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Analysis to driving forces of land use change in Lu'an mining area

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Abstract: By selecting impact factors of driving force and formulating evaluation criteria of the impacts, the evaluation system of corresponding driving force impact of land use change was established. Taking Lu'an mining area as an example, the specific impact factors of coal mine were comprehensively evaluated and analyzed in order to carry out qualitative and quantitative analysis for the driving force of mining-land use change. The principal component analysis shows that the social and economic development in mining area from 2000 to 2007 demonstrates continuous accelerate trends, and the impacts of its overall driving force to land use change are increased gradually. The socio-economic factors have more impacts to mining-land use change than those of the natural resources. The main driving force of mining-land use change also include population, technological progress and policy.

Key words: mining area; land use change; driving force; evaluation factor; principal component analysis

1 Introduction

Land use change reflects the change in the way and purpose of land use. The causes and sources of power for land use change are the actions of various driving forces. Therefore, the driving force research of land use change is an important way to understand the causes of land use changes [1, 2], which becomes the core issues to explore the driving mechanism of land use change, being helpful to explain internal mechanism of the interaction in man-land system [3]. According to methods classification, the driving force research in the past takes quantitative and qualitative analyses. According to characteristics of selected area, the force driving factors include natural and socio-economic ones [4, 5]. Among them, the majority is quantitative analysis and economic driving force analysis, which has achieved a lot. For examples, model method is introduced to the research of land use/cover change mechanism by GUNTHER [6]. FÜ et al [7] proposed that the driving forces of land use and land cover change were climate change and human activities, from which the selection of driving forces indicators should consider natural conditions and human activities. BAI et al [8] using the theory and methods of system theory, studied non-linear feedback relationship between driving forces and land use change, making in-depth analysis to integration, level and diversity in land use change under driving force and driving forces of land use change.

Coal mining area, as a special kind of small-scale typical area, has brought environmental pollution, ecological destruction, land covering and other issues due to energy demand increasing and large-scale exploitation. Its land-use change is a relatively complex process, being not only restricted by natural factors but also impacted by mining activities, socio-economic development, technological advances and policy factors [9]. That is why, taking Lu'an mining area as an example, this paper attempts to evaluate comprehensively the specific impact factors of coal mining areas through building an evaluation system of driving force impact of mining-land use change, and then make routine analyses for the driving forces of mining-land use change in order to discover its intrinsic mechanism.

2 General situation of research area

2.1 Natural conditions

Lu'an mining area is located in the southeast of Shanxi Province, crossing different regions including Changzhi, Lucheng, Xiangyuan, Zhangzi, Huguan, Tunliu and other counties' towns, belonging to Changzhi City. The main part of Lu'an mining area is located in the

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west side of Taihang Mountains' mid-piece within Changzhi basin. Its northern part is loess hills, while the central and southern terrain is relatively flat. It takes 900−930 m of height over sea level. It has dominancy location as close to the coal shortage zone including the eastern mid-southern China and other provinces' parts. The area is located inland, belongs to warm temperate continental climate, strongly affected by continental monsoon. It is windy and dry in spring, rain and hail in summer, cool and mild in autumn with more continuous rain. It is dry, cold with less snow, and blew by more northwest wind in winter under high pressure control from Mongolia. The annual rainfall concentrates during June and September. The number of annual sunshine takes 2511.1−2630.3 h; the annual average accumulated temperature over 10 °C takes about 3278.4 °C.

There are four soil kinds in the mining area, mainly including cinnamonic soil, moisture one, yellow loam and brown soil. Among them, moisture soil is the main composition for agricultural production in this area, with high fertility and humidity level. The area is a warm temperate zone and belongs to deciduous broad-leaved forest belt of North China, mostly being covered with forest grass and shrub types of vegetation, mainly including broad-leaved forest, coniferous forest, dwarf shrubs under shade, and dry agricultural land in two crops a year or three ones two years. The mining area is rich in water resources with larger quantity. Surface water sources are mainly from the west and south parts of Zhuozhang River, Jiang River and other rivers, and Zhangze, Houwan, Tunjiang as well as reservoirs. The groundwater level is shallow in good quality, easy to be mined. The main geological features take complicated structure and more faultage.

2.2 Socio-economic development situation

The whole area is 14215 km^2, with arable land 0.16 km^2 per capita. According to statistics, the total number of population in this area was 3.1221 million in 2000 with 0.7016 million of non-agricultural population, up to 3.2693 million in 2007 with 1.2950 million of non-agricultural population. The GDP per capita in 2007 is 16887 yuan.

The transport network in this area extends in all directions, with 34 million of road passenger traffic, 54 million tons of road freight. Tai-Jiao railway passes through north to south of the area, linking its east to Hebei's Han-Chang railway, connecting its south to Longhai line, and touching the east into Jing-Guang line; the Civil Aviation has opened Changzhi to Beijing, Shanghai, Guangzhou, Datong, Chengdu, and other routes.

3 Evaluation system of driving forces impact on mining-land use change

3.1 Impact factors selecting of driving forces

Driving actors of land use change involve many variables. Mining-land system is disturbed especially by exploitation and related production activities. From scientific, comprehensive, systematic and other principle for factors selecting, in line with natural conditions, socio-economic conditions and mining production layout of the mining area, the first level of driving-force impact actors are selected such as U_1 for natural resource factor, and U_2 for socio-economic factor of mining area; and the second level of factors such as U_{11} for climate weather, U_{12} for topography, U_{13} for soil, U_{14} for vegetation, U_{15} for water, U_{21} for coal gangue covering, U_{22} for mining subsidence, U_{23} for air quality, U_{24} for water environment quality, U_{25} for total output value per year, U_{26} for the amount of annual coal output, U_{26} for total population. From that, evaluation system of driving forces impact on mining-land use change is established and shown in Table 1.

Table 1 Evaluation factors of driving force impact to mining-land use change

First level	Weight	Second level	Weight
U_1	0.4	U_{11}	0.28
		U_{12}	0.25
		U_{13}	0.15
		U_{14}	0.10
		U_{15}	0.22
U_2	0.3	U_{21}	0.20
		U_{22}	0.30
		U_{23}	0.20
		U_{24}	0.30
		U_{25}	0.35
		U_{26}	0.30
		U_{27}	0.25

3.2 Evaluation criterions of driving force impacts

All levels of actors are assigned weights from AHP combined with expert consultation method. The factor values are normalized. Adopting index sum method, the two factors in first level and the integrated factor are evaluated, reflecting the impact conditions for driving force from natural resources, socio-economic of mining area and integrated aspects [10]. Finally, the evaluation criterions are obtained as Table 2.

Table 2 Evaluation criterions of driving force impact on mining-land use change

Grade	Impact value limit of driving force	Situation	Grade feature
I	S<0.4	Light	Good quality in ecological environment, suitable climate, high soil fertility, low impact of coal mining
II	0.4<S<0.6	Middle	Better ecological environment, perfect service function of land system, some impact of artificial actors
III	0.6<S<0.8	Mid-high	Worse ecological environment, some change in land use structure, increased impact of artificial activities
IV	S>0.8	High	Serious destructions in ecological environment, bad environment quality in air, soil and water, land subsidence and heavy coal gangue covering

$$S_i = \sum_{j=1}^{n} w_j \times P\left(x_j\right), (i \neq j)$$

In it, S_i is an impact value of driving force under first level; w_j is weight of each factor; $P(x_j)$ is the impact index of the number j factor.

3.3 Driving forces impact of land use in Lu'an mining area

From above evaluation on impact factors of driving forces in Lu'an mining area, it concludes that the area impacted in light and middle grade by integrated driving forces is dominant. It means that non-mining area has superior natural conditions with adequate rain, whose soil is suitable to agricultural production, where the influence of coal mining is low or lower without obvious pollution; in it, the impact of socio-economic actors is higher than natural resources'. Especially, the strong mining activities in coal industrial area have higher influence to land use change.

4 Comprehensive analyses to driving forces for land use change in Lu'an mining area

4.1 Qualitative analysis

Population is one of the most active factors in the driving forces of land use change, showing the quantity's increase and having obvious action on land use system. The quantity's increase of whole area's population specially non-agricultural one, inevitably leads to land requirement, which transfers the unused land into agricultural land, constructional one, the agricultural land to constructional one, bringing about extending unceasingly the industrial-mine land, urban and communication one [11, 12].

Economy development is an important driving force to land use change, mainly displaying the mutual action and impact between economy increase and land use. On the one hand, the economic fast development inevitably brings about the increase of the general land requirement quantity and related input of production factor, and the change of land use structure. For example, the increase of social actual income and the investment in urban development construction causes large scale extending for construction land, leading to arable land area decrease; meanwhile, the considerable increase of non-agricultural population speeds up the process of urbanization, and enlarge urban range. On the other hand, the sustainable land use also needs continuous economy development in order to supply sci-technological means and funds supporting [13−14].

The economy of Lu'an mining area had a sustainable fast development from 2000 to 2007. The whole area's GDP rose to 55.06 billion from 17.02 billion with growing rate 9%−15%; in 2000, the falling situation of economic growing rate since 1997 was reversed, but there were prominent contradiction in economy structure and problems as absent new growing aspect; up to 2007, the proportion among three industries was adjusted as 5.8:59.6:34.6, with 16887 yuan of GDP per capita and 57.93 million tons of raw coal in growing rate 14.8%. From above, it shows that the growing speed of mining area's economy is fast, with the industrial structure becoming reasonable and the living level going up yearly, which inevitably lead to conflict between agricultural land and construction one, and change of land use structure.

The role of sci-tech development embodies in the course of land resource developing, reconstructing and utilizing under human being. On the one hand, the progress of technological level and production means increases the breadth and depth of land use, bringing about changes in land use configuration; on the other hand, sci-tech progress pushes rapid social advances, resulting in increased demand for land, environmental pollution, ecosystem damage etc., which make land property changes and fertility decline [15]. Policy factors mainly refer to countries or regions' influence to resources utilization through making and promulgating laws and regulations, socio-economic policies and other means. The land use of Lu'an carries out national and provincial Torch Plan and Spark Program as well as other high-tech projects, promoting agricultural sci-tech achievements and developing new industrial technologies with independent intellectual property.

4.2 Quantitative analysis

In line with the actual situation of land use change in Lu'an mining area, combined relevant principles for driving force factors selecting, demographic factors represent as X_1 for population with unit million, X_2 for non-agricultural population with unit million; economic development factors represent as X_3 for GDP with unit 10^8 yuan, X_4 for fixed assets investment with unit 10^8 yuan, X_5 for increment of the primary industry with unit 10^8 yuan, X_6 for increment of the secondary industry with 10^8 yuan, X_7 for increment of the tertiary industry with unit million, X_8 for allocate income of rural residents with unit yuan; technology development factors represent as X_9 for total grain output with unit 10^8 kg, X_{10} for increment rate of raw coal output with unit %. The data shows as Table 3.

Using principal component analysis, the results through the statistics software SPSS are as follows. ① Table 4 is for the total explained variance, showing all characteristics root, total contribution rates which are the percentage in corresponding general eigenvalue and the cumulative percentage. The characteristic root of the first principal component is 7.950 over 1; the characteristic root of the second principal component is 1.581 over 1; the cumulative contribution rate is 95.306%, which equals to 79.497% plus 15.810% that means no necessary to increase principal component. ② The loading matrix of initial factor also being component matrix expresses the correlation coefficient between the given principal components and the original variables factors. ③ From Table 5, the variable X_{10} negatively relates to the first principal component; the correlation coefficients of variables X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8 to the first principal component are bigger than 0.6, indicating that the first principal component can fully explain the reasons for mining-land use change; the variable X_9 and X_{10} to the second principal components are positive correlated in a large grade; the correlation coefficients of other variables with the second principal component are less than 0.5 respectively, indicating that the second principal component can represent the development factors of science and technology for explain the reasons of the mining-land use change.

After the success of the principal component extraction, they should be named in order to facilitate the analysis. However, as the difference between each variable and its coefficient is not obvious, they must be rotated in order to be split apart toward maximum and minimum differentiation. Table 6 is the rotated component matrix. It can be seen that the loads of each variable to the main components have larger changes, highlighting the importance of its corresponding index.

To sum up the operation results, it can be drawn as follows. The first component focuses on population growth and economic development, reflecting the roles of eight indicator variables including population, GDP, total allocate income of rural residents and the increment of the secondary industry; the second principal component mainly reflects two indicator variables including the increment rate in general grain output and raw coal output, focusing on technology development factors.

$$F_1=0.350ZX_1+0.336ZX_2+0.348ZX_3+0.343ZX_4+0.337ZX_5+0.348ZX_6+0.341ZX_7+0.353ZX_8+0.178ZX_9-0.136ZX_{10}$$

$$F_2=0.100ZX_1+0.169ZX_2-0.132ZX_3-0.025ZX_4+0.192ZX_5-0.107ZX_6-0.188ZX_7-0.055ZX_8+0.628ZX_9+0.679ZX_{10}$$

Table 3 Data on socio-economy of Lu'an mining area from 2000 to 2007

Year	Population/ 10^4	Non-agricultural population/ 10^4	Total GDP/ (10^8 yuan)	Fixed assets investment/ (10^8 yuan)	Increment of primary industry/ (10^8 yuan)	Increment of secondary industry/ (10^8 yuan)	Increment of tertiary industry/ (10^8 yuan)	allocate income of rural resident/ yuan	Total grain output/ (10^8 kg)	Increment rate of raw coal output/ %
2000	312.21	70.16	170.20	46.30	23.20	97.00	50.00	2202.8	11.50	10.10
2001	316.17	90.06	185.00	50.85	27.00	101.00	57.00	2427	13.81	20.40
2002	318.26	104.48	206.00	68.16	26.30	112.00	67.70	2650	14.47	17.8
2003	319.93	107.28	255.66	127.86	27.44	153.45	74.77	2886	13.41	27.30
2004	321.66	110.97	318.47	163.07	29.81	201.59	87.07	3263	15.00	21.40
2005	323.41	120.49	398.75	183.27	28.90	230.63	139.21	3573	12.99	6.30
2006	325.18	125.06	460.40	184.02	29.98	270.20	161.23	3890	14.31	14.80
2007	326.93	129.50	550.63	224.45	32.17	328.15	190.31	4410.5	14.14	6.98

Table 4 Total variance explained

Composition number	Feature square root	Contribution ratio/%	Accumulation/ %
1	7.950	79.497	79.497
2	1.581	15.810	95.306
3	0.279	2.792	98.098
4	0.102	1.019	99.117
5	0.058	0.580	99.697
6	0.029	0.289	99.987
7	0.001	0.013	100.000
8	2.662×10^{-16}	2.662×10^{-15}	100.000
9	6.227×10^{-17}	6.227×10^{-16}	100.000
10	-1.617×10^{-16}	-1.617×10^{-15}	100.000

Table 5 Component matrix and component score coefficient matrix

Factor	Component matrix		Component score coefficient matrix	
	1	2	1	2
X_1	0.986	0.126	0.124	0.080
X_2	0.948	0.212	0.119	0.134
X_3	0.981	−0.166	0.123	−0.105
X_4	0.967	−0.032	0.122	−0.021
X_5	0.950	0.242	0.119	0.153
X_6	0.982	−0.134	0.124	−0.085
X_7	0.961	−0.236	0.121	−0.149
X_8	0.996	−0.069	0.125	−0.044
X_9	0.501	0.790	0.063	0.500
X_{10}	−0.384	0.854	−0.048	0.540

Table 6 Rotated component matrix and component score coefficient matrix

Factor	Component matrix		Component score coefficient matrix	
	1	2	1	2
X_1	0.983	0.146	0.122	0.082
X_2	0.943	0.231	0.116	0.136
X_3	0.985	−0.146	0.126	−0.103
X_4	0.968	−0.013	0.122	−0.018
X_5	0.944	0.261	0.116	0.156
X_6	0.984	−0.114	0.125	−0.082
X_7	0.966	−0.216	0.124	−0.147
X_8	0.997	−0.049	0.126	−0.041
X_9	0.485	0.800	0.053	0.501
X_{10}	−0.402	0.846	−0.059	0.539

where Z indicates standardization, as the units of variables are different and have to be handled by standardizing. Comprehensively, F is also known from F_1 and F_2 as follows

$$F=\frac{\lambda_1}{\lambda_1+\lambda_2}F_1+\frac{\lambda_2}{\lambda_1+\lambda_2}F_2 .$$

where λ_1 and λ_2 are the ratios of the first and second principal component accounts for the characteristic value corresponding to the total eigenvalues of the principal component extraction. Accordingly, the integrated model of principal components can be obtained as follows.

$$F=0.31ZX_1+0.31ZX_2-0.27ZX_3+0.28ZX_4+0.31ZX_5+0.27ZX_6+0.25ZX_7+0.29ZX_8+0.25ZX_9$$

Based on the above formula, the integrated principal component values of driving forces for mining-land use change during 8 years can be obtained, as shown in Fig. 1. The integrated values of driving force from 2000 to 2003 are negative, beginning gradually rose into positive in 2004, indicating that the combined effects of various factors on mining-land use have continuously increased since 2004.

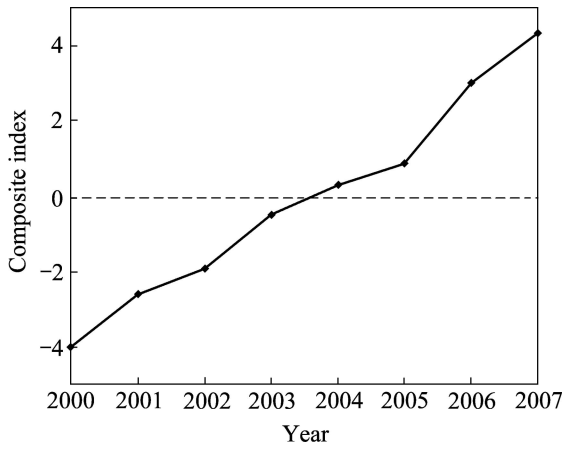

Fig. 1 Synthesized trend of driving forces

From above operating results, it can be drawn as follows. The first principal components focus on economic development and population factors, reflecting the role of indicators variables such as GDP, increment of the tertiary industry and second one, population and other. At first, that is to say that economic growth is the one of the main driving forces to mining-land use change. The GDP increased, the proportion adjustment of the secondary and tertiary industries in the three ones will inevitably lead to continuous increase in demand of industrial land, transportation and infrastructure ones, resulting in a large number of cultivated lands, forest lands changed into construction ones to meet their economic development requirement. Next, the population growth plays an important influence on mining-land use change. From 2000 to 2007, the population of mining area rose up to 3.2693 million from 3.1221 million, with the proportion of non-agricultural population rising to 39.61%, which was one of the main reasons for the scope of the eastern town in mining area continuously growing. The second component focuses on technology development factors. Technological progress is the driving force of economic growth, guaranteeing the development of advanced agricultural technology to improve land use efficiency.

5 Conclusions

1) From 2000 to 2007, the socio-economic development of the mining area shows unceasing accelerated trends, whose impacts of integrated driving force on land use change are gradually increased.

2) The impact of socio-economic factors on mining-land use change is bigger than that of the natural resources. Non-mining zones in the area have good ecological environment with less disturbance as mining activity has little influence. However, in the main mining zones where locate Zhangcun, Shigejie, Wangzhuang and other coal mines, as the mining activities are dramatic, the atmosphere and water environment quality are poor, with prominent damage such as coal mining subsidence and gangue piling up etc. In these zones, the degree of environment pollution and socio-economic disturbances are large, as mining activities have obvious influence on them.

3) The main driving force factors on mining-land use change still include population, technological progress and policy ones. Population is an important performance factor as the increase in non-agricultural population will inevitably lead to the increase of construction land and the decrease of agricultural land and forest one. Those driving factors in scientific and technological progress, government decision-making play roles in mining area with strong performance in large scale of mining activities so that cause transformation of different land-use types.

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