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Temporal and Spatial Changes of Vegetation Coverage in Shendong Mining Area based on Sentinel-2 Satellite Imagery

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Abstract

Shendong Coal Field is located in the northern part of Shaanxi Province and the junction of Shanxi, Shaanxi and Mongolia. It has a total area of 31,200 square kilometers and a proven reserve of 223.6 billion tons. It is one of the eight largest coal fields in the world. Its production methods and post-harvest effects are representative and typical. The 11 mining areas in the Shendong mining area, which are relatively concentrated in Shaanxi, Inner Mongolia, are used as the research area, supported by geographic information system (GIS) and remote sensing (RS) technology, based on the Sentinel-2 satellite imagery from 2017 to 2021, preprocessed , Using the Normalized Vegetation Index (NDVI) and the pixel binary model to estimate the vegetation coverage in the area, combined with the field investigation of the vegetation coverage in the study area, analyze the causes of vegetation changes, and discuss the intensity of coal mining and coal mining The impact of subsidence years on vegetation coverage in mining areas in different regions. Through the study of the temporal and spatial changes of the vegetation coverage on the surface of the goaf, the regularity of the temporal and spatial changes of the vegetation is explored, which provides a basis for revealing the evolution of the ecological environment in the mining area and the ecological management decision-making in the mining area, and has a goal and focus for the promotion of coal mines in the semi-arid area of the northwest. To provide technical support for promoting targeted and focused eco-environmental governance in the semi-arid region of northwest China.The results show that the vegetation coverage in the study area has fluctuated changes from 2017 to 2021. On the whole, the area of low-level vegetation coverage has not changed significantly, the area of medium-low-level vegetation coverage has increased, and the area of medium-high-level vegetation coverage has increased. Decrease, although the vegetation coverage is generally decreasing, the vegetation coverage in the ecological management area has increased significantly.

Keywords

Vegetation coverage, sentinel-2 satellite imagery, temporal and tpatial changes, shendong mining area.

1. Introduction

The Shendong mining area belongs to the transition zone between the Mu Us Desert and the Loess Plateau. It mainly includes the northern part of Shenmu County, Yulin City, Shaanxi Province, the western part of Fugu County, the southern part of Dongsheng District, Ordos City, Inner Mongolia, Yijinhuoluo Banner and the southwestern part of Zhungeer Banner. The region is arid and rainless, and the ecological environment is very fragile. It is a key monitoring area and control area for soil erosion in the country. Coal mining will cause surface subsidence, ground fissures and changes in geological structure [1,2], and the destruction of vegetation growth environment, which successively triggers various degrees of ecological and environmental problems, and ultimately affects the self-regulation function of the original ecosystem [3]. As a component of the ecosystem, vegetation is a sensitive target that reflects the impact of human activities and climate change on the environment, and intuitively reflects the state of the natural environment [4,5,6]. In order to better reflect the surface vegetation status and monitor the temporal and spatial changes of vegetation coverage in the area, the normalized vegetation index (NDVI) and vegetation coverage (FVC) are selected as indicators [7,8].

At present, the measurement methods of vegetation coverage can be roughly divided into ground field measurement and remote sensing monitoring and inversion. One is suitable for small-scale measurement, and the other is mostly used in large-scale national, regional and even global spaces. In the field survey on the ground, the visual estimation method is simple in principle and convenient to operate, but its human subjectivity is too strong, and the estimation accuracy depends on the experience of the surveyor. The research results of Zhang Wenbo et al. [9] show that the maximum absolute error of measuring vegetation coverage by visual estimation method can reach 40%. Different from the visual estimation method, the photographic method can quickly, accurately and efficiently extract the vegetation coverage. After comparing various vegetation coverage measurement technologies, White et al. [10] believed that digital camera photography is the easiest and most reliable technology to verify the accuracy of remote sensing extraction of vegetation coverage. Ji Zengbao [11] took digital photos as the research object, and proposed a method to use Photoshop software to quickly measure the coverage of forests and grasses. The calculation method is simple and convenient in actual operation. Compared with traditional calculation methods, the results of this method are influenced by humans. The subjective influence is small and the accuracy is high.

In the use of remote sensing image monitoring and inversion, the most widely used method is to use NDVI data and pixel dichotomy to estimate the vegetation coverage in the target area. In the past few decades, a variety of remote sensing data sources with different spatial resolutions have been widely used in the inversion of vegetation coverage. At present, the most commonly used data sources by scholars are MODIS NDVI products (spatial resolution of 250 m) or Landsat. TM/OLI images (spatial resolution of 30 m). In contrast, the Sentinel-2 satellite imagery was launched in 2015 and transits once every 5 days. It has special advantages and is a relatively new data source [12,13]. Scholars at home and abroad use single-scene Sentinel-2 data to realize crop recognition [14,15]. Vrieling et al. [16] showed that Sentinel-2 data has the ability to provide vegetation information, and compared the green chromaticity coordinate sequence calculated by the photographic method with the vegetation index sequence of Sentinel-2 data. Wu Qingyun et al. [17] showed that Sentinel-2A's vegetation coverage inversion ability is better than Landsat 8, and the pixel dichotomy method can be better applied to the vegetation coverage inversion in the study area. On the basis of the above research, this paper selects the Shendong mining area with fragile ecological environment as the research area, with geographic information system (GIS) and remote sensing (RS) as the technical support of the research area, combined with the ground field measurement of the photographic method, Calculate the vegetation coverage and analyze its changes in order to find out the temporal and spatial changes of the vegetation coverage in the Shendong mining area in recent years.

2. Materials and Methods

2.1. Study Area

Among the 13 production mining areas in Shendong Mining area, there are 7 in Inner Mongolia Autonomous Region, 5 in Shaanxi Province and 1 in Shanxi Province. In this paper, 11 mining areas in Inner Mongolia and Shaanxi province are selected as research areas. It is respectively: big liu tower mining area, live chicken rabbit mining area, go up bay mining area, fill connect tower mining area, hala gully mining area, Stone gedai mining area, Wulan mulun mining area, Liu tower mining area, Bultai mining area, inch grass tower one mining area and inch grass tower two mining area.

The study area (109°51 '~110°46 'E, 38°52'~39°41 'N) is about 1230 m above sea level. The region has a typical temperate continental semi-arid monsoon climate, with annual average precipitation of 368.2mm, decreasing from southeast to northwest, mainly concentrated in July to September. Groundwater resources are scarce at 3.9 percent of the national average. It is located in the junction zone of Ordos Plateau and Loess Plateau, with The Mu us Sandy Land in the north and the Loess Plateau in the south. It is a typical transition zone of geomorphological evolution of loess Plateau, and is a two-phase erosion area of water erosion and wind erosion. The mining area is a gentle hilly mountain with a relative height of 50m~90m and steep slope. Soil barren, soil pH value in 8.5 or so, generally alkaline or strong alkaline, soil organic matter content is low, N, P, K poor, water storage fertilizer and corrosion resistance. The vegetation species is monotonous, and the dominant species is Artemisia ordosica. The main companion plants are annual weeds, such as Setaria viridis, Tribulus terrestris and Chenopodium aristatum [18].

2.2. Data Sources and Methods

2.2.1. Field Survey Method of Vegetation Coverage

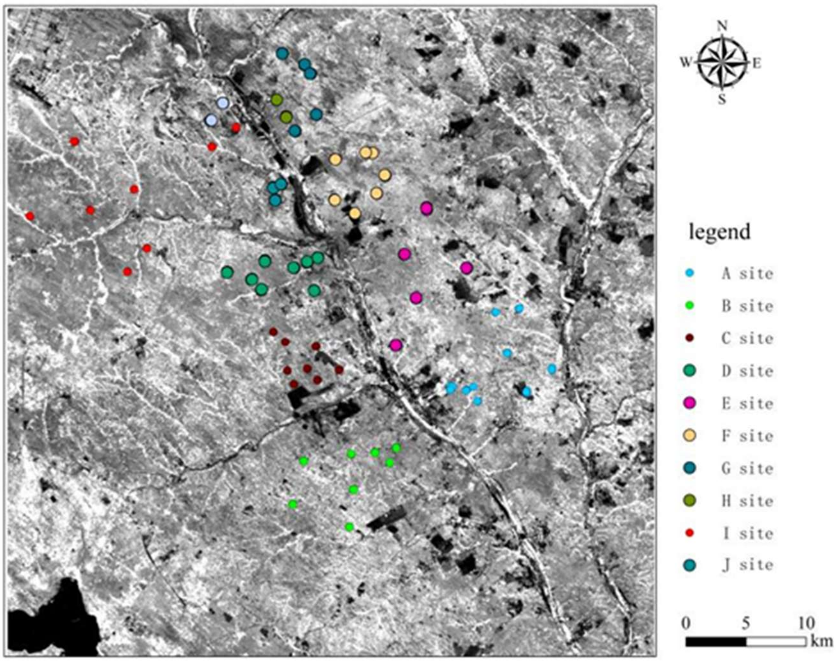

Fig. 1 Distribution map of measured sites in Shendong mining area

The on-site survey will be conducted from July 7 to 14, 2021. The 11 mining areas (A-J) in the Shendong mining area, which are relatively concentrated in Shaanxi, Inner Mongolia, are used as the research area. In the mining area, a representative measurement area of coverage type is selected as the location area, see Fig. 1. A large sample square of 100m×100m is set in each location, and the latitude, longitude and altitude are recorded. Three 1m×1m small squares are randomly set in each large square. This paper uses visual estimation and photographic methods to determine the vegetation coverage in the study area. The photographic method includes two steps: outdoor acquisition of sample photos and indoor photo processing. Outdoor 16 million pixel camera is used to take pictures vertically downward to obtain sample photos. In order to reduce the deformation of the edges of the photos, the surveyor should place the camera above the center of the sample while trying his best Increase the height of the photo, the height of the photo is about 1.8m. A total of 64 sites and 192 small plots were selected in 11 mining areas, and 3 photos were taken for each plot.

2.2.2. Processing Method of Vegetation Survey Photos

Sort and sort out the photos of each mining area for preliminary screening. Use ENVI5.3 software to correcting the shape and crop them. Select the 4 vertices and the center point of the 1m×1m sample box in the photo as correction points. The coordinates of these 5 points are determined as: (1,1 000), (1 000,1 000), (1 000,1), (1,1), (500,500). The rectified quadrat is a regular polygon, and then the redundant places outside the square in the rectified photo are cropped, and the processed quadrat image is used for vegetation spectral information identification and vegetation coverage calculation.

Refer to the research method of Ji Zengbao [10], the vegetation spectral information identification is carried out by Photoshop2021 software, mainly using the "color range" in the "selection" in the Photoshop software to select pixels with certain characteristics, so that the selected pixels account for the total pixels of the photo Calculate the vegetation coverage in the photo area. According to the research experience of relevant scholars, when the tolerance is 120~130, the selected vegetation area is the closest to the actual situation, and the calculation result is the closest to the actual situation [19,20,21,22]. Therefore, adjust the "Color Tolerance" in the "Color Range" dialog box to 125. After extracting the required pixel values of the selected range and the pixel values of the entire photo, the vegetation coverage is calculated, analyzed, and mapped in the Excel2019 software. Cv calculation formula is as follows:

$$C_V = \frac{P_1}{P_2} \tag{1}$$

Where, CV is vegetation coverage rate; P1 is the pixel value of the selected range; P2 is the pixel value of the whole photo.

2.2.3. Remote Sensing Analysis Method

This article selects the Sentinel-2 satellite imagery (spatial resolution 10m×10m) from the Shendong mining area in 2017, 2018, 2019, 2020, and 2021 from June to August. All images are from ESA website (https://scihub.copernicus.eu/dhus/#/home). The SNAP software developed by ESA for Sentinel series data is used for data preprocessing. Based on the preprocessed remote sensing image, the NDVI value is obtained, and the vegetation coverage is estimated using ENVI5.3 software.

NDVI (Normalized Difference Vegetation Index) is one of the important parameters that reflect crop growth and nutritional information. It can directly reflect the quantitative value of the vegetation coverage on the ground. The expression of NDVI is as follows:

$$NDVI = \frac{N_{NIR} - N_R}{N_{NIR} + N_R} \tag{2}$$

Among them: NNIR is the reflection value in the near-infrared band, and NR is the reflection value in the red band.The pixel dichotomy model is the simplest and most widely used linear mixed pixel decomposition model. It is a common method for calculating FVC. It is equivalent to dividing the pixel into only vegetation and non-vegetation coverage. The spectral information is also composed of only two groups. In linear synthesis, the ratio of their respective area in the pixel is the weight of each factor, and the percentage of vegetation coverage in the pixel is the vegetation coverage of the pixel [23,24]. The calculation formula of this method is as follows:

$$FVC = \frac{NDVI - NDVI_{Soil}}{NDVI_{Veg} - NDVI_{Soil}} \quad (3)$$

In the formula: NDVI represents the NDVI value corresponding to each pixel that needs to calculate the vegetation coverage; NDVIsoil is the value of the bare land pixel without any vegetation coverage on the surface, theoretically close to 0; NDVIveg represents the pixel corresponding to the complete vegetation coverage The value of is theoretically close to 1. Due to the presence of noise in the image, according to the frequency statistics, NDVIsoil and NDVIveg take 5% and 95% of the NDVI frequency accumulation table, respectively. Estimate the vegetation coverage of the Shendong mining area. The range of its value range is [0,1]. The larger the value, the higher the vegetation coverage. The vegetation coverage is classified according to the actual situation of the Shendong mining area. Combining field surveys with remote sensing images to study the temporal and spatial changes of vegetation coverage in the Shendong mining area over the past five years.

3. Results and Analysis

3.1. Analysis on the Dynamic Change of Vegetation Coverage in Shendong Mining Area

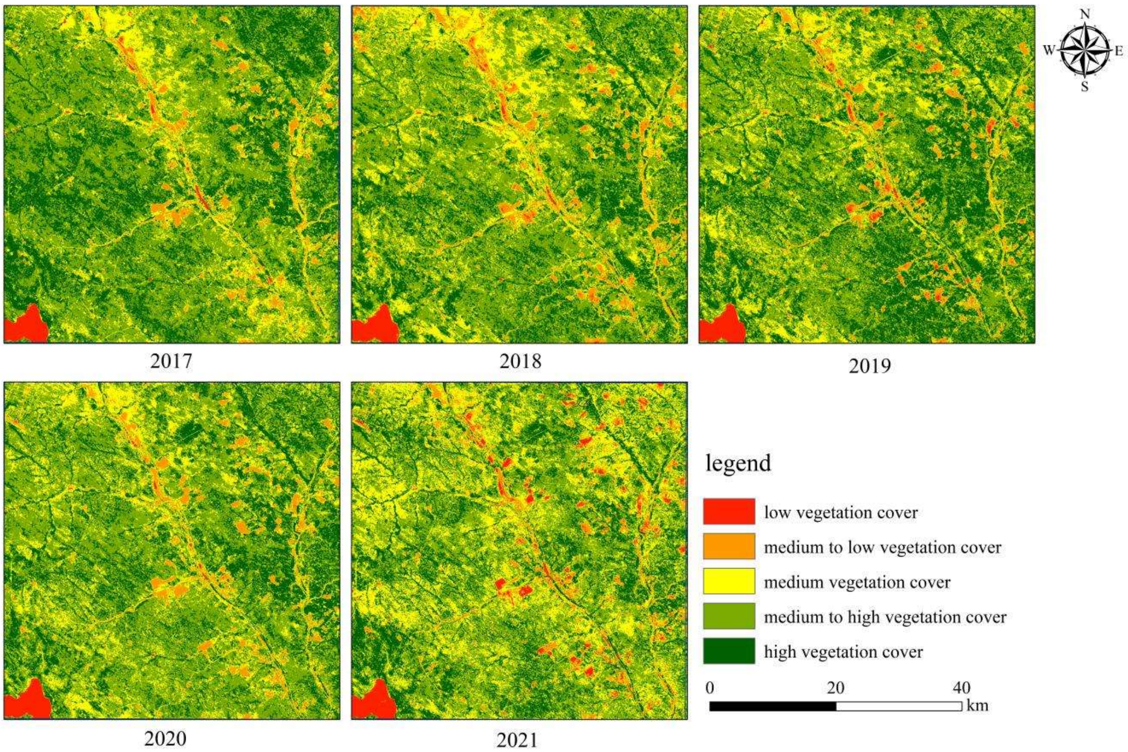

Fig. 2 Classification map of vegetation coverage in Shendong Mining Area, 2017-2021

In order to facilitate the analysis of dynamic changes, combined with the actual situation, the vegetation coverage of the study area is divided into five levels, namely low vegetation cover (0<FVC≤20%), medium to low vegetation cover (20%<FVC≤40%), medium vegetation cover (40%<FVC≤60%), medium to high vegetation cover (60%<FVC≤80%) and high vegetation

cover Vegetation coverage (FVC>80%). The vegetation coverage classification maps of the study area in 2017, 2018, 2019, 2020, and 2021 are obtained, see Fig. 2.

From 2017 to 2021, the vegetation coverage of the Shendong mining area showed a trend of first decline and then a slow recovery. The areas with a significant downward trend spread to the surrounding along the Ulan Mulun River in the central part. The western part of the study area shows a downward trend as a whole, especially in 2020 and 2021. The vegetation coverage in the central and eastern regions has been maintained well in the past five years.

According to statistical results, in the past five years in Shendong mining area, the proportion of vegetation coverage in the medium vegetation cover has shown a slow growth trend, from 15.26% in 2017 to 28.92% in 2021; Shendong mining area medium to high in 2017 The vegetation cover has the largest proportion of high vegetation coverage, accounting for 51.38% of the total area of the study area. The proportion of this graded vegetation coverage has been declining. By 2021, the medium to high vegetation cover of the Shendong mining area will drop to 38.84%. In the five years, the proportion of high vegetation cover has fluctuated from 28.16% in 2017 to 21.97% in 2018, and then rose sharply to 31.16% in 2019. However, in the next two years, the high vegetation cover has high vegetation cover. The coverage value is gradually decreasing, and will be reduced to 21.46% by 2021. From the perspective of the overall scope of the Shendong mining area, the change in vegetation coverage is unstable. In the past 5 years in the Shendong mining area, the proportion of areas with medium vegetation coverage and above has exceeded 88.6%. This result is consistent with Li Ruijun [25], indicating that the overall vegetation coverage in the study area is good, and the degree of desertification in the Shendong mining area is moderate. As a result, the ecological environment after the destruction of coal mining has been improved. In five years, the area of the medium to low vegetation cover in the study area has a slow increase in the area of low vegetation coverage and below. The area is about 210km2, but the change is not large. The area is mainly industrial and mining land, residential areas, and water areas. , Due to serious damage to coal mining in some dump sites and first mining areas of coal mines that have not been fully managed, it is difficult to restore vegetation conditions. Coal mining will change the vegetation coverage and the proportion of land use in the area[26]. The area of woodland, grassland, residential area, industrial and mining land in mining areas is increasing, and the area of cultivated land, other, water and water conservancy facilities is constantly decreasing. If not in time Control, the ecosystem will be out of balance.

3.2. The Influence of Different Mining Years on Vegetation Coverage in Shendong Mining Area

The mining of coal mines will be accompanied by large-scale surface subsidence, which will damage the surface soil and vegetation in the mining area. Based on the measured data in 2021, this study uses space instead of time [27] to analyze the impact of different coal mining years on the vegetation coverage changes in 11 mines and surrounding areas in the study area. The results of several representative mining areas show that in the Huojitu Coal Mine (B), surface subsidence has just occurred, that is, the area just after mining has a relatively high vegetation coverage, and the measured samples are mostly in the medium to high vegetation. Cover medium and high vegetation coverage area. A few samples of vegetation coverage in the medium vegetation cover, because their actual location is the area five years after coal mining subsidence occurred, the vegetation coverage has been reduced. Compared with other coal mines, Daliuta Coal Mine (A) has an earlier mining time and a larger area, and the time to take ecological restoration measures is also earlier. Residents in the mining subsidence area have been relocated, causing a large area of farmland to be abandoned. Analyzing the measured vegetation coverage combined with remote sensing images, the vegetation coverage of the samples in the area of 3-5 years of subsidence is relatively low, and the vegetation coverage of some samples of more than 10 years of subsidence will be restored, and the subsidence may be stabilized. After the period, the natural recovery capacity of the mining area will appear, coupled with the proper ecological restoration measures, the surface collapse and cracks will be filled, the dump site will be greened, and the vegetation coverage will be significantly improved.

Bulianta Coal Mine (D) is located in a windy and sandy area, the soil is relatively barren, and the vegetation type is dominated by sandy vegetation, mainly dwarf shrubs. Also due to the long time of mining subsidence, the vegetation coverage in the area is about 20%, the ecological restoration effect is poor, the survival rate of the planted Pinus sylvestris is low, and the management and protection measures are not in place.

There is the largest ecological demonstration base in the mining area in Haragou Coal Mine (E). Because the company attaches great importance to the construction of the ecological environment and has accumulated a lot of experience in the prevention and control of mining subsidence for a long time, the vegetation coverage in the treatment area has been steadily increasing. The environment of the mining area has been continuously improved. As the vegetation restoration of the dumping site takes a long time, in-depth research is needed in the future.

4. Discussion and Conclusion

The vegetation coverage in the mining area is not continuously decreasing year by year, but showing a trend of volatility, indicating that the vegetation in the mining area has not been continuously negatively affected, but the vegetation will be improved in some years, and the ecological restoration of the mining area needs further Strengthening. Due to the late launch of the Sentinel-2 satellite, the data source of this study, the selected image time series is relatively short, and the vegetation coverage of ten or even twenty years ago cannot be estimated. In the future, other data sources will need to be combined with the study area. The vegetation coverage is comparatively analyzed.

The growth status of vegetation is negatively correlated with different mining intensities in coal mines. The smaller the mining degree, the smaller the intensity of ground collapse and the smaller the impact on vegetation. With the increase of mining time, the vegetation condition of untreated areas will get worse and worse, and soil erosion will be serious. After reaching the stable period of mining subsidence, about ten years or so, the natural restoration of vegetation will improve the environmental conditions in the area, but it will not completely return to the state before the subsidence.

Through the research of this article, the increase of NDVI and FVC is not enough to show that coal mining has no effect on the surface ecology; the increase in the volatility of vegetation coverage in the coal mining area under manual intervention does not indicate that the surface ecological process of the mining area is in normal evolution. In the future, a large number of scholars are required to use research methods that combine ground experiments, remote sensing inversion and model simulation to build a multi-scale, multi-data source and multi-model coupling mechanism to provide a theoretical basis for high-precision vegetation coverage monitoring and ecosystem service inversion . How to balance the relationship between coal resource development and ecological environment protection is the key to supporting the high-quality development of the region and the green development of the national energy industry. More people need to be put into the team of mine restoration, so as to focus on prevention, combine prevention and control, and repair while mining, so as to minimize the damage to the environment during the mining process.

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