RICE YIELD PREDICTION USING ERS-2 SAR DATA: PRELIMINARY RESULTS OF A CASE STUDY IN THE MEKONG RIVER DELTA, VIETNAM

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ABSTRACT

The objective of the presented study is to validate the rice yield prediction method, which was developed by scientists of CESBIO, in Mekong River Delta. The approach consists in coupling ERS-SAR data and the ORYZA rice production model in order to simulate plant growth and thus the final yield. This paper describes a review of the previous research studies on rice monitoring using SAR data, and a preliminary result of rice yield prediction in the Mekong River Delta using multi-date ERS2-SAR data. Some of the yield estimates were reasonable compared to the statistical average rice yield, but it is necessary to have ground data for accuracy assessment. More work is being done to understand the capabilities of the new ENVISAT-ASAR sensor for rice monitoring.

1. INTRODUCTION

Rice is the second major crop in the world. It is not only planted in Asian countries but also in many other parts of the world. In Asia, food security has become a global key issue because of the rapid growth of Asian population. To control and maintain a close balance between rice production and food demands, an effective rice monitoring program is necessary at regional, national and global level.

Vietnam is one of the world's largest rice exporter countries and the fertile Mekong River Delta at the southern tip of Vietnam accounts for more than half of the country's rice production. At present, estimate of rice production in Vietnam 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 as well as predicting the rice crop yield. 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. Radar remote sensing data allow for observations independent of weather conditions and solar illumination, and are potentially well suited for rice field mapping and yield estimation in the country.

In fact, many research studies have been carried out on rice mapping and rice monitoring using satellite SAR data since the launch of the first European remote sensing satellite (ERS-1) in 1991. The studies covered the sites in Indonesia (Le-Toan et al., 1997, Ribbes and Le-Toan, 1999); in Japan (Kurosu et al., 1995, Le-Toan et al., 1997); in Vietnam (Liew et al., 1998, Kajalainen et al., 2000, Lam-Dao et al., 2005); in China (Shao et al., 2001, Li et al., 2003, Le-Toan et al., 2005, Bingbai et al., 2005); in Sri Lanka (Frei et al., 1999); in India (Choudhury and Chakraborty, 2006); in Philippine (Chen and Mcnairn, 2006); etc. They 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 modeling, determination of classifiers, development or application of classification methods, retrieval of biophysical parameters and interface with rice growth models for crop yield prediction and finally available software.

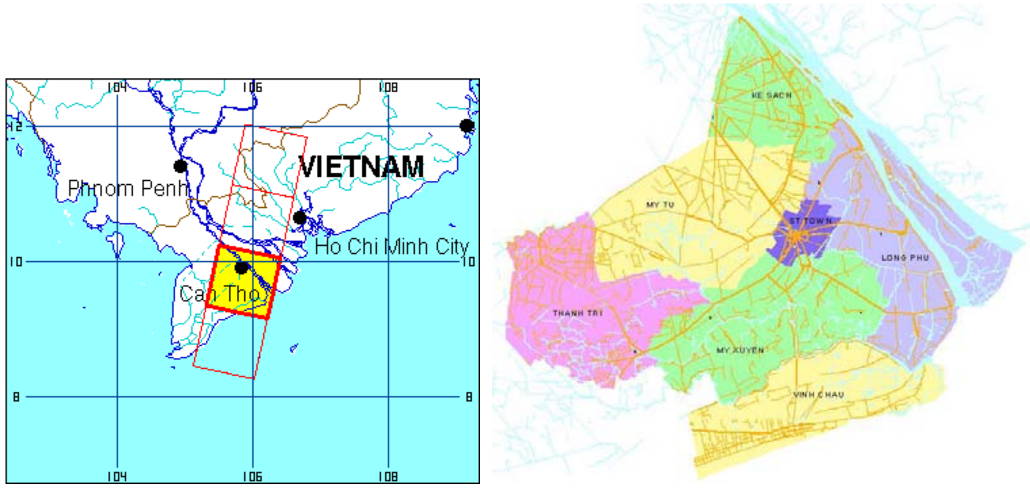
Inversion of the ERS-1 SAR image into a map of growth parameters (height and biomass) has been performed (Le-Toan et al., 1997). Ribbes and Le-Toan (1999) retrieved the sowing date and plant biomass at the date of SAR acquisition from time series of radar data. The coupling between SAR data and ORYZA agro-meteorological model gave good results of estimated rice yield. To predict the rice yield, Karjaleinen and their colleagues (2000) applied the CROPWATN crop growth model, which used the meteorological data from the growing season as well as soil data and information about different rice varieties. The predicted yield is close to the actual, measured yield, but the standard deviation is still quite high. Another approach of statistical model was used for rice yield estimation in the research projects (Li et al., 2003, Chen and Mcnairn, 2006). Li established a multivariate regression model based on radar remote sensing in order to reveal the relationship between the backscatter coefficient of time-series ScanSAR narrow band (SNB) data and rice yield. Chen has used a neural network-based yield model to predict rice yield on a regional basis. Both obtained an accuracy of 94% for the rice yield prediction.

In our previous study, the algorithm of rice cropping system mapping using a full-year ERS-SAR data has been proposed for Mekong River Delta (Lam-Dao et al., 2005). The objective of this presented study is to validate over the delta of the rice yield prediction method, which has been developed by scientists of CESBIO.

2. TEST SITE AND DATA USED

2.1 Test site

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, Hau Giang, Vinh Long and Tra Vinh provinces. Soc Trang with 3,223 square kilometers in acreage and 1,257,400 habitants (statistical data in 2004) is 231 km from Ho Chi Minh City. The rice growing stages and rice cropping systems in the test site are described in (Lam-Dao et al., 2005).



a) b)

Figure 1. Study site (a) and administrative boundary map (b) of Soc Trang province

2.2 Data used

ERS-2 SAR PRI images (track 75 and frame 3411) at 35-day repeat intervals were acquired from May 1997 to April 1998. These ERS-2 SAR C-band data were delivered by ESA/ESRIN in the framework of a CAT-1 project which is for the scientific exploitation of ESA data. The meteorological data at Soc Trang gauge station and average irradiance and sunshine hours at Can Tho gauge station (Lam-Dao, 2003) were provided by the Ho Chi Minh City Institute of Physics under Vietnamese Academy of Science and Technology.

3. METHOD

A methodology for rice yield estimation has been developed by Ribbes and Le Toan (1999). The approach consists in coupling ERS-SAR data and the ORYZA rice production model in order to simulate plant growth and thus the final yield. Seeding date and plant biomass as a function of time are key parameters that can both be retrieved from SAR data and are necessary inputs to production models. In order to estimate the rice yield of a field, the following operations in RISAR processing (2000) are performed: i. Calculate the radar backscattering coefficient of the selected rice fields within the ESR-SAR images; ii. Retrieve, from ERS-SAR data, plant parameters necessary to parameterize the rice growth model; iii. Simulate rice growth using ORYZA model parameterized with input data retrieved from SAR data and climatic data. The rice fields were selected using the vector cover in RISAR. These fields represented the various rice cropping systems.

The total irradiance was not available; therefore it was calculated from the average irradiance multiplied by day light of 11 hours (maximum sunshine hours during the time of May 1997 – April 1998 measured at Can Tho gauge station). The statistical data of average rice yield by district in 1995, 1998, 1999, 2000 and 2001 were provided by Soil science and Land management Department of Can Tho University.

4. RESULTS

Triple crop rice: In RISAR, the input of "rice" characteristics is optional. If unknown, the sowing date is estimated from σ^o and growth cycle length is set to 120 days for tropical regions. As mentioned in (Lam-Dao et al., 2005), the rice cropping systems in Mekong River

Delta are very complex. The growth duration ranges from 3 to 6 months, depending on the variety and the environment (Liew et al., 1998). Therefore, the sowing date and crop cycle length was deduced on the basis of the temporal change of backscattering coefficient (figure 2) and the growth cycle of rice cropping systems and was assigned into the model, because the ground data was not available during the acquisition time of ERS-SAR images. It was similar for the cases of single and double crop rice. The growth cycle of rice cropping systems was deduced based on the behavior of σ^o of 74 homogeneous rice sampling boxes, which were selected on the calibrated-registered images and 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 (Laur et al., 2002).

As an example, a rice field P1H1_1 located in Ke Sach district was represented for triple crop rice fields. The estimated rice yield result of HT crop in 1997 was 4,432 kg/ha (figure 2). It is noted that the statistical average yield of HT crop in 1998 was 4,802 kg/ha for Ke Sach district.

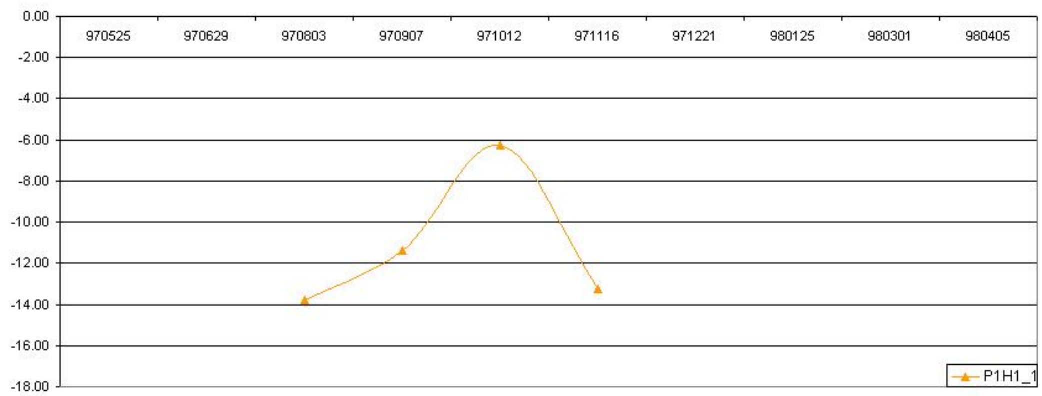


Figure 2. Temporal variation of σ^o of HT crop on triple crop rice fields

Double crop rice: For the case of double crop rice (DX-M), fields P3M1_1, P3M1_2 located in My Xuyen district were chosen to predict the rice yield of M crop. The estimated yield of 5,460 kg/ha for both fields (figure 3) is quite high compared to the others. According to the statistical data in 1995 and 1998, the average rice yields of M crop in My Xuyen district were 3,912 kg/ha and 3,372 kg/ha respectively.

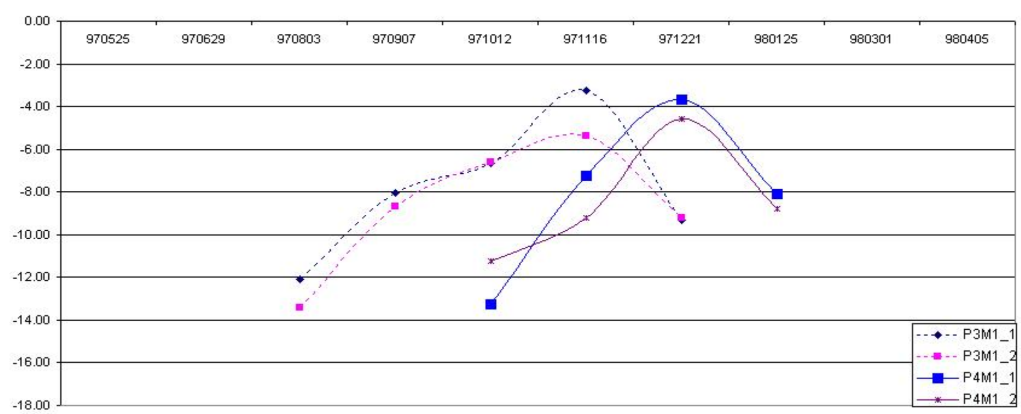


Figure 3. Temporal variation of σ^o of M crop on double crop rice fields (DX-M, HT-M)

The rice yields of fields named P4M1_1 in Soc Trang town and P4M1_2 in Ke Sach district were estimated for TD crop of double crop rice (HT-M). Their predicted yields were 4,886 and 4,562 kg/ha respectively (figure 3). The statistical average rice yields were 4,147 kg/ha (1995), 4,105 kg/ha (1998) in Soc Trang town and 3,987 kg/ha (1995), 3,634 kg/ha (1998) in Ke Sach district.

Single crop rice: The yield of rainy season rice or long duration rice was predicted from the fields P5M1_1 and P5M1_2 situated in Vinh Chau and Thanh Tri, respectively. Their productivity was 4,237 kg/ha for P5M1_1 and 4,274 kg/ha for P5M1_2 (figure 4), while the statistical data of average yields in Vinh Chau and Thanh Tri were 3,328 (1995), 1,952 kg/ha (1998) and 2,938 (1995), 2,948 kg/ha (1998) respectively.

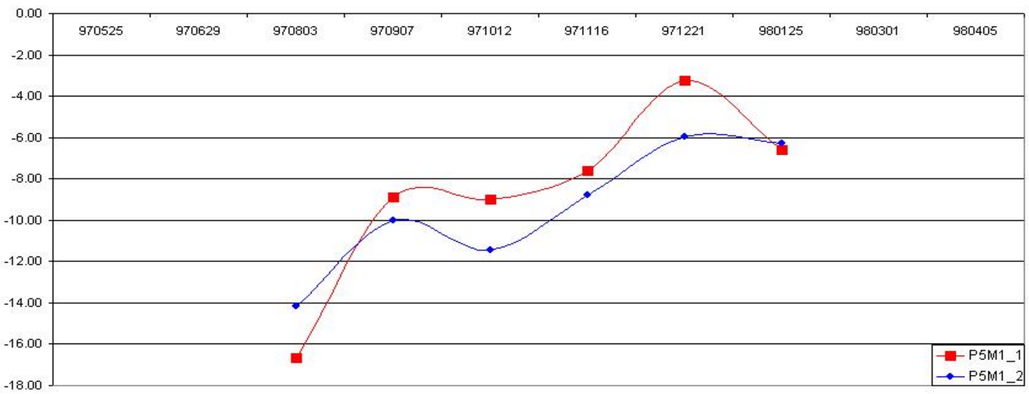


Figure 4. Temporal variation of σ^o of M crop on single crop rice fields

In summary, some of the rice yield estimates such as for triple crop rice fields (HT crop) and double crop rice fields (TD crop) were reasonable compared to the statistical average rice yield. It can be noted that the provincial average rice yields in the year 1998 were 4,521 kg/ha (DX crop), 4,348 kg/ha (HT crop) and 2,873 kg/ha (M crop). Unfortunately, the statistical data for all crops in 1997 was not available.

Because it was calibrated over long cycles, RISAR could not be used to predict the yield for the short duration rice crops (< 90 days) and the DX crops, those sowed at the end of year and harvested in the following year. Because the weather file, which has a strict format, contains figures for the same year only.

4. SUMMARY AND FURTHER WORKS

In this research, the use of ERS-SAR data has been demonstrated with application to rice yield prediction in Mekong River Delta, which has a very complex cropping system. The research results are summarized as follows: i. Some of the yield estimates showed good agreement with the statistical average rice yield; ii. Because of the 35-day cycle of ERS-SAR data, only few data points could be acquired during a rice crop cycle, so it is impossible to predict the yield for short duration rice (< 90 days).

The further works consist in validating the rice crop monitoring methods using ENVISAT-ASAR and another new generation SAR data, i.e. ALOS-PALSAR, especially for short duration rice varieties and in having the ground data for accuracy assessment.

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