Extraction of Hongze Lake Reclamation Area Based on RADARSAT SAR and LANDSAT ETM+

Shuang XIA¹,a, Renzong RUAN²,b, Meichun YAN¹,c, Yuanjian SHE¹,d

¹School of Earth Sciences and Engineering, Hohai University, China
²State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, China

Abstract

Due to some limitations of the visible and near infrared bands in remote sensing, radar remote sensing technology, which is capable in all-time, all-weather, and penetrating to some degree and so forth, has become a new technology and new method in rapid, large-scale information extraction. In this paper, the feasibility of using radar image as data source in terms of information extraction of Hongze Lake reclamation area is discussed. Firstly, based on RADARSAT-1 data, radar image was calibrated, geometrically corrected and filtered. Secondly, classification was carried out on SAR data and ETM+ data by using thresholds with the help of groundtruth data. Then, the ETM+ data was classified into the categories of aquaculture, open water, rice paddy and wetland vegetation by using wetness and spectral characteristics. Finally, the categories extracted from two different data sources were combined together. The results show that the methods used in this research are practical and efficient. The overall accuracy of classification is 93% with high Kappa Coefficient of 0.87.

Keywords: Hongze Lake; Reclamation Area; RADARSAT SAR; Extraction

Introduction

At present, remote sensing technology has been widely applied to environmental monitoring, natural disaster assessment, water resources survey, crop yield estimation and other fields[1,2]. In terms of extraction of reclamation information, it can provide relative departments of decision-making with a large amount of background information and reclamation information. Due to its capabilities in collecting information in high repetition rate and observing objects on the Earth in all-time and under different weather conditions, it greatly improves the objectivity and accuracy of the assessment of reclamation information. And also it can detect the spatial morphology of target objects effectively and enhance the topographic information. It is mainly applied to coastal observations, marine monitoring and topographic survey and so forth [3,4]. Scholars have different opinions on reclamation, which makes it a urgent problem on how to protect those wetlands in Hongze Lake. Since traditional methods of extracting reclamation area could not meet the realistic needs, people need to find new means and technologies of extracting that.
Study Area and Data Sources

Hongze Lake is located in cities of Suqian and Huai’an. It is a transitional lake, and its coverage changes greatly with fluctuations of water levels. The regular water level of the lake is 12.5 m. At the level, the area of the lake is 2069 km², and the volume 3.127 billion m³. It is the fourth largest freshwater lake in China. And it is one of the most important lakes and wetlands in Jiangsu Province. Most of the reclaimed areas in shallow water were previously covered with aquatic plants which are of highly ecological value. However, at present, many wetlands have been reclaimed, which causes the serious reduction of the area and the volume of the lake, especially the shallow areas of the Westside zone of Hongze Lake and lakes estuary of Huaihe River [5,6]. Due to the serious soil erosion of the surrounding land and the amazing input of lake sediment annually, the area of sands is increased rapidly. It not only directly reduces the area of the lake, but also creates objective conditions for the reclamation [7].

Data sets used in this experiment include Narrow-scan radar imagery of Canada’s RADARSAT and LANDSAT ETM + remote sensing imagery, which were acquired in July 9th, 2003 and August 5th, 2002 respectively.

Figure 1 Location of Hongze Lake in Jiangsu Province

Table 1 Parameters of RADARSAT-1 data products used in the study

| Beam Mode | Beam Position | Incidence Angle Range(deg) | Resolution(m) Range | Nominal Area(km²) |
|-----------|---------------|-----------------------------|---------------------|-------------------|
| ScanSAR Narrow | SN1 19.3-38.9 | 50(approximate) | 300*300 |

Methods

Data Preprocessing
(1) Calibration of the radar data

The following formula was used to extract the value of the radar brightness for pixels in the processed image.

$$\beta_j^0(dB) = 10 \cdot \log[(DN_j^2 + A3) / A2_j]$$  \hspace{1cm} (1)
*Where* $\beta_j$ *is the brightness value for the* $j$ *th. Pixel. $D_j$ *is the gray value. $A2_j$ *is the scaling gain value. $A3$ *is the fixed offset[8].*

(2) **Georeference of SAR imagery and ETM+ Imagery**

Ground control points were chosen, which should be distributed equally on the SAR image and ETM+ image. And a second order polynomial was used for geometric correction and cubic interpolation resampling was applied to keep edge information of the SAR imagery. Finally, Hongze Lake which is from 33°15’ to 33°25’ N and from 118°24’ to 118°40’ E is taken as the study area.

(3) **Filtering**

The selected Frost Filter is capable of maintaining the information of edges and textures of the original imagery and removing the noise speckles. The pixels were classified with the filter according to the threshold and $C_{max}$ (the maximum value of the distribution of $Cu$). If $Cv$ (coefficient of variation) $\leq Cu$ (coefficient of variation of multiplicative noise), the pixel value is considered homogeneous and its value will be replaced by mean value of the filtering window. If $Cu \leq Cv \leq C_{max}$, the pixel is considered heterogeneous and its value will be found though the convolution integral operation of the filter window which uses the impulse response as convolution kernel. If $C_{max} \leq Cv$, its value remains unchanged. $Cu$ and $C_{max}$ can be calculated as follows:

$$Cu = 0.532 \sqrt{L} \quad \text{and} \quad C_{max} = \sqrt{1 + 2 / L}$$

where $L$ is the scanning numbers of the same scene on SAR imagery. The imagery was filtered with a $5 \times 5$ Frost filter[9].

![Figure 2 Radar imagery of study area](image1)

![Figure 3 Composite of ETM+ (432) of study area](image2)

**Extraction of Reclamation information**

According to field surveys and the analysis of a variety of ancillary data, the characteristics of objects on both images are shown in Table 2.
Table 2 Image Characteristics of main objects in Hongze Lake

| Type          | Description                                    | Shape Features                      | Texture Feature               | Radar Echo |
|---------------|------------------------------------------------|-------------------------------------|-------------------------------|------------|
| aquaculture   | ponds for breeding prawns, crabs and other fish| grids or blocks in different sizes  | regular texture               | low echo   |
| rice paddy    | land for rice purpose                          | quadrilateral with regular geometric features | regular texture and blocky shape | medium echo |
| open water    | lake, rivers, canals, reservoirs, etc. without vegetation | large areas of shaped surface or continuous linear | fine texture | low echo |
| wetland vegetation | plants except, crops               | small pieces of continuous linear | coarse and irregular texture | medium echo |
| others        | residential areas, transportation, bare land including | irregular flakes area               | coarse texture               | high echo  |

Processing of SAR imagery

(1) Distinction between water bodies and non-water bodies

The radar brightness value was the most direct and important interpretation feature on the radar imagery. The mean value of the brightness values in water bodies on the radar imagery could be used to distinguish water and non-water bodies. Its extraction is as follows:

IF DN < K THEN the pixel was the water body
IF DN ≥ K THEN the pixel was the non-water body

where DN represents the brightness value, K represents the threshold [10]. When K is -22, the water body can be extracted accurately.

(2) Distinction between open water and aquaculture

Open water and aquaculture could not be distinguished from each other only by using the brightness values due to the similarity of their brightness values. However, due to big differences between textures of the two, the texture method was chosen. The texture mean of aquaculture was -14, while open water was close to -22. Therefore, textures could be used to effectively distinguish open water and aquaculture.

Processing of ETM+ imagery

(1) Distinction between open water and aquaculture

Classification results would not be good if we only use spectral characteristics to distinguish open water from aquaculture. Here the humidity index was chosen. It is up to -18 in open water, while aquaculture is close to -40. So, use of the spectral characteristics allowed us visually separate open water from aquaculture.

(2) Distinction between rice paddy and wetland vegetation

In the study, it is found that rice paddy and wetlands vegetation were greatly different in pixel brightness value in TM3. By trial and error, 47 is chosen as threshold.

(3) Distinction among emergent aquatic plants, floating aquatic plants and submerged aquatic plants

Figure 4 demonstrates the spectral response curves of aquatic plants. In TM4 pixel values of submerged aquatic plants are close to 10, while those of emergent aquatic plants and floating aquatic plants were greater than 30. And in TM5, pixel values of floating aquatic plants and submerged aquatic
plants were less than 20, while those of emergent aquatic plants were greater than 50. Therefore, pixel values in these two bands could be used to extract aquatic plants.

Combination of the extraction information of SAR imagery and ETM+ imagery

The extraction results by using two kinds of data were superimposed. By merging them, we can acquire more accurate classification results of Hongze Lake Reclamation area.

Figure 4 Spectral characteristics of aquatic vegetation

Results Analysis and Accuracy Assessment

The interpretation on classification results of two images could be more accurate. And the information extracted from the RADARSAT SAR imagery and LANDSAT ETM+ imagery were combined together. Classification results are shown in Figure 5, and the accuracy evaluation of classification results are shown in Table 3. The user accuracy in the accuracy evaluation of the table reflects the errors of commission, while the producer’s accuracy reflects the errors of omission. In this paper, the overall classification accuracy was 91.70 percent with high Kappa coefficient of 0.87. As spicy salt phenomenon was produced after classification, it must be eliminated. And the classification accuracies might have been affected by the determination of the size of the patches that should be removed.

It is easier to distinguish water bodies from non-water bodies by using their significant differences on SAR imagery. Due to low backscatter in radar data, the overall gray values of water bodies were quite low. In this paper by trial and error, it is found that when -22 is chosen as threshold, the results could be achieved better.

In the table 3, E represents emergent aquatic plants, F represents floating aquatic plants and S represents submerged aquatic plants. As the two images were acquired in July and August respectively, three kinds of aquatic plants were relatively prosperous and were widely distributed throughout rice paddies and aquacultures. And, they had the similarity of spectral characteristics. Therefore, the above four categories are confused seriously. It leads the classification accuracies of wetland vegetation based on the decision tree were quite low.

Meanwhile, we noted that there were some defects in the texture mean method used in this study. For example, its calculation process was relatively complicated, because it required the analysis of textures in different sliding window, angles, directions and steps. And its computational work is quite large, so it is time-consuming. In the future, better ways must be found to improve that method.
Table 3 Error matrix for classification in the study area

| open water | aquaculture | rice paddy | E     | F     | S     | others | User Accuracy (%) |
|------------|-------------|-------------|-------|-------|-------|--------|-------------------|
| 98.70      | 13.410      | 0           | 0     | 0     | 0     | 0      | 96.10             |
| 0.8        | 78.67       | 0           | 0     | 0     | 0     | 0.66   | 96.56             |
| 0          | 0           | 88.26       | 0.63  | 0     | 8.08  | 0.66   | 96.83             |
| 0.51       | 7.92        | 0.68        | 76.80 | 5.65  | 1.20  | 0      | 50                |
| 0          | 0           | 10.03       | 0     | 90.58 | 14.97 | 11.15  | 65.35             |
| 0          | 0           | 1.03        | 1.25  | 0     | 75.75 | 0      | 90.36             |
| 0          | 21          | 0.38        | 0     | 86.89 | 79.34 |        |                   |

Producer’s Accuracy (%)  
Overall Accuracy=91.70%  
Kappa Coefficient =0.87

Conclusions and Discussion

In terms of the distinction between water bodies and non-water bodies, the accuracy of extraction of the SAR imagery was fairly high. With the visual verification, the accuracy could reach 90%. For the distinction between open water and aquaculture, we could get a more accurate interpretation by integrating classification results of both SAR imagery and LANDSAT ETM + imagery.

Classification method of Decision Tree, which was supplemented by textures, humidity index and other information, plays a significant role in highlighting the reclamation information. The classification
accuracy of this method is fairly high. The only shortage of the method was that the threshold value needed to be determined by doing many experiments.

This study demonstrates that the combination of the RADARSAT SAR imagery and LANDSAT ETM + imagery can be used to extract information of Hongze Lake reclamation area. And this method has its practical significance. The complemented information of the same area, which is from different data sources, could be used maximally. It contributes to reducing uncertainty, incompleteness and error, which might exist in the environment interpretation of a single data source. This not only expands the scope of application of data sets, but also enhances the accuracies of analysis and use value.

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