Analysis of Land Use Change in Nanjing Based on Landsat Remote Sensing Images

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Abstract: Purpose: Using Landsat OLI remote sensing images in the two phases of 2015 and 2020. Taking Nanjing as the research area. Based on RS and GIS technology, adopting maximum likelihood method for supervised classification, extracting and producing a land use classification map for the two phases of Nanjing from 2015 to 2020. And further, using the land use change transfer matrix to analyze and summarize the characteristics and laws of the dynamic changes of land use in Nanjing. Result: From 2015 to 2020 in Nanjing, the overall land use change showed "two reductions and four increases". The area of arable land and bare land decreased by 729.46 km², 332.31 km²; the area of urban construction land, woodland, grassland, and water area increased by 448.39 km², 231.67 km², 216.87 km², and 164.84 km². And each land use type has a different amount of area conversion. Conclusion: The analysis of land use change based on Landsat remote sensing image research area can effectively predict the change trend of regional land use. It can provide a basis for the research on the driving forces of land use change in the region, and it can also provide decision-making support for the formulation of land-related policies in the region.

1. Introduction

Under the joint development of the International Geosphere and Biosphere Program (IGBP) and the Global Environmental Change Humanities Program (IHDP), Land Use/Cover Change (LUCC) has gradually become one of the key research factors in global change research. Land use can directly reflect the life and production activities of humans and land, and is one of the ways that human activities affect the natural environment. To a certain extent, it can comprehensively reflect the material circulation and energy flow between the human environment and the natural environment [1]. Therefore, researching and investigating the land use change in a certain area, studying the land use situation in the area, can predict the trend of land use change in the future, calculate the land use efficiency, and formulate effective land remediation plans and ecological protection plans for the area. Providing decision-making support has positive practical significance for the smooth development of land work.

Fast, accurate, and comprehensive acquisition and analysis of target features are the key to land use change research [2]. Remote sensing is a science and technology that focuses on the study of the interaction between electromagnetic waves and objects on the land surface, and detects, analyzes and reveals the spatial distribution characteristics and spatiotemporal changes of various elements on the land surface. In recent years, rapid development has provided land use change research [3]. Remote sensing image classification technology, as an important means of using remote sensing images to identify and interpret target features, has become one of the methods for studying land use changes efficiently [4]. People can directly interpret the land use map on the remote sensing image, which shows
a strong advantage in terms of work cycle and expenditure [1]. Therefore, the RS technology can be used to obtain land use information in a short time, with high quality and in an all-round way, which satisfies the current nature of land use. In this paper, the whole area of Nanjing is selected as the research area, based on Landsat 8 OLI remote sensing images, using RS and GIS technology, using computer-supervised classification methods to interpret the remote sensing images to obtain the land use status of Nanjing, forming a two-phase image Land use map to analyze the dynamic changes of land use in Nanjing from 2015 to 2020, in order to provide a theoretical basis for Nanjing’s future urban overall planning and land use planning.

2. Materials and Methods

2.1. Overview of the study area

Nanjing is located in the southwestern part of Jiangsu Province, my country, on the lower reaches of the Yangtze River. It starts at 31°14′ N in the south, reaches 32°37′ N in the north, 118°22′ E in the west, and 119°14′ E from the east to the east. The geographical plane is long from north to south and narrow from east to west. The widest from east to west is about 70 km, and the longest from north to south is about 150 km (Fig.1). Nanjing belongs to the Ningzhenyang hilly area. It is dominated by low mountains and gentle hills. The water area is more than 11%. The Yangtze River crosses the city and the total length of the river bank is nearly 200km. The climate is a humid climate in the northern subtropical zone, with four distinct seasons, abundant rainfall, an average annual temperature of 15.4°C, an average annual rainfall of 117 days, and an average rainfall of 1106.5 mm. Rich in regional water resources, biological resources, mineral resources and tourism resources.

Nanjing currently has 11 municipal districts and 1 state-level new district, with a total population of approximately 8.5 million, of which the urban permanent population is 7.072 million, and the urbanization rate is 83.2%. In 2020, Nanjing’s GDP will be 1481.795 billion yuan, of which the added value of the primary industry will be 29.68 billion yuan; the added value of the secondary industry will be 521.435 billion yuan; and the tertiary industry will achieve an added value of 930.68 billion yuan. The ratio of the three industries is 2.0:35.2:62.8 [5]. According to the city investment activity ranking announced in the release of the "New Decade of Development-China's Urban Investment Environment Development Report" in 2021, Nanjing ranks fourth in China, only behind Shenzhen, Shanghai, and Beijing.

Fig.1 Location of the study area

2.2. Image source

The remote sensing data which we used is download from the website of the United States Geological Survey (USGS, https://earthexplorer.usgs.gov/), covering the entire city of Nanjing. The study selected Landsat 8’s OLI remote sensing in January 2015 and February 2020. The images are all clear and of good quality. The land cloud cover rate is 5.63% and 0.27% respectively. The auxiliary data is the vector
layer of the administrative division of Nanjing in 2020, which is used to calibrate the whole area of Nanjing on the remote sensing image.

2.3. Data processing

Since the downloaded Landsat 8 OLI remote sensing images are all L1 products, they have been geometrically corrected. Therefore, using Envi to directly perform pre-processing work such as radiation calibration and atmospheric correction on remote sensing images, and then combine the vector layer of the administrative division of Nanjing to crop the pre-processed remote sensing image data, and then obtain the data that can be automatically classified by the subsequent computer. Complete remote sensing map of the study area. Combined with the development status of the study area and the image quality, the land use classification system of this study mainly adopts urban construction land, forest land, cultivated land, grassland, bare land and water area.

In order to improve the visual discrimination effect and the interpretation effect and accuracy, it is necessary to perform appropriate band compression on the remote sensing image when extracting typical features, that is, to select the best band [6]. So that most of the ground objects or ground types can be distinguished more easily through this band [7]. For this reason, in this study, bands 1, 5, and 7 are selected as the best band combination for land use classification of Landsat 8 OLI remote sensing image, and B7-5-1 is the combination band. Land use classification adopts automatic computer classification, supervised classification of remote sensing images on Envi 5.3, and supervised classification using maximum likelihood classifier to form preliminary classification results. Use the Clump Class method to integrate the finely divided plaques to the final supervised classification results.

2.4. Make land use classification map

Based on the ArcGIS platform, import the obtained supervision classification results into ArcMap 10.6 to make land use classification maps, adjust the color of the map spots, add legends, scales, north arrows, etc., and finally form two phases of 2015 and 2020 Land use classification map of Nanjing (Fig.2).

![Fig.2 Land use classification map in different years in Nanjing](image)
3. Results & Discussion

3.1. Land use area change analysis
Based on the two-phase land use classification map of Nanjing City obtained by the supervision classification, the Change Detection Tool in Envi 5.3 calculates the area of each land use type in Nanjing in 2015 and 2020, and summarizes the changes in the area of each land use type (Table.1).

| Land use type         | Area 2015 (km²) | Area 2020 (km²) | Area change 2015-2020 (km²) |
|-----------------------|-----------------|-----------------|-----------------------------|
| Urban construction    | 1878.07         | 2326.46         | 448.39                      |
| Woodland              | 631.41          | 863.08          | 231.67                      |
| Arable land           | 1589.93         | 860.47          | -729.46                     |
| Grassland             | 132.18          | 349.05          | 216.87                      |
| Bare land             | 1963.59         | 1631.28         | -332.31                     |
| Waters                | 394.03          | 558.87          | 164.84                      |

From Table 1, we can see that the area of urban construction land, woodland, grassland, and water area in 2020 has increased by 448.39 km², 231.67 km², 216.87 km², and 164.84 km² compared with 2015; the area of arable land and bare land has decreased by 729.46 km², 332.31 km².

Analyzing the various land use areas in Nanjing from 2015 to 2020, the changes in land use area are mainly manifested in the increase in urban construction land and woodland area, while the decrease in cultivated land and bare land area. This can be explained to a certain extent. With the continuous development and increase of the economic population of Nanjing, the cities and towns began to expand gradually, which led to a decrease in the area of arable land to a certain extent.

3.2. Land use dynamic analysis
One of the important indicators for analyzing land use changes is the dynamics of land use types. The dynamics of land use types can quantitatively describe the rate of change of various types of land use areas, and play a positive role in predicting future trends of changes in various types of land use areas. Land use type dynamics can be divided into single land use type dynamics and comprehensive land use dynamics. Single land use type dynamics expresses the change of a certain land use area within a certain period of time in a research area; comprehensive land use dynamics is Refers to the comprehensive situation of all land use area changes within a certain period of time in a research area [8].

This paper studies the changes of various types of land use areas in Nanjing during two periods, so it is necessary to select a single land use type dynamic degree for quantitative description. The calculation formula is

\[
K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\%
\]  

\(K\) is the dynamic degree of land use type; \(U_a\) and \(U_b\) are the area at the beginning and end of monitoring of a certain land use type; \(T\) is the monitoring duration). Therefore, the greater the absolute value of the dynamic degree of the land use type, the greater the change in the area of this type of land use; on the contrary, the stable change.

Analyze the dynamic changes of land use types in Nanjing from 2015 to 2020 (Table.2). It can be concluded that the area of arable land and grassland in Nanjing have changed significantly in 5 years, which are -9.18% and 32.81%; the area of urban construction land, woodland, bare land, and water area have changed slightly, which are 4.78% and 7.34%, -3.38% and 8.37%. The results show that in the five years in Nanjing, various types of land use areas have fluctuated relatively.

| Land use type         | Dynamic 2015-2020 |
|-----------------------|-------------------|
| Urban construction    |                   |
| Woodland              |                   |
| Arable land           |                   |
| Grassland             |                   |
| Bare land             |                   |
| Waters                |                   |
3.3. Land use transfer analysis
In order to understand the number of conversions between the various types of land use areas, it can be analyzed by constructing a land use transfer matrix. Based on the changes in the land use area of Nanjing from 2015 to 2020, on the Envi platform, the various land use areas in 2015 are taken as the rows of the transfer matrix, and the various land use areas in 2020 are taken as the columns of the transfer matrix. Land use transfer matrix (Table.3) [9].

It can be seen from the combination of Table.2 and Table.3 that the main reason for the decrease in the area of cultivated land and bare land is the conversion of land for urban construction; while the main reason for the increase of grassland area is the conversion of cultivated land to it. Combining the above conclusions, it can be inferred that due to the rapid social and economic development in Nanjing, the urban expansion has led to the reduction of the area of arable land and bare land; at the same time, the large outflow of rural labor has led to the conversion of part of the arable land to grassland.

| Table 3. Land use transfer matrix(km²) |
|--------------------------------------|
| 2015 Urban construction land | 2020 Urban construction land | 2015 Woodland | 2020 Woodland | 2015 Arable land | 2020 Arable land | 2015 Grassland | 2020 Grassland | 2015 Bare land | 2020 Bare land | 2015 Waters | 2020 Waters |
|--------------------------------------|
| Urban construction land | 1260.24 | 42.03 | 118.59 | 59.06 | 234.93 | 163.2 |
| Woodland | 43.46 | 489.91 | 20.63 | 18.30 | 58.14 | 0.97 |
| Arable land | 328.40 | 153.82 | 443.84 | 166.34 | 492.61 | 4.92 |
| Grassland | 56.41 | 6.27 | 29.55 | 14.89 | 23.00 | 2.06 |
| Bare land | 618.40 | 170.74 | 247.13 | 89.79 | 820.23 | 17.30 |
| Waters | 19.55 | 0.31 | 0.73 | 0.67 | 2.37 | 370.40 |

4. Conclusions
This study is based on Landsat remote sensing data, using Envi 5.3 and ArcGIS 10.6 at the same time, to briefly analyze the land use changes of Nanjing City in two phases, and draw the following conclusions:

(1) From 2015 to 2020 in Nanjing, the overall land use change showed "two reductions and four increases", that is, the area of cultivated land and bare land decreased; the area of urban construction land, woodland, grassland, and water area increased.

(2) In the five years, there have been mutual transformations among various land use types in Nanjing. Among them, the area of arable land shows a downward trend, and through the land use transfer matrix, the reduction of arable land and bare land mainly comes from the conversion to urban construction land and grassland, and the grassland as a whole shows a sharp upward trend, and its sources are mainly cultivated land conversion.

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