) and TSX SM (right) for sample rice fields in Cho Moi.**

The variation of average polarization ratios for multi-temporal radar images for 17 samples at Cho Moi is presented in Figure 3. The polarization ratio values of ENVISAT ASAR APP and TerraSAR-X SM increased in the period from 30 to 70 days after sowing.

### 3.2. Rice mapping

Rice/non-rice maps of Winter-Spring crop (WS) 2011 in Cho Moi district were produced using a threshold value of 5 dB for TSX SM data set (Figure 4a, 4b, 4c). The sowing date of rice areas was different several weeks. In which, the southern part (An Thanh Trung Hoa Binh, Hoa An and Hoi An commune) is sowed sooner than the other. Hence, there is a rather large difference between the estimated area from rice maps and the statistical data (Table 2). For this reason, the multi-temporal images were used and gave better results (Figure 4d, 4e, 4f).



(a) 31/01/2011 (b) 11/02/2011 (c) 22/02/2011

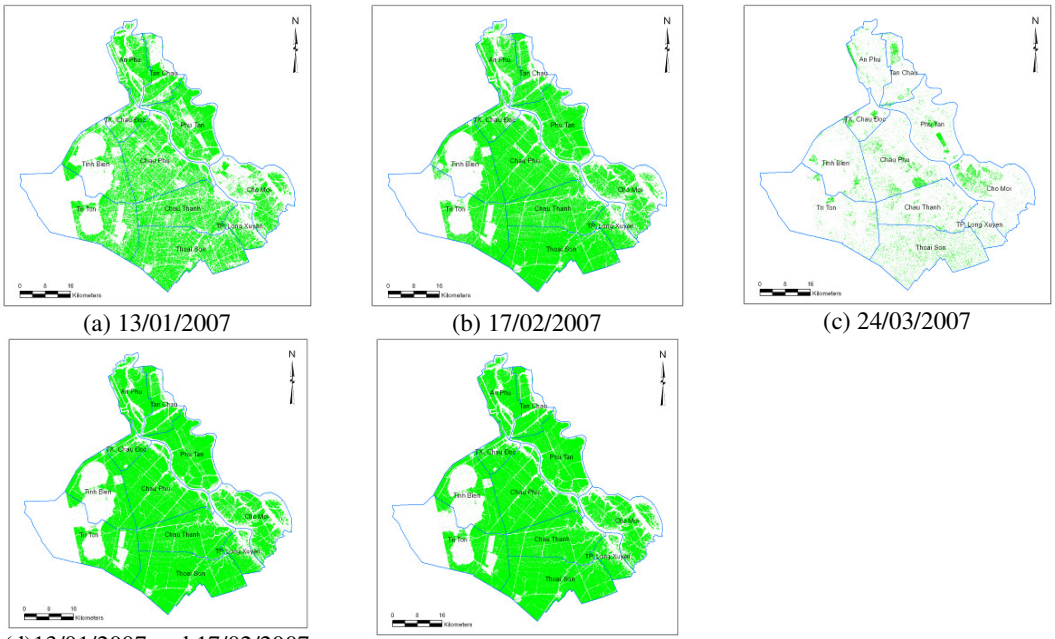
(d) 31/01/2011 and 11/02/2011 (e) 31/01/2011 and 22/02/2011 (f) 31/01/2011, 11/02/2011 and 22/02/2011

**Figure 4. Rice/non-rice maps from single- and multi-date TSX SM images of WS 2011 crop in Cho Moi district.**

The results of rice-growing area in the WS 2011 crop estimated from single and multi-date images were compared with the statistics. Communes of Cho Moi such as Kien An, My Hoi Dong, Nhon My, My Hiep and Binh Phuoc Xuan could not be compared, because the radar images did not cover all these areas. Remain communes are analyzed and proved a good agreement between estimated rice area and statistics with the difference under 10% when two or three-date images used (Table 2).

**Table 2. Comparison of estimated rice area and statistical data of WS 2011 crop in Cho Moi district.**

| Date of TSX SM image | Estimated area (ha) | Statistical data (ha) | Percentage difference (%) |
|---|---|---|---|
| 31/01/2011 | 8954 | 11992 | -25.3 |
| 11/02/2011 | 9260 | 11992 | -22.8 |
| 22/02/2011 | 7612 | 11992 | -36.5 |
| 31/01/2011 and 11/02/2011 | 12065 | 11992 | 0.6 |
| 31/01/2011 and 22/02/2011 | 12539 | 11992 | 4.6 |
| 31/01/2011, 11/02/2011 and 22/02/2011 | 12846 | 11992 | 7.1 |



(a) 13/01/2007 (b) 17/02/2007 (c) 24/03/2007

(d)13/01/2007 and 17/02/2007 (e)13/01/2007, 17/02/2007 and 24/03/2007

**Figure 5. Rice/non-rice maps from single- and multi-date ASAR APP images of WS 2007 crop in An Giang province.**

Rice/non-rice maps (Figure 5) from ASAR APP data are compared with the statistical data [AGSO, 2012]. Results showed that the use single-date ASAR APP image acquired in the middle of the season is still possible with less than 10% difference (Table 3).

**Table 3. Comparison of estimated rice area and statistical data of WS 2007 crop in An Giang.**

| Date of ASAR APP image | Estimated area (ha) | Statistical data (ha) | Percentage difference (%) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 13/01/2007 | 141388 | 193242 | -26.8 |
| 17/02/2007 | 184123 | 193242 | -4.7 |
| 13/01/2007 and 17/02/2007 | 206567 | 193242 | 6.9 |
| 13/01/2007, 17/02/2007 and 24/03/2007 | 209258 | 193242 | 8.3 |

## 4. CONCLUSIONS

The radar backscattering coefficient of HH and VV polarization of TSX SM and ENVISAT ASAR APP data changes according to the growing stages of rice plants, especially the polarization ratio HH/VV get highest values in the middle of crop season. Therefore, the threshold method is applied for dual polarization radar data to map the distribution of rice-growing areas. The use of multi-date TSX SM and single-date ASAR APP images provided good results when compared to the statistics. Therefore, the dual-polarization radar imagery with different resolutions can be used to support rice crop monitoring and management at local and regional scales.

## 5. ACKNOWLEDGMENT

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