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Vegetation Growth Monitoring Under Coal Exploitation Stress by Remote Sensing in the Bulianta Coal Mining Area

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Abstract: Coal exploitation inevitably damages the natural ecological environment through large scale underground exploitation which exhausts the surrounding areas and is the cause of surface subsidence and cracks. These types of damage seriously lower the underground water table. Deterioration of the environment has certainly an impact on and limits growth of vegetation, which is a very important indicator of a healthy ecological system. Dynamically monitoring vegetation growth under coal exploitation stress by remote sensing technology provides advantages such as large scale coverage, high accuracy and abundant information. A scatter plot was built by a TM (Thematic Mapper) infrared and red bands. A detailed analysis of the distributional characteristics of vegetation pixels has been carried out. Results show that vegetation pixels are affected by soil background pixels, while the distribution of soil pixels presents a linear pattern. Soil line equations were obtained mainly by linear regression. A new band, reflecting vegetation growth, has been obtained based on the elimination of the soil background. A grading of vegetation images was extracted by means of a density slice method. Our analysis indicates that before the exploitation of the Bulianta coal mining area, vegetation growth had gradually reduced; especially intermediate growth vegetation had been transformed into low vegetation. It may have been caused by the deterioration of the brittle environment in the western part of the mining area. All the same, after the start of coal production, vegetation growth has gradually improved, probably due to large scale aerial seeding. Remote sensing interpretation results proved to be consistent with the actual situation on the ground. From our research results we can not conclude that coal exploitation stress has no impact on the growth of vegetation. More detailed research on vegetation growth needs to be analyzed.
Key words: coal exploitation; linear regression; density slice; vegetation growth
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1 Introduction

The process of coal resource exploitation damages and changes the natural environment by such occurrences as subsidence and abundant cracks. More over, it may damage surface vegetation. These kinds of damage can induce serious ecological and environment problems and increase the conflict between the demand for resources and environmental protection and ultimately the preservation and self-modulation functions of the original ecological system, which will be, to some extent, impacted. Vegetation is an important part of the global environment and also its best indicator. How to obtain effectively vegetation growth under coal exploitation stress is always a detection problem in monitoring a mining environment. At the same time, it is an important step during the process of ecological restoration near coal mining areas.

Remote sensing has characteristics that can deal with large scale problems, has short repetition periods and provides abundant information. Therefore, it becomes a very useful tool for investigating such things as local environments, surveying, exploiting mineral resources, monitoring soil erosion and land use[1–5]. In the area of vegetation research, national and international experts have recently largely focused on the identification of vegetation types and vegetation indices[6–8]. However, research into vegetation growth, leaf area index (LAI) and vegetation stress by multispectral remote sensing technology is relatively rare[9]. National and international experts usually use hyper-

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spectral remote sensing data to analyze vegetation biomass, various stress and chemical parameters such as nitrogen and chlorophyll content and their concentrations[10–14]. However, we all know that hyperspectral remote sensing data is very expensive and very difficult to obtain. In a limited number of situations, extracting information on vegetation growth by multi-spectral remote sensing technology becomes imperative. In this paper we mainly analyze vegetation growth near the Bulianta coal mining area in the arid and semi-arid area under coal exploitation stress, using the method of three time phase TM (Thematic Mapper) of remote sensing data. The distributional characteristics of vegetation pixels have been analyzed in a scatter plot constructed by TM 4 and TM 3 bands. Soil lines have been extracted from the scatter plot by linear regression and the TM 4 infrared band has been rotated with the soil line in order to eliminate the impact of the soil background. Then, the new band, which can entirely reflect the information on the growth of the vegetation, will be sliced by a threshold. The setting of thresholds is largely determined from the inflection points of the frequency accumulation. Hence, the grading of the remote sensing images of vegetation growth has been achieved. The method introduced above may provide ecological restoration and environmental protection with very good technical support.

2 Experiment

2.1 Bulianta coal mine and exploitation stress

2.1.1 Introduction of the Bulianta coal mining area

The Bulianta coal mining area is one of the major mines of the Shendong Company[15]. It is located in the south-eastern part of Yinjinhuoluo Qi, Yikezhaomeng, Mongolia, about 35 km from Yijinhuoluo Qi. The mine was opened in 1997, with a designed production capacity of 6 million ton per year. In recent years, the production has been well over the designed production capacity. In 2004, the production was over 10 million ton. The coal area for the Bulianta coal mine is about 225 km^2 and the proven geological reserve are about 0.5 billion ton. The coal mine can be exploited for about seventy years.

2.1.2 Coal measure

The Bulianta coal mining area belongs to the coal measure of the Jurassic period[16]. There are six workable and partial workable coal measure from high to low, i.e., 1^{-2}, 2^{-2}, 3^{-1}, 4^{-2}, 5^{-1} and 5^{-2}. Among these, the 2^{-2} coal measure is the most important part of all the workable measure. The coal measure found in this mine has the following characteristics in its favor: ① the mine has abundant water, ② the coal has a low ash content, ③ it has a low sulfur content and ④ it has high heating value. The type of coal is a non-caking coal. The average reflectance of vitrinite at every level of coal measure gradually increases from high to low. It shows clearly that the quality of the coal production at the top part is higher than at the bottom part. This phenomenon fully conforms to Xierte's Law of coal degeneration.

2.1.3 Situation of coal exploitation stress

The Bulianta coal mine has now been exploited for ten years or so. Many years of over exploitation certainly has caused some damage, especially to the vegetation. Field investigations show that coal exploitation has resulted in the exhaustion of large areas under the surface. Exhausted areas cause surface cracks. The width of the cracks is usually very narrow, but the number of cracks is large. Almost every working face can cause hundreds of cracks where the direction of most cracks is along the direction of exploitation while other cracks are perpendicular to the direction of the working face. Moreover, the length of the cracks along the direction of exploitation is the same as that of the working face. As well, exhausted areas can cause subsidence on the surface, where the vegetation has already been moribund for some time. The soil type in the Bulianta coal mining area is an aeolian sandy soil. In this type of soil, whose structure is unconsolidated, water penetration is very strong and the capacity to hold moisture very small. The soil fertility is very poor. The major plant types are typical steppe vegetation: deciduous trees, broad leaf scrubs and sandy vegetation, whose characteristics are those of a short growing season, a long dormancy stage, poor canopy closure and a low coverage per cent. The main vegetation varieties are thyme grass and sand sagebrush, etc. Therefore, in this coal mining area the environment is very vulnerable, the ecology fragile with seriously damaged vegetation, combined with many years of coal exploitation.

2.2 Data source and remote sensing image preprocessing

The remote sensing data used in our paper consists of TM data obtained from the Landsat satellite for the time phases of August 1986, August 1990, July 1995, July 2000 and July 2006. For some reason, the remote sensing data for 2000 misses almost half of the entire study area and the data for 2006 just misses a small part of the study area. In order to monitor vegetation growth effectively and make certain comparisons between each research result, we mainly used the 1986, 1995 and 2006 3-time phases of the remote sensing data based on the consideration of the time of exploitation over a fixed number of years. At the same time, topographic scale maps of 1:50000 which include the Bulianta coal mining area were obtained. The quality of remote sensing images used in our paper is very good and there were no clouds in the images.

In order to accomplish a geometric correction，we initially calibrated the topographic maps, then made