Remote sensing monitoring land use change in Donglutian coal mine, Shuozhou City

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Abstract: This paper monitored the coal mine exploitation in Donglutian coal mine, Shuozhou city, Shanxi Province. Landsat satellite images from 2008 to 2016 were selected, and then 15m color composite images were obtained through data processing and image fusion. On this basis, the land use map from 2008 to 2016 was obtained using visual interpretation method. Results showed that the main land use type in this area was cropland, unused land and coalmine. Area of cropland and unused land kept decreasing year by year, while coal mine expanded rapidly. The expansion of coal mine concentrated on two time periods: from 2009 to 2010 and from 2012 to 2013. During these two time periods, topsoil stripping was the main exploitation type,while deep mining was the main type for other times. Results also presented that the exploitation number of small coals kept increasing year by year, from the initial number of 26 at 2008 to 42 at 2016.

1. Introduction

Remote sensing and GIS are the main techniques to study land use/land cover change [1]. Many scholars have conducted dynamic monitoring of environmental change in the mine area by using remote sensing data [2-4], and received ideal effect. Remote sensing also provides the possibility for long-term monitoring of land use [5], provide supervision measures to disordered mining, and also provide accurate and reliable data basis for the study of ecological environmental change.

Located in the east of loess plateau, Donglutian coal mine is a ecological environment system which are sensitive to the environmental change with small plasticity to maintain its stability. This paper chose Donglutian coal mine as the study area, and used Landsat7/8 remote sensing image as the main data sources. Visual interpretation was conducted to determine type, timing, quantity of land deterioration in the area from 2008 to 2016. The obtained results can provide scientific basis for the making of land reclamation planning [6].

2. Study area

Pingshuo coal mine is one of the large coal bases in the north of Shanxi province included in the 13 large national planning coal base. It was Located in the north of Ningwu coal mine, administrative belonging to Pinglu district, Shuozhou city. With the area of 380 km^2, the mine has geological reserves of 11221 Mt. In general, there are 16 fields (3 for open pit and 13 for wells). The total construction scale are 93.50Mt/a, among which the construction scale of three open pit mines are15.00Mt/a for

Antaibao open pit coal mine, 10.00Mt/a for Anjialing open pit mine, and 20.00Mt/a for Donglutian mine. The mine service life is 75a. Donglutian coal mine locates in the northeast of Pingshuo mine, 10km from the northeast of Pinglu district, 28km from Shuozhou city, administrative belonging to

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Shuozhou Pinglu area of jurisdiction. The geographical coordinates are longitude 112 ° 23 '58' ~ 112 ° 27 '52 " and latitude 39 ° 29' 58 "~ 39 ° 35 '33" (Figure 1). With 4.42 ~ 5.47 km long in the east-west direction and 6.53 ~ 10.3 km width in north-south direction, covering an area of 48.73 km^2, the mine had geological resource of 1848.92 Mt. A lot mines are in production and small mines prevails. By the end of May, 2004, there had 10 small coal mines with production life 3-5 years (Figure 2). Besides, the border of 5 small mines outside extended to the mine [7]. Small coal mine production capacity are below 0.15 Mt/a. Furthermore, the recovery rate is rather low, generally less than 30%. Disordered mining and resource waste is very serious. In order to put an end to combat phenomena of the disordered mining of small mines, Donglutian coal mine started officially in 2009.

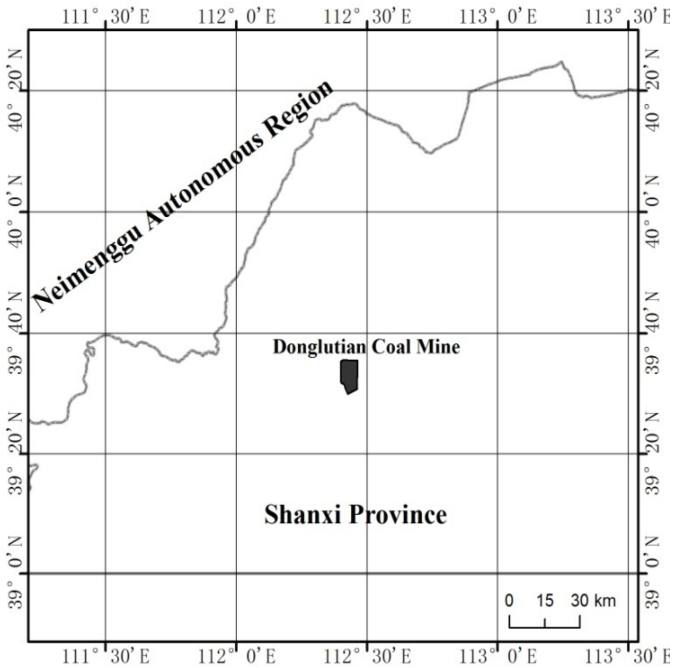

Figure 1. Location of Donglutian coal mine

3. Data source and processing

3.1. Remote sensing data

Remote sensing data used are mainly landsat7（ETM）/8(OLi) from 2008 to 2016 (Table 1). In total, 9 images downloaded from USGS websites were used, including 30m multiband spectral bands and 15m panchromatic band. Data acquired are mainly from May to October during which cloud cover was less than 1%.

3.2. Data processing and procedure

Envi5.2 are used to conduct the preprocessing work of remote sensing data, including atmospheric correction, radiation correction, geometry correction, and image fusion. Standard false color composite data are adopted, 432 band for ETM, 853 bands for OLi.

(1) The Landsat 7 scan-line corrector (SLC), a mechanism designed to correct the under sampling of the primary scan mirror, failed on May 31, 2003. With the SLC now permanently

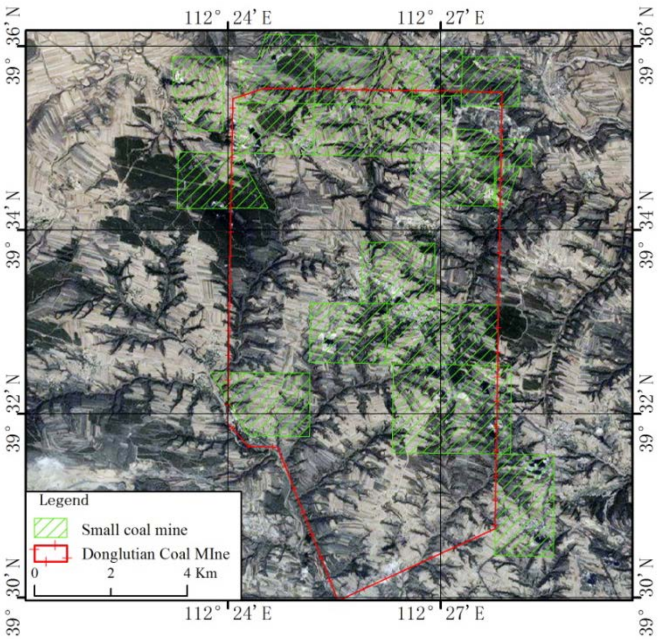

Figure 2. Distribution of small coal mines before 2005

turned off, the ETM+ is losing approximately 22% of the data due to the increased scan gap. So before using landsat 7, it is necessary to fill the gap. The specific method was to use the patches of each band and conducted interpolation processing.(http://landsat.usgs.gov/sci_an.php)

Table 1. Data source of remote sensing

sensor	path/row	date acquired	bands	resolution	source
ETM	126/33	2009/10/5	1-7,Panchromatic	30m/15m	USGS
ETM	126/33	2008/8/31	1-7,Panchromatic	30m/15m	USGS
ETM	126/33	2010/8/5	1-7,Panchromatic	30m/15m	USGS
ETM	126/33	2011/8/8	1-7,Panchromatic	30m/15m	USGS
ETM	126/33	2012/10/13	1-7,Panchromatic	30m/15m	USGS
OLI_TIRS	126/33	2013/9/6	1-11,Panchromatic	30m/15m	USGS
OLI_TIRS	126/33	2014/5/20	1-11,Panchromatic	30m/15m	USGS
OLI_TIRS	126/33	2015/6/8	1-11,Panchromatic	30m/15m	USGS
OLI_TIRS	126/33	2016/7/28	1-11,Panchromatic	30m/15m	USGS

(2) Firstly, to conduct atmospheric correction and radiation correction for 30m ETM multiband data.

(3)Then fuse the multiband data with 15 m pan band, and Gram-Schmidt Pan sharpening algorithm was selected.

(4) Conduct geometric correction to the fused images. 1:50 000 topographic maps in 1985 was selected as the control map, and using quadratic polynomial method to select more than 20 control points with RMS error o < 1. The corrected 2008 ETM image was chosen as the control image when doing the geometric correction to images from other years.

3.3 Remote sensing interpretation and extraction of change information

After image correction and interpretation key establishment, visual interpretation was done in ArcGIS 10.1 platform. The data was divided into Cropland, woodland, grass land, resident and coalmine, as well as unused land. Interpretation accuracy was controlled. The minimum interpretation chart spot for planar feature was 6*6 pixel (a pixel equals 15 meters), 2 pixel for linear feature. After interpretation, conduct topology processing and errors checking, and ultimately the land use map was obtained. Use the high resolution images to check the image, evaluate the result of the interpretation, and correct the wrong patches.

4. Results and analyzes

4.1. Area change of land use

Table 2. Area of every land use type from 2008 to 2016(km^2)

classes	2008	2009	2010	2011	2012	2013	2014	2015	2016
cropland	59.52	57.28	54.31	53.13	51.89	49.67	48.27	47.08	46.36
woodland	0.58	0.18	0.12	0.05	0.00	0.00	0.00	0.00	0.00
road	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31
resident	3.99	3.96	3.57	3.93	3.77	3.31	3.36	3.19	3.23
coalmine	2.04	6.32	11.38	12.33	14.20	17.50	19.28	21.30	22.11
unused land	20.71	19.09	17.46	17.40	16.98	16.36	15.93	15.28	15.13
Donglutian Coal Mine		4.44	9.29	10.12	11.71	15.47	17.15	18.08	18.79

The land use map and area of each land type were shown in Figure 3, Table 2.The land use type in this area was rather simple, mainly cropland, coalmine, and unused land. The change trend was shown in Figure 4. Cropland and unused land reduced year by year, and the coal mine increased gradually. Area of cropland decreased by 13.16km^2 in 8 years' time with average decrease rate 1.64km^2 per year, generally remained stable. Unused land decreased by 5.58 km^2 , with the average decrease rate 0.7km^2, remained rather stable too.

Area of coal mine increased by 20.07$km^2$with the average growth rate 2.51km^2. The increase is more significant from 2008 to 2010, as it is the preliminary stage of mine exploration, and the increase rate began decreasing from 2011 to 2016, which had closed linked with fall of domestic coal prices.

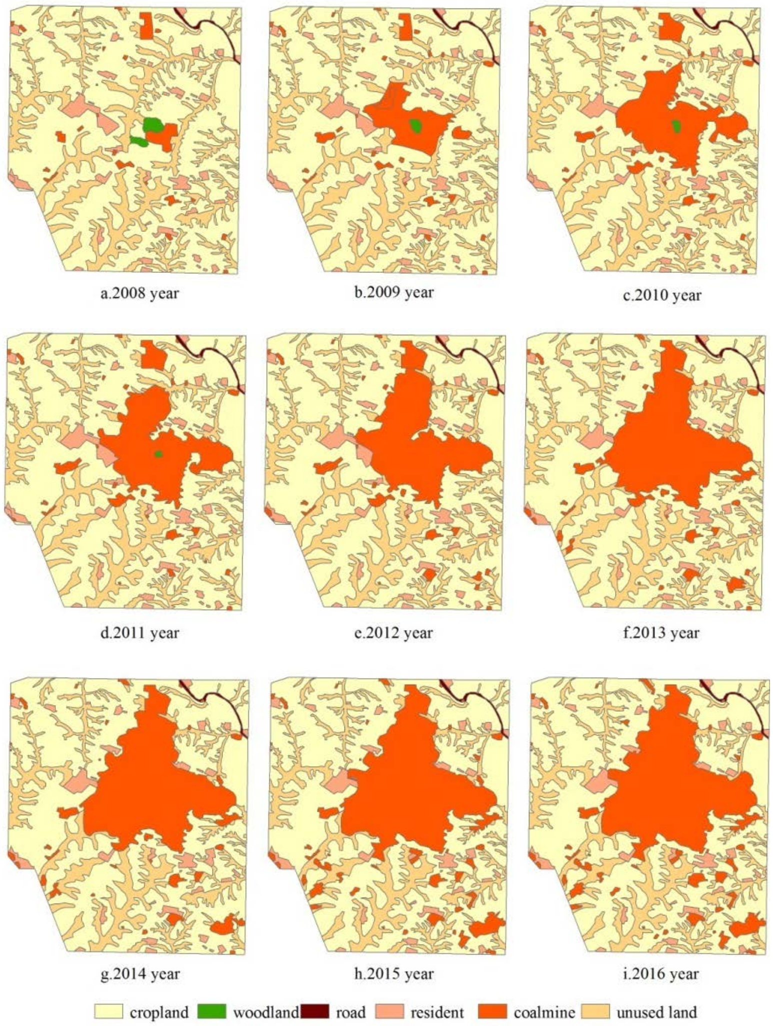

Figure 3. Land use map of the study area from 2008 to 2016

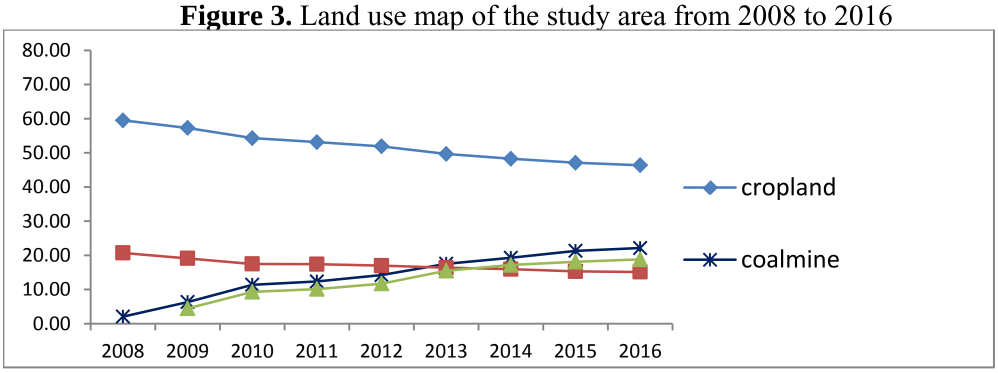

Figure 4. The area change of main land use type from 2008 to 2016

4.2. The monitoring of mining progress

Donglutian coal mine started from January, 2009, and covered an area of 4.44km^2, mainly for industrial construction. In 2010, the area reached 9.29 km^2, topsoil stripping work conducted except for the industrial construction. In 2011, coal mining started but the expansion was small. In 2012, the expansion remained small, and mainly for deep coal mining. In 2013, however, the expansion became obvious, increased by 3.75 km^{2}compared with area in 2012 with the southwest topsoil stripping the main cause. From 2014 to 2016, the mining activities were not as significant as before, and the area remain stable, mainly because the fall of international coal prices and national policies that reduce the coal production.

4.3. Monitoring the small coal mines

Through interpretation results, it was found that the number of small mine increased instead of decreasing. It increased from 26 in 2008 to 42 in 2016. The minimum mines of various periods covers an area of 0.003 km, and the largest is less than 0.773 km^2. The total area was 2.040- 3.326 km2 with the average size between 0.064- 0.079 km^2. On the whole, the area of the small mines gradually increased (table 3 and Figure 5). In spatial distribution (Figure 6), the latest mining of small coal mines mainly concentrated in the southeast and southwest side with no new small mines in the north. Therefore, data showed that the occurrence of Donglutiaon didn't changed the disordered mining of small mines in the area.

Table 3. Statistics of small mines from 2008 to 2016

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Count	26	31	28	32	34	32	32	42	42
Minimum(km^2)	0.003	0.003	0.004	0.003	0.004	0.004	0.004	0.004	0.003
Maximum(km^2)	0.750	0.439	0.773	0.773	0.773	0.256	0.500	0.696	0.682
Sum(km^2)	2.040	2.171	2.085	2.209	2.487	2.034	2.121	3.211	3.326
Mean(km^2)	0.078	0.070	0.074	0.069	0.073	0.064	0.066	0.076	0.079

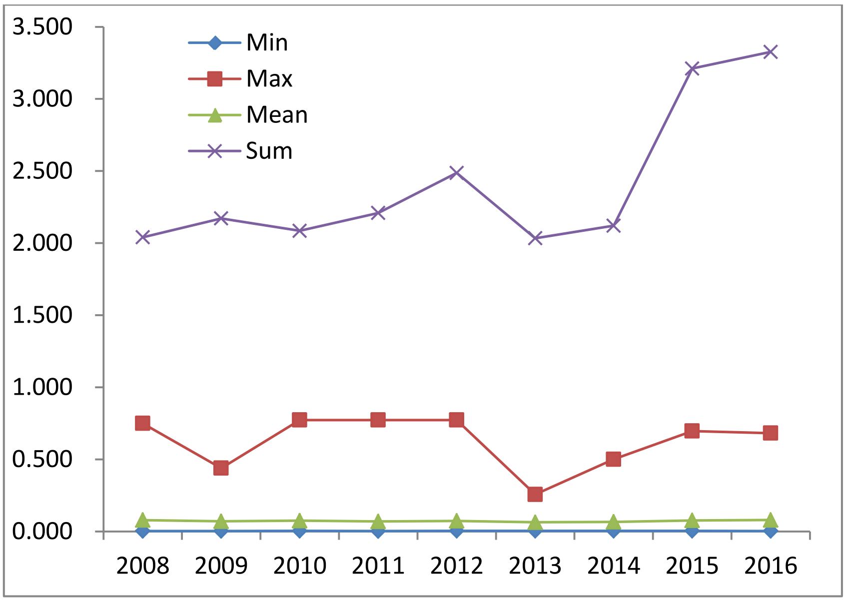

Figure 5. Statistical curve of small mine from 2008-2016

Figure 6. Spatial distribution map of coal mines in the study area

5. Discussion and conclusion

The study area was rather small, the range was 9km*10km, the largest resolution of landsat ETM(OLI) was 15m, so the image can only tell the general outline of the mines, but cannot clearly interpret the location and the border of mining pits, mine, industrial sites and stripping zone. In addition, On May 31, 2003, the scan-line corrector (SLC) for the ETM+ sensor on board Landsat 7 failed permanently. The SLC compensates for the forward motion of the satellite, and without an operating SLC, images have wedge-shaped gaps that range from a single pixel in width near the image-nadir, to about 12 pixels towards the edges of the scene. Missing pixels comprise about 22% pixels of these images, and loss about the width of 7 pixels [8-9].In this paper, The interpretation accuracy of this paper was 6 * 6 pixel. Therefore, the ground feature type less than 7*7 pixel, if in the position of the missing stripe, cannot be interpreted. Through the above statistics, it was found that there are some small mines with the area less than 7*7 pixel, so the result may be influenced to some extent.

Remote sensing technique is a effective way to monitor the long-term coal mining activities in the study area. Thus, it can provide the effective support for the exploitation of small mines, and also provide a favorable method for government to conduct mine reorganization and environmental protection.

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