Analysis of Temporal and Spatial Changes in Land Use in Beijing Municipality Over the Past Two Decades

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Abstract. To better plan and use the land resources in the region and master the changes of land use types and their temporal and spatial distribution characteristics, this paper takes Beijing as an example, obtained land use data based on Landsat remote sensing images, and studied the temporal and spatial changes of land use in Beijing from land use dynamics and land use state index in recent 20 years. The results indicate that the distribution of land use types in Beijing is mainly dominated by arable land, forest land, construction land, and grassland. In the past 20 years, urban development has been rapid, construction land has been continuously increasing, and there is a trend of arable land transferring to construction land.With the increase of population, economic development, and the improvement of urbanization level, the internal industrial structure adjustment of agriculture and urbanization.The expansion of rural construction land will lead to the occupation of a large amount of arable land, and the contradiction between more people and less land will further intensify. Protecting arable land should be given more extensive attention.

Keywords: Land use change; Dynamic degree of land use; Land use state index; Beijing; Urban expansion

1 Introduction

Land is a vital and reusable resource that possesses both natural and economic attributes. It forms the fundamental material basis and natural resource upon which humanity relies for survival and development [1]. The rational planning and utilization of land resources play a significant role in the development of human society. Altering various aspects of land use, such as types, structures, methods, and spatial distribution, not only affects the carrying capacity of regional land resources and the functionality of ecological service systems but also influences the distribution of biodiversity and other resources within that region [2]. Therefore, the analysis of changes in regional land use types, structures, and methods has become one of the main focuses of research on global environmental changes and sustainable resource utilization [3].

Beijing Municipality is a modern metropolis characterized by economic and cultural prosperity, a large population, and limited land resources. With the rapid development of the economy and a significant increase in population, the pace of urbanization in Beijing has accelerated noticeably. Factors such as the accelerated expansion of urban areas have led to an increased demand for land resources. In order to gain a more accurate understanding of the rational utilization of land resources in Beijing and to analyze the temporal and spatial

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characteristics of land use types, this study focuses on the Beijing metropolitan area. It uses Geographic Information System (GIS) and Remote Sensing (RS) technologies to acquire land use status data from the period between 2000 and 2020. Through the use of land use dynamic degree models and land use status index models, this research conducts an analysis to quantitatively assess the dynamic evolution patterns of land use in Beijing Municipality, as well as the changes in temporal and spatial patterns. The objective is to provide valuable insights for the more rational and effective planning, management, and sustainable utilization of land resources in Beijing Municipality.

2 Study Area Overview

Beijing Municipality is located in the northern part of the North China Plain, bordered by Hebei Province and Tianjin Municipality to the north, with higher terrain in the northwest and lower terrain in the southeast. It is surrounded by mountains on the west, north, and northeast, with an average elevation of 43.5 meters above sea level [4]. The city is divided into 16 districts, including Dongcheng District, Chaoyang District, and Haidian District, covering a total area of 16,410.54 square kilometers.

The primary data for this study were obtained from Landsat remote sensing imagery with a spatial resolution of 30 meters. A series of preprocessing steps, including geometric correction and atmospheric correction, were applied to the image data using ENVI software. Subsequently, supervised classification was performed using the maximum likelihood method, and reference data from sources such as Google Earth imagery were used to interpret the remote sensing data, resulting in six periods of land use data. The accuracy of the classification results was assessed using a random sampling point method, and based on the analysis of the sampled pixels, the accuracy assessment yielded Kappa coefficients and classification accuracy exceeding 85%, indicating a high-quality classification result that meets the precision requirements for land use change analysis research.

3 Research Methodology

Analyzing and studying the dynamic changes in regional land use allows for the quantitative description of the dynamic changes in land use categories and quantities during a specific period. This helps in gaining a better understanding of the spatial and temporal distribution differences of land use types, making it a valuable dataset for predicting future trends and intensity of land use type changes [5-6]. In this paper, we analyze and study the dynamic spatial-temporal changes in land use in Beijing Municipality from 2000 to 2020, focusing on three aspects: changes in the quantity of different land use types, changes in their spatial distribution over time, and the intensity of land use type changes during different periods.

3.1 Land Use Dynamic Degree

Utilizing the concept of land use dynamic degree allows for not only the quantitative description of the speed and magnitude of changes in different land use types within a specific time period but also provides further insights into the intensity differences in the quantity

changes of various land use types within the region. This is of significant importance for predicting future trends in land use changes [7]. Its mathematical expression is as follows(1):

$$K = \frac{S_{t2} - S_{t1}}{S_{t1}} \times \frac{1}{T} \times 100\% \quad (1)$$

where St1 represents the area of a specific land use type at the beginning of a specific time period, St2 represents its area at the end of that specific time period, and T represents the time interval under study, measured in years.

3.2 Land Use Status Index

The Land Use Status Index is a mathematical model used to study the change trends and intensity of a specific land use type within a given region. It plays an important role in assessing the degree and status of different land use types during a specific time period [8,9]. The mathematical model is as follows(1):

$$P = \frac{\Delta S_{in} - \Delta S_{out}}{\Delta S_{in} + \Delta S_{out}} \quad (2)$$

where the value of P falls within the range [-1, 1], describing the degree and status index of land use for different land types during a specific period. ΔS_{in} represents the area of land that transitions into the i-th land use state from other land use types during the research period, and ΔS_{out} represents the area of the i-th land use type that transitions into other land use states during the study period.

4 Analysis of Land Use Change in Beijing

4.1 Quantity Changes and Dynamics

Analyzing remote sensing imagery data for land use in Beijing's sixth period, we used ArcGIS software to calculate data for different land use types in various years. Analyzing land use types and quantity changes, it can be observed that the primary land use types in Beijing are cropland, forestland, construction land, and grassland. Among these, cropland in Beijing has been decreasing year by year from 30.38% of the total area in 2000 to 22.18% in 2020, with a total decrease of 1343.35 km². The change was substantial, with a decrease of 712.01 km² between 2015 and 2018. Forestland is the most extensive land type in Beijing, accounting for approximately 45% of the total area. From 2000 to 2015, the forestland area decreased slowly by about 37.13 km², but from 2015 to 2018, it increased significantly by 206.08 km². By 2020, the forestland area decreased to 45.68% of the total area. The changes in grassland areas followed a similar trend to forestland, with a decrease of 13.6 km² from 2000 to 2020. Specifically, the change was slow from 2000 to 2015, with a decrease of 8.98 km², but more significant changes occurred after 2015, including an increase of 16.51 km² from 2015 to 2018 and a decrease of 21.15 km² from 2018 to 2020, accounting for 7.8% of the total area. From 2000 to 2018, the water area decreased annually, from 507.11 km² in 2000 to 418.81 km² in 2018. However, by 2020, it increased to 437.67 km², with a total decrease of 69.44 km². The

rate of decrease was relatively stable. Conversely, the area of construction land showed an opposite trend to water areas, rapidly increasing from 13.63% of the total area in 2000 to 21.62% in 2020. The area exhibited a consistent annual increase, with a total increase of 1309.23 km². Unused land accounted for only 0.01% of the total area, and its changes were minimal. The most significant change occurred between 2015 and 2018, with an increase of 8.23 km².

The analysis assessed the intensity of changes in different land use types in Beijing from 2000 to 2020 using land use dynamics. Calculation and analysis of the change areas and dynamics of different land use types in each year were conducted using Formula (1), as shown in Table 1 below. It can be observed that, in various study periods, cropland showed negative change areas, indicating a year-by-year decrease in cropland area. Among these periods, the most significant change occurred during 2015-2018, with a cropland dynamic rate of -5.38%. Forestland exhibited an increasing trend in area only during 2015-2018, with a dynamic rate of 0.94%. In other periods, it showed a decreasing trend, with the most significant decrease during 2015-2018, having a dynamic rate of -0.39%. Grassland displayed an overall fluctuating pattern of "increase-decrease-increase-decrease." From 2000 to 2005, the grassland area slightly increased with a dynamic change rate of 0.02%. During 2015-2018, there was a significant increase in grassland area with a dynamic rate of 0.43%. However, from 2018 to 2020, the grassland area decreased with a dynamic rate of -0.81%. The water area underwent the most noticeable changes from 2015 to 2020. Specifically, during 2015-2018, the water area decreased with a dynamic rate of -3.64%, while from 2018 to 2020, the water area increased with a dynamic rate of 2.25%. Construction land exhibited positive dynamic rates in all study periods, indicating a continuous increase in construction land area. Among these, the most significant change occurred during 2015-2018, with a dynamic rate of 6.16%, while the smallest change occurred during 2010-2015, with a dynamic rate of 0.65%. The area of unused land showed the most significant change during 2015-2018.

Table 1. Area Changes and Dynamics of Different Land Use Types in Various Periods

Land Use	2000-2005		2005-2010		2010-2015		2015-2018		2018-2020	
	Area Changes(km²)	Dynamics(%)	Area Changes(km²)	Dynamics(%)	Area Changes(km²)	Dynamics(%)	Area Changes(km²)	Dynamics(%)	Area Changes(km²)	Dynamics(%)
Cropland	-365.11	-1.47	-120.89	-0.52	-80.05	-0.36	-712.01	-5.38	-65.292	-0.88
Forestland	-11.97	-0.03	-17.08	-0.05	-8.08	-0.02	206.08	0.94	-58.925	-0.39
Grassland	1.08	0.02	-8.02	-0.12	-2.02	-0.03	16.51	0.43	-21.148	-0.81
Water area	-25.009	-0.99	-10.991	-0.46	-1.009	-0.04	-51.29	-3.64	18.8598	2.25
Construction land	401.01	3.59	156.98	1.19	91.16	0.65	532.48	6.16	127.595	1.87
Unused land	0	0	0	0	0	0	8.2297	279.89	-1.0891	-5.91

4.2 Land Use Status Index

To study the changing trends and status of different land use types in Beijing from 2000 to 2020, we analyzed the Land Use Status Index for different land use types during this period. It

can be observed that the Land Use Status Index for each land use type varies, and each has its own characteristics. Cropland and construction land exhibit opposite trends in the Land Use Status Index. Cropland shows a decreasing trend, while construction land shows an expanding trend. The period from 2015 to 2018 witnessed significant changes, with a Land Use Status Index of -0.99 for cropland and 0.96 for construction land. Forestland and grassland follow similar changing trends. Forestland reached its lowest index value during 2005-2010, with a Land Use Status Index of -1, while grassland reached its lowest index value during 2015-2020, with a Land Use Status Index of -1. Afterward, both gradually rebounded, with their status indices increasing over time. Water area and unused land had relatively stable Land Use Status Indices from 2000 to 2015, with minimal fluctuations. However, from 2015 to 2020, their changing trends diverged significantly. During 2015-2018, the Land Use Status Index for water area was -0.13, while for unused land, it was 0.92. In contrast, from 2018 to 2020, the Land Use Status Index for water area was 0.42, while for unused land, it was -0.21.

5 Conclusion

Taking Beijing as an example and based on the land use data from the sixth period spanning from 2000 to 2020, the analysis conducted using DDMLU and LUSIM provides the following conclusions:

(1) Beijing's primary land use types include cropland, forestland, construction land, and grassland. During the period from 2000 to 2020, the area of cropland in Beijing decreased year by year, with the most significant change occurring during 2015-2018. The trend in grassland area changes closely resembled that of forestland, with more noticeable changes after 2015. The period from 2015 to 2018 saw a significant increase in grassland area, with a dynamic rate of 0.43%, while from 2018 to 2020, grassland area decreased but rebounded to 437.67 km^2 by 2020. The area of construction land rapidly increased from 13.63% of the total area in 2000 to 21.62% in 2020. Unused land occupied only 0.01% of the total area, with relatively minor changes, but the period from 2015 to 2018 saw the most significant change.

(2) The Land Use Status Index for cropland and construction land exhibited opposite trends, with cropland showing a decreasing trend and construction land showing an expanding trend. Forestland and grassland showed similar changing trends, with forestland reaching its lowest index value during 2005-2010 and grassland reaching its lowest index value during 2015-2020. Due to the rapid economic development in Beijing, the conflict between urbanization and the environment has become more pronounced. This has led to a sharp increase in urban built-up areas, a decrease in water areas, and varying degrees of encroachment on cropland and forestland. In the future, urban development in Beijing should prioritize the protection of water areas and forestlands, harnessing their ecological value. While pursuing economic prosperity, it is essential to preserve natural beauty and ecological assets, promoting efficient land use, regional economic development, and ecological sustainability in harmony.

Due to the rapid economic development of Beijing, the conflict between urban expansion and the natural environment has become more pronounced. With the increase of population, economic development, and the improvement of urbanization level, the internal industrial structure adjustment of agriculture and urbanization.This has led to a significant increase in the city's built-up areas, a reduction in water bodies, and varying degrees of encroachment on

arable land and forests. As the city continues to grow, it becomes essential to shift focus towards the preservation of water bodies and forests, and fully realize their ecological value. While pursuing economic prosperity, it's equally important to conserve our "green landscapes" and promote the efficient use of regional land, facilitating sustainable economic and ecological development in harmony.

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