

CHANGE DETECTION OF WETLAND IN HONGZE LAKE USING A TIME SERIES OF REMOTELY SENSED IMAGERY

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ABSTRACT:

The main aim of the study was to assess the potential of a time series of remotely sensed data for the change detection of wetland in Hongze Lake in the Northern Jiangsu Province. The raw data comprised three digital images acquired between 1979 and 2002. The task proceeded in three parts. First, following pre-processing and registration to the topography at the scale of 1:100,000, the ETM+ image of 2002 was classified by using hybrid classification techniques. A thematic feature space image of near-infrared versus red was created based on the above classification results. Second, the historical remotely sensed data were clustered using standard unsupervised classification technique ISODATA and then the clusters were labelled into information classes by means of the selection of core clusters, the relationship of clusters between clusters in feature space and geographical space. Third, the class "Emergent" was extracted from the three dates of thematic maps and recoded respectively as three files. The three files were then overlaid for the analysis of wetland change. The distribution of the class "Emergent" and its change as time and in space were used as indicators for the change of wetland environment. The results showed that a great loss of wetland has occurred in the study area in the past more than 20 years.

1. INTRODUCTION

Wetland, one of significant components of regional ecosystem, has many functional services such as the regulation of climate, purification of environment, and balance-keeping of regional water. As a special ecosystem, it locates in the transition zone between land ecological and aquatic ecosystems, a mix of characteristics from upland areas and the characteristics of aquatic environments. This mix of characteristics creates a unique habitat for life and earth processes. Since late 1980s, wetland has been under the impact of human disturbance in the world. The human disturbance includes reclamation of wetland, pollution etc. Now a lot of wetland has been lost in the world (Mitsch and Gosselink, 1993). This endangers the sustainable development of humankind. The wetland in Hongze Lake of Northern Jiangsu Province has been on the risk of loss because of a large of reclamation and net culture in recent years. For the protection of the wetland, a state-level preserve has been established. This study was to find the trend of wetland change in the study area so that a basis could be provided for the decision-making in the protection of the wetland.

2. STUDY AREA

Hongze Lake is located between 33° 06' —33° 40' N in latitude, 118° 10' —119° 00' E in longitude, and the fourth biggest fresh water lake in China(Wang and Dou, 1998). The lake mainly have its water supply from Huai River and discharge mostly through Sanhe River and Gaoyou Lake into the Changjiang River, the rest of water discharged into East China Sea through the Northern Jiangsu Main Irrigation Canal. The average water depth of Hongze Lake is 1.77 meters, with the deepest part being 4.37 meters (Wang and Dou, 1998). There are a variety of wetland plants in Hongze Lake watershed.

From the bank of the lake to its deeper parts, wetland plants such as *Phragmites australis*, *Zizania caduciflora*, *Nelumbo nucifera*, *Euvyale ferox*, *Trapa matans*, *Potamogeton malaianus*, *Myriophyllum spicatum* and *Hydrilla verticillata* var. *roxburghii* distribute. In recent nearly 30 years, the wetland has lost a lot and about 209 km² wetland has been lost, accounting for 13% of the total area of the lake (Luo, 1990). Moreover, the extent of wetland is greatly influenced by the water level of the lake. Since the construction of the Sanhe Dam, the level of water storage has been lifted significantly, and this has caused a great reduction of the extent of *Phragmites australis* (Wang, 1995). The study area includes the most part of Jiangsu Sihong Hongze Lake Wetland Natural Reserve. The reserve lies between the longitude 118° 13' 9" E—118° 28' 42" E and the latitude 33° 20' 27" N—33° 10' 40" N. The total area of the reserve is 23453hm², in which the core area is 2205 hm², the buffer area 4659 hm² and the test area 16589 hm², accounting for 9.4%、19.9% and 70.7% of the total area respectively. The reserve is set up for the protection of Hongze Lake wetland ecosystem and rare birds. The study area is characterized by a great diversity in landscape. There is a variety of wetland and upland types in this area (table 1). Wetland types consist of natural and artificial wetlands. Natural wetlands include the wetland with submerged plants, the ones with emergent plants, the ones with floating plants and open water. In this paper, submerged, emergent and floating are used to denote these three categories of wetlands with submerged, emergent and floating plants. Artificial wetland mainly consists of fishing ponds and rice paddy. In this paper, lake wetlands are mainly reclaimed into fishing ponds. Therefore, rice paddy and dryland are grouped into a class called agriculture. They are the dominant upland type. Besides the class agriculture, the other upland types still include urban and forest categories. In the past, most of natural wetlands have been reclaimed into fishing pond or used for net fishing.

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Class	Class name	Description
1	submerged	Potamogeton malaianus, Myriophyllum spicatum etc.
2	emergent	Phragmites australis, Zizania Caduciflora etc.
3	floating	Euvyale ferox, Trapa matans
4	open water	Lake water body, natural river, canal, channel, reservoir and ponds, without any wetland plants
5	fishing pond	Water areas for fishing farm such as crab and fish raising
6	agriculture	Rice paddy and dryland
7	forest	Include natural and planted forest
8	urban	Land for settlement, communication, other industry and exposed land

Table1 Landuse /cover classification scheme for the study area

3. METHODOLOGY

3.1 Data sources and preprocessing

The images of Landsat MSS and Landsat TM, ETM+, acquired respectively on August 6, 1979, October 25, 1988 and August 21, 2002, were used. First, the image of 2002 was geometrically corrected and georeferenced by using the topography at the scale of 1:100,000. Then the geometrically corrected 2002 image was used as a master image for the registration of two other historical images. Finally, the landuse/cover classification scheme (see table 1) was made by using the false color composites of images in conjunction with field investigation data and relative thematic maps.

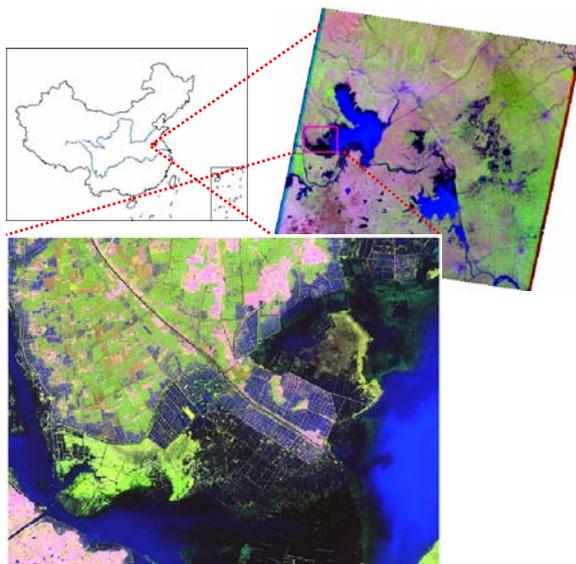


Figure 1. Location of the study area (composite of 2002 ETM+ in RGB453)

3.2 The 2002 base image classification

First, the standard unsupervised classification of the 2002 Landsat ETM+ image of the study area was performed by using ISODATA algorithm, yielding 50 clusters. The preliminary labelling of clusters was done and the stratified sampling was

carried out, yielding 256 sampling points. After the analysis of the 256 points, some of them were removed because of their location in the boundary of two types. The remaining 231 points were uploaded into GPS for the navigation of field investigation. In the field investigation, the type of landuse/cover was recorded. These 231 points were also labelled on the original image of 2002, and their mean DN values, variance and covariance computed. The 231 points were used as seeds for a supervised maximum-likelihood classification of the 2002 base image (Jensen et al., 1987). The total accuracy of the classification was 83.81%, and the kappa coefficient 0.8164.

Although the classification of historical remotely sensed data can be performed under the aid of the investigation by interviewing old people, the past topography and relative thematic maps etc., the lack of the data for the study area matching in time with the remotely sensed data has hindered the quality classification and the evaluation of the classification accuracy. However, a careful selection of data sources such as the data of the same season and near-anniversary data can to some degree improve the classification accuracy of historical images. This will reduce the effects of solar altitude, azimuth, atmospheric condition and vegetation phenology on the interpretation of imagery (Munyati, 2000).

The latest 2002 remote sensing imagery and its classification results were used to understand where the important wetland and upland classes were located in the multi-spectral feature space (Jensen et al., 1995; Jensen et al. 1997). Spectral vectors were extracted from the 2002 ETM+ image at those 231 points and plotted in red versus near-infrared feature space. It was shown that wetland and upland classes occupied specific space. So a thematic feature space image of red versus near-infrared was created based on the classification of 2002 image to aid the labeling of spectral clusters in later historical image classification (Fig. 2).

It could be found that in red versus near-infrared feature space, the distribution of different classes was relative constant. The class Submerged lies in the left lowest corner because of small spectral response in both bands. Since submerged plants can purify hydrological environment, the water grown with the plants is clear and transparent. More visible light will travel through water body and go into its interior. In addition, the water can absorb greatly the energy of near-infrared band (Jensen et al., 1984). Thus the spectral response of the class is low in both red and near-infrared band. Moreover, the substrate mud rich in organic matter and organic carbon in submerged area also attributes to the more absorption of light. Open water absorbed about the same amount of near-infrared radiant flux as the class Submerged. However the class Open water scatters more radiant flux in red band due to great water turbidity and high concentration of suspended solids. Because of high concentration of algae in fishing ponds, the spectral response of the class was great in near-infrared band. In the feature space, the class Floating lies above the class submerged and under the class agriculture. Usually, the floating plants have more biomass than that of submerged plants and less than that of rice paddy. The floating plants emit more near-infrared energy than submerged plants. That was why the class floating was located above Submerged, Fishing pond and Open water classes. The spectral response of the class Emergent in near-infrared band was the highest and lies left highest corner. Although the overlay existed between the spectral feature distribution of the class Agriculture and that of the class Emergent, and caused

confusion in classification, this problem can be significantly reduced by masking out upland using hydrological map of Hongze Lake. The class Urban lies in right area and its distribution was sparse. This was because the composition of the class Urban was much more complicated.

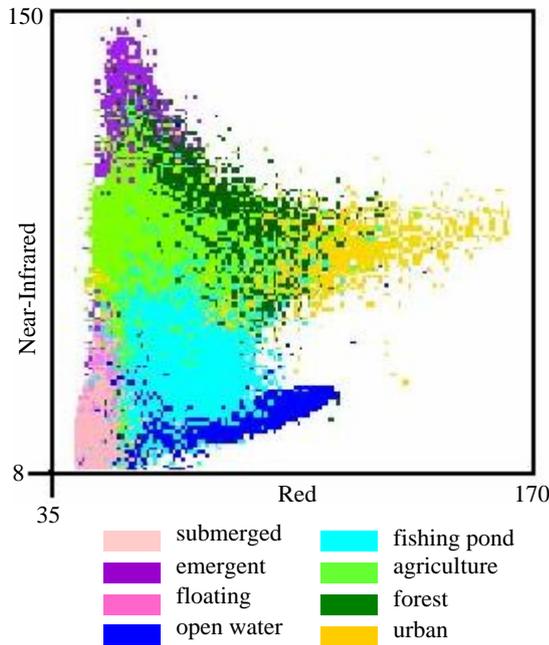


Figure 2. Distribution of classes of 2002 image classification

3.3 Labeling clusters extracted from historical remotely sensed data classification

It was hypothesized that the feature space relationships for the major wetland classes and upland classes would be relatively constant between the various dates of imagery. Therefore each remotely sensed data of 1979 Landsat MSS and 1988 Landsat TM was analyzed using unsupervised technique ISODATA to yield 50 clusters (Jensen, 1996). In order to label the 50 clusters on each date of imagery into information classes as accurately as possible, the following techniques were used: (a) Mean vectors of clusters were plotted in red versus near-infrared feature space for each date of imagery; (b) Clusters were overlaid upon a false color composite of RGB(RGB = near-infrared, red and green bands) of the study area. (c) An individual cluster under investigation was highlighted (e.g. in yellow) showing its geographical distribution and relationship with other clusters already evaluated (Jensen et al., 1995).

At first, using the above mentioned techniques in conjunction with the investigation on the local old people, the core clusters were identified and labeled. The core clusters are those clusters in each data of imagery having more than 10000 pixels and spectral homogeneity within clusters according to 2002 classification map. These clusters were also easy to label into information classes from the aspect of the geographical distribution of clusters.

It was possible to use core clusters as “anchor points” to subjectively evaluate and label surrounding non-core clusters using information provided in the overlay map. Those clusters which were relatively near the core clusters “Emergent” in the feature space and /or geographic space on an individual date were assigned to Emergent class. Using the same logic, clusters

which were relatively near the core “Urban” in the feature space and /geographical space were assigned to Urban class.

3.4 Change detection of wetland

The goal of wetland change detection was to identify the trend of wetland change in quality and space. Therefore it was a straightforward task that post-classification comparison technique was used to compare the individual wetland classification maps of each date for exploring the change trend (Table 2). Macrophytes such as *Phragmites australis* can be used as an indicator of the presence of wetland. Their changes in space usually indicate the change of hydrological environment in lake. In this paper, the spatial distribution of Emergent class was extracted from each of the classification maps and recoded into a new file according to a coding scheme in which the class Emergent in the classification maps of 1979, 1988 and 2002 was assigned to 1, 2 and 3 respectively. Then the three files were converted into grid formatted files and imported into GIS software to yield change detection map by overlaying those three files. As for the types of change, see Table 3.

4. RESULTS AND DISCUSSION

Firstly, it was a straightforward work to compare the individual wetland classification maps using “post-classification” method to find out the trend of wetland change in quantity over the past more 20 years. Three classification maps were compared to compute the change percentage of each class, especially of wetland classes (Table 2).

class	Coverage (Ha)			Change Percentage	
	1979	1988	2000	1979-1988	1988-2002
1	16248.87	9163.71	12365.40	-43.60%	34.94%
2	4958.17	4600.67	2529.18	-7.21%	-45.03%
3	3163.52	3498.29	2830.16	10.58%	-19.10%
4	3180.45	10296.19	8919.25	223.73%	-13.37%
5	460.91	577.49	4940.22	25.29%	755.46%
6	12349.18	11867.02	10609.24	-3.90%	-10.60%
7	2981.24	2139.69	882.47	-28.23%	-58.76%
8	784.94	1881.37	948.48	139.68%	-49.59%

Table 2 The coverage of Classes and Their Change Percentage

It was shown in Table 2 that the greatest change from the year 1979 to 1988 in the study area was the class “Open water”, increased by two times. This increase was mainly due to the lift of water storage level by Sanhe Dam. The rise of water level in the lake has caused a significant decrease of emergent and submerged plants. In the study area, submerged plants usually grow in the area of 2 to 3 meters depth and emergent plants in the area of less than 2.5 meters in depth. When water storage level rises, the distribution of submerged and emergent plants will shift toward the bank (Yu, 1994). However due to the limit of bank, the space for their growth was limited. That was the main cause for the decrease of wetland plants in this period. From the year 1988 to 2002, the most outstanding change was the increase of fishing ponds and the decrease of emergent plants. Since the late 1980s, fishing farm, especially crab culture, has been surging up. Not only a lot of farmland has been changed into fishing ponds, but also a large area of

shallow fresh water wetland have been reclaimed for net fishing. Here aquaculture is obviously the main cause for the loss and degradation of inland fresh water wetland. Especially the crab gnaws the shoot of wetland plants and is a great destroyer to wetland plants.

Code	Type	Description
000	Background	
003	1	Emergent plants occurred in 2002
020	2	Emergent plants occurred in 1988
023	3	Emergent plants occurred in 1988 and 2002
100	4	Emergent plants occurred only in 1979
103	5	Emergent plants occurred in 1979 and 2002
120	6	Emergent plants occurred in 1979 and 1988
123	7	Emergent plants occurred on three dates

Table 3 Coding scheme for change detection in the study area

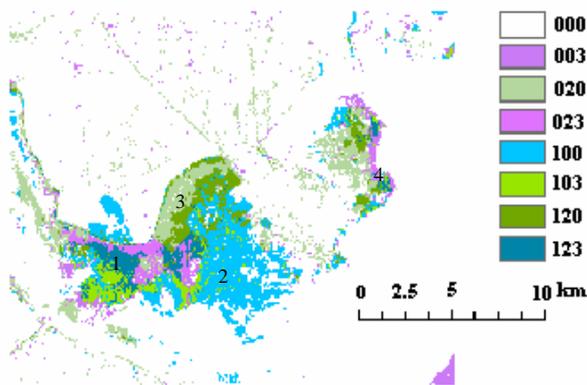


Figure 3. Change map of emergent plants in the study area

It was shown in change map that in the area to the south of Linhuai(marked with number 2 and light blue) there was plentiful of emergent plants in 1979. It was said that in 1980s, emergent plants such as *Phragmites australis* were dense here. Since the late 1980s, large scale reclamation of inland fresh water wetland has begun. This area has been reclaimed for a long time and emergent plants have disappeared completely, only some submerged plants exist now. At present, the underwater dams are here and there. The dams, usually 1m high, are constructed by fishing farmers for the keeping of water when water level of lake lowers. The construction has damaged the connectivity of landscape in lake and damaged the spawning of fish in lake. The area near Dazhakou(marked with 3 in Fig. 3) has now been fishing ponds, while in 1988, emergent plants grow thick. The area marked with 1 is the Jiangsu Sihong Wetland Natural Reserve. Due to the good protection, emergent plants there are thick and wild birds such as pheasants and wild ducks are flocks. Near Wangsha island (marked with 4), there were lots of *Phragmites australis* in 1988. However since 1990s, the area has been reclaimed for network fishing and *Phragmites australis* is disappearing rapidly.

5. CONCLUSIONS

Time series imagery can play a significant role in tracing the change of wetland in Hongze Lake. The relationship between major wetland classes and upland classes in feature space and in geographical space can aid the interpretation of historical imagery. The spatial distribution of emergent plants can be used as an indicator to show the change of wetland ecological environment. The change map derived from recoding the spatial distribution of emergent plants can show the trajectory of wetland change. The study shows that in the past more than 20 years, significant loss of natural wetland has been occurred in the study area due to the reclamation of wetland and net fishing.

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