Research on Change in Use Of Land As Well As Driving Forces Within Xi'an Using Landsat Remote Sensing Images

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Abstract. As studies regarding global environmental change and development have intensified on observation techniques on the ground, changes in use of land studies have become the main method for studying urban and regional development and change. Xi'an, the biggest city in northwest China, has experienced significant alternations in its urban landscape due to its economic development. This research examines the changes in use of land in Xi'an over three periods (2010, 2015, and 2020) by analyzing Landsat satellite images and via satellite-based classification methods, as well as geographic information system spatial assessment methods. The research identifies the spatial as well as temporal features of changes in use of land in Xi'an and their driving factors. The findings reveal a decline in land for agriculture region from 2010 to 2020. During this period, construction land has grown every year, primarily cutting down on land for agriculture. Moreover, the grassland, area for water, and non-used land have shown an overall fluctuating increase. For the period 2015-2020, a use of land Dynamic Index for Comprehensive use of land has been developed, which is much greater than for the 2010-2015 period, with the largest single use of land dynamics index being non-used land. The main drivers of change in land for construction region are construction output, gross industrial product, local fiscal expenditure, gross product, and gross secondary sector. In terms of land for agriculture, the gross primary sector, the number of rural residents, and the number of urban residents are the main drivers of change.

Keywords: Use of Land; Xi'an; Transfer Matrix; Pearson Correlation Coefficient; Driving force.

1. Introduction

A major change in the environment is Earth's use of land and Land Cover Change (LUCC) resulting from human activities, and land cover changes are manifested in biodiversity, soil quality, surface runoff and erosion deposition, and actual and potential first productivity of the land [1].

LUCC has an important impact on surface energy, water cycle, and atmospheric circulation. Studying changes in use of land patterns from a regional perspective has become the focus of LUCC research [2]. As one of the metropolises in western China, Xi'an has undergone great alternations in its urban landscape with economic development. It is meaningful to study and analyze the changes in use of land as well as driving forces in Xi'an to improve environmental quality and contribute to economic development and policy implementation in northwest China. Existing studies primarily use remote sensing images, integrated classification and GIS techniques, transfer matrix and Markov prediction models, combined with mathematical statistics to carry out studies on regional changes, The field of use of land research encompasses various studies, such as predicting changes in use of land in cities that are experiencing rapid growth as well as analyzing ecological response to use of land transformation [3,4]. Additionally, specific regions have been the subject of use of land studies, including the use of the transfer matrix approach to mine regional use of land evolution information in Suzhou city and analyzing ecosystem service score alternations in Inner Mongolia over 20 years, where a dynamic approach to use of land transfer is used in conjunction with the use of land transfer matrix [5,6]. Another example is the assessment of use of land transfer characteristics and dynamic attitude in the Loess Plateau region based on the use of land transfer matrix [7]. Meanwhile, studies on use of land impacts on terrestrial carbon emissions, habitat quality, and air pollution have been continuously updated and refined [8-10]. While there have been some prior investigations into changes in use of land in Xi'an, this study aims to provide an up-to-date analysis that takes into account the city's rapid development [11]. Based on Landsat remote sensing images from 2010, 2015, and 2020, the current study presents a land transfer matrix and dynamic attitude of land use, in addition to an analysis of correlation factors, to examine changes to use of land and its driving forces between 2010 and 2020.

2. Overview of the Study Region

Xi'an is situated between 107°40′ and 109°49′E and 33°39′ and 34°44′N. It is bounded on the south by the Qinling Mountains and on the north by the Wei River (Fig. 1). The climate is warm and semi-humid with continental monsoons in the city, and the majority of its land region comprises Land for agriculture, land for forest, and land for construction [11].

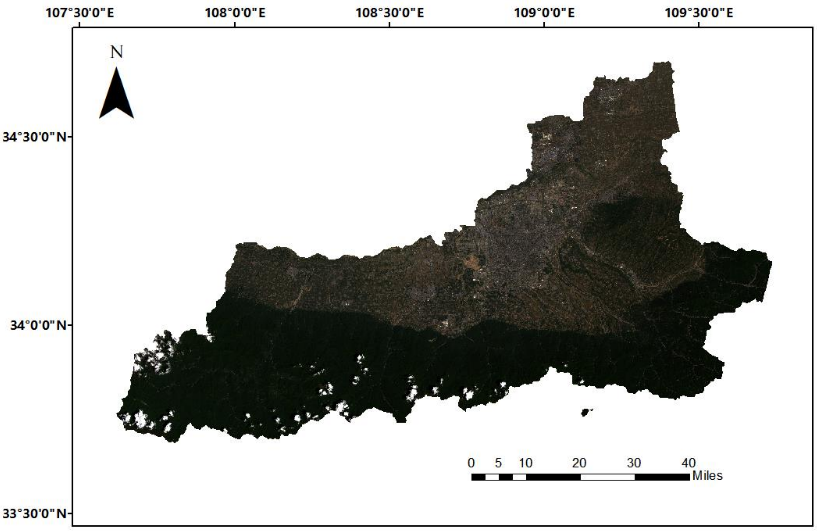

Fig. 1 Schematic diagram of Xi'an city limits

3. Sources of Data

The research employs images acquired from Landsat7 OLI remote sensing for the 2010 remote sensing information and landsat8 OLI remote sensing images for the 2015 and 2020 remote sensing data. Both sets of remote sensing images are acquired from the official website of Geospatial information Cloud (http://www.gscloud.cn). The Landsat7 and landsat8 images are radiometrically calibrated and atmospherically corrected using ENVI software, and then cropped using the administrative boundary map of Xi'an, and the cropped images are transferred to Arcmap for use of land classification and subsequent use of land correlation analysis. The Network of Geographic Remote Sensing Ecology (www.gisrs.cn) provided the vector information for the administrative boundaries used in this study. The Xi'an Municipal Bureau of Statistics (http://tjj.xa.gov.cn/) was the source of the gross product, urban and rural population numbers used for statistical analysis in this paper.

4. Research Methods

4.1. Image Processing for Remote Sensing

The K-means method was used to perform unsupervised classification of remote sensing images in this study. On this basis, the supervised classification is performed by using neural network method. The results of supervised classification are verified by comparing and sampling with high-resolution remote sensing images, and the overall accuracy is calculated to be 94.69%, and the Kappa coefficient is 0.94.

4.2. Use of Land Transfer Matrix

The current standard practice for researching kinds of use of land on an international level is to utilize remote sensing images or use of land maps from various time periods to identify the transfer matrix of kinds of use of land over the course of the research using spatial superposition operations [11]. The expression used to represent type of use of land could be found in reference [12].

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \tag{1}$$

The variable S denotes the area of use of land, while i and j represent the initial and final kinds of use of land, respectively. Additionally, n denotes the total number of kinds of use of land.

4.3. Use of land Dynamic Index

The use of land dynamics index is capable of indicating the rate of change in the quantity of a particular type of use of land over the course of the study period. This index could be further classified into two categories, namely the dynamics index of single use of land and the dynamics index of integrated use of land [13,14].

The former is employed to describe the transformation of a specific type of use of land within the study region and could be computed using the formula below:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \tag{2}$$

In the Eq. 2, variable K denotes the dynamics index of use of land of a particular type of use of land within the study area, expressed as a percentage. Additionally, Ua and Ub denote initial and final areas of the type of use of land, respectively, while T denotes the study period duration.

Apart from the dynamics index of single use of land, there is also the comprehensive use of land dynamics index that provides an overview of the changes in use of land across the entire study area. This index could be computed using the following formula:

$$LC = \left(\frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \right) \times \frac{1}{T} \times 100\% \tag{3}$$

Where the integrated use of land dynamic attitude is represented by the variable LC, expressed as a percentage. The formula for calculating this index involves several components, including LU_i, which refers to the starting region of type of use of land i in the study period. Additionally, ΔLU_{i-j} denotes the score in absolute terms of the region that has been converted from type of use of land i to type of use of land j over the duration of the study period T. The variables i and j represent different kinds of use of land.

4.4. Analyzing Driving Forces via Pearson Correlation Coefficient

Alternation in use of land is a complex process in natural environments that is influenced and constrained by various factors, including natural, social, economic, and policy factors [15]. The main emphasis of this research is on two kinds of use of land: land for agriculture and land for construction, which undergo significant transformation. To determine the primary driving forces behind these changes, the Pearson Correlation Coefficient (PCC) is used. It measures the linear correlation between two sets of information X and Y, also known as the Pearson product moment correlation coefficient. Its score falls from -1 to 1 and could be expressed in the formula [16].

$$\rho_{X,Y}=\frac{\operatorname{cov}(X,Y)}{\sigma_X\sigma_Y}=\frac{E(XY)-E(X)E(Y)}{\sqrt{E\left(X^2\right)-\left(E(X)\right)^2}\sqrt{E\left(Y^2\right)-\left(E(Y)\right)^2}}=\frac{n\sum_{i=1}^{n}x_iy_i-\sum_{i=1}^{n}x_i\sum_{i=1}^{n}y_i}{\sqrt{n\sum_{i=1}^{n}x_i^2-\left(\sum_{i=1}^{n}x_i\right)^2}\sqrt{n\sum_{i=1}^{n}y_i^2-\left(\sum_{i=1}^{n}y_i\right)^2}} \tag{4}$$

In this formula, cov(X,Y) denotes the covariance between X & Y, while δX & δY represent the standard deviations of X and Y. There is a range of correlation coefficients between -1 and 1, with a score between 1 and -1 indicating a stronger correlation, and a score between 0 and 1 indicating a weaker correlation between the two variables.

5. Results and Assessment

5.1. Results of Use of Land Classification

In the study region of the years 2010, 2015, and 2020, types of use of land were classified using the supervised classification method. These categories include land for agriculture, land for forest, grassland, region for water, land for construction, and non-used land.

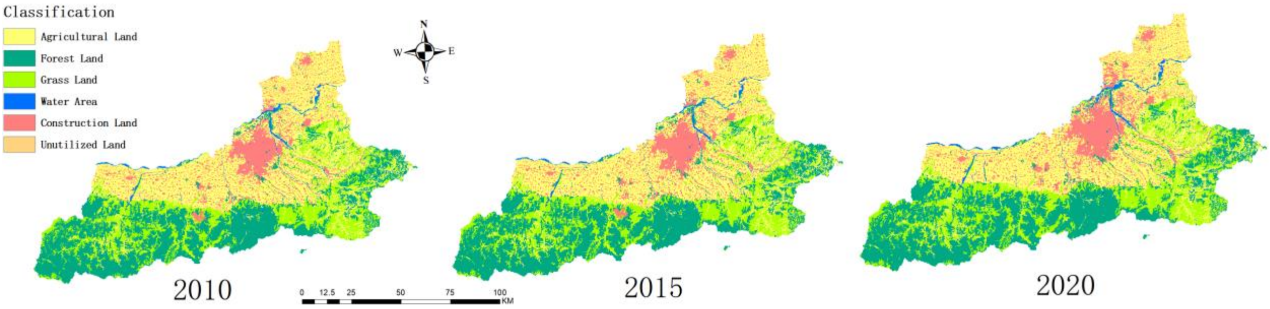

Fig. 2 Diagram depicting kinds of use of land in Xi'an in 2010, 2015, as well as 2020

Fig. 2 shows that land for agriculture, land for forest, and land for construction were the largest kinds of use of land in Xi'an in 2010, 2015, and 2020. Agricultural and land for construction were primarily located in the northern and central parts of the country, while land for forest was primarily located in the southern areas. The most significant change in use of land depicted in Fig. 2 is the land that has been converted from agricultural use to construction use, resulting in the occupation of a substantial amount of arable land by land for construction from 2010 to 2020.

5.2. Land Transfer Matrix and Use of Land Dynamic Index Analysis

Table 1. Matrix of use of land transfer in Xi'an between 2015 and 2020 (unit: km^2)

2015 2010	Land For Agriculture	Land For Forest	Land For Grass	Area For Water	Land For Construction	Non-Used Land	Total
Land for agriculture	3666.3086	5.4539	9.7255	3.2673	56.1254	1.3229	3742.2035
Land for forest	5.4941	3041.1681	10.3309	1.2536	1.5648	0.2272	3060.0387
Land for grass	10.7171	10.4708	1998.5753	0.7405	1.3105	0.2046	2022.0187
Water Land	4.8636	1.2111	2.4687	131.7430	0.6322		140.9186
Land for construction	11.9806	0.5363	0.5728	0.1406	1117.4797	0.0052	1130.7151
Non-used Land	0.0362	0.0298	0.0187		0.0009	3.5437	3.6292
Total	3699.4002	3058.8700	2021.6918	137.1449	1177.1134	5.3036	10099.5239

Table 2. Matrix of use of land transfer in Xi'an between 2015 and 2020 (unit: km^2)

2020 2015	Land for Agriculture	Land for Forest	Land for Grass	Area for Water	Land for Construction	Non-used Land	Total
Land for Agriculture	3324.5317	33.7112	76.1544	29.6640	234.8249	0.3904	3699.2767
Land for Forest	26.0118	2911.3770	108.4972	3.7128	7.8057	1.2476	3058.6522
Land for Grass	52.8053	52.5066	1903.9530	8.9553	3.0609	0.3175	2021.5988
Area for Water	10.5820	2.7454	3.8911	118.0572	1.8197		137.0953
Land for Construction	119.0007	27.0647	7.3234	1.9069	1021.7826	0.0166	1177.0949
Non-used Land	1.4196	0.3952	0.5786		0.1921	2.7170	5.3025
Total	3534.3511	3027.8002	2100.3978	162.2962	1269.4859	4.6892	10099.0204

Table 3. Dynamic analysis use of land in Xi'an between 2010 and 2020

	2010-2015		2015-2020	
	Region Change (km²)	Dynamic Index of Use of Land for Single use of land(%)	Region Change (km²)	Dynamic Index of Use of Land for Single use of land(%)
Land for Agriculture	-42.8169	-0.2288	-164.9244	-0.8916
Land for Forest	-1.1624	-0.0076	-30.9034	-0.2021
Land for Grass	-0.3248	-0.0032	78.8118	0.7797
Area for water	-3.7773	-0.5360	25.2169	3.6770
Land for construction	46.4032	0.8208	92.3944	1.5698
Non-used Land	1.6744	9.2272	-0.6111	-2.3045
	Index for Comprehensive Use of Land(%):	0.0952	Index for Comprehensive Use of Land(%):	0.8916

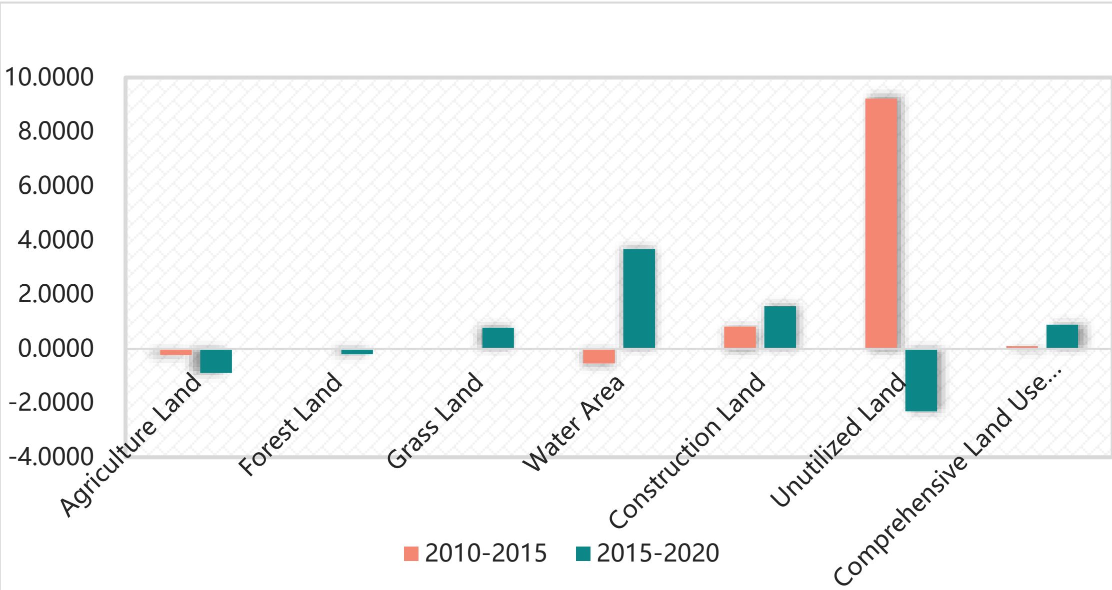

Fig. 3 Histogram of the use of land dynamic degree in Xi'an between 2010 and 2020

The Xi'an region has undergone significant changes in use of land in recent years, as evident from Fig. 2 and Table 1 and Table 2. These changes were dominated by structural adjustments and an increase in land for construction, which resulted in a large decrease in land for agriculture. Although the region of water region decreased slightly between 2010 and 2015, it increased by about 18.38% between 2015 and 2020, which is favorable for Xi'an, a city with a dry and water-scarce climate. The construction region expanded rapidly. There was an annual growth rate of 1.2%, with the non-used land region experiencing the fastest rate of growth, increasing by approximately 29.21% in the study period.

The use of land transformation revealed that land for agriculture was primarily converted into land for construction and grassland. The rapid expansion of land for construction came at the cost of a significant amount of land for agriculture, with almost 30 km2 of land for agriculture being converted into land for construction each year in the study period. The significant rise in water region primarily originated from land for agriculture and to a lesser extent from grassland. Land for forest revealed a decreasing trend in the study period, primarily converted to grassland and land for agriculture, possibly due to excessive felling of trees and clearing of cultivated land. The significant expansion in the region of non-used land primarily resulted from converting lands into forests and agricultural lands due to rapid urbanization, development zone planning, and urban transformation, resulting in a large amount of non-used land in the urban-rural border area.

From Fig. 3 and Table 3, from 2015 to 2020, it has been observed that the comprehensive use of land dynamic degree has increased is much higher than that during 2010-2015. This indicates that the overall land type shift in Xi'an was more obvious during 2015-2020, possibly due to the more rapid urbanization and industrialization in the region during this period. Among the single types of use of land, land for forest had the least use of land dynamic degree, whereas land for non-used land had the highest. As a result, the rate of change has been the fastest in the region of non-used land within the study period, while the land for forest showed the slowest rate of change.

5.3. Study of Changes in Use of Land Drivers

Table 4. Pearson correlation coefficients for alternations in land for agriculture and land for construction region in Xi'an

Pearson Correlation Coefficient			
	Land for Construction		Land for Agriculture
Output score of Construction Industry	0.9993	Grain Yield	0.5919
Gross score of Industrial Production	0.9928	Gross Agricultural Output Value	-0.8736
Local Fiscal Expenditure	0.9671	Annual Mean Temperature	0.6594
Gross Product	0.9972	Power Generated by Agricultural Machinery	0.5453
Enterprise Number	0.7744	Mean Annual Precipitation	0.8402
Primary Sector's Gross Domestic Product	0.7832	Primary Sector’s Gross Domestic Product	0.9593
Secondary Sector’s Gross Product	0.9785	Gross Regional Product	-0.9273
Tertiary Industry’s Gross Product	0.8716	Rural Population	0.9327
Total Foreign Trade Volume	0.4265	Urban Population	-0.8902

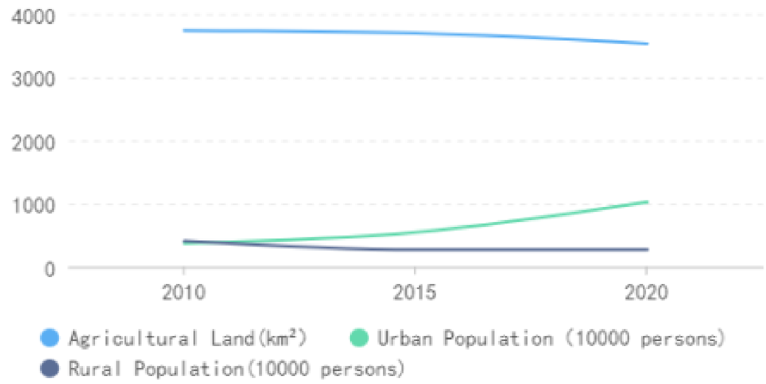

Fig. 4 Trend of urban population, rural population and land for agriculture region in Xi'an

According to Table 4, there is a positive correlation between land for construction region and five factors: construction output, gross industrial product, local fiscal expenditure, gross product, and gross secondary sector. The correlation coefficients are all above 0.9, indicating that these factors are the key determinants behind the expansion of land for construction area. The expansion of land for construction region is presumed to be due to the financial support provided by the construction industry, industry, secondary sector, and government finance. This expansion results in better efficiency, larger production scale, and an increase in the output score of the construction industry, gross product of Secondary Sector, and related industries, forming a sustainable virtuous circle.

Table 4 shows that Land for agriculture region is most strongly correlated with the gross score of primary sector, followed by the number of rural population. Land for agriculture region also is negatively correlated with the number of urban population. This phenomenon is thought to be due to the fact that the primary sector is based on agriculture, forestry, animal husbandry, and fishery, which are more dependent on Land for agriculture. The gross score of primary sector promotes the development of agriculture and provides financial support in order to expand agricultural land. The land expansion for agriculture can increase the sales of agricultural by-products and drive the production of primary sector, resulting in a strong correlation. The decline in the number of main agricultural population due to young and middle-aged laborers leaving rural areas, combined with the low efficiency and low income of agricultural production, leads to the abandonment of a large amount of arable land as well as a decrease in the land region for agriculture. This phenomenon is reflected in the correlation between the region of land for agriculture and the number of township population. The massive movement of population from rural areas to cities has led to an increase in urban population. In response to the rigid housing and education demands of this newly arrived population, industrial and mining lands have been developed for construction purposes, encroaching on part of the land for agriculture area. This phenomenon is in line with the trend of urbanization. The alternations in land for agriculture area, urban population, and rural population from 2010 to 2020 are shown in Fig. 4. The alternations in Land for agriculture region and rural population have similar positive trends and are inversely correlated with urban population. Combining Table 4 and Fig. 4, it could be concluded that the three main drivers affecting land for agriculture region are the gross primary sector, the number of rural population, and the number of urban population.

6. Conclusion

By correlating changes in use of land in Xi'an for 2010, 2015, as well as 2020 with the matrix of land transfer and analyzing all driving forces of major alternations in use of land, this paper draws the following conclusions. Throughout the study period, land for agriculture and land for forest have decreased while land for construction has increased. Grassland, water bodies, and unused land have fluctuated in overall increase. The use of land transfer matrix primarily indicates a decrease in land for agriculture area, which is mostly transformed into land for construction and, to a lesser extent, grassland, land for forest, and area for water . In general, the level of comprehensive use of land dynamic was much higher during 2015-2010 than during 2010-2015. Non-used Land has the highest degree of use of land dynamic change and has experienced the greatest alternation, while the dynamic index of use of land for forest is relatively small. The primary drivers of alternations in use of land for land for construction in Xi'an are primarily socio-economic factors, specifically construction output, gross industrial product, local financial expenditure, gross product, and gross product of secondary sector. For land for agriculture, the main drivers are the gross score of primary sector, the number of rural populations, and the number of urban populations.

References

[1] Soo-Bin Lee. The core area of global environmental change research: international research trends in land use/land cover change. Journal of Geography, 1996, 51(6): 553-558.

[2] Lu Yunge, Xu Yueqing, Cai Yunlong. Analysis of land use/cover change in small watersheds based on remote sensing technology and GIS [J]. Advances in Geographical Sciences,2005(01):79-86+138.

[3] Wang X D,Yao Y,Ren S L,et al. A coupled FLUS and Markov approach to simulate the spatial pattern of land use in rapidly developing cities[J]. Journal of Geo-information Science, 2022,24(1):100-113.

[4] Wang FH,Zhao RF,Zhang LH et al. Land use transition process in the middle reaches of the Heihe River and its impact on regional ecological quality[J]. Journal of Applied Ecology 2017,28(12):4057-4066.

[5] Qiao Weifeng, Sheng Yehua, Fang Bin et al. Information mining of land use evolution in highly urbanized regions based on transfer matrix--Suzhou City, Jiangsu Province as an example [J]. Geography Research,2013,32(08):1497-1507.

[6] Wang N,Yang G,Han Xueying et al. Land use changes and ecosystem service values in Inner Mongolia from 1990-2018 [J]. Journal of Soil and Water Conservation,2020,34(05):244-250.

[7] Li Yannan. Study on the dynamic change of land use in Loess Plateau area [J]. Agriculture and Technology,2021,41(21):117-120.

[8] LI Yan-Min, SHEN Yusheng, WANG Shi-Hang. Spatial and temporal characteristics and effects of terrestrial carbon emissions in Anhui Province based on land use change [J]. Journal of Soil and Water Conservation,2022,36(01):182-188.

[9] Wang Chao, Chang Y, Hou Xiyong et al. Spatial and temporal evolution characteristics of habitat quality in the Jiaodong Peninsula based on land use pattern changes [J]. Journal of Geoinformation Science,2021,23(10):1809-1822.

[10] Zhou Tao,He Shu. Study on the relationship between urban land use patterns and air pollution--based on empirical evidence in the main urban area of Chongqing [J]. Construction Management Research,2021(01):109-123.

[11] Xie Xiu-Ping,Zhou J. Research on the prediction of land use change--example of Xi'an region[J]. Arid Zone Research,2008(01):125-130.

[12] Wu Lina,Yang Shengtian,Liu Xiaoyan et al.Response of land use change to the degree of human activity in the Beiluo River Basin since 1976[J]. Journal of Geography,2014,69(01):54-63.

[13] Zhang Yun,Peng Jiandong,Wang Jingjing et al. Analysis of spatial and temporal changes of land use in Jianghan Plain based on geological information mapping [J]. Soil and water conservation research,2020,27(04):85-92+2.

[14] Xiao Jianjian,Qiao Bin,Chen Guoxi et al. Evolution of land use and ecosystem service values in Mado County, Yellow River source area[J]. Journal of Ecology,2020,40(02):510-521.

[15] WANG Bao,SHI Peiji,KANG Jianfang. Evolution of information entropy of land use structure in Tianshui city and analysis of driving forces[J]. Land and Natural Resources Research,2010,No.129(05):22-24.

[16] Xiao XY, Jiang B, Ren QW, et al. PV data cleaning based on interpolation method and Pearson correlation [J]. Information Technology,2019,43(05):19-22+28.