A GIS-Based Data Mining of Landuse Changes in the Yellow River Basin, China

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Keywords: Yellow River Basin, Landuse Change, Landscape Pattern, Landscape Ecology, Spatiotemporal Evolution.

Abstract: This study provides an empirical example of data mining on landuse changes in the Yellow River Basin using Geographic Information System (GIS). Time series of Landsat remote sensing images of 1980, 1990, 2000, 2010 and 2020 as well as ArcGIS software are used to calculate transfer matrixes of landuse changes and estimate the degree of land development to mine information on landuse changes over time and across space. Two points of key findings are outlined here. (1) The dominant class of landuse in the basin were grassland, followed by cultivated land. The cultivated land area showed an overall decreasing trend with a wave of first increasing and then decreasing over the study period. The areas of forest land, construction land, and grassland had increased, while the areas of water and unused land had decreased. (2) The overall level of land development in the basin was relatively high, but heterogeneity was also shown at different times and across space.

1 INTRODUCTION

In recent years, Geographic Information Systems (GIS) have been developed rapidly and its application scope has been continuously expanding. For example, it has been intensively applied to the studies on landuse patterns in urban planning and land resource management. Recently, many studies on the landscape patterns of different watersheds have been conducted, and the results show that the stability of watershed landscapes is declining, which restricts the sustainable development of regional economy and society (Yang, etc,2020). However, previous research focuses on local areas in space and a relatively short period in time, which fails to reveal the spatiotemporal changes in landscape patterns under large-scale and long-term time series. There is less research on the spatiotemporal dynamic evolution at the entire watershed scale(Yao, 2013).

This paper takes the entire Yellow River Basin as the study area and uses GIS technologies to analyse five remote sensing images from 1980 to 2020 to examine the spatiotemporal dynamic evolution characteristics of the watershed landscape patterns. The results provide insights on the relationship between the landscape pattern and the environment, human production and life. Knowledge advanced in this study forms a scientific and reasonable basis for the overall planning and management of the watershed.

2 STUDY AREA

The spatial range of the Yellow River Basin involves in 9 provinces, which set from 32°N-42°N and 96°E-119°E, and the area is about 7.95×105 km2, almost accounts for 8.3% of China(Chris, 2004).

The watershed area is a typical continental climate, and the northwest is mainly the source water area of the river. The glacier landform is developed and the grassland area is wide. The central part is mainly less landform, with broken terrain and fragile ecological environment. Previous research shows that the ecological function of the Yellow River Basin has seriously degraded, and its ecological environment protection and development are facing serious challenges(Lu,etc. 2019).

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3 DATA SOURCES AND RESEARCH METHODS

3.1 Data Sources

The basic data source for this study is Landsat TM interpretation data, which are downloaded from the Earth System Science Data Sharing Platform of the National Earth System Science Data Center, with a spatial resolution of 1km (www.geodata.cn/data). Referring to the "Classification of Land Use Status" standard, the 25 landuse classes in the Yellow River Basin were reclassified into 6 types: cultivated land, forest land, grassland, water area, construction land, and unused land(Hu,2021). Other basic geographic information element data were obtained from a 1:1000000 national basic geographic database.

3.2 Research Methods

3.2.1 The Landuse Transfer Matrix

The land use transfer matrix represents the transfer structure, source and destination, and spatial distribution characteristics of various landuse types in the study area. It can quantitatively describe the quantity, direction, and transfer rate of mutual transformation between landuse types, reflect the transformation process of the landscape in the region from the beginning to the end of the study period, and reveal the specific process of dynamic development and change of the landscape pattern during over the time(Nassauer and Corry,2004).

The calculation formula is as follows (Cheng, etc., 2002):

$$S_{ij} = \begin{bmatrix} s_{11} & \cdots & s_{1n} \\ \vdots & \cdots & \vdots \\ s_{n1} & \cdots & s_{nn} \end{bmatrix} \quad (1)$$

Where, S_{ij} is the area (km^2) converted from the i-th type of landuse to the j-th type of landuse, n represents the classification number, and vector S_{11}..., S_{1n} is the area of various land use types.

3.2.2 The Comprehensive Degree Index

The comprehensive degree index of landuse is an evaluation and grading system that assigns a certain grading index to reflect the depth of regional landuse and the intensity of human activities on land. The calculation formula is as follows(xia, etc., 2022):

$$L_i = 100 \times \sum_{i=1}^{n} (A_i \times C_i) \quad (2)$$

Where, A_i represents the classification index of the i-th landuse type in the study area (A_i takes values of 1, 2, 3, and 4 if landuse types are unused land, forest land or grass land or water, cultivated land, and construction land, respectively), and C_i represents the percentage of the classified area of the i-th landuse type to the total utilization area. The larger the value of the comprehensive degree index of land use, the higher the degree of the landuse development(Chen,etc,2022 and Zuo,etc., 2022).

4 RESULTS AND ANALYSIS

4.1 Dynamic Change of Landuse

The results of landuse transfer matrix are shown in Table 1. The change of landuse types between 1980 and 1990 is inconspicuous. The addition of cultivation land is 877.43km^2, transferred from grass land and water, while the reduction of water area is 1253.69km^2, which is either transferred to cultivation land or grass land.

The change of landuse types between 1990 and 2000 is obvious. The addition of cultivation land is 2104.58km^2, transferred from grass land. The reduction of grass area is 1901.62km^2, which is transferred into cultivation land and others. The addition of construction is 1164.70km^2, transferred from cultivation land.

From 2000 to 2010, however, cultivated land decreased 2704.89km^2, mainly transferring to grassland. Grassland increased 4544.50km^2, mainly from cultivated land and unused land. Unused land decreased by 1541.64km^2, mainly transferring to grassland. The change of other landuse types were not significant. The water area decreased 642.37km2, which was the remarkable value in the four periods.

The spatial change of landuse between 2010 and 2020 is significant. The cultivated land decreased by 9840.40km^2, mainly transferring to grassland, construction land and forest land, which attributed to the implementation of ecological protection measures and the rapid development of urbanization. Forest land, water area and construction land increased 2754.68km^2, 1641.54km^2 and 12060.59km^2, respectively. Among them, forest land was mainly transferred from grassland and cultivated land, which attributed to the

Table 1: Land use type transfer matrix in four periods from 1980 to 2020 (Unit:km^2).

Years	Landscape Type	Cultivated Land	Forest Land	Grass Land	Water Area	Construction Land	Unused Land
1980-1990	Cultivated Land	209909.84	59.83	228.37	250.86	338.40	68.72
	Forest Land	48.04	102680.22	73.56	7.16	4.00	2.09
	Grass Land	683.47	104.04	386793.90	185.00	123.94	360.43
	Water Area	800.32	40.18	709.27	12180.37	111.95	246.15
	Construction Land	68.30	0.19	12.53	1.56	13019.95	0.42
	Unused Land	317.83	30.83	261.28	226.31	20.56	66482.74
	Area Increment	877.43	115.54	-48.40	-1253.69	526.14	-154.56
1990-2000	Cultivated Land	207839.84	278.28	1915.78	279.21	1134.73	381.82
	Forest Land	309.11	101449.28	1052.95	21.18	27.55	53.44
	Grass Land	4198.90	821.25	380620.47	303.84	123.22	2059.32
	Water Area	940.89	26.50	159.06	11588.34	14.37	122.46
	Construction Land	186.06	0.45	26.30	0.48	13402.25	3.40
	Unused Land	648.42	128.00	2430.17	86.75	19.62	63848.22
	Area Increment	2104.58	-140.52	-1901.62	-544.88	1164.70	-683.84
2000-2010	Cultivated Land	206365.65	1475.90	3774.96	739.07	1437.27	333.16
	Forest Land	174.31	101818.91	526.35	39.49	97.40	51.22
	Grass Land	2443.03	1683.34	378592.78	315.39	335.14	2829.54
	Water Area	416.54	28.99	206.57	11322.65	34.73	271.13
	Construction Land	192.18	7.92	68.08	21.85	14424.77	6.75
	Unused Land	315.73	130.49	1566.11	186.61	66.38	64201.99
	Area Increment	-2704.89	953.87	4544.50	-642.37	-772.78	-1541.64
2010-2020	Cultivated Land	126633.75	11326.23	54091.97	2767.64	12730.59	2005.07
	Forest Land	10585.05	65313.81	26478.08	534.00	993.55	921.27
	Grass Land	50588.63	27052.94	280664.98	3037.09	5019.51	17610.73
	Water Area	2552.07	414.26	2832.68	5515.46	530.66	706.96
	Construction Land	7595.85	498.08	2188.64	316.15	5514.08	239.43
	Unused Land	2273.15	1313.94	24662.09	947.51	872.80	37360.99
	Area Increment	-9840.40	2754.68	387.91	1641.54	12060.59	-6764.02

implementation of the policy of returning farmland to forest. Construction land was mainly transferred from cultivated land. The area of unused land decreased 6764.02km^2, indicating the rapid development of a large amount of unused land.

The most obvious changing landscape types over the past 40 years in the study basin were firstly cultivated land, then grass land, construction land, and followed by unused land. The area of cultivated land over the period showed a trend of firstly increasing and then decreasing, mainly transferring from and into grassland. The area of grassland showed an increasing trend, mainly transferring from cultivated land, then forest land, and followed by unused land. The area of construction land also showed an increasing trend, mainly transferred from cultivated land and followed by forest land, grassland and unused land. However, unused land showed a decreasing trend, mainly transferring to grassland.

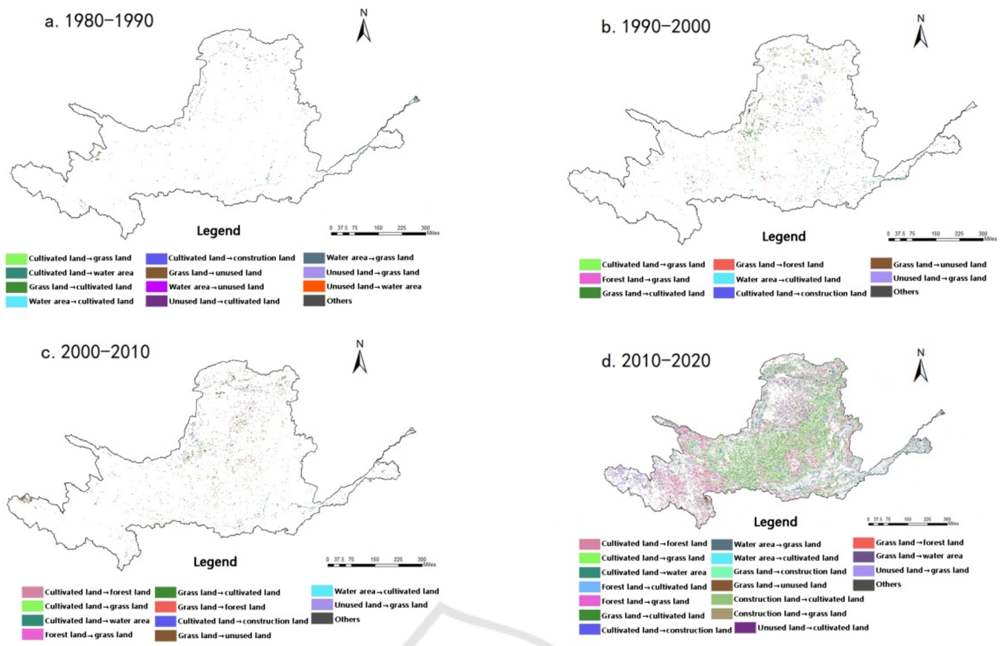

Figure 1: Evolution array of landscape types in the Yellow River Basin from 1980 to 2020.

Table 2: Comprehensive land use degree index of the Yellow River Basin from 1980 to 2020.

Years / Land Use Index	1980	1990	2000	2010	2020
C_1	8.80%	8.79%	8.79%	8.77%	8.70%
C_2	62.94%	62.78%	62.40%	62.90%	62.95%
C_3	26.32%	26.42%	26.66%	26.28%	24.83%
C_4	1.94%	2.01%	2.15%	2.53%	3.53%
L_i	221.41	221.64	222.18	223.51	223.19

4.2 The Evolution Process of Landscape Types

The common evolution of the above six landscape types resulted in the spatial changes of land use pattern in the study area. To analyze the spatial evolution process of the landscape patterns in the Yellow River Basin from 1980 to 2020, four transition maps of landuse types were generated using ArcGIS software, as shown in Figure 1, where the arrays in the map legends indicated the flow directions of landuse type transition. The results demonstrated that grassland was the most dynamic landuse type in terms of transfer-in and transfer-out types over the 40-year study period.

The evolution of landscape types can be divided into two main periods: from 1980 to 2010 and from 2010 to 2020. Firstly, the main changes from 1980 to 2010 were grassland flowing into unused land, grassland flowing into cultivated land and unused land flowing into grassland. Secondly, the landscape pattern changed dramatically, and the degree of landscape transfer increased. Within the ecological control line, there were mutual transfers among cultivated land, forest land and grassland, and mutual transfers between grassland and unused land. The expansion of construction land mainly came from cultivated land.

4.3 Analysis of Landuse Degree

Using the formula of landuse comprehensive degree index and the land use classification standard of the Yellow River Basin mentioned above, the landuse comprehensive degree indexes of five years from 1980 to 2020 were calculated, which were presented in Table 2.

In the past 40 years, the landuse degree in the study area of the Yellow River Basin has been relatively high, with the index values above 220, the minimum value of 221.41 in 1980, and the maximum value of 223.51 in 2010.

From different time points, the degree of land use in the Yellow River Basin was first in a period of rapid development, and then slightly attenuated. From 1980 to 2010, the land use index of the Yellow River Basin kept rising steadily. The reason is that the ecological protection measures mentioned above were effective, and the natural ecological landscape had been restored to a certain extent. From 2010 to 2020, the land use in the Yellow River Basin declined, and the land use index decreased by 0.32, indicating that there were unreasonable human activities, which destroyed the original high utilization degree.

It is suggested that the environmental departments strengthen the land management policy in the Yellow River Basin, especially for the improvement of unused land such as sandy land, and improve its classification level to improve the overall land use degree index of the Yellow River Basin. Hopefully, a sustainable land development direction is forward on the way.

5 CONCLUSION

The landscape types that are dramatically changed in the spatial evolution of the Yellow River Basin over the past 40 years are farmland, grassland, construction land, and unused land. The loss of cultivated land area is mainly due to transferring into grasslands. The gain of grassland area mainly coming from cultivated land, followed by forest land and unused land. The gain of unused land area mainly converting from grassland, and the overall unused land area has slightly decreased. The construction land area continues to increase, mainly from cultivated land.

The main types of transfer in and out were grasslands, and the main transitional landscape type was unused land. The two main lines of landscape type evolution are: (1) from 1980 to 2010, grassland flowed into unused land and cultivated land, and unused land flowed into grassland; (2) the landscape pattern has undergone significant changes from 2010 to 2020, with the transfer of cultivated land, forest land, and grassland, as well as the transfer of grassland and unused land. The overall level of land development during the research period was relatively high. The land use index continued to steadily increase from 1980 to 2010, indicating that ecological protection measures have been effective and natural ecological landscapes have been restored to a certain extent.

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