

# Dynamic Monitoring and Assessment of Vegetation Cover in Mining Areas Based on Remote Sensing Technology

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**Abstract.** Mining activities often damage natural ecosystems, leading to soil erosion, vegetation destruction, and a decline in biodiversity. Monitoring and evaluating ecological restoration is crucial to address these environmental issues and restore ecological balance effectively. The application of remote sensing technology in the ecological restoration of mining areas is of great significance. This study focuses on the subsidence area of the Xishan coalfield in Shanxi Province, using remote sensing data from the Landsat series of satellites to assess the progress of vegetation restoration. The study indicates that from the beginning of the restoration in 2007 to 2021, the vegetation growth in the Xishan coalfield subsidence area has significantly improved, with the area of restored vegetation gradually increasing. Since the implementation of the ecological restoration plan by the city of Taiyuan in 2008, the vegetation coverage in the mining area has increased yearly, especially after 2010, with a noticeable acceleration in the restoration speed. The vegetation restoration in the Xishan coalfield subsidence area has significantly increased within the main subsidence area and extended to the surrounding regions. However, the expansion of Taiyuan has somewhat impacted vegetation coverage in certain areas. This study emphasizes the importance of remote sensing technology in ecological restoration and provides data support for continuously monitoring and assessing the ecological environment in mining areas.

**Keywords:** Remote sensing; monitoring; vegetation restoration; Xishan Coalfield.

## 1. Introduction

The pattern of world mineral production is that "Asia is the world's mineral production center, and China is the Asian mineral production center" [1]. Against the backdrop of high-quality economic and social development and accelerated industrialization, China's demand for mineral resources is very strong. However, while mineral resource development activities such as open-pit mining have made great contributions to industrial production and economic development, they have also brought about problems such as surface environmental damage, wastewater pollution, and land abandonment [2]. The assessment and restoration of abandoned open-pit mines has always been a hot issue in the field of land resources and regional environment.

Nanjing Tangshan Mine Park [3] referred to a series of internationally recognized standards in the process of ecological restoration. With the collaboration of multiple disciplines and perspectives, the characteristics of the mine and the landscape on site were combined to create a rich landscape experience. In Yellowstone National Mine Park [4], there is the largest mine in Asia with a pit area of 1.08 million square meters - the "Mining and Metallurgical Grand Canyon". Continuous mining makes the ecological environment of the region deteriorating. Still, technicians planted saplings in the cracks of the stone, screened out the appropriate plants, and created the ecological miracle of "planting flowers on the stone". Canada's Butchart Gardens [5] combine ecological restoration with exquisite garden design to demonstrate the ecological protection concept of "taking from nature and giving back to nature".

Artificial field detection is a more traditional method for obtaining data on ecological restoration of mines. It meets the data needs of mine ecological restoration, but it has problems such as low

operating efficiency and poor worker safety. Remote sensing technology can detect the reflection and emission characteristics of electromagnetic waves of an object on the surface through sensors, thereby extracting information and completing the identification of distant objects. Through various types of sensors, it is possible to obtain large-scale, high-resolution surface information, including topography, vegetation cover, soil type, etc., which provides data support for the monitoring and assessing abandoned land. Remote sensing has technical advantages such as short revisit cycle and large coverage area, and has the characteristics of accuracy, rapidity and objectivity. In the restoration process, remote sensing technology can regularly or irregularly monitor the relevant area to evaluate the long-term treatment effect. Tao Peifeng et al. sorted out the framework of remote sensing application of national space ecological restoration. Taking Chongqing as an example, they used domestic high-resolution satellite images such as Gaofen No. 1 (GF-1) and Gaofen No. 2 (GF-2) to identify mine environmental elements through high-resolution and hyperspectral remote sensing images. It provides data support for mine restoration and governance, and then discusses the application of remote sensing technology in the field of national space ecological restoration [6]. Xie Jianwen et al. summarized hyperspectral remote sensing technology's application measures and practical applications in mine ecological restoration and management, such as building ecological parks, reclamation, and rapid identification of my environmental problems. They concluded that hyperspectral remote sensing technology can quickly and accurately obtain relevant environmental information and thus be more effectively used in the restoration and management of the ecological environment of mine [7]. Qiang Jianhua specifically used medium and high spatial resolution remote sensing images, combined machine automatic recognition and human-computer interactive recognition methods, to extract relevant information about mines in southern Xinjiang, reflecting the importance of remote sensing technology's application in ecological restoration [8].

The Xishan area of Taiyuan, Shanxi Province, is the core area of Taiyuan's heavy chemical industry base. At its peak, there were more than 2,700 polluting enterprises of various types. The mountain in the area was severely damaged, forming the Xishan coal mining subsidence area, which covers an area of more than 100 square kilometers and was once the main source of pollution in Taiyuan. In 2008, the Shanxi Provincial Party Committee and the Provincial Government listed the comprehensive treatment of the Xishan area as one of the four major key projects of the province [9]. More than ten suburban forest parks have been built, including the Yuquanshan Suburban Forest Park and the Xishan Suburban Forest Park.

This paper uses remote sensing technology to effectively monitor the geological environment of mines. It selects the Xishan Ecological and Cultural Tourism Demonstration Area in Taiyuan City, Shanxi Province as the study area. The NDVI data of the study area were calculated by obtaining the relevant remote sensing data from Landsat series remote sensing satellites. By comparing the NDVI data at different times, the environmental status of vegetation restoration in the coal mining subsidence area of Xishan, Shanxi Province is understood. We will actively promote the environmental protection of mines as well as plan and implement the restoration project of environmental problems in abandoned mines.

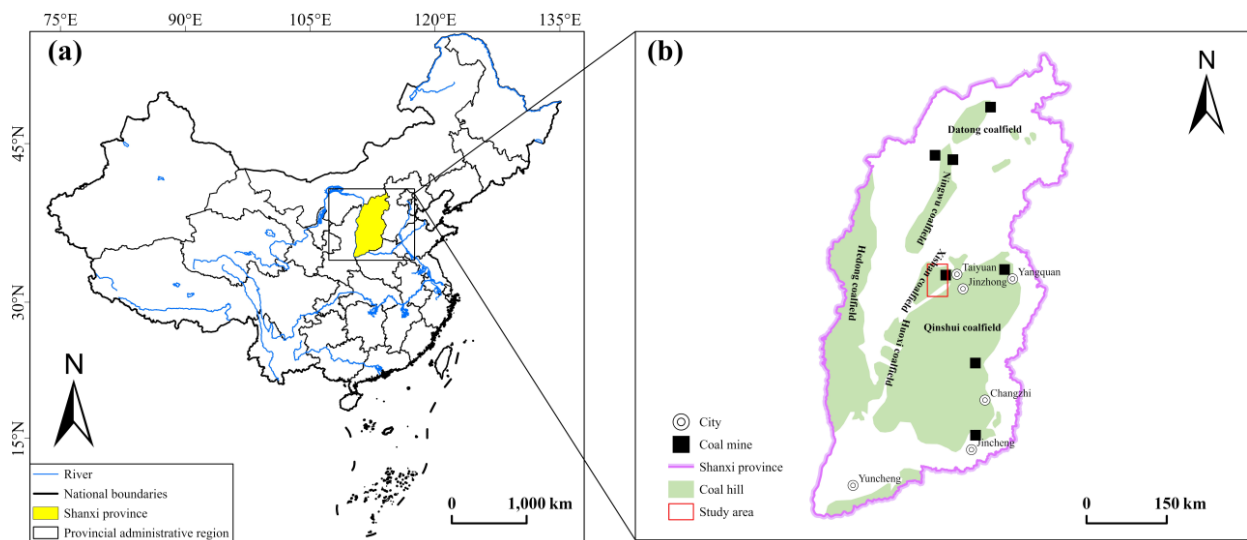
## **2. Data and Methodology**

### **2.1. Overview of the Study Area**

Shanxi Province belongs to China and is located in the middle of the Yellow River Basin. The geographical location of Shanxi Province is shown in Fig. 1. The overall latitude and longitude range is 34°34'~40°44' north latitude and 110°14'~114°33' east longitude. The climate of Shanxi is characterized by four distinct seasons, synchronized rain and heat, and significant differences in climate between the north and south. Precipitation is relatively concentrated in June-August in summer.

The coal varieties in Shanxi Province include gas coal, fat coal, coking coal, lean coal, anthracite, lean coal, long flame coal, weakly caking coal and lignite. As shown in Fig. 1[10], the coal resources in Shanxi Province are mainly distributed in six major coalfields: Datong, Ningwu, Hedong, Xishan, Huoxi and Qinshui. The Xishan coalfield in Shanxi Province is located in the central part of Shanxi Province, west of Taiyuan City. The coal varieties include high-quality coking, fat, lean, and lean coal. Before 2008, the Xishan coal mining subsidence area, an area of more than 100 square kilometers, quarrying mountain damage surface of about 1300 places, mining abandoned area of nearly 10 square kilometers. In order to restore the ecology and improve the environment, Taiyuan City formulated a comprehensive remediation and sustainable development program for the Xishan area in 2008. It implemented a series of projects such as Xishan ecological restoration, Xishan water system restoration, 10,000-acre ecological park construction, river management and greening. As of 2021, 6 million square meters of broken surface will be treated [11].

The overall longitude and latitude range of the Xishan Coalfield is 111°8'-112°15' east longitude, 37°58'-38°01' north latitude. The red box on the right side of Fig. 1 is the study area, and the longitude and latitude range is 112°15'-112°49' east longitude, 37°58'-38°01' north latitude.



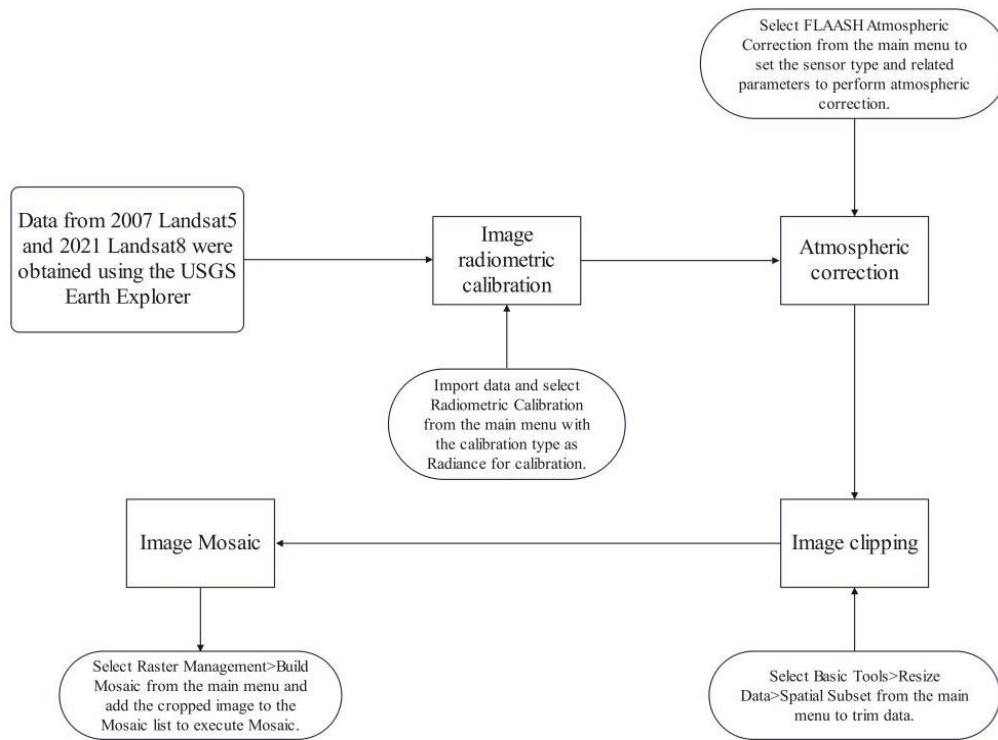
**Figure 1.** Distribution of Coal Fields in Mining Areas of Shanxi Province

## 2.2. Remote Sensing Data Sources

Since 1972, the LANDSAT series of satellites have been launched successively. They are a series of earth observation satellite systems the United States uses to detect earth resources and environment. Landsat 5 is an optical earth observation satellite. It was launched in March 1984 and retired in June 2013. Its payload is the Thematic Mapper (TM) and Multi-spectral Sounder (MSS). Landsat 5 TM images are composed of seven bands with a spatial resolution of 60 meters. Landsat 5 MSS images are composed of seven spectral bands, with the spatial resolution of band 6 (thermal infrared band) being 120 meters, and the spatial resolution of bands 1 to 5 and band 7 being 30 meters. Landsat 8 has the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). It was launched in February 2013 and will remain in normal operation as of June 2024. Landsat 8 OIL and TIRS imagery consists of nine spectral bands, of which bands 1 to 7 and 9 have a spatial resolution of 30 meters. Band 8 (panchromatic band) has a resolution of 15 meters. TIRS bands 10 and 11 have a resolution of 100 m and were resampled to 30 m during the primary product generation process.

In order to eliminate the impact of seasonal differences on vegetation coverage and accurately evaluate the vegetation restoration effect in the mining area, this paper used USGS Earth Explorer (U.S. Geological Survey) to obtain Landsat 5 satellite data on August 14, 2007 and Landsat 8 satellite data on September 21, 2021 with cloud cover between 5% and 10%.

### 2.3. Remote Sensing Data Preprocessing



**Figure 2.** Flowchart of data processing

The Landsat series satellite data have been geometrically corrected and terrain corrected. The data processing flow is shown in Fig. 2. Radiometric calibration is carried out first after importing remote sensing image data into ENVI. Radiometric calibration is when the user needs to calculate the spectral reflectance or spectral radiometric brightness of the object, or when the user needs to compare images acquired at different times and with different sensors, the brightness grayscale value of the image must be converted into absolute radiometric brightness. Radiometric calibration can eliminate the sensor's error and determine the accurate radiometric value at the sensor entrance. Atmospheric correction is then performed to convert the radiance or surface reflectance to the actual reflectance of the surface. In this way, the influence of factors such as atmosphere and light on the reflection of the object can be eliminated, and the real physical model parameters such as the reflectivity and radiometric rate of the object, the surface temperature, etc. can be obtained, which can be used to eliminate the influence of atmospheric water vapor, oxygen, carbon dioxide, methane and ozone on the reflection of features, and to eliminate the impact of atmospheric molecules and aerosol scattering. Finally, the remote sensing image data is cropped and mosaicked to obtain the remote sensing image of the selected study area.

### 2.4. NDVI Calculation

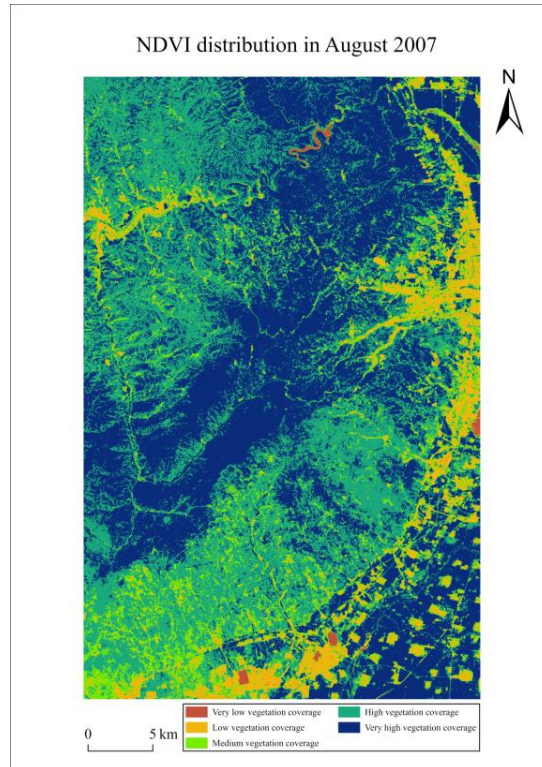
Normalized Difference Vegetation Index (NDVI) is a commonly used tool in remote sensing and image processing to analyze and present the status of surface vegetation. The range of NDVI is always from -1 to +1.  $NDVI < 0$  indicates the presence of clouds, water, and snow,  $NDVI = 0$  indicates the presence of rocks or bare soil, etc., and  $NDVI > 0$  indicates the presence of vegetation cover, which increases with the increase of the cover. In order to monitor the changes in vegetation coverage before and after ecological restoration in the study area, this paper uses NDVI images at different times for comparison.

NDVI measures the growth and density of vegetation by analyzing light reflected in different spectral bands. It is calculated using the formula

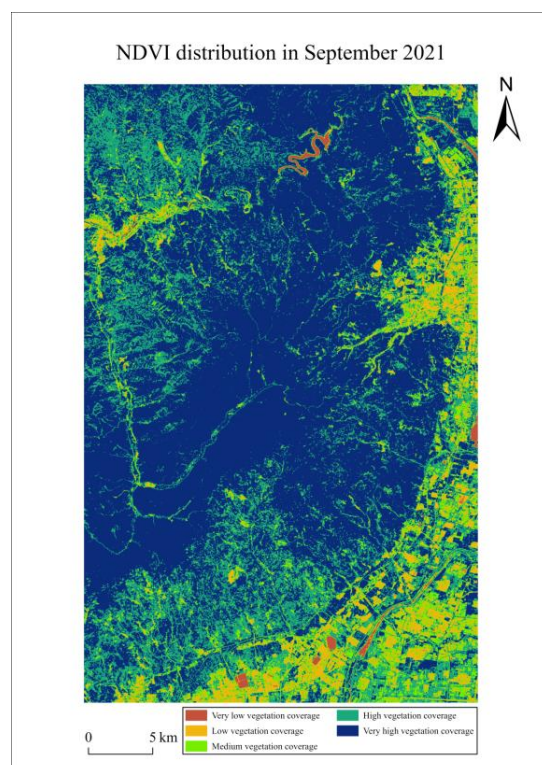
$$NDVI = (NIR - R)/(NIR + R) \quad (1)$$

In the formula, NIR is the near-infrared band and R is the red band. NDVI was calculated using the NDVI tool in the ENVI software. selected mosaiced image data. Set the IR band (Band 3) and NIR band (Band 4) for Landsat5 and the red band (Band 4) and NIR band (Band 5) for Landsat8. Finally, NDVI calculations are executed to generate NDVI images.

### 3. Results



**Figure 3.** NDVI classification chart on August 14, 2007



**Figure 4.** NDVI classification map on September 21, 2021

This study conducted dynamic monitoring and evaluation of vegetation coverage in the Xishan coalfield mining area using remote sensing technology. By acquiring remote sensing data from the Landsat series of satellites, NDVI (Normalized Difference Vegetation Index) analysis was used to assess vegetation restoration from 2007 to 2021 systematically. The data processing procedures included remote sensing data preprocessing, image mosaicking, and NDVI calculation. By comparing NDVI images from different years, changes in vegetation coverage in the mining area were analyzed.

Fig. 3 and Fig.4 represent the NDVI classification maps for August 14, 2007, and September 21, 2021, respectively. The legend shows deep blue indicating very high vegetation coverage, dark green indicating high coverage, light green indicating moderate coverage, and yellow and red indicating low and shallow coverage. The comparison reveals a noticeable increase in vegetation coverage over the years. In 2007, moderate vegetation coverage dominated, which by 2021 had transitioned to high and very high coverage. However, the eastern, southeastern, and southern parts of the Xishan coalfield subsidence area, adjacent to the expanding Taiyuan city, showed decreased vegetation coverage, creating a contrast in the imagery.

#### **4. Conclusion**

Based on remote sensing technology, this study dynamically monitored and evaluated vegetation coverage in the Xishan coalfield subsidence area in Shanxi Province. By acquiring remote sensing data from the Landsat series of satellites and employing NDVI analysis, the study assessed vegetation restoration from 2007 to 2021. The research included preprocessing remote sensing data, image mosaicking, and calculating NDVI. By comparing NDVI images from different years, the study analyzed changes in vegetation coverage in the mining area and found significant improvements. From 2007 to 2021, the main subsidence areas of the Xishan coalfield saw substantial increases in restored areas, with a gradual reduction in areas affected by geological environmental problems. Future research can extend the application of remote sensing data, combining higher resolution satellite images and other geographic information technologies for more detailed ecological environment monitoring and assessment. Further studies can investigate the recovery rates and effectiveness of different vegetation types and develop more comprehensive ecological restoration models for mining areas.

#### **Authors Contribution**

All the authors contributed equally and their names were listed in alphabetical order.

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