Detection of Black Soil Change in the Jiguan District Based on Sentinel-2 Satellite Remote Sensing Images

Yuejiao Han, Ping Zhang *

Faculty of Environmental Arts and Architectural Engineering, Heilongjiang University of Technology, Jixi, Heilongjiang, China

**Corresponding Author.*

Abstract: In this paper, the sentinel-2 satellite remote sensing images are mainly used to detect the changes of black soil in Jiguan District, Jixi City. Satellite remote sensing images in the same month of 2021 and 2024 were selected to complete the land use classification based on the maximum likelihood method, and the dynamic change trend of black soil land use in the study area in the past four years was discussed by combining the transfer matrix and spatial distribution. The experimental results show that the overall classification accuracy of time series images is better than 99%, and the Kappa coefficient is more than 98%. From 2021 to 2024, the area of black soil meadow will decrease significantly. There are transfers of black soil and transfer-out, among them, the transfer is manifested as the conversion of black soil woodland to black soil and the conversion of black soil meadow to black soil, and most of the transfer-out is black soil to black soil woodland, and the overall transfer out is greater than the transfer-in.

Keywords: Land Use; Change Detection; Jiguan District; Black Soil

1. Introduction

With the multidisciplinary integration of remote sensing technology, the detection of dynamic changes of land use cover information through time-series satellite remote sensing images has become a research hotspot [1-3]. As the essence of cultivated land, black soil is the "stability maintenance agent" to ensure China's grain production, so it is of great significance to dynamically grasp the spatiotemporal evolution of black soil to ensure the sustainable use of resources and regional sustainable development. Li Dan et al. used the land use transfer matrix to extract the amount of cultivated land transformation in four periods from 1980 to 2015, and the dynamic degree of cultivated land use determined the activity of cultivated land dynamic change in each period, which provided suggestions for ensuring food security in Heilongjiang Province [4]. Man et al. used Landsat data to accurately extract the distribution of cultivated land, and used the land use transfer matrix to analyze the change of cultivated land in detail [5]. Grasping the changes in the use of black soil in small areas is conducive to the rational use and planning of black soil. Combined with the concept of generalized black soil [6], this paper uses Sentinel-2 satellite remote sensing images to study land use classification and black soil transfer, so as to provide effective data support for land management and black soil loss prevention.

2. Data Sources and Methodology

2.1 Overview of the Study Area

Jiguan District (130°50′12"E~131°4′12"E, 45°13′48"N~45°22′18"N) belongs to Jixi City, Heilongjiang Province, located in the southeast of Heilongjiang Province, with an area of 153.2 square kilometers. As of the end of 2020, Jiguan District has 7 sub-districts and 2 townships. Jiguan District is the transportation center of Jixi City, and is the railway, highway and aviation hub in the southeast of Heilongjiang Province. The Jiguan District belongs to the middle temperate continental monsoon climate zone, which is rich in forest resources and mineral resources.

2.2 Data Sources

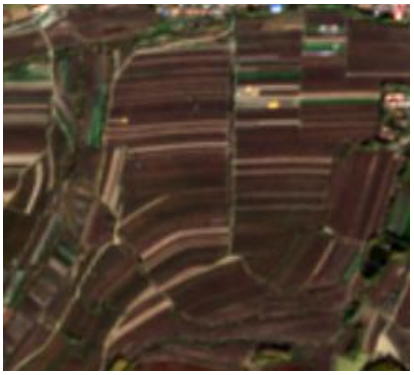
The satellite remote sensing images are derived from the Copernicus data space ecosystem, and the remote sensing images of two scenes in October 5, 2021 and October 5,

2024 are selected, and the cloud coverage does not affect the subsequent classification results. The integrated data of land use classification in 2020 in the annual China land cover dateset (CLCD) were used as the benchmark data to verify the accuracy of land use classification in 2021 and 2024. The data comes from the Earth System Science Database (HTTP://WWW. earth-system-science data.net/).

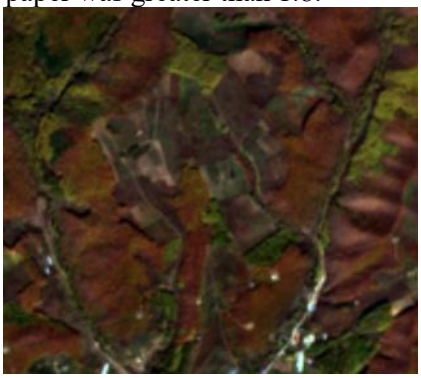
2.3 Research Methodology

2.3.1 ROI construction and separability calculation

Based on the classification system of the China Multi-period Land Use Remote Sensing Monitoring Dateset (CNLUCC) and the national standard of Classification of Land Use Status (GB/T21010-2017), this paper was divided into five types of soil layers: black soil cultivated land, black soil woodland, black soil meadow, black soil construction land and water. Combined with the concept of black soil in a generalized sense, it is determined that black soil represents the category of black soil cultivated land. Select uniformly distributed, pure, and representative training area samples, as shown in Figure 1. The separability coefficient between all categories was calculated, and the closer the coefficient value was to 2 in the interval [0~2], the higher the sample distinguish ability and the more accurate the classification. It was verified that the separability coefficient of all samples in this paper was greater than 1.8.



(a) black soil



(b) black soil woodland

(c) water

(d) black soil meadow

(e) black soil construction

Figure 1. Sample Example of Study Area

2.3.2 Maximum likelihood

The maximum likelihood classification is a widely used supervised classification method based on Bayesian classification criteria [7]. In this method, the distribution functions are assumed to be normally distributed, and the classification is realized by selecting the sample training area and calculating the belonging probability of each sample area to be classified.

The study area can be divided into g category by prior knowledge, and when the population is multivariate normal population $N(\mu_g, \Sigma_g)$, the probability distribution density of the pixel eigenvector X in class g is as follows:

$$f_g(X) = \frac{1}{(2\pi)^{\frac{m}{2}} |\Sigma_g|^{\frac{1}{2}}} \exp\left(\frac{-(X-\mu_g)^T \Sigma_g^{-1} (X-\mu_g)}{2} \right) \quad (1)$$

where μ_g and Σ_g are the mean vectors and covariance matrices of the class g population.

According to the Bayesian formula, the probability of belonging to category g is:

$$P(g/X) = \frac{P_g f_g(X)}{\sum_{i=1}^{g} (P_i f_i(X))} \quad (2)$$

In the case of multi-class discrimination, the Bayesian discriminant is:

$$P(g^*/X) = max(P(g/X)) \quad (3)$$

2.3.3 Analysis of land use change

In this paper, the land use transition matrix is used to explore the changes of various types of transfer [8-10], and the specific calculation formula is as follows:

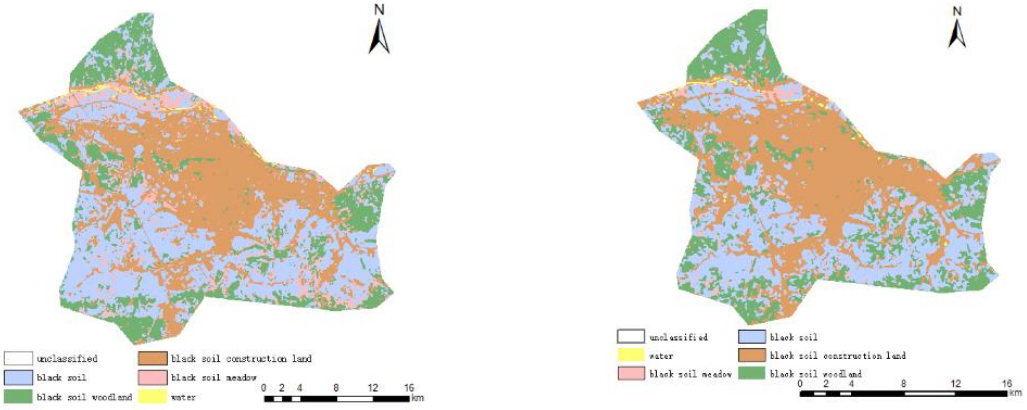
$$T_{ij} = \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1n} \\ T_{21} & T_{22} & \cdots & T_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ T_{n1} & T_{n2} & \cdots & T_{nn} \end{bmatrix} \quad (4)$$

where: T_{ij} is the area of the land class conversion; i and j represent pre-temporal type and post-temporal type, respectively; n is the number of land types.

3. Results and Analysis

3.1 Research Methodology

According to the concept of generalized black soil, this paper classified the land use types of Jiguan District into five categories: black soil woodland, black soil meadow, black soil, black soil construction land and water. The separability coefficient of the classified samples in the study area was greater than 1.8, which belonged to the qualified samples. Then, the land use classification of the Jiguan District in 2021 and 2024 was completed based on the maximum likelihood method using the qualified samples, and the land use classification results of the Jiguan District were obtained after classification and processing, as shown in Figure 2, where (a) the land use classification results of the Jiguan District in 2021; (b) the results of land use classification in the 2024 Jiguan District. In order to verify the validity and reliability of the classification results, the overall classification accuracy and Kappa coefficient were mainly used to evaluate the classification accuracy. In 2021, the overall classification accuracy and Kappa coefficients of land use classification in the Jiguan District were 99.74% and 0.9964, and the overall classification accuracy and Kappa coefficients of land use classification in the Jiguan District in 2024 were 99.26% and 0.9897, respectively.



(a) results in 2021 (b) results in 2024

Figure 2. Land Use Classification Results

According to the land use classification results of 2021 and 2024, the main surface cover type of the Jiguan District is black soil construction land, accounting for about 69% of the total area of the study area, black soil and black soil woodland accounting for about 28% of the total area, and the water and black soil meadow cover area is small, about 3%. The black soil construction land is mainly distributed in the central region, and through the comparison of the classification results of the two phases, the southwest direction of the black soil construction land increases significantly, and most of it is converted from the black soil, which is closely related to the local economic development, and reflects the good economic development effect of the Jiguan District. Most of the black soil is concentrated in the south, and a small part is scattered next to the water and in the northern woodland, and the area of black soil near the water shows an increasing trend, and the black soil in the south of the study area is more transferred. According to statistics, the area of black soil in 2021 will be about 52.88km^2, and in 2024, the area of black soil will be about 49.22km^2, a decrease of about 3.66km^2. The proportion of black soil converted into black soil woodland is relatively large. The area of black soil woodland has increased significantly in the southwest and east, which is related to the new local forestry and grassland policy, mobilizing the whole people to "increase greening" and escorting the construction of the local ecological environment. The area of black soil meadow distributed near the river water decreased significantly, and most of it was converted into cultivated land, and the black soil meadow distributed in the south side of the urban area also showed a decreasing trend, and was converted into cultivated land and black soil woodland. Compared with the former, the change of water area is not obvious, and the overall area decreases by about 0.19km^2.

3.2 Analysis of Land Use Change

In this paper, the land use transition matrix was obtained by comparing and analyzing the land use classification results in 2021 and 2024, as shown in Table 1. In Table 1, the rows represent the land use types in 2021 and the columns represent the land use types in 2024. As shown in Table 1, from 2021 to 2024, the transfer in and out of black soil exists at the same time, including the transfer of black soil meadow and local black soil woodland and the transfer of black soil woodland and black soil construction land. The total amount of black soil construction land in 2021 will be 188.96km^2, and in 2024, it will total 195.63km^2, an increase of about 6.67km^2. The total amount of black soil meadow is 12.27km^2 in 2021 and 4.37km^2 in 2024, a decrease of about 7.9km^2. Among them, the conversion of black soil meadow into black soil cultivated land accounted for a relatively high proportion, which mainly occurred near river waters, which had a great relationship with the reclamation behavior of nearby residents. The total area of black soil black soil woodland in 2021 was 28.78km^2, and the total area in 2024 will be 33.34km^2, which is related to the positive response of the local forest enhancement policy. The changes in the water are less pronounced.

Table 1. Land Use Type Transfer Matrix in the Jiguan District from 2021 to 2024 (unit: km^2)

Use Types	water	black soil meadow	black soil	black soil construction	black soil woodland	Total
water	0.4568	0.0194	0.0232	0.2304	0.0017	0.7315
black soil meadow	0.0043	1.6049	2.1243	0.2926	0.3438	4.3699
black soil	0.0257	6.1233	34.0913	2.7432	6.2374	49.2209
black soil construction	0.4193	1.9381	6.6675	184.2081	2.4012	195.6342
black soil woodland	0.0112	2.5872	9.9677	0.9783	19.7907	33.3351
Total	0.9173	12.2735	52.8761	188.9642	28.7807	

4. Conclusion

Through the processing and analysis of the two remote sensing images in 2021 and 2024, the land use classification results were obtained, and the transfer matrix was combined to analyze the transfer of black soil use types in the Jiguan District. The conclusions are as follows: (1) In general, the area of black soil, black soil meadow and water in the Jiguan District area decreased, of which the area of black soil decreased by about 3.66km^2, and the

area of black soil construction land and black soil woodland increased. (2) Through the transfer matrix analysis, the black soil in the Jiguan District mainly flowed to the black soil construction land and black soil woodland from 2021 to 2024.

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