Research on evaluation of mining area ecological security based on GF-1 satellite imagery—taking Fushun West open-pit mine for example

Qi Yu-na¹, Liao Shun-bao*, Wang Qiu-ling¹
(¹ Institute of Disaster Prevention, Langfang, Hebei, 065201, China)
First author’s E-mail: moon1341@126.com
Corresponding author’s E-mail: liaoshunbao@cidp.edu.cn

ABSTRACT: Carrying out the evaluation of the ecological environment of the mining area is the basis for the protection and prevention of the environment of the mining area. This paper takes Fushun West Open-pit Mine as the research area, uses the remote sensing image data of Gaofen-1 (GF-1) satellite, and uses remote sensing and GIS technology, firstly obtains high-resolution multi-spectral remote sensing images, and then extracts environmental information of the mining area from the images, such as vegetation coverage, water bodies, soil index, and then normalizes the ecological impact factors, and at last uses the comprehensive index method to construct a comprehensive evaluation model of the mining area's ecological environment to analyze and evaluate the mining area's ecological environment. The mining area ecological environment assessment method based on the Gaofen-1 satellite data is simple and easy to implement, and the evaluation results can provide a reference for understanding the mining area's ecological environment and make reasonable protection measures.

1. Introduction
With the development of society, the demand for mineral resources continues to rise. The rapid mining of open-pit mines ignores the safety of the ecological environment, causing serious damage to the mining area, causing natural disasters, and harming human society. Therefore, the ecological environment of the mining area has received extensive attention from the academic circles, government and the public, and the research on the environment of the mining area has also become a focus and hot issue in the field of natural sciences.

The topography of the mining area is generally more complex, with the characteristics of large topography, complex topography and difficult to obtain ground feature information. In the past, people usually learned about the mining environment by means of dynamic inspections of land and resources, level-by-level reporting, and public reporting, but these methods were not time-efficient, inefficient, and could not meet the requirements of real-time monitoring [1]. With the rapid development of remote sensing technology, we can already acquire images with high temporal resolution, high spectral resolution, and high spatial resolution for most regions. Some scholars have carried out research on the use of remote sensing data for ecological environment assessment, and have achieved certain results. For example, Pradhan et al., based on remote sensing data and GIS technology, used neural network models to evaluate the ecological safety of landslides in mining areas [2]; Yuan Dingbo et al. used 30m resolution TM images as the data basis, and used multi-scale segmentation and supervised classification methods to evaluate, the mining area environmental information is obtained [3]; Song
Qifan et al. use WorldView-2 images to extract mining area information through the spectrum relationship method, normalized differential water index and supervised classification methods [4]; Yang Jing et al. use "pressure-state -Response to the conceptual model, to evaluate the ecological environment of the mining area by establishing a mining area ecological safety evaluation index system[5]. In these studies, due to the accuracy of the data and the application of the method, the environmental information of the mining area could not be obtained more accurately and applied to the ecological environment assessment.

GF-1 satellite data has the advantages of high spatial resolution, high temporal resolution, multi-spectrum and large area. Aiming at the complexity of the mining area, this paper takes Fushun West Open-pit Mine as the research area, based on GF-1 satellite data, and through the application of various methods and models to extract and evaluate the mining area environmental information. The research conclusions are helpful for the safety assessment of the ecology of the mining area and provide a reference for the designation of ecological protection measures in the mining area.

2. Study area and data preparation

2.1 Overview of the study area
Fushun West Open-pit mine is located in the west of Fushun Coalfield. The pit is 6.6km long from east to west, 2km wide from north to south, with a total area of 13.2 km², and a vertical mining depth of 388m. The Fushun West Open-pit mine produces 2600kt of raw coal per year, stripped 15000km², and has a rich ore supply capacity of 7000kt. After long-term development, the mining area has formed a stable ecological environment system and is a representative open-pit mining area in China. In the mining area, there are also buildings such as a large-scale machinery exhibition area, an entertainment center, and a viewing platform. Regardless of the factors of ecological environment or social conditions, Fushun West Open-pit mine has the information needed for research, so it is reasonable to choose Fushun West Open-pit mine as the research area in this paper.

2.2 Data preparation
The data used in this study include GF-1 data, DEM (resolution 30m), and basic geographic data of the mining environment. Among them, the GF-1 data is PMS data and the shooting date is March 25, 2014. The GF-1 satellite is equipped with two high-resolution cameras (PMS) with a resolution of 2m panchromatic and 8m multi-spectrum and four multi-spectral wide-format cameras (WFV) with a resolution of 16m. The repetition period is 4d. As my country’s first high-resolution Earth observation system, the GF-1 satellite has the advantages of high spatial resolution, high time resolution, multi-spectrum, and large-area imaging.

3. Research method

3.1 Ecological evaluation process of mining area
In the study of the ecological environment of the mining area, first determine the evaluation factors that reflect the quality of the ecological environment, extract ground information through remote sensing technology, GIS spatial analysis and model application, and then use the method of ecological factor normalization to unify the factors. Through the comprehensive index method to determine the weight index of each influencing factor, establish the ecological environment evaluation model system, and then realize the comprehensive evaluation of the ecological environment of the mining area, and finally obtain the comprehensive evaluation map of the ecological environment of the mining area. The technical flow chart is shown in Fig. 1.
3.2 Remote sensing data processing

Firstly, the GF-1PMS data were preprocessed to obtain the high-precision and high-resolution hyperspectral image of the target region. In the process of improving the accuracy, it is necessary to eliminate the errors of the multi-spectral image and the panchromatic image respectively. For radiation calibration, enter the calibration parameters according to different years. It is necessary to calibrate the apparent reflectance of panchromatic data because atmospheric correction cannot be carried out for panchromatic images. For atmospheric correction, the Sub-Arctic Summer atmospheric model is selected by comparing the imaging time and latitude and longitude of the image. Through visual interpretation, the selected aerosol model is a city. In the aerosol inversion method, since no suitable waveband is found for inversion, the visibility value is used in the calculation. Through the database survey, the weather was clear on the day when the data was obtained, and the visibility was set to 40km for atmospheric correction. For ortho-rectification, this time it is done in the form of RPC files, ground control points and DEM data.

In the process of image fusion and image cropping, the processed multi-spectral image and panchromatic image are fused to obtain a high-resolution multi-spectral remote sensing image, and then image fusion is performed by the nearest approach sharpening method. This method uses multi-threaded calculations to process output results faster. Because of its support for standard geographic and projection coordinate systems, RPC information, and several geographic information metadata types based on pixel location, the color and image quality of the output image. The texture and spectral information of the image are relatively better. Through visual judgment, manual cropping is performed to obtain a suitable project area image. The pre-processed data are as follows. (Fig. 2)
Fig. 2 Data preprocessing result map

3.3 Extraction of environmental information in mining areas

3.3.1 Vegetation coverage
First, use the difference in the response of green plants to the red light band and the near-infrared band, and compare the spectral brightness values of the red light band and the near-infrared band in the image to obtain the normalized vegetation index, which separates the vegetation and other. Combined with vegetation coverage, get the NDVI estimation model as follows:

\[ FC = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \]  

Among them, \( FC \) is the vegetation coverage, \( NDVI \) is the normalized vegetation index, and \( NDVI_{\max} \) and \( NDVI_{\min} \) are the maximum and minimum values of \( NDVI \). Since noise cannot be avoided in the calculation process, in order to obtain the effective maximum and minimum values of \( NDVI \), it is necessary to determine the approximate value based on the inflection point of the histogram, that is, to determine the confidence level. Based on the statistical results, this paper chooses to take the cumulative percentage as the standard and 5% as the confidence level, read the corresponding pixel values at 5% and 95% respectively, determine the maximum and minimum effective \( NDVI \), and finally get the vegetation in the study area Coverage graph (Fig. 3a).

3.3.2 Soil index
Soil brightness index and greenness index can be used to judge bare soil and vegetation, so the bare soil vegetation index is formed by linear combination of greenness index and soil brightness index [6]. This index can reflect the bareness of the soil. The bare soil vegetation index is used in the study of soil index, and its calculation formula is:

\[ GRABS = VI - 0.9178BI + 5.58959 \]

Among them, \( GRABS \) is the bare soil vegetation index, \( VI \) is the greenness index of the ear-cap transformation, and \( BI \) is the soil brightness index of the ear-cap transformation. After the ear-cap transformation, the soil index map is obtained through calculation (Fig. 3b).

3.3.3 Water extraction
Water has the strongest absorption in the range of near-infrared and short-wave infrared bands, and there is almost no reflection. Vegetation has a large reflectivity in the near-infrared band, so the information of suppressing vegetation can be processed by the ratio of the green light band to the near-infrared band. According to this feature, the normalized water body index is constructed, and the calculation formula is:

\[ NDWI = \frac{G - NIR}{G + NIR} \]

Among them, \( NDWI \) is the normalized water index, \( G \) is the green light band, and \( NIR \) is the near-infrared band. However, when extracting water bodies, some non-target information will also be mixed in the output results. Therefore, it is necessary to extract the effective NDWI value. In this study,
the DN value of the water body area is found by visual interpretation method. Through the analysis and calculation of the DN value of the water in the figure, the water index chart of the research area was obtained (Figure 3C).

3.3.4 Supervised classification
This supervision classification adopts the maximum likelihood method. Firstly, samples are selected for the training areas that need to be classified, and then the required classification results are obtained through the discriminant rules of the maximum likelihood method. In this study, in addition to vegetation, soil and water, it is also necessary to classify mining areas and buildings (Fig. 3d).

![Image classification result map](image)

Fig. 3 Image classification result map

3.4 Ecological environment assessment

3.4.1 Ecological factor normalization
Vegetation coverage and soil index can be studied as ecological factors. First, normalize the data. This evaluation research is divided into ten levels, and the level is proportional to the contribution of factor values to the ecological environment. For the level, the coding method is applied, and the coded value is proportional to the level. After normalizing the data of the factors involved in the evaluation, a set of values from 1 to 10 reflecting its characteristics will be formed.

According to the above principles, the vegetation coverage and soil index are divided into 10 levels, and the level value is proportional to the size of the vegetation coverage, and also proportional to the contribution of vegetation to the quality of the ecological environment. The composition of the soil is closely related to phenomena such as soil erosion. Here, the bare soil vegetation index is used as the soil factor, and its condition is proportional to the level [7].

3.4.2 Index system establishment
Ecological environment assessment is the application of biological and ecological concepts and methods, through the interpretation of image data, etc., to quantitatively determine the status of the ecological environment in the studied area [8]. This article applies the comprehensive index method,
under an evaluation index system, weighted average of various indexes, and evaluates the researched project by calculating the comprehensive value. The evaluation model is:

$$E = W_1 \times S_1 + W_2 \times S_2$$ (4)

Among them, E is the comprehensive index value, W is the weight value, and S is the number of indicators. The weight distribution is roughly estimated based on the contribution of each factor, and the contribution is proportional to the weight. The weight distribution is carried out with reference to the ecological environment evaluation technical specifications issued by my country in 2015, in which the weight ratio of vegetation coverage and soil index is 8:2. Divide the 10 levels into 4 major levels, and construct the ecological environment assessment grading table (Table 1).

Table 1 Classification table of ecological environment assessment

| Evaluation grade | Comprehensive evaluation index | Description |
|------------------|-------------------------------|-------------|
| excellent        | 9–10                          | The ecological environment has not been destroyed, the ecological structure is reasonable, and the ecological system's own functions and self-recovery capabilities are strong. |
| good             | 6–9                           | The ecological environment has not been destroyed, the ecological structure is reasonable, and the ecological system itself has strong functions and self-recovery capabilities. |
| medium           | 3–6                           | The ecological environment is destroyed, the ecological structure is basically reasonable, and the ecosystem's own functions and self-recovery capabilities are weak. |
| Poor             | 1–3                           | The ecological environment is severely damaged, the ecological structure is unreasonable, and the ecosystem's own functions and self-recovery capabilities are weak. |

4. Evaluation results and analysis

The vegetation coverage and soil index extracted from the GF-1 image are used as ecological image factors, and they are normalized. The comprehensive index method was used to obtain the ecological environment index results of the study area. The density segmentation method is used to classify the image information, and finally the ecological environment evaluation results of Fushun West Open-pit Mine at four grades of excellent, good, medium and poor are obtained (Fig. 4).

Table 2 Statistical results

| Partition | Poor | medium | good | excellent |
|-----------|------|--------|------|-----------|
| Percentage of total area (%) | 18.09 | 41.30 | 32.47 | 8.14 |

The area statistics of the four sub-regions of the ecological environment in the mining area were carried out (Table 2). The evaluation results show that the evaluation index accounts for the majority (about 74%) in the range of 3-9, indicating that most of the natural ecology in the area is in a good state; about 8% of the evaluation index is 9-10, the area is natural. The ecology is in an excellent state. Most of these areas are concentrated in plains or jungle areas where the crops are growing well; about
18% of the areas are in a poor comprehensive index. Most of the areas are mining areas and water areas, and the rest are mainly concentrated in residents. Land, transportation land area; from the figure, about 2% of the area is in poor condition, and this area is mainly concentrated in the mining area. It is concluded that the ecological environment of this area is in a relatively good state.

5. Conclusion
In this study, the Fushun West Open-pit Mine was used as the research area, and remote sensing and GIS technology were used to process and analyze Gaofen-1 (PMS) remote sensing data, DEM data and geographic basic data to obtain ecological environment information in the mining area such as vegetation coverage, water body information, soil index. On this basis, comprehensive index method is used to analyze and evaluate the ecological environment of the mining area. The research results show that the ecological environment of Fushun West Open-pit Mine is relatively good, and the evaluation result is consistent with the fact. Compared with other remote sensing data, the Gaofen-1 satellite data used in this study has the advantages of high resolution, multi-spectrum and large area. At the same time, the evaluation method is simpler and easier than traditional methods. For the next step, it is necessary to increase the richness of the types of geological information extracted in the mining area, and then conduct a more comprehensive evaluation of the mining area environment.

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Reference
[1]Research on Investigation and monitoring of mine exploitation based on remote sensing in Gannan polymetallic mine area [D]. Central South University, 2011.
[2] Biswajeet P, Saro L. Utilization of Optical Remote Sensing Data and GIS Tools for Regional Landslide Hazard Analysis Using an Artificial Neural Network Model[J]. Earth Science Frontiers, 2007, 14(6):0-151.
[3] The Application and the research of object-oriented method for extraction of mining area information [J]. Remote sensing information, 2013, (02): 110-115.
[4] Song Qi-fan, Wang Shao-jun, Zhang zhi, et al. A Water Information Extraction Method Based on World View II Remote Sensing Image in Tungsten Ore Districts : A Case Study of of Dayu County in Jiangxi Province [J]. Remote Sensing for Land and Resources, 2011, (02): 33-37.
[5] Yang Jing, Wang Li-qin. Study on Index System for Ecological Safety Evaluation in Mining Areas [J]. Journal of Shandong University of Science and Technology( Natural Science),2005(03):36-39.
[6] Zhang Hui, Tan De-bao, Wang Bao-zhong, et al. Method of Measuring Soil Moisture with Thematic Mapper Data [J]. Journal of Yangtze River Scientific Research Institute, 2008, (01): 34-35.
[7] Chen Kai, Shi Hong-liang. Ecological security evaluation about Jiangsu Province [C]. Chinese Society For Environmental Sciences: 2008: 132-136.
[8] Cui Li-chang. Research on mine ecological environment impact assessment and restoration countermeasures—taking limestone mining as an example [D]. Hebei Normal University, 2003.
[9] Wen Qing-chun. Revision of “Technical Criterion for Ecosystem Status Evaluation” and impact on Ecological evaluation work [J]. Environmental Protection and Circular Economy, 2016, (10): 69-71.