LANDSCAPE DYNAMICS ANALYSIS OF GUIDE WETLANDS IN YELLOW RIVER WATERSHED BY LANDSAT SERIES DATA

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WG II/2 - Spatial Reasoning, Analysis, and Data Mining

KEY WORDS: Image interpretation; Landuse; Terrestrial photogrammetry; Spatial-temporal analysis; Dynamic Change; Hydrology; Wetlands; Yellow River

ABSTRACT:

Wetlands are resources of paramount importance with many values and functions. However, with the economy development and the population growth, wetlands have undergone great changes. This study investigated the land-cover and landscape pattern dynamics of Guide wetlands in the periods 1977-2006. Four Landsat images were used to locate and quantify the changes. The study revealed the area of wetlands previewed a downward trend during the past 30 years, whereas the area of cultivated land increased all the time. From 1997 to 2000, the wetland landscape pattern became more fragile and less connective. The landscape types converted to each other dramatically. During 2000 to 2006, both dominant and contagion indices on the whole area were enhanced. Its driving forces were analyzed according to socioeconomic development and climatic information. Remote sensing (RS) and Geographic information system (GIS) technologies have proved to be useful tools for assisting decision-makers to locate and quantify changes in land resources, and hence to identify appropriate solutions for sustainable management of wetlands.

1. INTRODUCTION

Wetlands are in the amphibious staggered zone of transition, which comprise about three to six percent of the earth's land surface, but they have various ecology function, economy value and society value, including agricultural production, fisheries, provision of wildlife habitat and so on (Acreman and Hollis, 1996； Sugumaran et al., 2004). However, with the socioeconomic development and the human activities reinforcement, wetland resources have been seriously disturbed, especially the large numbers of reservoirs are constructed on the Yellow River, which greatly impacts the wetland hydrological process and characteristics. Therefore, the study of dynamics in Guide wetlands in Yellow river watershed has an important significance for the wetland protection and local environmental management.

After the construction of reservoirs, the land-cover and landscape pattern along the Yellow river changed obviously. Many researchers focus on a lot of studies associated to sediment, flood, and runoff of the Yellow River (Huang, 2002; Xu, 2002; Jiang, 2008). Also many scholars study the wetland ecosystem and landscape dynamics of the Yellow River Delta (Li, 2007; Yoshiki Saitoa, 2000; Cai, 2006). However, relatively less attention has been paid to studying the wetland landscape and land-cover change along the Yellow River and the factors affecting the change. Therefore, elucidation of the dynamic change of Guide wetlands is essential for wetland management.

With rapid changes in landscape occurring over large areas, remote sensing has become an essential tool for monitoring such changes, particularly as a means of complementing or updating conventional data gathering techniques (Nellis, 1986; Baker et al., 1991). The objective of this study is to investigate the dynamics of Guide wetlands through the analysis of changes in land-cover and landscape pattern from 1977 to 2006, and the impacts of human activity on wetlands by utilizing RS and GIS techniques.

2. MATERIALS AND METHODS

2.1 Description of the study area

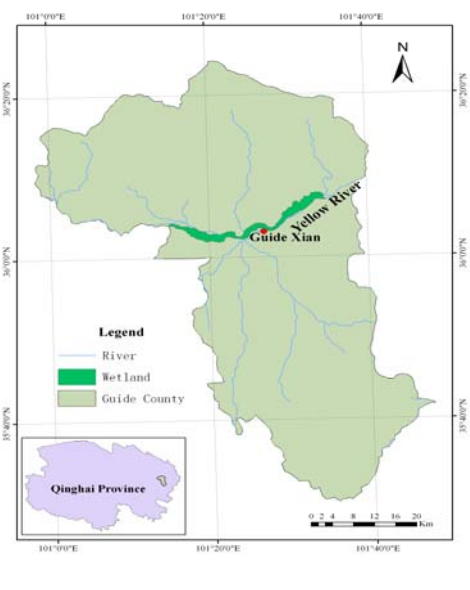

Figure1. Location of the Guide wetlands

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The study area is located in Guide country (N35° 30'～36° 30', E101° 0'～101° 50'), Qinghai province, with an area of approximately 6028ha (Figure1).

The Guide wetlands are joined by a narrow band of land along the Yellow River, which situated between the Longyangxia reservoir and the Lijiaxia reservoir. This region belongs to the transition zone between Qinghai-Tibetan Plateau and Loess Plateau. The feature of climate is the typical alpine continental climate with hyper-arid natural condition. Mean annual solar radiation is 2928h and yearly mean air temperature is about 7.2℃. The coldest and warmest average annual temperature is -23.8℃ in winter and 34℃ in summer. Rainfall is highly variable between 251-599mm per year. The study area includes 78.8km long stretches of the Yellow River and has abundant wetland types such as shrub wetland, reed marsh and meadows wetland. With the population growth and economy development, the human being and nature have put wetlands under the enormous pressure. Vast areas of wetlands continue to be converted to cultivation and grazing, both of the land-cover and the landscape pattern have undergone great changes. This paper therefore examines the dynamics of Guide wetlands and their implications.

2.2 Data and land cover classification

The wetlands dynamic information was extracted from the interpretation of RS data in 1977, 1994, 2000 and 2006. Table 1 presents the satellite imagery input data used for study. The Landsat images were enhanced using the linear contrast stretching and histogram equalization to a common ALBERS coordinate system based on 1:50000 topographic maps of China. With the aid of Global Positioning System (GPS) equipment, maps and key informants, the various land-cover types were located in the field and their positions recorded. The unsupervised classification with the maximum likelihood method algorithm was conducted to classify the image containing the study area. Combined with field survey, the following major land-cover categories were identified: cultivated land (CL), watershed (WA), tidal flat (TF), reed marsh (RM), meadows wetland (MW) and shrub wetland (SW).

Image	Path/Row	Year	Season	Format
Landsat MSS	142/35	1977-07-15	Wet	GeoTIFF
Landsat TM	132/35	1994-08-16	Wet	GeoTIFF
Landsat TM	132/35	2000-07-05	Wet	GeoTIFF
Landsat ETM	132/35	2006-08-05	Wet	GeoTIFF

Table1 Landsat images applied in analysis

2.3 Methods

The magnitude and direction of changes in landscape are the most important factors relating to landscape evolution (Antrop, 2000). With the wetlands information of land-cover types from the four images, land-cover transition matrices were elaborated for the three periods by using Overlay Tool in the GIS software. Each matrix represents either the probability of persistence of the period, or the probabilities of transition to another land-cover category during the same period (Alejandro, 2007).
The Patch Analyst module was used to calculate the landscape metrics, which is an extension to the ArcView GIS system that facilitates the spatial analysis of landscape patches, and modeling of attributes associated with patches (Rempel and Carr, 2003). By FRAGSTATS, two levels of metrics were computed. i.e., class level, which means each land use type in the landscape mosaic, and landscape level, which means the landscape mosaic as a whole (Lu et al., 2003). In order to detect landscape change of the study area, seven indices were analyzed: patch density (PD), mean patch area (AREA_MN), landscape shape index (LSI), contagion index (CONTAG), dominance index (D), Shannon's evenness index (SHEI) and Shannon's Diversity Index (SHDI) (Table 2).

Index	Mathematic model	Ecological significance
LSI	$LSI = 0.25E/\sqrt{A}$ E is length of total patches borderlines; A is the total area.	Landscape shape index indicates the complexity of shape.
SHDI	$SHDI = -\sum_{i=1}^{m}(P_i \ln P_i)$ Pi is proportion of the landscape occupied by patch type (class) i ; m is number of patch types (classes) present in the landscape.	Shannon's diversity index is a popular measure of diversity in community ecology, applied here to landscapes.
SHEI	$SHEI = \frac{-\sum_{i=1}^{m}(P_i \ln P_i)}{\ln m}$	Shannon's evenness index is expressed such that an even distribution of area among patch types results in maximum evenness.
D	$D = H_{\max} + \sum_{i=1}^{m}(P_i)\times\log_2(P_i)$, $H_{\max} = \log_2(m)$	Dominance index indicates one or fewer dominant classes exist in the landscape

Table2 Models and significances of landscape indices

3. RESULTS AND DISCUSSION

3.1 The analysis of wetland land cover change

In general, the results show that only the CL area increased noticeably during 30 years. The SW area had no obvious change, while the areas of other landscape types all registered a descending trend. The WA area which occupied 2479ha in 1977, and decreased to 1417ha in 1994, was the most remarkable change, and the reed marsh was the second (Figure2). Based on the four-year land-cover information analysis, the land-cover transition matrices for the periods of 1977-1994, 1994-2000 and 2000-2006 were obtained (Table3-5). During the period 1977-1994, both RW and WA areas dropped dramatically. The annual average changing rates of RW and WA reached -4.22 and -2.53, respectively. The cause of decrease in RW and WA area was changing into MW, TF and CL. It demonstrated that the water source was scarce and human beings disturbed wetlands frequently. From 1994 to 2000, except TF, the changing rates of other types were all positive values. The area of TF was mainly converted into RM (10.48%) and WA (33.95%). The changing rate of CL was 0.35 compared with 8.83 for 1977-1994. It indicated that the water source of wetlands was supplied in time, and the trend of changing wetland to CL decreased. During 2000-2006, the CL area increased remarkably from 30.76% to 40.36%. The expansion of CL mainly resulted from shrinkage of MW (20.43%), WA (3.78%) and TF (4.77%). It previewed that the human beings reclaimed farmland from the wetlands dramatically.

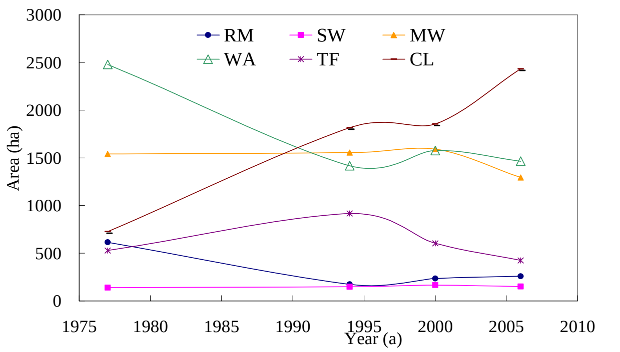

Figure2. Total area of different land covers from 1977 to 2006

3.2 The analysis of landscape pattern dynamics

All these land use changes affected landscape patterns. The calculated results of landscape indices were listed in Table 6 and Table7. The results show that the values of SHEI and SHDI had nearly no change during 30 years. Both of them only dropped lightly after 2000. It demonstrated that the landscape heterogeneity decreased, and the distribution of land-cover became uneven after 2000. The dominance index had a certain extent rise, which resulted from the area of CL increased remarkably and became the dominant landscape type.

The PD of wetlands on the whole area increased from 1977 to 2000, while decreased from 2000 to 2006. The CONTAG had a converse trend compared with the PD. It showed that the wetlands became more fragmented during 1997-2000, whereas trended to concentration after 2000. The PD of RM, WM and CL had the same trend with the whole landscape. During 2000-2006, the PD of CL and WA decreased while the AREA-MN of them was on an ascending trend. The fragmentation decreased on the whole mainly because that CL extended to connect each other.

Except TF, the LSI of other land covers all showed a rise trend from 1977 to 1996, the LSI of WA which reached 7.0112 in 1996, was the most obvious change. It indicated that the shape of patches inclined to complicated and irregular. The main reason was that the landscape types converted to each other dramatically. The LSI of CL was on a descending trend after 1996, which was mainly attributable to the area of CL increased continually and the shape of CL patches inclined to regular and simple.

1994 \ 1977	RM	SW	MW	WA	TF	CL	Total1977	PL (%)
RM	17	6	232	96	91	173	615	10.20
SW	0	5	0	0	0	135	140	2.32
MW	21	56	366	282	489	326	1540	25.55
WA	117	44	728	907	181	502	2479	41.12
TF	8	0	112	80	96	232	528	8.76
CL	11	38	118	52	59	448	726	12.04
Toatl1994	174	149	1556	1417	916	1816	6028	
PL (%)	2.89	2.47	25.81	23.51	15.20	30.13		100.00
AACR (%)	-4.22	0.38	0.06	-2.53	4.32	8.83		

Table 3 Land cover transition matrix in 1977-1994 (ha)

PL: percent of landscape; AACR: annual average changing rate.

2000 \ 1994	RM	SW	MW	WA	TF	CL	Total1994	PL (%)
RM	68	20	65	1	20	0	174	2.89
SW	12	124	13	0	0	0	149	2.47
MW	27	20	1079	31	93	306	1556	25.81
WA	38	1	74	1228	33	43	1417	23.51
TF	76	0	96	311	430	3	916	15.20
CL	15	1	265	6	27	1502	1816	30.13
Total2000	236	166	1592	1577	603	1854	6028	
PL (%)	3.92	2.75	26.41	26.16	10.00	30.76		100.00
AACR (%)	5.94	1.90	0.39	1.88	-5.70	0.35		

Table 4 Land cover transition matrix in 1994-2000 (ha)

2006 2000	RM	SW	MW	WA	TF	CL	Total2000	PL (%)
RM	32	16	81	85	22	0	236	3.92
SW	0	112	28	13	0	13	166	2.75
MW	63	14	754	190	74	497	1592	26.41
WA	101	8	243	1065	68	92	1577	26.16
TF	62	2	135	66	222	116	603	10.00
CL	0	0	54	46	39	1715	1854	30.76
Toatl2006	258	152	1295	1465	425	2433	6028	
PL (%)	4.28	2.52	21.48	24.30	7.05	40.36		100.00
AACR (%)	1.55	-2.33	-3.11	-1.18	-4.92	5.20		

Table 5 Land cover transition matrix in 2000-2006 (ha)

	Year	RM	SW	MW	WA	TF	CL
PD	1977	0.4142	0.1160	0.4970	0.1325	0.2816	0.2319
	1996	0.9281	0.0994	0.7624	0.0663	0.2320	0.5138
	2000	1.0109	0.3812	0.9115	0.0166	0.1326	0.5469
	2006	0.4640	0.0663	0.8783	0.0166	0.2320	0.4309
AREA_MN	1977	24.6132	20.0443	41.4030	346.7362	31.0712	52.5921
	1996	16.3591	24.8400	31.6780	354.1275	12.5293	61.9171
	2000	13.1739	11.7783	28.9587	1342.35	20.7900	56.3100
	2006	14.9496	38.5875	26.9609	1422.99	18.4114	90.4431
LSI	1977	6.9217	3.2785	8.6128	7.8693	5.8896	7.0331
	1996	12.4901	3.1829	10.5686	14.8805	5.1685	9.1058
	2000	12.1111	7.7545	11.9438	13.7429	3.6860	9.0521
	2006	8.2774	2.9036	11.6680	12.2857	5.1759	8.4877

Table 6 Landscape indices of wetlands during 1977-2006

Year	CONTAG	PD	SHDI	SHEI	D
1977	51.6748	1.6733	1.4726	0.8219	0.4173
1996	47.3397	2.6021	1.5282	0.8529	0.3755
2000	46.0629	2.9996	1.5555	0.8681	0.3904
2006	50.3289	2.0881	1.4626	0.8163	0.4858

Table 7 Landscape indices of wetlands during 1977-2006

3.3 The reasons analysis for wetlands dynamics

3.3.1 Population growth impulses landscape change

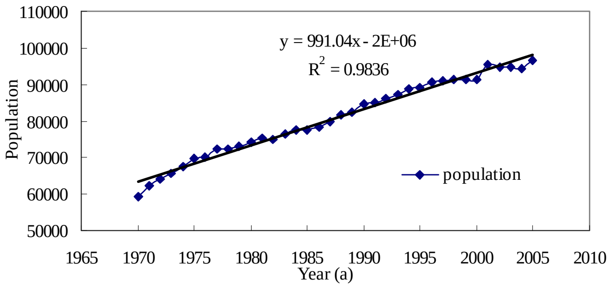

Figure3. Population in Guide Country during 1970-2006

Over the past 30 years, the population of Guide country grew very fast (Figure3). The population in 2000s is about 1.6 times as that in 1970s. The growth in population reflects on the farm produce and water consumption. At the same time, the area of CL increased noticeably from 726ha in 1977 to 2433ha in 2006. Large areas of MW and WA converted into CL, which caused in the shrinkage of wetlands and the changes of landscape pattern.

3.3.2 Economic policy spurred landscape change

Since 1978, China initiated the economic reform and open-door policy, the GDP of Guide country has clearly increased, and the area of CL expanded from 1977 to 2000. During the period 1994-2000, the trend of changing wetlands to CL decreased, which was attributable to the ecology construction policy of the country in the end of 1980s, such as the conversion of farmland to grassland. After 2000, the area of CL increased remarkably again and became the dominant landscape type, the influence of human beings was a main reason. The shape of CL patches was regular and the CL extended to connect each other, which resulted in the increase of dominant index and contagion index on the whole.

3.3.3 Construction of reservoir results in landscape change

The construction of reservoir greatly impacts the wetland hydrological balance, and in consequence the landscape pattern changed remarkably. Guide wetlands situated on the downstream of Longyangxia reservoir and the upstream of Lijiaxia reservoir. After the storing water and running of Longyangxia Hydroelectric station in 1987, the freshwater source of wetlands was obstructed, and the area of WA decreased during 1977-1994. Many washes disappeared and the

PD of WA dropped greatly. Almost all the wetland types had undergone a significant change during the same period. The Lijiaxia reservoir was constructed in 1996. The freshwater source of wetlands was supplied in time by the Lijiaxia reservoir storing water, especially in dry season, which caused the increase of WA area during 1994 to 2000. Many large areas of TF converted into WA and other wetland types in this period. The construction and operation of reservoirs is very important to irrigation. The area of CL nearby watershed increased continuously following the reservoir construction.

3.3.4 Climatic information affects landscape change

According to the climatic changes in Guide country during the period 1970-2006 (Figure4), the mean annual air temperature was on a ascending trend with a rate of 3.43℃ per decade, and increased noticeably with a higher rate in the 2000s. The annual precipitation was highly variable and had no notable change on the whole. Overall, the climate became warmer and dryer during the past 30 years, which was one main reason for the shrinkage of wetlands. During 1994-2000, the annual precipitation value was lower than the perennial average value, however, the landscape of wetlands was improved obviously. This was mainly because that the reservoirs self-function supplied freshwater source to wetlands in time. It indicated that the reservoir self-function played a very important role in maintaining the hydrological balance of wetlands.

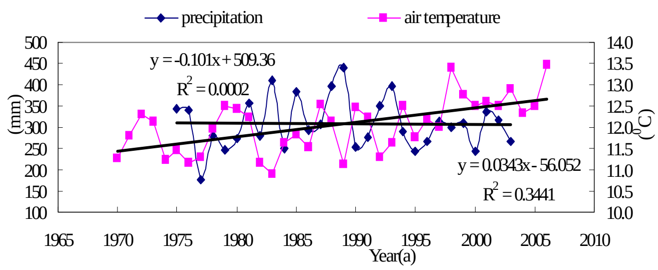

Figure4. Climatic variations in Guide County during 1970-2006

4. CONCLUSIONS

(1) As a whole, the area of wetlands showed a downward trend during the past 30 years. The area of wetlands decreased from 5302ha in 1977 to 4212ha in1994, which mainly resulted from the exquisite decrease of WA and RW area. During 1994-2006, the shrinkage of wetlands was restrained effectively, whereas the area of CL was on an ascending trend all the time.

(2) From 1997 to 2000, the wetlands became more fragile and less connective. The landscape types converted to each other dramatically, which resulted in the shape of patches inclined to complicated and irregular. During 2000-2006, the area of CL expanded more noticeably compared with that during 1994-2000, both the dominant and contagion indices on the whole area were enhanced.

(3) After analyzing the dynamics of Guide wetlands, the result shows that many large areas of wetlands converted into CL during 1977-2006. It revealed that the human beings explored wetland resource very dramatically. The warming and drying climate of the country was also the direct reason for the shrinkage of wetlands. The Longyangxia and Lijiaxia reservoirs, located in the upper Yellow River, which greatly impacted the wetland hydrological process and characteristics, was the driving force for dynamics of Guide wetlands.

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