# Rice Recognition Using Multi-temporal and Dual Polarized Synthetic Aperture Radar Images

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## Abstract

*Synthetic aperture radar has been used widely in crop recognition and monitoring. In the past, most of the studies of rice mapping and yield estimation are based on single polarized SAR data. In order to evaluate the feasibility of rice recognition approach and compress the amount of SAR data, multi-temporal and dual polarized SAR data were used here. In rice growing stage, two dates and dual polarization （VV & HH） ENVISAT ASAR data were acquired in Changle study area. With the analysis of rice and other land cover classes backscatter coefficient, an image processing method of difference index was applied to enhance rice information and decreased the confusion between rice and non-rice. Threshold technique was carried out finally for extracting rice information. Results indicate that the rice information extraction achieves a 91.02% overall accuracy. Therefore, the method is an effective one for SAR information recognition in distinguishing rice and other land cover categories.*
*Keyword: Multi-temporal; dual polarization; SAR; rice recognition*

## 1. Introduction

Rice is the most important staple food crop for people in the world. As the largest rice production and consumption country, rice planting is significant in China. Therefore, it is of great importance to obtain rice planting area timely, objectively, and accurately for China's grain reservation and food market decision-making. Because most of the rice cropping regions are distributed in humid Yangtze river and south of China with cloud and rainfall influenced frequently, in the rice growing stage, it is difficult to acquire timely and suitable optical remote sensing data. Synthetic Aperture Radar (SAR), without influence of cloud, rain and fog, and with day or night imaging capabilities, is anticipated to be a reliable technique for rice recognition.

In recent years, many domestic and foreign researchers have taken advantage of SAR data for rice monitoring. Chakraborty et al, (1997) used temporal ERS-1 SAR data to classify rice grown and exceeding 90% classification accuracy were obtained, the research results also showed that the classification was mainly affected by the presence of rivers and streams [1]. Le Toan et al, (1997) used ERS SAR data to assess rice fields mapping and to monitor rice growth, the experimental results showed that the variations of rice radar backscatter coefficients were able to be used for mapping rice fields [2]. Liew et al, (1998) used ERS and RADARSAT SAR data in rice crops monitoring, the results showed that different growth stages of rice can be identified well by using ERS-RADARSAT false color composite images [3]. Lim et al, (2007) used multi-temporal C-band radar data were used to investigate the relationship between backscatter measurement on the physical structure of rice fields and its growth stages, and the experiment results indicated that multi-temporal and multi-polarization radar data are helpful in understanding the backscatter behavior of rice field and in monitoring rice field [4]. Panigrahy et al, (1999) used two-date SAR data to detect rice fields in India, but results showed that this method was not feasible to estimate early season rice due to misclassification of rice fields with water bodies [5]. Tan et al., (2007) used multi-temporal SAR images for rice classification by applying Entropy Decomposition and Support Vector Machine technique based on theoretical modeling, the results showed that the proposed method not only gives rice classification, but also extends the application of Entropy Decomposition to cover multi-temporal data [6]. Oguro et al, (2001) used multi- temporal optical remote sensing and SAR data to estimate the rice planted area in Higashi Hiroshima city, the results indicated that optical

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data can be used for monitoring rice planted area and multi-temporal SAR data are useful especially for the area with high cloud coverage [7]. Shao et al, (2001) used multi-temporal RADARSAT data were used for rice monitoring and production estimation in China, the results showed that high accuracy of the rice classification providing confidence that multi-temporal RADARSAT data is capable of rice mapping and three different stages of rice crop growth and development radar data should be required for rice production estimation [8]. The studies have been described above are mainly based on single polarized and multi-temporal SAR data (including simple several SAR data band composed). Moreover, a number of ASR bands should be required to process. Therefore, the shortcomings of high costs and a large quantity of data processing should be difficult to overcome.

The advanced synthetic aperture radar (ASAR) instrument on board the ENVISAT satellite was launched on March 2002. It would be able to acquire multi-polarization (HH & VV，HH & HV，VV & VH，HV & VH) radar data. This enhances the development direction of multi-polarization radar remote sensing. How to extract information from multi-polarization radar data, while further compress the amount of data, has becoming the current hot spot.

The objective of this study is to test an approach of difference index based on multi-temporal and dual polarization radar data for rice extraction. This method is generated after analyzing the rice backscatter characteristics of two date and dual polarization ENVISAT ASAR data. To test the reliability of rice recognition result, ground truth data were used to assess. Furthermore, higher classification accuracy than the result from multi-band SAR data composition has also proved the feasibility.

## 2. Study area and data set

The study area is situated in Changle, the eastern region of Fuzhou city, Fujian province, China (Fig.1). It lies in 119°23′~119°42′E and 25°41′~ 26°04′N. As a result of the influence of subtropical and monsoon climate, mildness and wetness are its features. In Changle area, spring and autumn are mainly rice planting season. Because the best imaging time of radar data for rice monitoring is transplanting and heading growth stages (Y.Shao et al, 2001) [8, this paper also mainly chooses the SAR data at the rice growth stages to test difference index approach for rice mapping. The imaging dates of ENVISAT ASAR dual-polarization data in this study are April 22 and May 27, 2005.

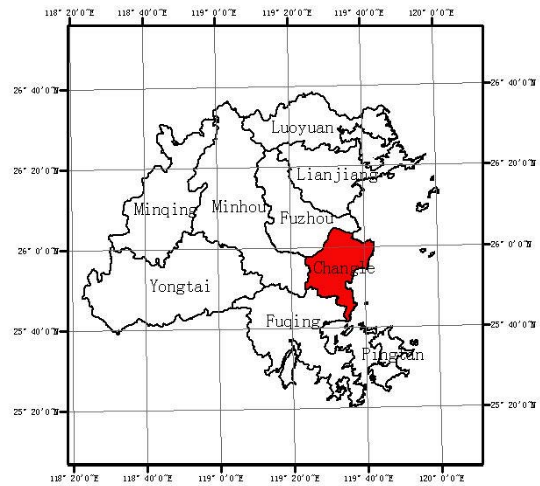


**Fig.1 Changle study area (eastern Fuzhou, Fujian, China)**

## 3. Methodology

### 3.1. SAR data pre-processing

ENVISAT ASAR data pre-processing mainly includes radiometric calibration, correlation matching, geometric correction, speckle noise reduction and producing backscatter coefficient ($\sigma^0$). In order to improve visual interpretation, multi-channel filtering has been applied (Quegan, 2001) [9]. The data processing works were operated by Best software, which is a special software tool that has been developed to facilitate the use of ESA SAR data. Detail technique flow as Fig. 2.

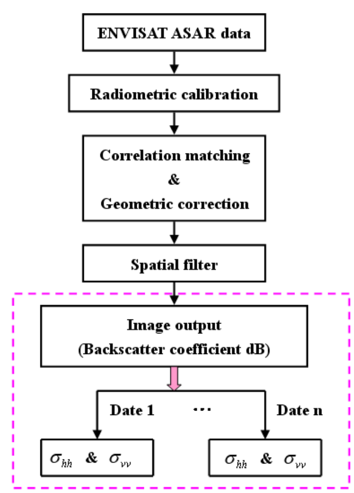


**Fig.2 The flow of SAR data processing**

### 3.2. Rice backscatter characteristics analysis

Radar backscatter coefficient indicates the scattering echo intensity of land cover categories. From two pairs of

ENVISAT ASAR images, the backscatter characteristics change trend (Fig.3) of major land cover classes has been analyzed in Chanle.

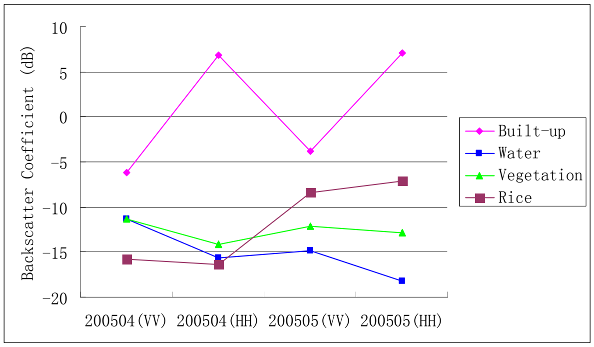


**Fig.3 Major land cover categories backscatter characteristics**

As is showed as figure 3, the value of backscatter coefficient of built-up is obviously highest among the major land cover classes, and its backscatter coefficient of VV polarization is lower than the value of HH polarization. The variety range of backscatter coefficient between VV and HH polarization is about 10 dB. The backscatter coefficient of vegetation is lower than built-up, and its value of HH polarization is also lower than that of VV polarization at the same time, and the rate of variety is quite small in the short term. Generally, the backscatter coefficient of water is small, and its value of HH polarization is lower than that of VV polarization. With the growth of rice, its value of backscatter coefficient appears regularity. At the beginning of rice transplanting, the backscatter coefficient of VV polarization is higher slightly than that of HH polarization. With the growing of rice continually, its backscatter coefficient of HH polarization would exceeds that of VV polarization. We can take this change regulation of rice backscatter coefficient as an important reference for distinguishing rice with other land cover categories.

## 3.3. Multi-temporal and dual polarization radar backscatter difference index constructing

On the basis of analyzing the backscatter characteristics of main land cover types of two date and dual polarization ENVISAT ASAR data, in order to expand the contrast of image between rice and other land classes and enhance rice information, multi-temporal, dual polarization difference index approach was used here. The equation is as follows:

$$\Delta\sigma = \sigma_{hhvv}^{t1} - \sigma_{hhvv}^{t2} = \sigma_{hh}^{t1} \bullet \sigma_{vv}^{t1} - \sigma_{hh}^{t2} \bullet \sigma_{vv}^{t2} \qquad (1)$$

Where $t1$ and $t2$ are represent the different imaging date, $\sigma_{hh}$ and $\sigma_{vv}$ are represent the radar backscatter coefficient of HH and VV polarization.

## 3.4. Rice information extraction

According to formula (1), multi-temporal and dual polarization difference index image (Fig.5) was produced. The dates of $t1$ and $t2$ are respectively represent 27 May, 2005 and 22 April, 2005.

In order to reveal the change between original SAR image and difference index image, a multi-band SAR composite image was produced (Fig.6).

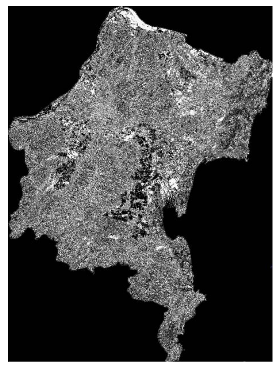

**Fig.5 Difference index image**

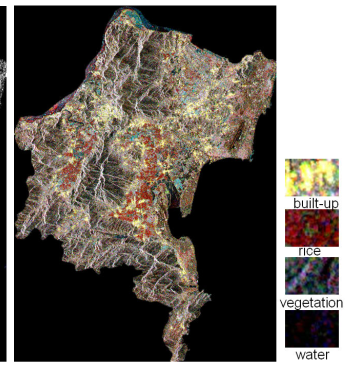


**Fig.6 Multi-band SAR composite image (R=200505HH; G=200504HH; B=200504VV)**

In multi-band SAR composite image (Fig.6), the built-up land shows bright white, vegetation appears gray, the color of rice is salmon pink, water displays black. While in difference image, we can see that rice information was enhanced and other non-rice information were restrained. The color of rice appears black; Vegetation and built-up present gray; water color is ash grey. Besides, part of water color also shows black, but we can remove the interferential information easily by comparing the water backscatter characteristics of HH and VV polarization in different time, or identify them from their geographical distribution and texture characteristics. So we can distinguish rice with non-rice information clearly from the change index image.

In addition, we also found that the mean value variety between rice and non-rice in difference index image is more obvious than that in single polarization SAR image. From Tab.1, we can see that the variety range of mean value between rice and non-rice is about 2~20 in single polarization SAR image; While in difference index image, the change range of mean value dramatically expands 77~131. The higher mean value variety between rice and non-rice, the more easily distinguish between them.

**Table 1 The differences of mean values of difference index and single polarization SAR among major land cover classes**

| | ① | ② | ③ | ④ | ⑤ |
|---|---|---|---|---|---|
| **built-up** | -7.807 | 6.805 | -5.546 | 7.793 | 10.954 |
| **water** | -16.368 | -18.723 | -13.411 | -16.246 | -86.523 |
| **forest** | -12.531 | -13.592 | -11.087 | -12.558 | -33.065 |
| **rice** | -14.329 | -14.950 | -8.953 | -5.837 | -164.492 |
| **min difference (rice vs. non-rice)** | 1.798 | 1.358 | 2.134 | 6.721 | 77.969 |
| **max difference (rice vs. non-rice)** | 6.522 | 21.755 | 4.458 | 13.63 | 131.427 |

Note: ①, ②, ③, ④ and ⑤ are represent the images of 20050422VV, 20050422HH, 2050527VV, 20050527HH and $\sigma^{t1}_{hhvv} - \sigma^{t2}_{hhvv}$ respectively.

According to Tab.1, we found that the value of rice is lowest in multi-temporal and dual polarization difference index image, so we can easily use threshold technique to extract rice information. After repeated threshold value adjustment, when the value is less than -102, the full rice information would be obtained. However, we also found that part of the water information was mixed up with rice. The error reason is that the SAR image signal of meadow in the beach is similar to rice SAR signal. We should remove water meadow interfered information, and the complete and accurate rice information would be extracted. After analyzing the backscatter characteristics of the land cover categories (Fig.3), we found that the rice backscatter coefficient of HH polarization is larger than that of VV polarization on 27 May, and the water backscatter coefficient is opposite at the same time. Then we can eliminate the part water information from rice by comparing the relation between HH and VV polarization on 27 May, 2005. Finally, we established the rice decision-making recognition rule (Fig.7) and extracted rice information (Fig.8) easily.

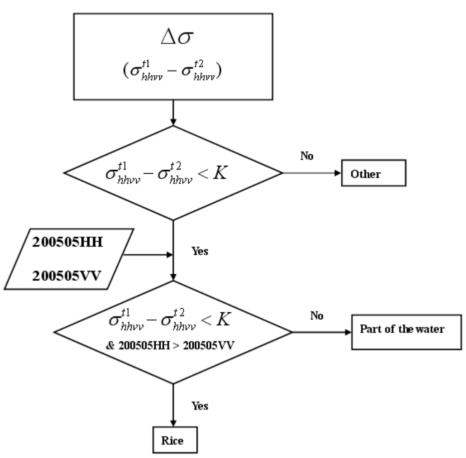


**Fig.7 Rice decision-making recognition**

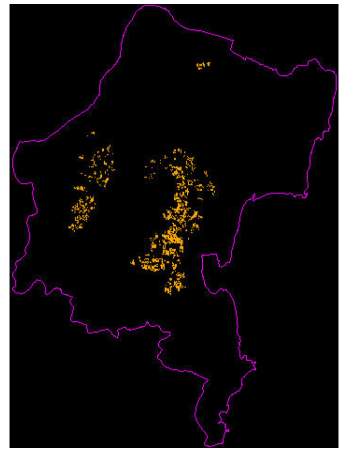

**Fig.8 Rice extracted from difference index image**

## 4. Accuracy validation

Accuracy assessment is a very important step after information extraction, which is considered as a reliable verification approach. Generally, there are two accuracy verification methods: ground truth data verification; higher resolution image or correlative data verification. The former verification method and human-computer interaction were combined to complete accuracy validation here. As to evaluate the reliability of difference index approach for rice extraction, we also applied traditional supervised classification to extract rice information from multi-band SAR composite image, and compared their results. Before verifying the extracted information accuracy, we converted the extracted rice information into binary thematic map (1 delegates rice, and 0 delegates non-rice), and imported the binary maps into international remote sensing software ERDAS to calculate the classification accuracy. The accuracy assessment result see stand error matrix (Tab.2).

**Table 2 Accuracy assessment error matrix**

| | | Rice | Non-rice | Total | User's |
|---|---|---|---|---|---|
| ① | Rice | 84 | 18 | 102 | 82.35% |
| | Non-rice | 9 | 145 | 154 | 94.16% |
| | Total | 93 | 163 | 256 | |
| | Producer's | 90.32% | 88.96% | | |
| | Overall accuracy: 89.45%; Kappa: 0.7767 | | | | |
| ② | Rice | 94 | 8 | 102 | 92.16% |
| | Non-rice | 15 | 139 | 154 | 90.26% |
| | Total | 109 | 147 | 256 | |
| | Producer's | 86.24% | 94.56% | | |
| | Overall accuracy: 91.02%; Kappa: 0.8147 | | | | |

Note: ① represents SAR band composite image; ② represents multi-temporal and dual polarization difference index image

According to the statistics from table 2, we can find that the rice information could be extracted well from two-date and dual polarization difference index image, and the overall accuracy and Kappa coefficient achieve 91.02% and 0.8147 respectively. The numbers are higher than that of multi-band SAR composite image. Besides, for the 256 random verified pixels, only 23 mix-up pixels in difference index image, which is less than that of SAR composite image. By contrast with 18 non-rice random pixels were identified rice pixels in composite image, the number of 8 random pixels is smaller in difference index image, which indicates that multi-temporal and dual polarization difference index approach is effective to reduce the confusion between rice and non-rice and enhance rice information.

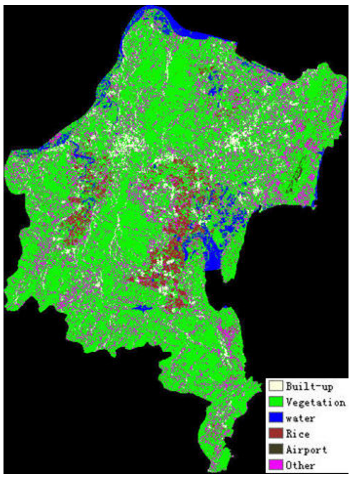


**Fig9 classification from SAR bands composite image**

## 5. Conclusion

Rice recognition and extraction could be realized by constructing multi-temporal and dual polarization difference index image. Because the difference index image can reveal the rice signal intensity in SAR image at the growing stage, and restrain non-rice reflection signal. This method not only reduced the confusion between rice and non-rice, but also lessened the amount of processed data. We can use simple threshold technique to recognize rice information effectively from SAR data.

Owing to the imaging radar date near the rice transplanting, the confusion of SAR signal between rice and some meadow in the beach near the riverside or seashore may appear. This situation mainly caused by tide height. We can remove mix-up information by comparing the backscatter coefficient characteristics of multi-temporal and different polarization SAR data between rice and non-rice, and get required rice information.

In a word, the image process approach of difference index can be used to extract rice information, which provides a new way to identify and monitor rice crop planting area from SAR data. With the popularity of multi-polarization SAR data, the application of SAR data in image processing and information identification will have a broad development.

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