Study of the Human-Driven Mechanism of LUCC in the Shenfu Mining Area, NW of China

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Abstract. Taking the Shenfu mining area, located in the northwest of China, as an example, temporal and spatial changes of land use/cover and its human-driven mechanism were analyzed based on the land use and MODIS NDVI data. The results show that: (1) by the implementation of the Grain for Green Project (GGP), the area of cultivated land decreased, and grassland increased. By the exploitation of coal and other resources and the development of social and economic levels, the area of construction land increased. (2) The vegetation cover level in the mining area significantly increased from 2000 to 2015, and the implementation of GGP and the increase of precipitation were the main reasons. (3) The driving force of land use to forest land and grassland could increase the level of vegetation cover, such as with the GGP, and the promotion of cultivated land and construction land will lead to the reduction of vegetation cover level, such as with urban expansion and mining area construction caused by population growth and industrial development.

1. Introduction

Land use and land cover change (LUCC) is one of the hot issues of concern to domestic and foreign scholars [1-2]. Although it is an international research program, LUCC has been replaced by the Global Land Program (GLP). However, as a recognition of the ecological environment, LUCC is still an important basis for understanding the global and regional ecological environment changes [3-4], and LUCC plays an important role in the study of the natural ecological environment and human activities [5-6].

LUCC research includes structure and process research, drive mechanism research, model and simulation research, and so on. Li et al. (2015) and Sun et al. (2016) studied the LUCC process in the Loess Plateau and the Cold Region of China, respectively, reflecting the effects of human activities such as the Grain for Green Project (GGP) and climate change [7-8]. Chen et al. (2015) and Lu (2016) studied LUCC in administrative units of the provincial and county levels, which played an important role in assessing regional changes in the ecological environment and policy adjustments [9-10]. In addition, Xing et al. (2013) studied the LUCC process in the Huaihe River basin, reflecting the effect of LUCC on hydrological processes [11]. Government policies, socioeconomic development and

population migration are important drivers of the LUCC process [12-14]. CLUE-S model CA and Markov model and other LUCC process and predication models have been developed and applied [15-18].

In addition to urban areas, mining areas are one of the most dramatic areas of human activity, and their LUCC process is clearly driven by human activities. This paper studies the human-driven mechanism of the LUCC in a mining area, which can provide a theoretical basis for the scientific adjustment of ecological and environmental protection policies and reasonable restrictions on the scope of human activities.

2. Materials and Methods

2.1. Study area

The Shenfu mining area is located in Shenmu and Fugu Counties in the northern part of Shaanxi Province, China. The northwestern part of the region is the southern margin of the Mu Us sandy land, and the southeastern part of the region is the hill and gully region of the Loess Plateau. The total area of the region is 10.67×104 km2, and it has a temperate continental monsoon climate. The annual average temperature and annual precipitation are 9℃ and 450 mm, respectively. Limited by precipitation, the Shenfu mining area has low levels of surface vegetation coverage and a fragile ecological environment, which are sensitive to human activities, especially mining activities. The Shenfu mining area is an important coal producing area in Shaanxi Province and even China. The exploitation of coal and the construction of mining areas have promoted the expansion of industrial and mining land and squeezed the other land in the adjacent areas, which may have an important influence on the process of LUCC.

2.2. Data

The data for the study include: (1) 1:10 000 land use datasets for the Shenfu mining area in 2000, 2005 and 2010, which were collected from the National Ecological Decade Remote Sensing Assessment Project. Land use data is divided into 6 first class and 20 second class datasets. (2) MODIS NDVI datasets of 250 m resolution and 16 d composition in the Shenfu mining area from 2000 to 2015, downloaded from https://ladsweb.nascom.nasa.gov. The NDVI data were obtained from 2000 to 2015 by using the Maximum Value Composition (MVC) method. (3) The temperature and precipitation data from 2000 to 2014 were downloaded from http://data.cma.cn, and the meteorological station included Yulin of Shaanxi Province, and Hequ and Xing Counties of Shan Province.

2.3. Methods

2.3.1. Linear trend method. Linear trend method are mainly used in two aspects: one is temporal analysis of NDVI time series data to reflect vegetation NDVI change trend over time, the other is spatial analysis of NDVI to show vegetation NDVI change trend in the study area. Linear trend method is calculated as follows [19]:

$$a = (\sum_{i=1}^{n} x_i y_i - nx'y') / (\sum_{i=1}^{n} x_i^2 - nx'^2)$$ (1)

Where Y is MODIS NDVI images of study area from 2000 to 2015, X is the years from 2000 to 2015, and a is coefficient, b is constant value. The x′ and y′ are average value of X and Y, respectively. The value with positive or negative areas reflect linear increase or decrease trend of vegetation NDVI.

2.3.2. Correlation coefficient. The correlation coefficient is mainly used to analyze the relationship between two independent variables, calculated as [19]:

$$r = \left[\sum_{i=1}^{n}(x_i - x')(y_i - y') \right] \Big/ \left[\sqrt{\sum_{i=1}^{n}(x_i - x')^2} \sqrt{\sum_{i=1}^{n}(y_i - y')^2} \right] \qquad (2)$$

Where x and y is annual NDVI and precipitation, respectively. The value of r is distribution between [-1, 1], and r=0 indicate no correlation between two variables, while r value close to -1 which indicate strong negative correlation, and vice versa, strong positive correlation.

3. Results

3.1. Land use change

The area of land use type in the first class data and construction land in the second class data were obtained, and the changes in area and ratio of land use type during 2000-2005, 2005-2010 and 2000-2010 were also calculated. The results are shown in Figure 1.
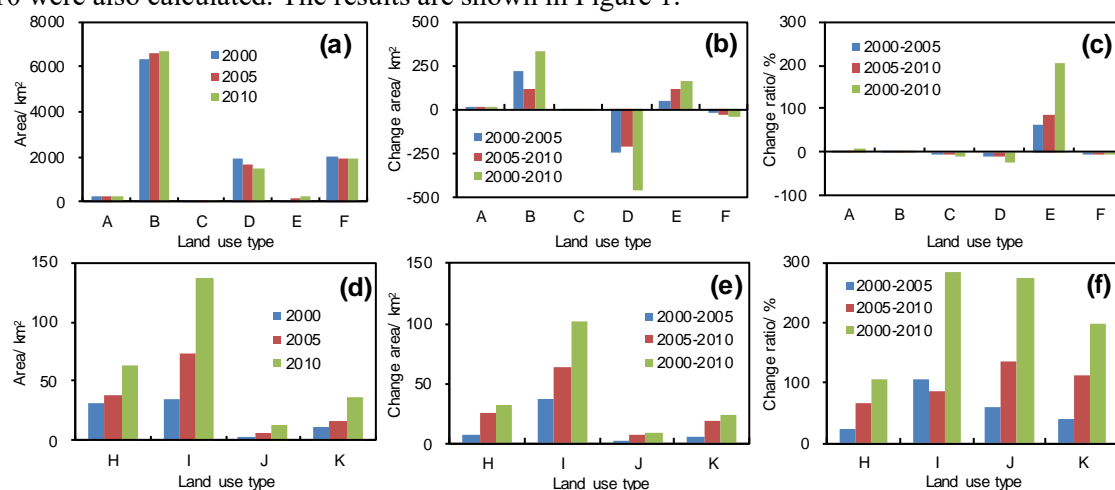
A-forest land, B-grassland, C-water, D-cultivated land, E-construction land, F-unused land, H-residential land, I-industrial land, J-traffic land, K-mining land.

Figure 1. Area and proportion of land use change.

The land use types in the Shenfu mining area were mainly grassland, unused land, and cultivated land, accounting for 61.52%, 18.23% and 15.96% of the total area, respectively. The area of cultivated land decreased by 458.05 km2, whereas grassland increased by 333.61 km2, which was mostly affected by the implementation of GGP beginning in 1999. Through the development of coal resources and other industrial resources, construction land increased by 166.95 km2, followed by grassland. The construction land increased by more than 203%.

The implementation of GGP is the main driving factor for the decrease in cultivated land and the increase in forest and grassland in the Shenfu mining area. In addition, the most prominent characteristics of the mining area are the coal resources and coal industry development, causing the local economy to be improved and causing population growth, which led to the expansion of construction land in the region. The construction land is divided into residential land, industrial land, traffic land and mining field land. Among them, residential land is related to population growth, industrial land is related to industrial development, traffic land is related to the relevant cooperation of economic development, and mining land is related to coal resources development. From 2000 to 2010, the ratio of industrial land in the Shenfu mining area was the highest, accounting for 50.96% of the total area, followed by residential land at 20.70%. The increased area of industrial land was also the largest (101.03 km2), followed by residential land (32.58 km2), and mining land (23.76 km2). The growth rate of industrial land was the largest (284.71%), followed by traffic land (273.61%) and mining land (199.63%).

3.2. Vegetation cover change

The normalized difference vegetation index (NDVI) is an important indicator of vegetation coverage. The higher the NDVI value, the higher the vegetation coverage level, and vice versa. Therefore, the NDVI represents both vegetation cover level and vegetation cover type. In this paper, the NDVI was used to express vegetation coverage. The annual average value of the NDVI was calculated from 2000 to 2015, and the spatial distribution of the linear trend was also calculated. The results are shown in Figure 2.
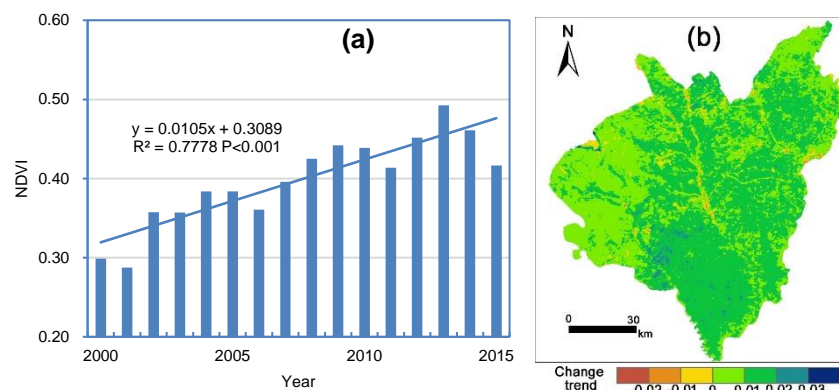

Figure 2. Trend of the temporal (a) and spatial (b) changes in NDVI.

The Shenfu mining area is located in the semi-arid and arid climate zone of northwest China. The ecological environment is fragile, and the precipitation is small, so the surface vegetation cover is low. The average NDVI between 2000 and 2015 was 0.3978, and the lowest value was 0.2875 in 2001, while the highest was 0.4924 in 2013. With the implementation of GGP, a large area of cultivated land converted to grassland and forest land promoted the improvement of surface vegetation, showing a significant linear growth trend ($P<0.001$) of NDVI from 2000 to 2015 and indicating that vegetation will continue to improve in the future. The spatial distribution of the change trend was also confirmed by the improvement of vegetation, and the trend of linear change was mainly positive. The trend of linear decrease was mainly distributed in the river valley, urban and other human activities regions.

3.3. Effects of temperature and precipitation on vegetation

The spatial distributions of temperature and precipitation were obtained by the inverse distance weight (IDW) interpolation method, and the results were resampled to 250 m resolution. Then, the spatial distribution of the correlation between NDVI, temperature, and precipitation in the Shenfu mining area was calculated. The results are shown in Figure 3.
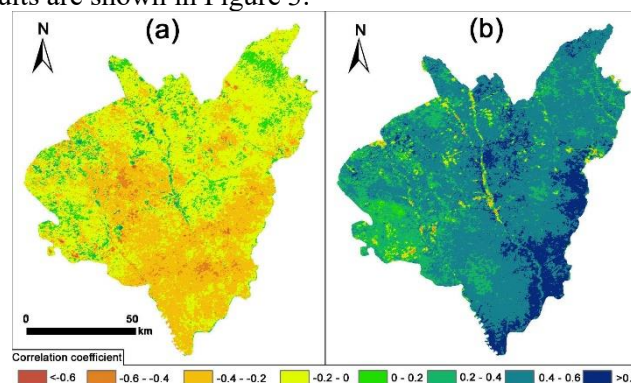

Figure 3. The spatial distribution of correlation between NDVI
and temperature (a), precipitation (b).

The relationship between NDVI and temperature in the Shenfu mining area was not obvious, and there is a negative correlation within the large area, which may be related to the drought condition in the area. The increase in temperature increases the surface evaporation, and the surface water was not conducive to the growth and development of vegetation. Precipitation, as a limiting factor for the growth and development of vegetation in arid regions, had a high correlation with NDVI, and there was a positive correlation between DNVI and precipitation, excluding river valley, urban area, and other regions of intense human activity.

3.4. Effects of land use change on vegetation

The annual average NDVI values of forest grassland (including forest land and grassland), cultivated land, construction land and unused land were obtained. At the same time, the annual average NDVI value of the region that included the four land use types mentioned above in 2010 were converted from other types in 2000. The latter was subtracted the former, and the difference between the change in area of the land use type in 2010 and the overall average NDVI was obtained. The results are shown in Figure 4.
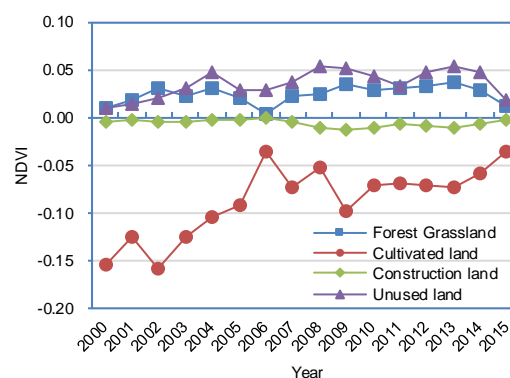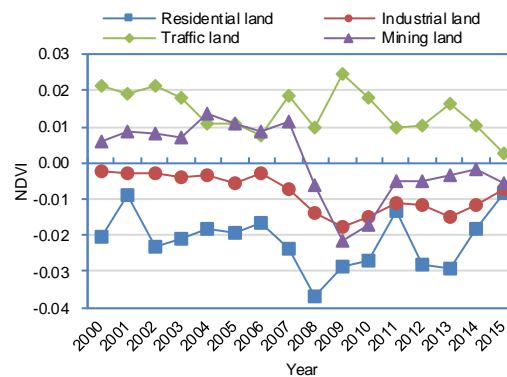

Figure 4. Change in the NDVI difference between changed area and total area of the first class land use type in 2010.

The NDVI value in the region that was converted from others land use types in 2000 to forest grassland and unused land in 2010 was higher than the overall NDVI value of forest grassland and unused land in 2010. The NDVI value in the region that was converted from other land use types in 2000 to cultivated land and construction land in 2010 was lower than the overall NDVI value of cultivated land and construction land in 2010. This indicated that the increase in the forest grassland caused by the implementation of GGP improved the overall level of NDVI and vegetation cover level. However, human activities such as coal resources development and urban expansion will destroy the surface vegetation, causing the NDVI value to decrease and leading to the instability of the vegetation ecosystem.

3.5. Effects of mining activities on vegetation

To further analyze the effect of construction land on NDVI, the difference between the change in area of the second class of construction land in 2010 and the overall average NDVI was obtained. The results are shown in Figure 5.

Figure 5. Change in the NDVI difference between changed area
and total area of the second class of construction land in 2010.

The NDVI value in the region that was converted from other land use types in 2000 to residential land and industrial land in 2010 was lower than the overall NDVI value of residential land and industrial land in 2010. The NDVI value in the region that was converted from other land use types in 2000 to traffic land in 2010 was lower than the overall NDVI value of traffic land in 2010. In addition, the NDVI value in the region that was converted from other land use types in 2000 to mining land in 2010 was higher than the overall NDVI value from 2000 to 2007, but lower from 2008 to 2015. In the second class of construction land, any human activities such as residential land and industrial land development will lead to the destruction of surface vegetation cover.

4. Conclusion
(1) By the implementation of the Grain for Green Project (GGP), the area of the cultivated land decreased by 458.05 km2 and the grassland increased by 333.61 km2. By the exploitation of coal and other resources and the development of social and economic levels, the construction land increased by 166.95 km2 (an increase of more than 203%), of which industrial land increased by more than 101.03 km2 (an increase of more than 284%).

(2) The vegetation cover level in the mining area was significantly increased from 2000 to 2015, and the implementation of the GGP and the increase in precipitation were the main reasons.

(3) The driving force of land use to forest land and grassland could increase the level of vegetation cover, such as with the GGP, while the promotion of land use to cultivated land and construction land will lead to a reduction in vegetation cover level, such as with urban expansion and mining area construction caused by population growth and industrial development. This study can provide a theoretical basis for the scientific adjustment of ecological and environmental protection policies and reasonable restrictions on the scope of human activities.

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