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Evolution characteristics and driving forces of wetland changes in the Poyang Lake eco-economic zone of China

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Wetland ecosystem is known as the "kidney" of earth and the "gene pool" of species. It has the functions of regulating climate, flood storage and degradation of pollution. In this paper, based on GIS technology and landscape ecology, wetland changes and its driving forces in the Poyang Lake Eco-economic Zone of China are analyzed. The analysis of landscape pattern demonstrates that there is an increase in the degree of fragmentation of wetlands in the study area. At the same time, the overall aggregation degree of the lake is in the rise. The increased Perimeter-area fractal dimension indicates that the shape of wetland becomes more and more rules. The main driving forces of wetland changes in the Poyang Lake Eco-economic Zone include natural factors and human activities. This study also indicates the main natural factor is the changes of precipitation, though for now, there is increase of average temperature. At the moment, the rapid population growth, regional economic development and other human activities are also the key driving forces of wetland landscape changes in the Poyang Lake Eco-economic Zone.

Key words: Wetland change, landscape pattern, climate change, ecosystem management, Poyang Lake.

INTRODUCTION

Land use/land cover change (LUCC) in the field of global environmental change research has been gaining increasing degree of attention because of its role in the social and ecological environment (Vitousek, 1997; Li, 1996). As one of the important land types, wetlands are also increasingly becoming of widespread concern by many scholars (Huang et al., 2012; Nagabhatla et al., 2012; Scott and Metts, 2012). Wetland ecosystem, which is known as the "kidney" of earth and the "gene pool" of species, has become one of the most productive ecosystems on the planet (Whigham, 1999; Cserhalmi et al., 2011). Wetland is not only a valuable natural resource for human survival, it is also one of the most important environments (Kingsford, 2011). It not only directly provides the raw material for production and human life, it performs some environmental functions such as regulating climate, flood storage, control of pollution as well as degradation etc (Traill et al., 2010). Analysis of the driving force of various wetland changes is one of priorities and focuses of wetlands LUCC research (Akin et al., 2012). The dynamic monitoring and evaluation of wetlands and its driving force have become the hotspot of current wetland changes research (Behera et al., 2012; Jiang et al., 2012; Kayastha et al., 2012; Landmann et al., 2013). At present, a large number of studies show that the driving forces of wetland changes concerns climate change, vegetation and human disturbance (Guardiola-Albert and Jackson, 2011; Lopez-Merino et al.,

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2011; Miller et al., 2012; Zhen et al. 2011). Urbanization is an irresistible trend of the development of human society in the 21st century. Most arable lands have been converted to construction land by urban expansion in China. This made a large number of ecological land including wetlands, which plays a pivotal role in ecological service function, exploited to arable land for meeting the objective of arable land protection. The newly formed wetlands in western China were caused primarily by climate warming over that region whereas the newly created artificial wetlands were caused by economic developments (Gong et al., 2010). Therefore, it is meaningful to explore the mechanisms of wetlands evolution.

Poyang Lake Region of China is recognized as one of the fundamental ecological function districts by the World Wide Fund for Nature (WWF). It plays a vital role in the provision of fresh water resources, the maintenance of the regional water balance, the homogenization of the flood, the regulation of regional climate and the conservation of biological resources (Deng et al., 2011; Yan et al., 2013). In recent years, some activities including reclamation of land from the lake and agricultural development have made wetland of Poyang Lake region change dramatically, bringing about increasing obvious ecological problems (Chen and Chen, 2012; Feng et al., 2012; Shankman and Liang, 2003). In view of the high service value of wetland and the vast eco-environment effect of LUCC, it is necessary to study process and mechanism of wetland in the Poyang Lake Eco-economic Zone (Huang et al., 2012). The Mountain-River-Lake Program (MRL) was implemented since 25 years ago in the Poyang Lake basin, southern China. It consists of series of forest restoration projects that aim to address severe soil and water losses, and improve farmer's livelihoods (Huang et al., 2012). Therefore, the study of changes in wetlands in the Poyang Lake Region of China becomes increasingly urgent. As we all know, the study of wetland landscape pattern can better understand the ecological processes. Exploring the change of natural wetland landscape pattern over time and revealing its driving forces are an urgent need to study the issue for the Poyang Lake (Huang et al., 2012; Yan et al., 2013).

The main purposes of this study are: 1) how to study the characteristics of wetland changes based on the theories and methods of landscape ecology; 2) to explore the evolution pattern of different kinds of wetlands; 3) and to find the driving forces of wetland changes in the Poyang Lake Eco-economic Zone for Sustainable Watershed Management.

MATERIALS AND METHODS

Study area

The study area (28°30′N to 30°06′N, 114°29′E to 117°25′E) is located in Jiangxi Province, a southern region of China, with a surface of approximately 51,200 km^2 (Figure 1). The area belongs to the subtropical humid climate zone, with an annual average temperature of 16 to 18°C and an annual average rainfall of 1,600 mm. Annual average sunshine is about 1,473.3 to 2,077.5 h. Annual sunshine total radiation is about 97 to 114.5 Kcal/cm^2. Soils are predominantly red soil, yellow soil and paddy soil. Poyang Lake is the largest freshwater lake in China and is one of the six wetlands with rich biodiversity in the World. Taking Poyang Lake as the core and relying on the Poyang Lake city circle, the Poyang Lake Eco-economic Region is the significant economic zone for protecting the ecology and developing economics. The study area includes 38 counties and has a population of 20.06 million and GDP of 3,948.17 billion Yuan (RMB) in 2008. One of goals of the study area is to build an international demonstration zone for the harmonious ecological and economic development.

Data

Land use data of 1990, 2000 and 2005 employed in this study came from the 1:100,000 national land use database of the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC). Wetland types in this study are divided into three classes and 11 subclasses (Table 1). Based on the ArcGIS9.3 software, land use data resampled at the spatial resolution of 100 m × 100 m. Climatic data came from the China Meteorological Data Sharing Service System. Social-economical data at the county level in this study derived from the Jiangxi province statistics yearbook from 1985 to 2006.

Land dynamic degree

Land dynamic degree is used to measure the number of changes in the situation for some time within certain land use types. The formula is given as:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

Where K is the dynamic degree of a certain land types within the study period; U_a and U_b respectively represent the area of land use types in the beginning and at the end of the study; T is the length of the study period. When T is set for the year, the value of K is the average annual rate of the area change of a certain land type.

Transfer matrix of land use change

On the basis of the transfer matrix of land use types, transition probability matrix of land use types is established to describe the changes in the intensity of land use types. The formula is given as:

$$D_{ij} = \sum_{ij}^{n} [\frac{dS_{i-j}}{S_i}] \times 100\% \quad (2)$$

Where D_{ij} is the transition probability of land use type *i* converted into land use type *j* in the study period; S_i is the total area land use type *i* of the beginning of the study; $dS_{i\text{-}j}$ is the sum of the areas of land use type *i* converted into the land use type *j* in the study period; n is the number of land use types changed in the study area.

Conversion contribution ratios

The transfer matrix method describes the evolution of different land

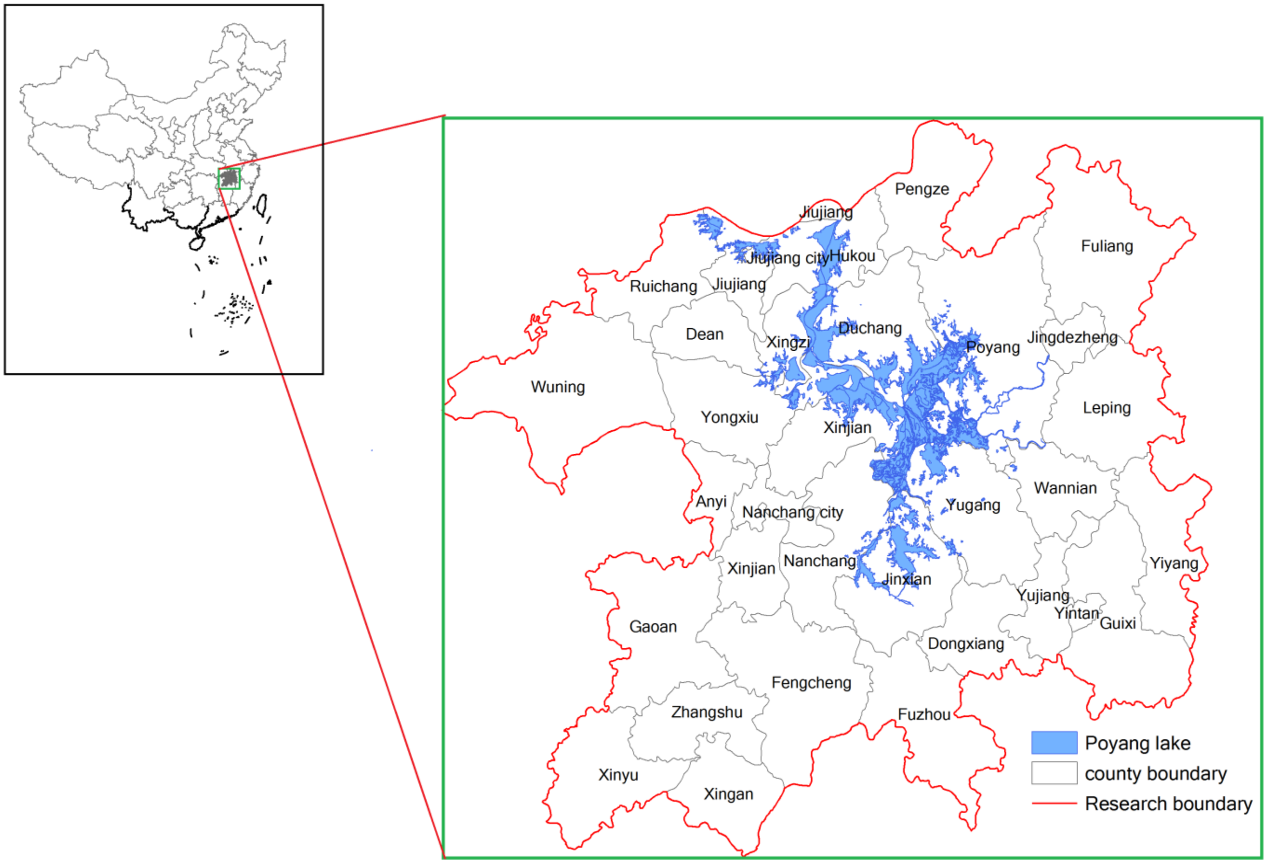

Figure 1. Location map of Poyang Lake Eco-economic Zone in China.

Table 1. Wetland classes of the study area.

Wetland class	Wetland subclass
Natural wetland	Lake
	River
	Lakeshore
	Swamp
Artificial wetland	Paddy field
	Reservoir and pond
Non-wetland	Forest
	Grass
	Dry field
	Constructed land
	Other non-wetland

use types. In order to fully reflect the status and role of information of different land types in the land use pattern, the method of conversion contribution ratios of transfer to/from the land use types is conducted in this study. It can comparatively analyze spatial pattern and quantity characteristics of the transfer-in and transfer-out of the various types of land use. The formula of conversion contribution ratios of transfer-in of land use types is given as:

$$L_{ji} = \sum_{j=1}^{n} S_{ji} / S_t \quad (3)$$

Where L_{ji} means the proportion of the area of other kinds of land use types except *i* converted into land use type *i* accounting for the total area transferred; S_{ji} refers to the transfer area of the land use type *j* converted to land use type *i*; S_t is the total area of land use type transferred; n is the number of land use types. L_{ji} can be used to compare the area differences of increment allocated for the various kinds of land in the transfer-in process of land dynamic change.

The formula of conversion contribution ratios of transfer-out of land use types is given as:

$$L_{0j} = \sum_{j=1}^{n} S_{ij} / S_t \quad (4)$$

Where L_{0j} means the proportion of the area of land use type *i* converted into other kinds of land use types accounting for the total area transferred; S_{ij} refers to the transfer area of the land use type *i* converted to land use type *j*; S_t is the total area of land use type transferred; n is the number of land use types. L_{0j} can be used to compare the area differences of decrement allocated for the various kinds of land in the transfer-out process of land dynamic change.

Landscape pattern analysis

Landscape ecology can provide new theories and methods for a comprehensive solution to the resource and environmental problems and to carry out a detailed ecological environment construction. In this study, we selected seven landscape indices to reflect the characteristics of the wetlands changes at landscape and class level.

Number of patches of a particular patch type is a basic measure of the extent of subdivision or fragmentation of the patch type. The formula of Number of Patches (NP) is given as:

$$NP = n_i \quad (5)$$

Where *NP* represents the number of patches; n_i is the number of patches in the landscape of patch type (class) *i*.

Patch density has the same basic utility as the number of patches as an index, except that it expresses the number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. The formula of Patch Density (PD) is given as:

$$PD = \frac{n_i}{A} \quad (6)$$

Where *PD* represents the patch density; n_i *is the* number of patches in the landscape of patch type (class) *i*; A is the total landscape area.

Largest Patch Index at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a basic measure of dominance. The formula of Largest Patch Index (LPI) is given as:

$$LPI = \frac{Max(a_1, \cdots, a_n)}{A} \quad (7)$$

Where *LPI* represents the Largest Patch Index; a_i is the area of patch (class); A is the total landscape area.

Perimeter-area fractal dimension is appealing because it reflects shape complexity across a range of spatial scales (patch sizes). A fractal dimension greater than 1 for a 2-dimensional landscape mosaic indicates a departure from a Euclidean geometry (that is, an increase in patch shape complexity). The formula of Perimeter-area fractal dimension (PAFRAC) is given as:

$$\ln(P/4) = k\ln(A) + c, PAFRAC = 2k \quad (8)$$

Where *PAFRAC* represents the perimeter-area fractal dimension; *A* is the area of patch (class); *P* is the perimeter of patch (class).

Landscape division is based on the cumulative patch area distribution and is interpreted as the probability that two randomly chosen pixels in the landscape are not situated in the same patch. The formula of Landscape Division Index is given as:

$$DIVISION = \left[1 - \sum_{i=1}^{M}\sum_{j=1}^{N}\left(\frac{a_{ij}}{A}\right)^2\right] \quad (9)$$

Where *DIVISION* represents the Landscape Division Index x; a_i is the area of patch (class); A is the total landscape area.

Shannon's Diversity Index is a popular measure of diversity in community ecology, applied here to landscapes. The formula of Shannon's Diversity Index (SHDI) is given as:

$$SHDI = -\sum_{i=1}^{m}[P\ln_i(P_i)] \quad (10)$$

Where *SHDI* represents the Shannon's Diversity Index; p_i is the proportion of the landscape occupied by patch type (class) *i*.

Aggregation index is calculated from an adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type appearing side-by-side on the map. The formula of Aggregation Index (AI) is given as:

$$AI = [\frac{g_{ii}}{\max \to g_{ii}}](100) \quad (11)$$

Where *AI* represents the Aggregation Index; g_{ii} is the number of like adjacencies (joins) between pixels of patch type (class) *i* based on the single-count method.

RESULTS AND DISCUSSION

Overall analysis of wetland dynamic changes

The areas and its changes of different kinds of wetland during the period 1990 to 2005 in the Poyang Lake Eco-economic Zone are listed in Table 2. From Table 2, we can see that there was an increasing trend of natural wetland and the artificial wetland in the study area showed a decreasing trend from 1990 to 2005. For natural wetland, lake increased from 200,523 hm^2 in 1990 to 284,300 hm^2 in 2005, an increase of 41.78%. As can be seen from the Figure 2, there is a rapid growth of the construction land. Figure 2 also shows that the increase in the lake is more obvious from 1990 to 2005 due to the conversion of a large area of the lakeshore.

Figure 3 shows the dynamic degree of different wetland types during the period 1990 to 2005 and the period 2000 to 2005 in the Poyang Lake Eco-economic Zone. As can be seen from the Figure 3, the value of dynamic degree of the lake is largest, 9.22 during the period 2000 to 2005. The value of dynamic degree of paddy field is smallest, -0.05 during 1990 to 2005. The value of dynamic degree of most wetland types is negative except lake.

The transfer matrix of different types of wetlands from 1990 to 2005 is listed in the Table 3. Many lakes, rivers, lakeshores, reservoir and ponds transformed into paddy fields, the area respectively 2955, 189 and 3072 hm^2 (Table 3). This means that many natural wetlands were replaced by the artificial wetlands. As can be seen from the Table 3, 34% of the paddy fields were pushed back the natural wetlands, and 25% of the paddy fields were occupied by the constructed land during the period 1990 to 2005 in the Poyang Lake Eco-economic Zone. At the same time, there is a greater conversion between the different types of wetlands. The main types mainly transferred to the lakes are the beaches, marshes and rivers.

The conversion contribution ratio of different kinds of

Table 2. Wetland change during the period 1990-2005 in the Poyang Lake Eco-economic Zone.

Wetland type	Area/hm^2			2005-1990	
	1990	2000	2005	Value change/hm^2	Rate of change/%
Natural wetland	**508836**	**517904**	**520518**	**11682**	**2.30**
Lake	200523	194575	284300	83777	41.78
River	83208	83230	75164	-8044	-9.67
Lakeshore	133724	149184	99822	-33902	-25.35
Swamp	91381	90915	61232	-30149	-32.99
Artificial wetland	**1725821**	**1712303**	**1690627**	**-35194**	**-2.04**
Paddy field	1602788	1599564	1591100	-11688	-0.73
Reservoir and pond	123033	112739	99527	-23506	-19.11
Non-wetland	**3042230**	**3046680**	**3064455**	**22225**	**0.73**
Forest	2204498	2205681	2204023	-475	-0.02
Grass	218270	216548	212752	-5518	-2.53
Dry field	478998	474293	470504	-8494	-1.77
Constructed land	139852	149526	176544	36692	26.24
Other non-wetland	612	632	632	20	3.27

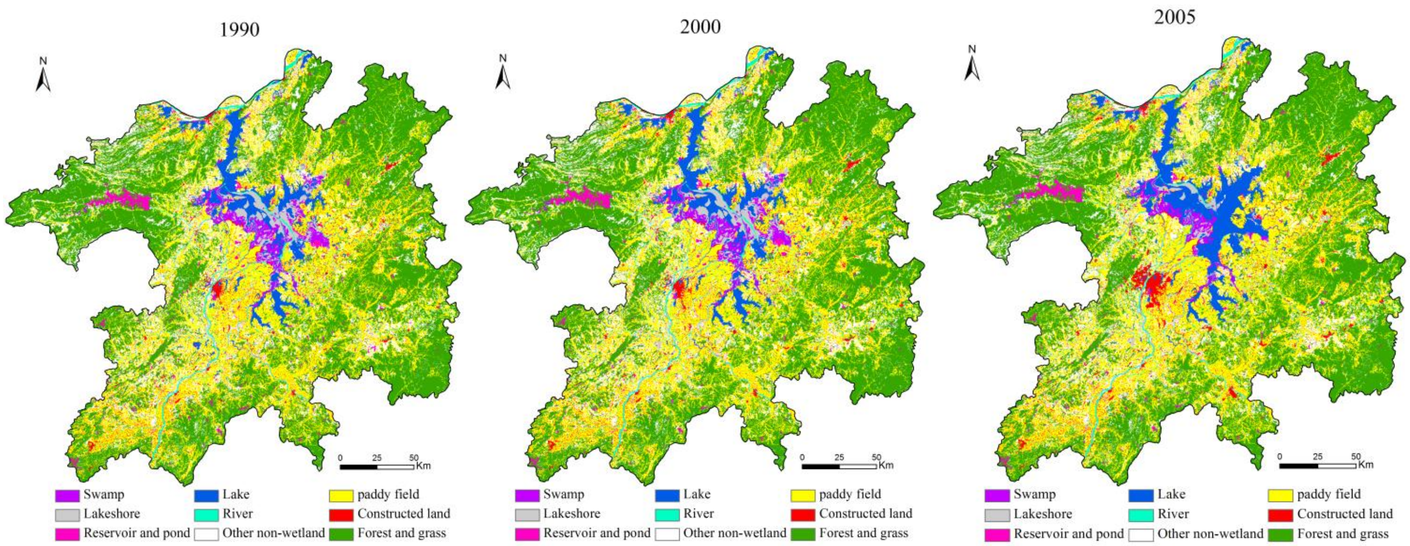

Figure 2. Spatial distribution of wetlands of Poyang Lake Eco-economic Zone in 1990, 2000 and 2005.

wetlands from 1990 to 2005 is listed in the Table 4. Compared with the contribution ratios of other transfer-in landscape components, the contribution ratios of transferring into the lake are the largest, 62.18% during the period 2000 to 2005 (Table 4). While the contribution ratio of transfer-in is less than transfer-out during the period 1990 to 2000, in general, the contribution ratio of transferring into the lake is greater than transferring out of the lake. This is because a large number of lakes have been reclaimed into the paddy fields during the period 1990 to 2000.

The concern is that the contribution rate of transferring into or out the landscape components directly or indirectly is controlled by the change of the lake in the Poyang Lake Eco-economic Zone. During the period 1990 to 2000, the conversion contribution ratio of transferring into the lakeshore is the maximum, 42.11% because large areas of ponds and lake converted into lakeshore. During the period 1990 to 2005, the conversion contribution ratio of transferring into the lake is the maximum, 51.22% due to

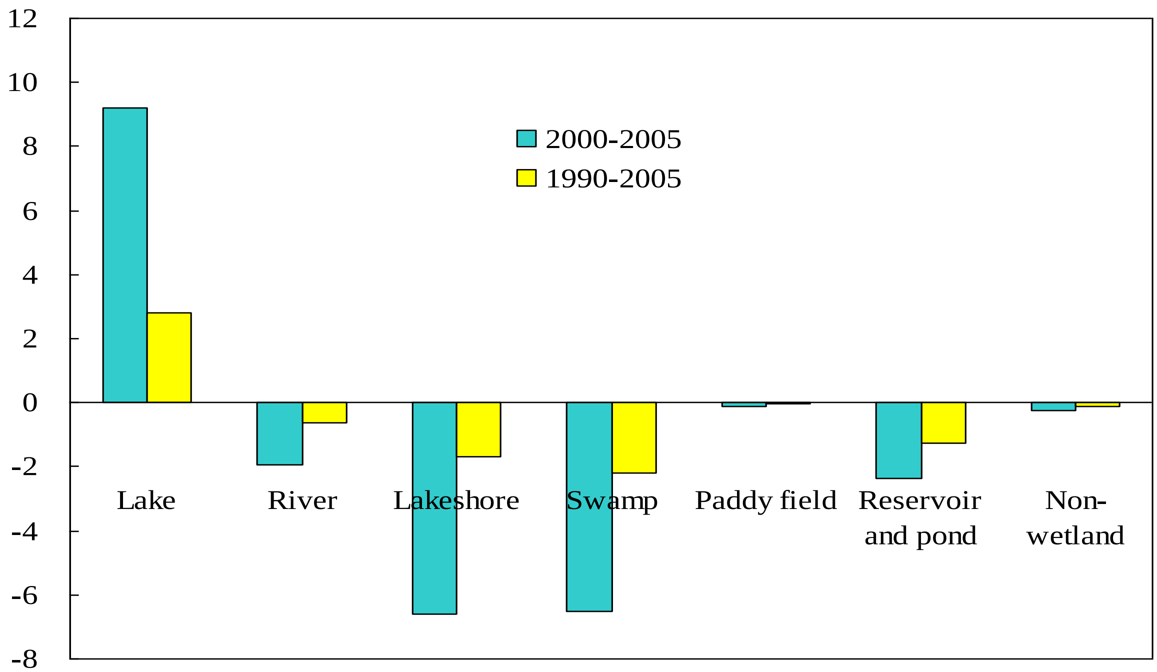

Figure 3. Dynamic degree of different wetland types during the period 1990-2005 and the period 2000-2005 in the Poyang Lake Eco-economic Zone.

Table 3. Transfer matrix of different types of wetlands from 1990 to 2005 (hm^2).

1990-2005	Lake	River	Lakeshore	Swamp	Paddy field	Reservoir and pond	Forest	Grass	Dry field	Constructed land	Other non-wetland
Lake	-	4	4834	61	2955	278	14	399	200	520	0
River	8197	-	285	2	189	35	4	0	71	63	0
Lakeshore	48248	123	-	21	3072	2152	367	1057	272	627	0
Swamp	31694	37	50	-	125	125			277	77	0
Paddy field	1920	597	3660	1304	-	3893	1544	13	3129	19926	5
Reservoir and pond	2036	1	12063	306	14059	-	370	358	1320	1095	0
Forest	136	23	120	12	1579	581	-	5106	2558	5958	63
Grass	399	0	402	119	984	215	9501	-	343	652	0
Dry field	398	21	615	219	1152	779	4330	161	-	9076	0
Constructed land	16	3	15	194	876	52	34	3	108	-	0
Other non-wetland	0	0	0	0	0	0	48	0	0	0	564

Table 4. Conversion contribution ratio of different kinds of wetlands from 1990 to 2005 (%).

Period	Conversion type	Lake	River	Lakeshore	Swamp	Paddy field	Reservoir and pond	Non wetland
1990-2000	Transfer-in	3.77	0.44	42.11	0.23	17.93	20.10	15.41
	Transfer-out	17.08	0.39	7.53	1.27	25.14	43.13	5.46
2000-2005	Transfer-in	62.18	0.41	3.72	1.46	13.56	1.81	16.85
	Transfer-out	1.44	5.87	37.13	21.55	18.83	10.75	4.43
1990-2005	Transfer-in	51.22	0.45	12.14	0.51	13.76	4.46	17.46
	Transfer-out	5.10	4.87	30.80	17.83	19.10	17.40	4.91

Table 5. Change of landscape indices of whole wetland from 1990 to 2005.

Year	NP	PD	LPI	PAFRAC	DIVISION	SHDI	AI
1990	15974	0.7148	9.7702	1.5132	0.9743	1.0361	82.0775
2000	16249	0.7286	9.7818	1.5151	0.9743	1.0361	81.9827
2005	15988	0.7231	9.9693	1.5216	0.9689	0.9942	82.4600

the large number of the lakeshore and swamp converted into lake. During the period 1990 to 2000, the conversion contribution ratio of transferring out the paddy field is the maximum, 25.14% due to the large areas of paddy field converted into constructed land. Because of the large areas of lakeshore converted into the lake, the conversion contribution ratio of transferring out the lakeshore is the maximum, 37.13% during the period 2000 to 2500 and 30.8% during the period 1990 to 2000. This is mainly because of the increase in rainfall during this period.

Pattern change of wetland landscape

The change of landscape indices of whole wetland in the Poyang Lake Eco-economic Zone from 1990 to 2005 is listed in Table 5. As can be seen from Table 5, the patch number of wetland landscape increased from 15974 in 1990 to 15988 in 2005, which showed an increasing trend in the Poyang Lake Eco-economic Zone. At the same time, Landscape Division Index (DIVISION) showed a downward trend from 1990 to 2005. It means that the separation degree of wetland increased. According to the changes of Number of Patches (NP) and Landscape Division Index (DIVISION), we can infer that there is an increase in the degree of fragmentation of wetlands in the study area.

Average fractal dimension index means the self-similar degree of the patch, to some extent, and it can reflect the impact degree of human activities on the patch. The Perimeter-area fractal dimension increases from 1.5132 in 1990 to 1.5216 in 2005 (Table 5). The increase of average fractal dimension means that the shape similarity of wetland landscape patch increases and the shape become more and more rules. This is mainly because the large number of marsh wetlands reclamation becomes more regular paddy fields.

From Table 5, we can see that Shannon's Diversity Index (SHDI) decreased from 1.0361 in 1990 to 0.9942 in 2005. Shannon's Diversity Index (SHDI) can reflect the landscape heterogeneity and is extremely sensitive to the non-equilibrium distribution of each patch type in the landscape. It emphasizes the contribution of rare patch types of information. The decrease of Shannon's Diversity Index shows that wetland type in the regional landscape is more monotonous, and the contribution of information of rare patch types reduced.

The result of landscape indices of different kinds of wetlands in 1990 and 2005 is listed in Table 6. In respect of the lake wetland, as can be seen from Table 6, the number patches of the lake are in decline, and the largest patch index shows an upward trend from 1990 to 2005.

The largest patch index (LPI) can reflect the effect degree of the maximum patch on the entire landscape. The increase in the largest patch index of lake indicated that the degree of Poyang Lake landscape controlling the whole wetland showed an enhanced trend. Meanwhile, Aggregation Index (AI) of lake increased from 92.7145 in 1990 to 94.6958 in 2005. It shows that the overall aggregation degree of wetland is in the rise.

As for the swap wetland, the largest patch index shows a downward trend from 1990 to 2005. Meanwhile, the Perimeter-area fractal dimension decreased from 1.4568 in 1990 to 1.4296 in 2005 (Table 6). It indicates that the large patch of wetlands is fragmented and becomes increasingly irregular. The increase in the number of patches and reduction in patch density of swamp also supports this conclusion.

As for the reservoir and pond, the patch number and largest patch index shows a downward trend from 1990 to 2005. Meanwhile, the Aggregation Index (AI) decreased from 72.37 in 1990 to 71.84 in 2005. The Perimeter-area fractal dimension increased from 1.4297 in 1990 to 1.4415 in 2005 (Table 6). This means that pond wetland is fragmented and becomes increasingly regular by the human disturbance.

As can be seen from Table 6, for all wetlands, the patch number and patch density of paddy field is largest. This means that the paddy field is the largest wetland type interfered by human. Aggregation degree of the lake is highest, which means that the connectivity of the lake is the best. Overall, the patch number of artificial wetlands is greater than natural wetlands. Simultaneously, the patch density and separation degree of artificial wetlands is greater than natural wetlands. This is mainly a result of manual interference. Table 6 shows that the connectivity of natural wetlands is higher than artificial wetlands.

Driving forces of wetland change

The main driving factors of wetland changes in Poyang Lake Eco-economic Zone include natural factors and human activities. Natural factors usually include climate, geology, geomorphology, hydrology, vegetation, soil, and so on. Human activities are mainly reflected in the

Table 6. Landscape indices of different kinds of wetlands in 1990 and 2005.

Type	Year	NP	PD	LPI	PAFRAC	DIVISION	SHDI	AI
Lake	1990	482	0.0091	0.7929	1.3749	98.7594	0.9999	92.7145
	2005	447	0.0085	3.1949	1.3987	99.5089	0.9989	94.6958
River	1990	691	0.0131	0.6528	1.6611	98.7521	1.0000	75.0698
	2005	636	0.0121	0.5283	1.6534	98.5275	1.0000	75.2963
Lakeshore	1990	1292	0.0245	0.2730	1.4515	96.0796	1.0000	83.6639
	2005	1926	0.0365	0.0829	1.4614	92.2784	1.0000	77.2215
Swamp	1990	213	0.0040	0.4486	1.4568	98.5830	1.0000	89.2230
	2005	181	0.0034	0.3696	1.4296	98.4530	1.0000	89.3645
Paddy field	1990	8053	0.1526	4.1375	1.5515	99.4854	0.9956	81.3159
	2005	8178	0.1550	4.1784	1.5504	99.4812	0.9957	81.34
Reservoir and pond	1990	5243	0.0994	0.4455	1.4297	94.7593	1.0000	72.3708
	2005	4620	0.0876	0.4785	1.4415	95.5238	1.0000	71.8425

demographic, economic, and policy aspects. Natural factors often have a role in the landscape at the larger spatial and temporal scales. In other words, environmental backgrounds control the main changes of wetland. Meanwhile, factors of human activities are the main driving force of the dynamic changes of the wetland at a shorter time scale. Wetland is a special type in the watershed landscape. Water is the fulcrum needed to maintain its ecological structure, function and spatial characteristics of landscape and is the main carrier of material, energy and information flow within the wetlands and other land type. Water environment is the motivating factors directly promoting the formation and evolution of wetland.

Atmospheric rainfall becomes the main replenishment water for the wetland. Thus precipitation directly impacts on the regional wetland area. Figure 4 shows the change of annual mean precipitation in Poyang Lake Region from 1981 to 2010. According to Table 2, lake decreased from 200,523 hm^2 in 1990 to 194,575 hm^2 in 2000, then increased 284,300 hm^2 in 2005. At the same time, annual precipitation decreased from 1543 mm in 1990 to 1455 mm in 2000, then increased in 2005 to 1472 mm (Figure 4). There is a strong correlation between the average annual rainfall and the area of Poyang Lake. This is mainly because a lot of lakeshore land turned into lakes when annual precipitation is abundant.

In addition to the effects of precipitation, temperature changes are also critical factors that affect the wetland landscape changes. Temperature not only affects the vegetation growth status and biomass, it also affects the process of evaporation, intensity of surface and surface evaporation. Figure 5 shows the change of annual mean temperature in the Poyang Lake Region from 1981 to 2010.

As can be seen from Figure 5, in general, the annual average temperature in the Poyang Lake Eco-economic Zone shows a rising trend. From Figure 3, we can see that the average annual rainfall of Poyang Lake Ecological Economic Zone shows an overall decreasing trend. Reduced rainfall will reduce the water supply of upstream river runoff on wetlands, reduce soil moisture, exacerbates the drought level, eventually leading to the degradation of the swamp. The rise in temperature will increase the surface evaporation, affecting the wetland area. Meanwhile, some rivers shrinking dry and the many bubble marsh shrink or disappear due to reduction of water. Therefore, the changes of annual rainfall and temperature become the main driving forces of natural wetlands change.

With the rapid economic development, over-exploitation of wetland resources is the main reason for the loss of a large area of wetlands in the Poyang Lake Eco-economic Zone. This is mainly because the economic development and population growth will inevitably lead to the rapid increase of the construction land and other non-wetlands, which occupied more natural wetlands, especially the beaches.

According to the analysis related statistics, during the period 1990 to 2005, the non-agricultural population of the Poyang Lake Eco-economic Zone grows rapidly from 3,591,700 in 1990 to 5,678, 500 in 2005, an average annual growth of 139,100. Accordingly, the proportion of the non-agricultural population increased from 21.3% in 1990 to 28.3% in 2005. The proportion of the non-agricultural population growth reflects a trend of

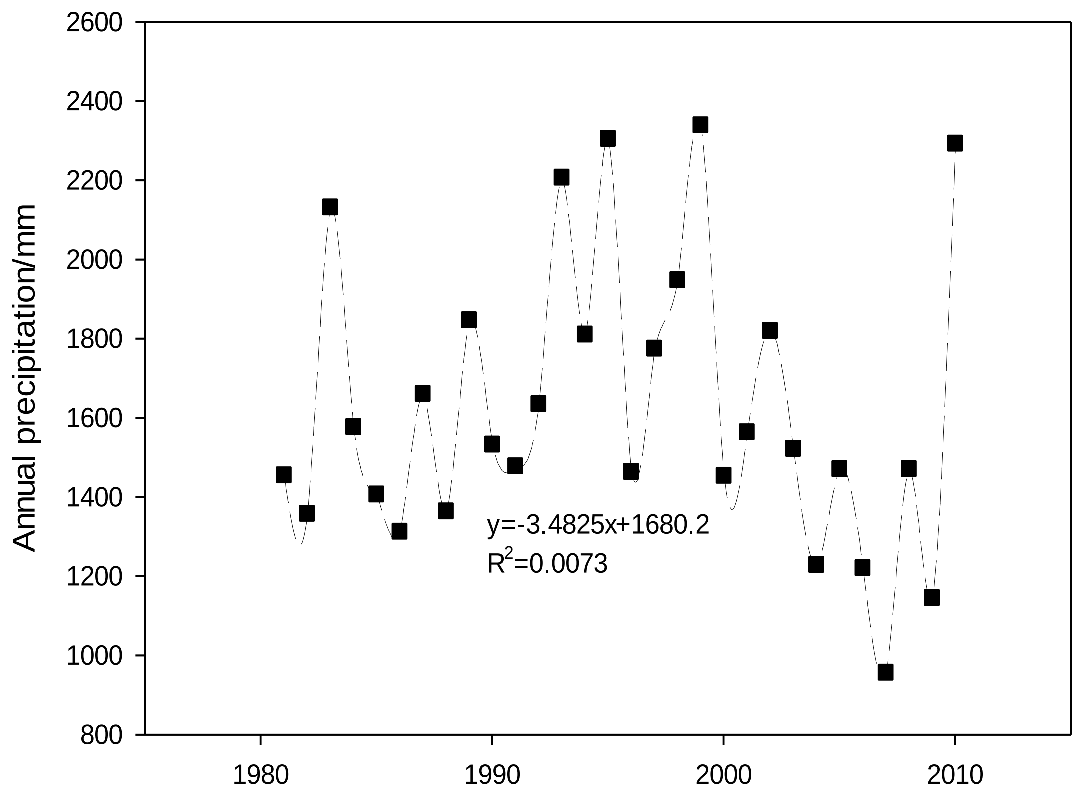

Figure 4. Annual mean precipitation of Poyang Lake Region from 1981 to 2010.

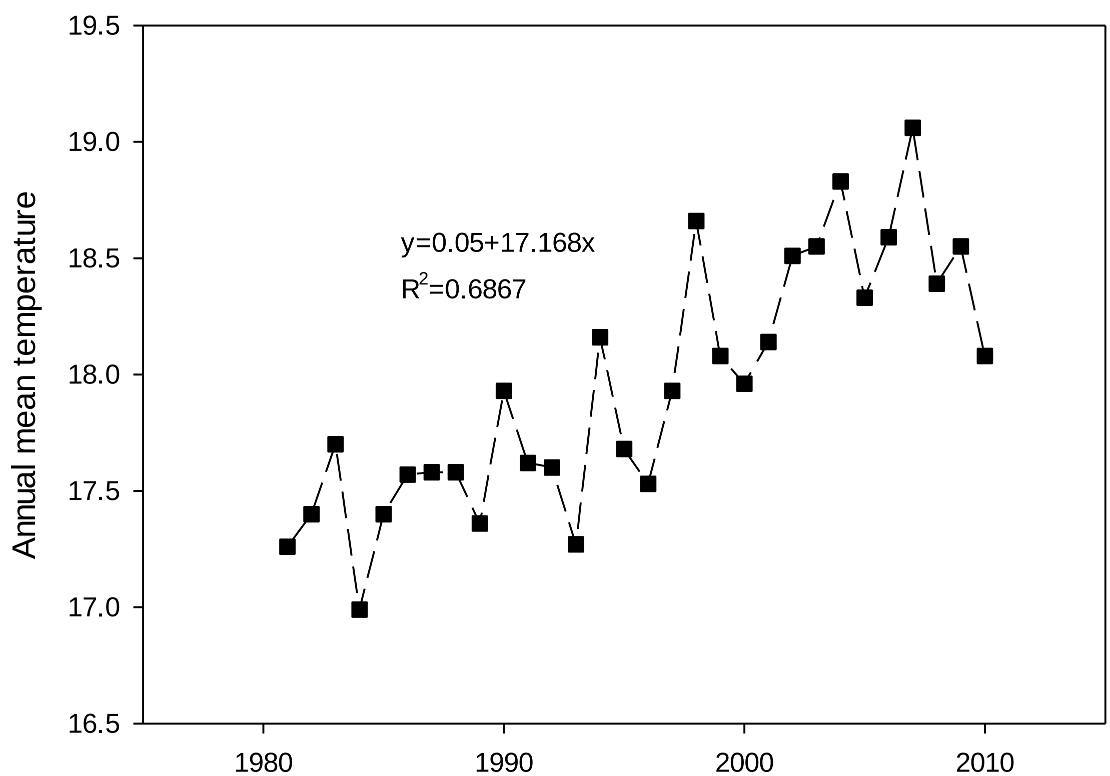

Figure 5. Annual mean temperature of Poyang Lake Region from 1981 to 2010.

urbanization and industrialization. Therefore, industrialization and urbanization are also extremely crucial driving forces of wetland changes in the Poyang Lake Eco-economic Zone. Industrialization and urbanization in the study area has made the land use of non-farm through the population concentration, industry concentration and the geographical spread of occupied land. As the weak link in the land use structure, wetland has become the most obvious type of land use change in the non-agricultural conversion process. In the past 15 years, a large number of ponds and paddy fields occupied construction land in the study area, which can be seen from Table 3. Therefore, a large number of natural wetlands have gradually reclaimed the artificial wetlands or artificial landscape in the interference of human activities for economic benefits. This is mainly in the agricultural development activities such as paddy field development and urban construction such as transportation and urban settlements.

Some policies have a profound impact on the wetlands change of Poyang Lake Eco-economic Zone, especially in playing a key role in the process of protecting their reasonable evolution. Since the late 1980s, the study area is in the implementation of the Mountain River Lake Development Program, which is a watershed integrated management program for the sustainable development of Poyang Lake watershed. The object of the project is to achieve the harmonious development of the economy, society and environment. It has formed a governance guideline "Governing lakes must be preceeded by first regulating the rivers, regulating the rivers must be preceeded by first managing mountains, managing the mountains must lead to poverty reduction". Implementation of the project has protected the water quality of Poyang Lake and reduced the degradation of wetlands.

Other policies like “cultivated land balance” has been negative on the wetland changes of Poyang Lake Eco-economic Zone. In the context of increasing demand for construction land, swamps and ponds are facing threat of agricultural development because of meeting the requirements of “cultivated land balance”. Forest restoration projects implementation and farmers’ livelihoods improvement are the important measures to protect wetlands in the Poyang Lake Eco-economic Zone. How to use quantified methods, such as correlation analysis, factor analysis, and so on, to explore the driving forces of wetland changes is important for future research.

Conclusions

There is an increasing trend of natural and artificial wetlands in the study area which shows a decreasing trend from 1990 to 2005. The value of dynamic degree of the lake wetland is largest, 9.22 during the period 2000 to 2005. The main types mainly transferred to the lakes are the beaches, marshes and rivers during the period1990 to 2005.

The contribution ratio of transferring into the lake is the largest, 62.18% during the period 2000 to 2005. Overall, the contribution ratio of transferring into the lake is greater than transferring out the lake from 1990 to 2005. During the period 1990 to 2005, the conversion contribution ratio of transferring into the lake is the maximum, 51.22% due to the large number of the lake and swamp converted into lake. 25% of the paddy fields were occupied by the constructed land during the period 1990 to 2005 in the Poyang Lake Eco-economic Zone.

The analysis of landscape pattern indicates that there is an increase in the degree of fragmentation of wetlands in the study area. The Perimeter-area fractal dimension increased from 1.5132 in 1990 to 1.5216 in 2005, which indicates that the shape of wetland becomes more and more rules. The Aggregation Index (AI) of lake increases from 92.7145 in 1990 to 94.6958 in 2005, which means that the overall aggregation degree of the lake is in the rise. The aggregation degree of the lake is highest, which means that the connectivity of the lake is the best.

The change of temperature and precipitation of the study area has a significant impact on wetland changes. The rapid population growth, regional economic development and other human activities are also the key driving forces of wetland landscape changes in the Poyang Lake Eco-economic Zone.

The above conclusions in this study provide the basis for the sustainable management and decision-making of the Poyang Lake Watershed.

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