The study on landscape pattern change of wetland based on GIS and RS: An example of Dongting Lake area

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ABSTRACT

As one of three important ecosystems in the world ,wetland has complex , various and specific functions. With the change of its component ,the wetland ecosystem function is changing . Analyzing the process of wetland landscape change can expose the mechanism and rules of wetland landscape change and provide academic supply for sustainable use of wetland resource .In this paper the landscape pattern change of Dongting Lake wetland was studied. Dongting Lake wetland is one of the most important wetland ecosystems in China and it has complex and various functions and values.From 1980 to 2000,Dongting Lake wetland changed gradually due to natural factor and human activities.In order to better understand physical and human effect on wetland, protect and use the wetland resources sustainably in Dongting Lake area, it is necessary tor study the change of wetland landscape in Dongting Lake area .Some indices of the landscape pattern, such as landscape diversity index, landscape dominance index, landscape fractal dimension index are adopted .This study was on the basis of Chinese Academy of Sciences resource and environment spatial-temporal database and the two-stage remote sensing data: Landsat MSS data captured in 1980 and Landsat TM/ETM data captured in 2000. The result showed that wetland area increased by 16307hm^2, of which paddy field and riverwetland decreased largely, but pond wetland area increased obviously.Totally artificial wetland area increased, while natural wetland decreased. Accordingly the landscape pattern indices changed with the changes of area and perimeter of several wetland types in Dongting Lake. These changes are the result of interactions between human activities and natural factor.But the human impact on wetland is the most important causation in the past two decades. The changes of wetland landscape made environmental quality and ecological function decade in Dongting Lake area, especially the flood disaster aggravate.

Key words: Wetland; Dongting Lake area; Landscape change; RS

1.INTRODUCTION

Landscape spatial pattern, which is an important demonstration on the landscape heterogeneity and the result of interaction of various ecological processes in different scale [1], refers to the spatial distribution of patches in different sizes and forms. The study on landscape spatial pattern may provide valuable information for rational management of the environmental resources . And it has been one of the key study areas in landscape ecology[2] . Presently the study mainly concentrates on two sides [3 ~ 5]. One is statistic spatial pattern analysis, which mainly discusses the landscape spatial heterogeneity, and another is the landscape temporal heterogeneity that discusses the landscape pattern temporal change [6 ~ 9]

As one of three important ecosystems in the world, wetland has complex and various , specific functions and scattered around the world [10] .The landscape pattern of wetland depends on the spatial distribution of wetland resources and its component. Because of effect of all kinds of factors, the wetland landscape pattern always changes .The present landscape pattern is on the basis of the past landscape, so analyzing the process of wetland landscape change can expose the mechanism and rules of wetland landscape change and provide academic supply for sustainable use of wetland resources. Many researchers have carried out several studies on wetland landscape pattern change in China and other countries[11 ~ 14].

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The wetland landscape change is the basis of wetland resources management, planning or regional policy program .So in order to better understand physical and human effect on wetland, protect and use the wetland resources sustainably in Dongting Lake area, it is very important that accurate and timely information on landscape pattern change is obtained. Remote sensing offers an ideal tool for monitoring local landscape pattern change, particularly as a means of complementing or updating conventional data. GIS is a good data management tool. With the application of GIS and Remote sensing,this paper studied on the wetland landscape pattern change in Dongting Lake area by analyzing 1980 MSS and 2000 TM images. The objective of this study is to know the situation of landscape pattern change and discover the reason why landscape pattern changed. What is more important is to make rational use of local wetland resources and to realize the regional sustainable development.

2.GENERAL SITUATION OF STUDY AREA

Dongting Lake area, located on the southern bank of the middle Yangtze River in central China(28°30′ ~ 30°20′N, 110°40′ ~ 113°10′E).According to Chinese Academy of Sciences resource and environment database, the study area, Dongting Lake region including Yue-yang city, Yue-yang county, Hua-rong county, Yuan-jiang city, Nan county, Xiang-yin county, Mi-luo city, Yi-yang county, Yi-yang city, An-xiang county, Han-shou county, Li county, Chang-de city, Jin-shi city, and Shi-shou city, Gong-an county, Song-zi city and so on, has an total area of 28,737 km^2, of which 22,875 km^2 are in Hunan province, and 5,862 km^2 in Hubei province.The Dongting Lake in this area, the second largest fresh water lake in China, holds huge amount of water coming from the Xiangjiang River, Zishui River, Yuanjiang River and Lishui Rivers, and three diversions of Yangtze River(Songzi, Taiping and Ouchi Rivers) and miluojiang, Xinqiang river around the lake area. After regulated and stored by the lake, the lake water flows out into the Yangtze River at Chenglingji.

The area has a subtropical monsoon climate, with an average annual rainfall range of 1100 ~ 1400 mm, and annual mean temperature of 16℃. The annual rainfall does not distribute meanly, mostly in summer (rainfall in summer account for 80 percent of all-year rainfall, according to the average data of many years). This area is a lacustrine and fluvial plain, with the average elevation of 25-40m, but the majority of the cultivated land elevation is below 35m.The special geographic environment and climate are fit for wild animals and plants to propagate and grow. The wetland resources in this area are abundant, and its distribution is extensive [15].

Dongting Lake wetland, which consists of river, lake, paddy field, bottomland, swamp, pond, is one of 200 important ecological regions all over the world, and one of 7 wetlands included in the Ramsar List of Wetlands of International Importance in China. But wetland landscape has changed greatly due to effect of natural factor and human activities. Especially excessive exploitation of lake wetland resources has devastated many local natural ecosystems.. As a result, the local wetland ecosystem is becoming more and more fragile and a series of environmental problems occurred, especially frequent flood disaster, which has hindered the sustainable development of social economy.

3.DATA AND STUDY METHODS

3.1Data Sources

The data of this study came from the national resource and environment database. We extracted the wetland information using the two-stage remote sensing data in this study: Landsat MSS data captured in 1980 and Landsat TM data captured in 2000. Additionally, topographic map, regional thematic research data and maps were consulted as reference data.

3.2Data processing

The first step was to define the wetland types and build the wetland classification system. Wetland was classified for 6 types including river wetland class, lake wetland class, paddy field wetland class, bottomland wetland class, swamp wetland class, pond wetland class, according to the characteristic of local wetland. In addition, local hydrological and ecological conditions and plant community were considered. The next step was to composite single band image and to preprocess the composite image using Envi 4.0 software. The composite contained three bands: green (0.52-0.60μm), red

(0.63-0.69μm) and near infrared (0.76-0.90μm). The pre-processing course mainly included radiometric correction, geometric correction and image enhancement. Besides the image was projected with Albers Conical Equal Area in order to make the area changeless. Thirdly, the image classification and mapping was conducted. Considering that image characteristics of different wetland types vary with not only the spectral reflectance but also the shape, size, position, etc and the automated image classifier is on the basis of spectrum in general, we adopted the method of visually interpreting image on screen with ArcGis 8.3 software. Many ground data on different wetland types were used to check and correct the classification mistakes. At last, the attribute information was extracted using ArcGis 8.3 software.

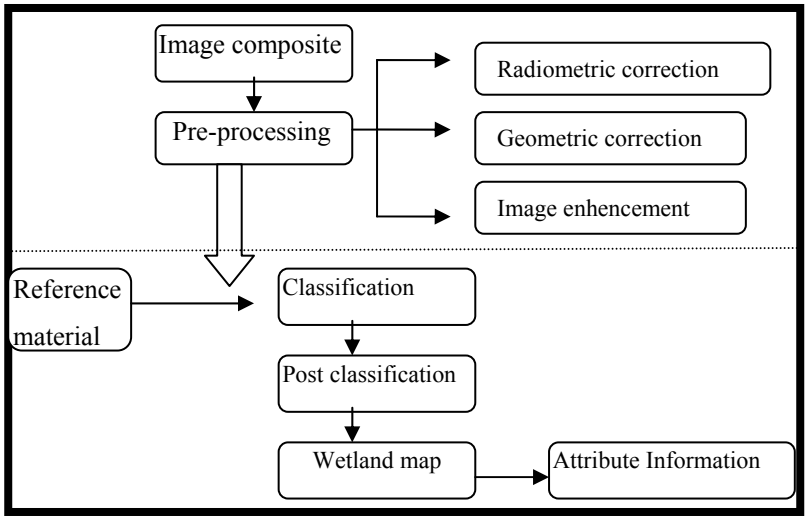

Fig. 1 The flow chart of the study

3.3 The characteristic index of wetland landscape pattern

Quantitative description of landscape spatial pattern and landscape heterogeneity is the basis of analyzing landscape structure, function and course [16]. So in order to further analyze the wetland pattern change and impacts of natural factor and human activities, the following quantitative indices of wetland landscape pattern were selected according to the characteristics of the area: diversity, dominance, mean patch size and fractal dimension and so on.

3.3.1The landscape diversity index

The landscape diversity index, which reflects the degree of abundance and average of landscape patch, refers to frequency of patch occurring in regional landscape. When the landscape that consists of one element is homogenous, the landscape diversity index is zero. To the landscape consisting of two landscape types or more, the landscape diversity index is highest when the proportions of all landscape types are equal, but the landscape diversity index will decline if the difference between proportions of landscape types increases.

$$H = -\sum_{i=1}^{N} (P_i) \times \ln (P_i) \quad (1)$$

where P_i is the probability of the frequency of the ith landscape type, N is the number of total landscape types. H is the landscape diversity index. The bigger H is, the more abundant the landscape type is. Moreover the index reflects the landscape heterogeneity too.

3.3.2 The landscape dominance index

The index reflects the dominating degree of one or several landscape types. In other words, it measures the departure of landscape diversity to the maximal diversity. If D is zero, the proportion of each landscape type is entirely equal, namely only a landscape type. The bigger D is, the more obvious the difference of the landscape type in proportion is.

$$D = H_{\max} + \sum_{i=1}^{N} (P_i) \times \ln(P_i) = H_{\max} - H \quad (2)$$

$$H_{\max} = \ln(N) \quad (3)$$

where D is the landscape dominance index , P_i is the probability of the frequency of the ith landscape type, N is the number of total landscape types

3.3.3 The landscape fractal dimension index

The index which is between 1.0 and 2.0 is used to indicate the complex degree of patch shape.The value 1.0 represents the simplest foursquare patch and 2.0 represents the most complex patch in shape. The smaller the value of this index is, the simpler the shape of patch is. The index may reflect the disturbance degree of human activities to landscape

$$FD = 2\ln(P/4)/\ln(A) \quad (4)$$

where FD is fractal dimension index, P is the perimeter of patch and A is the area of patch.

3.3.4 The mean patch size

It is a simple landscape index ,but its ecological significance is important due to its sensitivity to landscape change.It can be a index to compare the fragmentation or aggregation of different landscape, and to a certain extent it can indicate the impact of human activities.

$$MPS_i = \frac{A_i}{N_i} \quad (5)$$

Where MPS_i is the mean patch size index, A_i and N_i are area and number of ith wetland type respectively.

4. RESULTS AND DISCUSSION

4.1 The regional landscape pattern change

Table 1 Comparison of wetland landscape dynamics from 1980 to 2000

Year	Number of patches	Total area (hm^2)	Total perimeter (m)
1980	7316	1881125	87902190
2000	7573	1897432	88090825

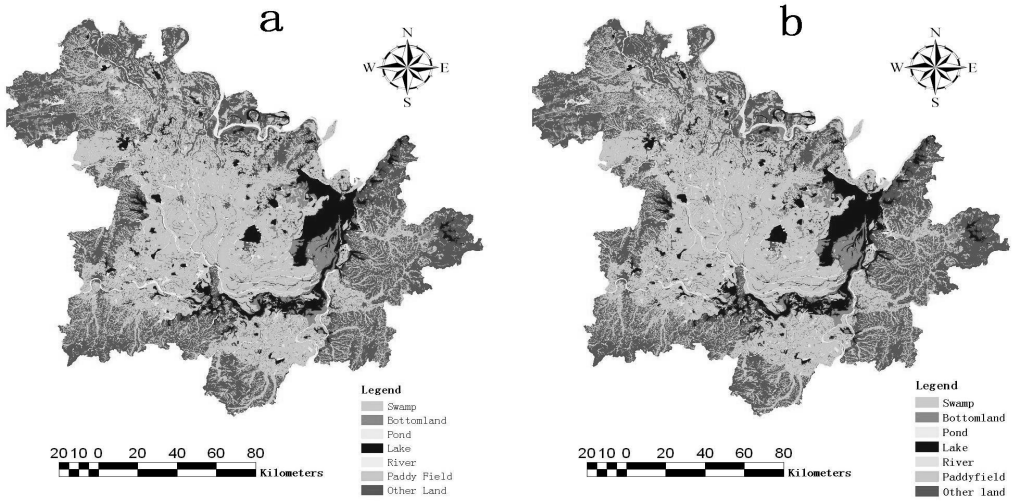

Fig.2 The distribution maps of the wetland resources of Dongting Lake area in 1980 (a) and 2000 (b)

The total area of the wetland in Dongting area was 1881125hm^2 in 1980 and 11897432hm^2 in 2000 respectively (table1). The total area increased by 16307hm^2.The number of patches was 7316 in 1980 and 7573 in 2000 respectively. To individual, river wetland area, Lake Wetland area, paddy field wetland area, bottomland wetland area, swamp wetland area, pond wetland area accounted for 4.84%, 12.44%, 68.51%, 6.18%, 4.16% and 3.88% respectively in 1980. While in 2000, the ratio is 4.74%, 12.35%, 67.59%, 6.31%, 4.12% and 4.89% respectively. The average patch area and average patch perimeter were 2.57km^2, 12015m in 1980 and 2.51 km^2, 11632m in 2000 respectively. All of those showed the wetland landscape change was great under the impact of human and natural factor from 1980 to 2000. Especially after the flood in 1998, China took many measures to reduce the disturbance on natural ecosystem and add natural wetland area. One of the main reasons is the engineering of Returning Farmland to Lake .The direct result was increase of the wetland area and the total perimeter of patch. Moreover the increase of the number of patches and the decrease of average patch area indicated that fragmentation was increased.

4.2 Change of the regional wetland landscape index

The landscape diversity index rose from 1.095 in 1980 to 1.121 in 2000.Though the change is small, but to a certain extent the rise of index showed that the landscape heterogeneity increased .In this area the maximum of the landscape diversity index is 1.792.This indicated that there was some difference among the proportion of every wetland landscape type and with the increase of the landscape diversity, difference among the proportion of each wetland landscape type is inclined to reduction. The landscape dominance index was 0.697 in 1980 and 0.671 in 2000, which indicated there were some dominant landscape types in Dongting Lake area. According to statistic result, the paddy field landscape and lake wetland was dominant, in which the paddy field landscape was most. The proportions of other landscape types are small.

The regional landscape fractal dimension index decreased from1.430 in 1980 to 1.428 in 2000 respectively. It indicated the patches shapes were inclined to simple and regular. Farther it showed the human disturbance to the wetland in Dongting Lake area was increased gradually. At the same time this can be indicated from the mean patch size, which was 257 hm^2 in 1980 and 250 hm^2 in 2000 separately. Though the engineering of Returning Farmland to Lake was put in practice after1998. But due to long-time reclamation of wetland, the wetland resources had been greatly damaged, and the most of increased wetland was pond wetland type, which was regular and dispersive, so the regional landscape fractal dimension index decreased.

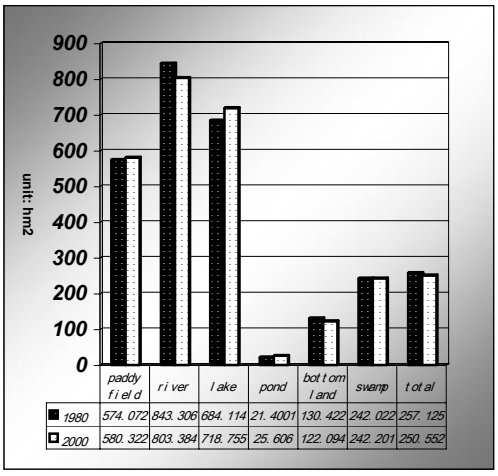

Fig3 the MPS map of wetland type in 1980 and 2000

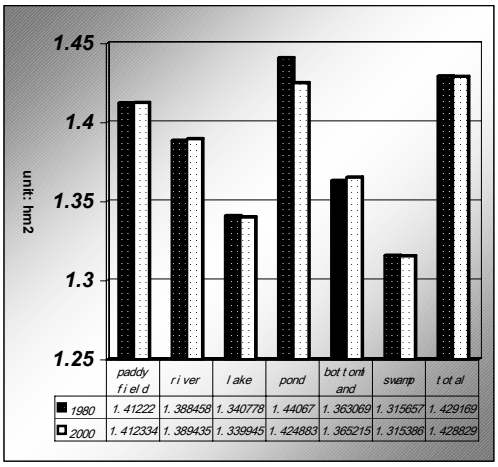

Fig4 the FD map of wetland type in 1980 and 2000

4.3 The analysis of change of single wetland landscape index

4.3.1 The dynamics of paddy field wetland

There was an obvious decrease in area of paddy field wetland. From 1980 to 2000 the area of paddy field wetland decreased 6281hm^2, about 0.49% of the area of paddy field in 1980.Accordingly the number of paddy field patches decreased, too. During the past two decades FD hardly changed .The average area of patches changed from 574 hm^2 in 1980 to 580 hm^2 in 2000, and the average perimeter of patches were 24532m in 1980 and 24868m in 2000. All these indicated that the fragmentation of paddy field had no further development; on the contrary the landscape fractal dimension index was increased. Reclaiming land from other wetland types, especially lake wetland, had decreased greatly. Returning land to lake had some effect.

4.3.2 The dynamics of river wetland landscape

According to the statistic result, the area of river decreased by 1.21%, while the perimeter increased 0.17%, about 11007m.The number of patches nearly changed in two decades. FD changed from 1.3885 in 1980 to 1.3894 in 2000. The river channel tended to be complex. In Dongting Lake area the river water derives from the Yangtze River, in which the sediment charge is high, so the river channel is liable to silt up. The river channel shape became more complex and more sinuous. Some small rivers were fully stagnated to dry, and disappeared at last. The direct disturbance of human being to river is very small, but indirectly human activities affected the river landscape. Mostly land use change caused the water loss and soil erosion increased.

4.3.3 The dynamics of lake wetland landscape

From1980 to 2000 the change of lake wetland was not obvious, with only an increase of 347hm^2.The number of lake wetland patches changed very small, too. But the increase of area and decrease of patch number made the average patch area increase from 684 hm^2 to 718 hm^2. This showed degree of fragmentation decreased. As we know, the main purpose of Returning land to lake is to increase the area of lake in Dongting Lake and alleviate pressure of flood disaster. But why did the area of lake only increase a little, while the farmland decrease largely? After investigation, we found that one cause was that water level of lake was extremely variable seasonally. Even at the same time in different years the water level was different. Another cause was that many farmlands were changed to pond, but not lake. The detailed statement is the following. In addition, the last cause was that sediment accumulation makes the area of lake shrink.

4.3.4 The dynamics of pond wetland landscape

In all wetland types of Dongting Lake area, the change of pond wetland was the most obvious, with an increase of 19835 hm^2 from 1980 to 2000.The number of patches increased by 6.31%. The average patch area increased from 21 to 26 hm^2. Compared to 1980,the total perimeter increased more than 100,000m.The landscape fractal dimension index was 1.441 in 1980 and 1.424 in 2000, which indicated that the disturbance degree of human activities strengthened and the patch shape was inclined to regular. According to first-hand investigation the increased pond mostly came from farmland and

the artificial pond shape was regular generally. The profit in fishery was more than that in crop cultivation. Furthermore, the policy of returning land to lake accelerated the conversion from farmland to fishpond. It was very prevalent to convert farmland into fishpond in order to achieve the assignment of returning land to lake. In fact only a fraction of farmland was converted into lake.

4.3.5 The dynamics of bottomland and swamp wetland landscape

There was a slight increase in the area of swamp wetland, while the area of bottomland wetland increased largely. During two decades the area of bottomland and the number of patches increased 3.0% and 10% respectively. The number of swamp patches didn't change .The average patch area of bottomland changed from 130 hm^2 to 122 hm^2, but to swamp that hardly changed. By analyzing the transfer matrix, we found that the conversion among lake, swamp and bottomland was very large. This was affected by water level. FD of bottomland was 1.3631 in 1980 and 1.3652 in 2000,but to swamp the FD hardly changed. On the whole disturbance degree of human activities to bottomland and swamp was small. The change was mostly affected by natural factor, especially water level of lake or river.

5. CONCLUSION

Human activities and natural factor affect evolvement of Dongting Lake wetland system. Based on GIS and remote sensing technology, the wetland landscape change in Dongting Lake area was analyzed with two-stage remote sensing data. The result showed that, the wetland area increased in the past two decades. But the degree of fragmentation also increased due to effect of human activities and natural factor. The wetland landscape diversity index rose, accordingly the landscape dominance decreased. In two decades, in all wetland types of Dongting Lake area, the pond wetland increased most, while the paddy field decreased most. And paddy field decreased was mostly converted into pond. The swamp and bottomland changes were mainly affected by natural factor, especially precipitation. In theory the area of lake should increase largely after returning land to lake, but not so. The main cause was that the land didn't be converted into lake but into fishpond mostly. So the administering authority should take some measures to avoid those occurring. In addition, the natural siltation also made lake shrink. The wetland landscape pattern change made flood disaster aggravate and ecological function decline. But with further implementation of Returning land to Lake and the reinforcement of human consciousness on environment protection, the wetland landscape pattern in Dongting Lake will tend to optimal, and environment quality will get better gradually.

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