The Use of SAR Data for Rice Crop Monitoring
A Case Study of Mekong River Delta – Vietnam

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Abstract: In this paper, the use of multi-date ERS2-SAR data has been demonstrated with application to rice mapping and monitoring in Soc Trang - Mekong river delta, which has a very complex cropping system (single, double, even triple rice crops per year). The algorithm of rice cropping system mapping using SAR data was proposed.

Key words: Microwave Remote Sensing, Rice Monitoring, Agriculture.

1. Introduction

Vietnam is one of the world’s largest rice exporter countries. At present, estimate of rice planting area is based on ground survey. The use of satellite remote sensing data acquired at the appropriate time is expected to help in producing synoptic rice field maps. Optical remote sensing images such as NOAA/AVHRR or SPOT/Vegetation are required to monitor temporal growth patterns of rice crop. But their spatial resolution is not adapted to field based monitoring. Landsat and SPOT satellites could, in principle, be used for this purpose. Unfortunately, a large part of rice crop growing time coincides with a rainy season, resulting in a limited number of cloud-free images. Synthetic aperture radar (SAR) data allow for observations independent of weather conditions and solar illumination, and are potentially well suited for rice field mapping and yield estimation.

2. Methodology

The microwave portion of the spectrum commonly used for remote sensing of land surfaces covers the range from approximately 1cm to 1m in wavelength. Because of their long wavelengths, compared to the visible and infrared, microwaves have special properties that are important for remote sensing. These are:
- small dependence on atmospheric conditions,
- control of the emitted (for active remote sensing) and received electromagnetic radiation: power, frequency, polarization,
- ability to choose an incidence angle and an azimuth angle to meet the objectives of the study,
- possibility to obtain information on subsurface features, when low soil density and moisture permit.

Study area

The study area, Soc Trang province is covered by the entire 100 x 100 km ERS scene (Figure 1). Soc Trang is located in the Mekong river plain, South of Vietnam and is surrounded by Bac lieu, Can Tho and Tra Vinh provinces. Soc Trang with 3,223 square kilometres in acreage and 1,213,400 habitants (statistical data in 2001) is 231 km from Ho Chi Minh City.
Rice growing stages

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, and the after-harvest period [2].

1) **The sowing-transplanting period**: The fields are flooded in order to prevent self-propagating vegetation and pests. The water depth varies from 2 to 15 cm.

2) **The growing period**: The tropical rice varieties complete their life cycle within 110-120 days. Vegetative, reproductive, and grain filling/maturity stages can be identified.

3) **Fallow**: After harvest, fields can be either bare and dry at the end of the dry season or covered with weeds in wet conditions.
Rice cropping systems in the Mekong River Delta

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<th>Rice-based cropping system</th>
<th>Rice season</th>
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<td>Rice/shrimp system</td>
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The complicated rice cropping systems in the Mekong river delta are characterised by:
- size of rice field ranging from small (0.5 – 1 ha) to large;
- sowing dates are different from field to field (several weeks);
- different rice cropping systems from one area to another (single, double or triple crop rice);
- cultural practices (sowing, transplanting);
- seeds.

Remote sensing data used

ERS-2 SAR PRI images (track 75 and frame 3411) at 35-day repeat intervals were achieved from May 1997 to April 1998. These images were delivered by ESA/ESRIN in the framework of a CAT-1 project. Four additional ERS-2 SAR PRI images acquired in Summer-Autumn rice crop of 1996 were used to prove the potential of SAR data for rice monitoring.

The methodology used

In this research work, the methodology used for rice crop monitoring in the Mekong river delta is based upon previous research results in [2] and using the resulting RISAR software module developed imbedded in the MULTISCOPE platform.

The experimental and theoretical research results show that rice fields present a large variation in their temporal radar response. 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 temporal change of the ERS-SAR signal is estimated by dividing the intensity values of each pixel between two dates. In order to maximise the intensity ratio (the temporal change), the Maximum Temporal Change (MTC) is calculated as the following equation:

\[
    \text{MTC}_{i,j} = \frac{\text{Max}(I_{i,j,k})}{\text{Min}(I_{i,j,k})}
\]

With
- \( i \) and \( j \) = pixel column and line coordinates respectively
- \( k \) = number of the image

The principle is to threshold the maximum temporal change image to identify image pixels that change by more than x dB in order to produce a rice/non rice image map.

3. Analysis

Multi-temporal ERS data interpretation

The high dynamic range and the temporal change of the rice backscatter are unique for SAR data. Colours in multi-temporal SAR images are mainly related to changes of rice growing in the fields during the period of image acquisitions.

In figure 3, blue colour corresponds to triple crop rice (DX-HT-TD), except for one part of blue pixels located in South-East of Soc Trang town that presented either triple crop rice or double crop rice (DX-M). Double crop rice regions (DX-HT), which were nearby the river, exhibit a green colour. Soc Trang town appeared in white in colour, because the double bounce scattering mechanism is dominant in urban areas. Grey coloured areas have low temporal change of backscattering coefficient (less than 2 dB) from August 1997 to April 1998; these areas were forests, sugarcane, orchards, etc.
SAR data analysis

In total, 74 homogeneous rice sampling boxes have been selected on the calibrated-registered images acquired in 1996 and 1997-1998. These samples were extracted for various rice cropping systems such as single, double or triple crop rice. The box size of 14x14 pixels was chosen to attain a 90% confidence level for radiometric resolution bounds of +/-0.5 dB.

The backscatter values of rice vary from –18 to –2 dB during a full year time from May 1997 to April 1998. In case of one rice crop, maximum temporal change of $\sigma^0$ was 12dB. While urban, orchard, sugarcane and forest show the stable backscatter with maximum temporal change of 2dB corresponding well to the expected low dynamic of C-band signal over these areas.

Fig. 4: Temporal variation of $\sigma^0$ of ERS-SAR data in triple crop rice fields
Figure 4 presents the temporal variation of $\sigma^o$ in triple crop rice regions (DX-HT-TD). Three peaks were observed in the curves. The second peak (TD crop) was lower than the other. This is possibly an artifact of temporal sampling because of the 35-day cycle of ERS-SAR data, only two images are acquired in the case of short duration rice varieties, the actual peak should have been missed.

Fig. 5: Temporal variation of $\sigma^o$ of ERS-SAR data in double crop rice fields (DX-HT)

The temporal variation of $\sigma^o$ in double crop rice (DX-HT) was illustrated in Figure 5. The backscattering behaviour of HT and even DX crop was different from one field to another. Figure 6 presents the temporal variation of samples of single crop rice (M), long-duration rice.

Fig. 6: Temporal variation of $\sigma^o$ of ERS-SAR data in single crop rice fields (M)

Rice crop distribution maps

Figure 7 described the algorithm of rice/non-rice mapping and rice cropping system mapping. The algorithm of rice/non-rice mapping was developed by CESBIO and SCEOS (Sheffield Centre for Earth Observation Science) [10]. By using the algorithm, a rice/non-rice binary image (figure 8) was produced from the maximum temporal change of nine images and of four selected images.
The algorithm of rice cropping system mapping is proposed and the steps to classify rice cropping systems are:

1. applying maximum temporal change (MTC) for each three consecutive images (MTC > 3 dB);
2. for each three consecutive images, applying $\sigma^0_{2}\text{nd Image} - \sigma^0_{3}\text{rd Image} > 1.5 \text{ dB}$, $\sigma^0_{2}\text{nd Image} - \sigma^0_{1}\text{st Image} > 0 \text{ dB}$.

It means that $\sigma^0$ increases during growing cycle from the date of acquisition of the first image to that of the third image.
the second image and quickly reduces after rice field harvested (in the date of acquisition of the third image);

3. using the logical operator “And”, the result images in step 1 and 2 as input images. The output images are monthly harvested rice images. The harvested time can be between the date of acquisition of the second and of the third image (figure 9);

4. combining suitably these monthly harvested rice images in order to produce each layer of rice cropping system such as triple crop rice (DX-HT-TD), double crop rice (DX-HT, DX-M, HT-M). Single crop rice area is the remaining rice area in rice/non-rice map.

5. applying the 3x3 window size low pass filter to each type of rice cropping system in order to product the output image smoother.

6. combining all layers of rice cropping systems to produce the map of rice cropping systems (figure 10).

Fig. 9: An example of three consecutive images taken before and after harvested date

Fig. 10: Rice cropping systems map
4. Conclusions

In this research, the use of ERS-SAR data has been demonstrated with application to rice mapping in Mekong river delta, which has a very complex cropping system. The algorithm of rice cropping system mapping using SAR data was proposed. This algorithm may be applicable for ERS-SAR data acquired on another years.

It is necessary to validate the rice crop monitoring methods using ENVISAT-ASAR and another new SAR data, especially for short duration rice varieties. Multi-incidence techniques can help reducing the delay between acquisitions. Dual polarisation of ASAR can be used to increase the accuracy or to reduce the number of temporal acquisition.

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References