Surface Coal Mining Impacts On Land Use Change And Ecological Service Value: A Case Study In The Shengli Coalfield, Inner Mongolia

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Abstract

Coal plays a crucial role in global economic development, which is still the most common and widely distributed fossil fuel in the world. As the world's largest developing country, China's mining and utilization of coal resources make great contributions to the rapid growth of China's economy. Inner Mongolia lies in the arid and semi-arid areas of China, its ecological environment is very fragile. The exploitation of opencast mining seriously hinders the sustainable use of regional land and the promotion of residents' well-being. This paper uses 2000, 2005, 2010, 2015 and 2020 remote sensing imageries, Based on ENVI, using a random forest algorithm to divide the land utilization type into construction land, vegetation, cultivated land, bare land and water area，and analyses the evolution characteristics of land use and ecosystem service value during the past 20 years. The results showed that: (1) Between 2000 and 2020, the construction land, vegetation and water of mining area were reduced, the bare land and cultivated land showed an increasing trend. The largest ratio changed is bare land, the smallest changed rate is water area. (2) The total ecosystem service value of the mining area reduced from10.939 billion yuan to 9.527 billion yuan. Among them, vegetation ecosystem service value is the highest, followed by cultivated land and water, and bare land ecosystem service value is the lowest. (3) From the spatial scale, the total ecosystem service value of the Shengli mining area decreases year by year, which shows that the land-use change in the mining area does have an impact on the ecosystem service value.

1. Introduction

Coal plays a crucial role in global economic development, which is still the most common and widely used fossil fuel in the world. As the world's largest developing country, China's mining and utilization of coal resources have been making great contributions to the rapid growth of the economy. China's economy will still be highly dependents on coal mining and production at present and in the future (Bi et al., 2019; Wang., 2014; Lin et al., 2014). Coal mines cause high-intensity disturbance to land-use changes and ecosystems inevitably while promoting economic development (Xiao and Zhang et al., 2020). Opencast mining destroyed the ecological environment of the mine (Mukhopadhyay et al., 2016) by removing vegetation and soil, changing terrain, disturbing surface and ground hydrological systems. Therefore, it is necessary to monitor and study the impact of mining exploitation on ecosystem services, especially in the Shengli field such an ecologically fragile area. The successful mining of the Shengli coalfield has caused a certain degree of damage to the regional ecosystem, resulting in a series of ecological and environmental issues, and has caused a wide range of society.

Ecosystem services refer to various benefits that humans directly or indirectly from ecosystems (Costanza et al., 1997). In the past 20 years, the development of ecosystem services has developed rapidly. Ecosystem services meet the needs of human important impact on the well-being of human society (Smith et al., 2013), which is the basis of human survival and development (Li et al., 2013; Peng et al., 2021). Ma (2005) divides the ecosystem into supply services, support services, regulation services, and cultural services (Liu et al., 2014). The supply service is mainly to provide the production of raw materials, fuel, food, etc., such as wood, fuel, etc. to produce food, collect food through farming, fishing, collecting food; adjustment service mainly refers to climate adjustment, flood regulation, disease regulation, water quality purification, etc such as adjusting the temperature, precipitation, and other climate processes, regulating water flow, storing and keeping water; support services mainly refer to nutrient cycle, soil formation, primary production, such as nutrient storage and internal circulation; cultural services mainly refer to entertainment, aesthetics, culture, tourism, etc., such as the aesthetics, art, education, spiritual and scientific value of ecosystems; ecotourism and other activities.

Some scholars believe that support services are process products, are the basis of supply, adjustment, and cultural services, not the final product. Therefore, in the MA evaluation process and many scholars' ecosystem service accounting, not alone account value, but Divide the ecosystem service types into supplies services, regulation services, and cultural services in the accounting service, adjustment services, and cultural services (Zhou et al., 2014). Constanza et al and Daily assess the global ecosystem service value and provide methods and cases for ecosystem service value calculations. In 2003, he has organized the "China's land ecosystem area ecological service value ecosystem" following the status quo of China's land-use status, according to China Land Use Status. It laid a foundation for scientifically quantifying ecosystem service values in different regions. (Xie et al., 2003). The ecosystem service assessment method is mainly divided into three categories: energy value analysis, material assessment method and value quantity assessment method (Zhao et al., 2000). At present, domestic scholars' related research is mostly based on the ecosystem service value equivalent factor table which was revised and supplemented by Xie, and combined with the economic value of the study area ecosystem services to estimate the regional ecosystem service value (Li et al., 2018; Xie et al. 2020).

With the increase of population growth and technology level, human society has increased the demand for ecosystem services, and human activities have also become one of the main factors affecting ecosystem services (Maltitz et al., 2016). Land use change is the most direct form of human activity on the effects of Earth's surface system, playing an important role in the global environmental changes (Liu et al., 2018). Studying the ecosystem service value of specific regions based on the various characteristics of land use has great significance for revealing the impact of human activities on the ecosystem and the relationship between coordinators and nature (Ren et al., 2019). Through the analysis of land-use changes on the value of ecosystem services, many scholars reveal the negative impact of urbanization, etc., which is the negative impact of ecosystem service value, and preliminarily explores the cause of the impact, and puts forward the future land use needs more consideration. Its impact on the ecological environment (Zhang et al., 2013; Xiao and Lv et al., 2020). Related research showed that the change in land use modification and ecosystem service value has strong relevance, agricultural development and urbanization, and the change of land use modes, which often lead to a decline in regional ecosystem service, indicating that humans should consider ecological environmental effect in land use practice(Wang et al., 2020). Different scholars' research on land use changes on ecosystem services, and analyze the effects of different land use patterns, different land use patterns, and different land use intensities on ecosystem services (Fu et al., 2014). Evaluation application is the most extensive for the evaluation of ecosystem services based on land use types (Wang et al., 2020).

Mineral resources exploit a large amount of land, China 95% of energy, 70% agricultural production materials and more than 80% of industrial raw materials from mining industry (KexinRen et al., 2000), and most of the open-air coal mine is located in drought, semi-arid ecological fragile area (Bradshaw et al., 2000). Currently, there are more research-based on local utilization types of ecosystem services to be subject to certain administrative regions or natural ecosystems (Guan et al., 2021; Peng et al., 2021; Bao et al., 2021; Lin et al., 2021; Guo et al., 2021; Qi et al., 2021), and showing the variation of ecosystem services with the help of models and other research methods (Dun et al., 2015; Lu et al., 2015). There is still a shortage of research on the special land use unit of the open-air mining area. Compared with well working, the open-air coal mine mining is more disturbance of regional land use, landscape pattern and biological habitats, which leads to major changes in mining area ecosystem service function, seriously hindering regional economic and social sustainable development and residents' well-being. (Lu et al., 2015). Therefore, there is an urgent need to research land use and ecosystem service value change in the open-air coal mine of ecological fragile dissensions. Since the reform and development, the Inner Mongolia region has made important contributions to energy development and economic development. At the same time, as an important ecological function area in the north, an important ecological safety barrier that should be played has been affected and restricted. This study selected the Shengli coalfield in eastern Inner Mongolia Highlands, and the disturbance surface experienced the peeling of soil rock formation, coal seam mining, solid backfilling, surface soil backfill and reclamation. The paper analyzes the change of land use and ecosystem service value, reveals the impact of land use evolution in minerals on the value of the ecosystem, is providing a reference for rational development and protection of mining regions, which is important for regional economic and social development.

Beginning in 2005, affected by the policy of returning farmland to forest and grassland, cultivated land has decreased. Since then, some scholars use three levels of ecological evaluation index system by selecting diversity, representative air pollution concentration, heavy metal pollution, soil erosion, groundwater pollution, etc., and the results showed that the ecological quality of Shengli coalfield is very good, meets the requirements of sustainable development (Ma et al., 2006),and results in reaction mining area ecosystem service value reduced year by year, shows that the mining area ecological environment quality is reduced. In 2020, the Inner Mongolia Autonomous Region drafted the "Opinions on Promoting the High-Quality Development of Coal Industries" and sought advice. It put forward strict new coal mine access. It shows that the government has enhanced control of the coal industry. This paper is intended to: (1) Based on GEE to touch the land use coverage of the region, clarifying the structure and change of mainland use; (2) Based on the land use condition and equivalent factor method for the regional ecosystem service based on the region. Evaluation, judging the variation of the value of the local service value of the mining area; (3) Based on land use change and ecosystem service value changes, exploiting the impact of land use changes on the value of ecosystem services, and this is the sustainable use of local land resources and Environmental protection provides decision support.

2. Study Area

Shengli coalfield (43°54'15"—44°13' 52"N,115°24'26"—116°26'30" E) is located in the northwest of Xilinhart, Inner Mongolia Autonomous Region, Northwest Susu and Illlamise. The overall appearance of the North East - South West strip-shaped display, the towing is 45 km long, the tendency width is 7.6 km, and the coal-containing area is 342 km^2 (Fig. 1). There are two coal segments in the coal mine: the chalk is a coal section in the chalk, and there are 7 coal sections. There are 7 coal mining groups, with an average depth of 200–500 m, with an average thickness of 8–60 m, and 1989 proven reserves of 15.932 billion tons, the reserved reserves are 15.931 billion tons. Mining area elevation of 970 ~ 1212m, the terrain for the slow waves of ups and downs piedmont plain, temperate continental climate, is a typical temperate semi-humid half dry with extremely maximum temperature 38.3 ℃ and extreme minimum temperature − 42.4 ℃, The average temperature is 1.7 ℃, the annual maximum precipitation is 481.0mm, the annual minimum precipitation is 146.7 mm, the average annual precipitation is 294.74mm; the annual evaporation is 1794.64mm; spring vents, wind speed 2.1–8.4 m/s, soil organic matter content, soil fertility is poor. The area is an important source of China's green livestock products. There is high-quality natural grassland in the whole district 13786 km^2, and vegetation coverage is usually kept at around 40%. The mainland use types near the study area are grassland, mining land and unused land (Xiao and Deng et al., 2020).

3. Materials And Methods

3.1 Data and Classification of LUCC

We download Shengli coalfield research zone 2000, 2005, 2010, 2015, and 2020 Landsat images through geospatial data cloud, based on ENVI, using the same time interval, the same time phase remote sensing data, this can reduce the season Error information caused by differences. Based on the pretreatment of the band combination of remote sensing images, geometric correction, projection conversion, image mosaic and regional crop, the research area is divided into five types of construction land, vegetation, cultivated land, bare land and water body. Assisted the relevant social statistics related to the training area of the Shengli coalfield, coal mine distribution map, topographic map, and statistical year data, and data reserves for later analysis.

Table 1 Remote sensing parameters information

Num	Satellite	Time	Scale
1	Landsat 5 TM	Jun 5th 2000	30m
2	Landsat 5 TM	Jun 7th 2005	30m
3	Landsat 5 TM	Jun 5th 2010	30m
4	Landsat 7 TM	Jun 10th 2015	30m
5	Landsat 8 OLI	Jun 7th 2020	30m

3.2 Land Use Transfer Matrix based on overlay analysis

This paper makes statistics on the land use type data of Shengli Coalfield in 2000, 2005, 2010, 2015 and 2020, respectively. Using ArcGIS software, attribute query and statistical analysis of these data can be concluded that Shengli Coalfield around the area, scale, and distribution. Thus, it can be seen that during the study period, the main land use types of Shengli coalfield are construction land, vegetation, cultivated land, bare land and water. Under the same spatial coordinate system, the spatial attribute data of different geographic characteristics of the same area are superimposed to generate multiple characteristics of the spatial region or establish a spatial correspondence between the geographic objects. Based on this and the land coverage of different phases in the same area, using the land utilization data of different years. can draw a two-dimensional matrix, which is the land utilization transfer matrix. Through land utilization transfer matrix, it is possible to reflect the case of mutual conversion between two different land utilization types, and can describe the structural characteristics of the raised land use, and be able to highlight an area during the initial and final classes differently during change direction, at the same time can show better land use types of the space-time evolution process. Using ArcGIS software, the land utilization of land use transfer matrix can be obtained from 2000–2005, 2005–2010, 2010–2015, 2010–2020, and the land utilization map can be obtained from land utilization transfer matrices to study the land use type of Shengli coalfield. Thus, the transformation between the land use type of the Shengli coalfield can be analyzed, and the inflow and outflow direction of each land type can be analyzed. Its mathematical expression is:

$$S_{ij} = \begin{vmatrix} s_{11}s_{12}\cdots s_{1n} \\ s_{21}s_{22}\cdots s_{2n} \\ \cdots\cdots\cdots\cdots \\ s_{1n}s_{n2}\cdots s_{nn} \end{vmatrix}$$

1

Among them, S is the land use area;i,j is the type of land utilization at the beginning of the study period
n is the number of land use.

3.3 Calculation of Ecosystem Service Value

Based on the economic value of the unit area ecosystem, the value coefficient multiplies the ecosystem value obtained by the area of the corresponding land use type (Costanza et al., 1997; Kindu et al., 2016). Xie et al (2008, 2003) have developed an equivalent factor method and belongs to the unit value method. Assuming that the equivalent of the farmland unit area is 1, the equivalence of other ecosystems can be quantified by comparing its utility with farmland food production (LIN et al.,2018), this method has been widely used in ecosystems service value research. Therefore, this study adopts the 2003 revised ecosystem service value table of Xie, (Table 1), and the construction land equivalent value is 0. It is determined that the economic value of ecological service value equivalents is about one of the national average grain market values according to the relevant research results, and then calculates 2000, 2005, 2010, 2015 and 2020 ESV.

Table 2
China terrestrial ecosystem unit area ecological service value equivalent

Indicators	Vegetation	Cultivated land	Water	Bareland
Gas regulation	0.8	0.5	0	0
Climate regulation	0.9	0.89	0.46	0
Water conservation	0.8	0.6	20.38	0.03
Soil formation & protection	1.95	1.46	0.01	0.02
Waste treatment	1.31	1.64	18.18	0.02
Biodiversity protection	1.09	0.71	2.49	0.34
Food production	0.3	1	0.1	0.01
Raw material	0.05	0.1	0.01	0
Entertainment culture	0.04	0.01	4.34	0.01

According to the actual situation in the victory mining area, using the ecosystem service value measurement method of Costanza et al. and Xie to calculate the ecosystem service value of various land use types of the victory mine, the formula is:

$$\mathrm{ESV} = \Sigma(\mathrm{A}_i \times \mathrm{VC})$$

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Among them, ESV is used to characterize the ecosystem service value (yuan); A is the area of a kind of land utilization type of the research area (km^2); VC is the coefficient of ecosystem services (yuan / km^2); i is the type of land use.

4. Results

4.1 Analysis of LUCC in Mining Areas

4.1.1 Structural changes of LUCC

LUCC plays an important role to monitor in the mining process, and its information is helpful to reconstruct the optimized land use pattern (Cheng et al., 2019). Between 2000 and 2020, the current type of land use in the mining area is shown in Fig.2. In 2000, the Shengli mining area was dominated by vegetation as a whole, and a small amount of cultivated land was distributed in the southwest; From 2000 to 2005, the vegetation coverage in the northeast and southwest was good, and some cultivated land was added in the south of the central part; From 2005 to 2010, part of the vegetation in the South northeast and southwest of the mining area was transformed into bare land and construction land, and the cultivated land in the middle was also reduced; From 2010 to 2015, the area of bare land and construction land continued to increase and the vegetation continued to decrease; From 2015 to 2020, the area of bare land and construction land still increased. From the whole study area, the vegetation coverage in the mining area has been in good condition for many years (Fig.3); From 2000 to 2020, the vegetation decreased year by year, the bare land increased year by year, the change proportion of construction land and water area was the smallest, and the cultivated land was basically stable since 2005 (Fig.4), the largest change in area proportion is vegetation, and the smallest is water (Table2).

Table 3
Mining area of land use type change during different period in Shengli coalfield(km^2)

Year	Urban	Vegetation	Cultivated land	Bareland	Water
2000–2005	0.15	-9.01	7.72	1.19	-0.06
2005–2010	0.88	-29.58	-2.11	30.87	-0.05
2010–2015	0.47	-19.36	-0.25	19.05	0.09
2015–2020	0.25	-13.88	0.21	13.43	-0.01

4.1.2 Spatial pattern change of LUCC

Using ArcGIS 9.2 superposition analysis function, the land utilization transfer matrix was analyzed, and the transfer matrix analysis was performed on the land use data of Shengli coalfield 2000–2020 (Table 3). There is almost no change in the construction land of the mining area; vegetation is mainly transformed into bare land and cultivated land, with transformation areas of 63.66 and 12.36 km^2 respectively; Cultivated land is mainly transformed into bare land and vegetation, with transformation areas of 0.86 and 5.37 km^2 respectively; Bare land is mainly transformed into vegetation, with a transformation area of 0.02 km^2; The water body is mainly transformed into vegetation, with a transformation area of 0.06 km^2 respectively.

Table 4

Land Use Transfer Matrix (km^2)

LUCC		2000					
		Urban	**Vegetation**	**Cultivated land**	**Bare land**	**Water**	**SUM**
2020	**Urban**	0.19	1.55	0.20	0.00	0.00	1.93
	Vegetation	0.00	397.99	5.73	0.02	0.06	403.80
	Cultivated land	0.00	12.36	4.67	0.00	0.00	17.03
	Bare land	0.00	63.66	0.86	0.62	0.05	65.19
	Water	0.00	0.09	0.00	0.00	0.00	0.09
	SUM	0.19	475.64	11.45	0.64	0.11	488.04

4.2 Change analysis of Ecosystem Service Value in Shengli coalfield

Based on the new 2003 China Land Ecosystem Service Value equivalent Table of Unit Area by Xie et al., according to the correction coefficient, one unit ecosystem service value of the Shengli coalfield is calculated,its value is about 310 yuan.And then analysis the value coefficient of ecological system type corresponding to the type of land use. The highest value coefficient is water area, which has great ecological value and function of water conservation and wastes treatment. Secondly, vegetation and cultivated land have similar ecological value coefficients, and both have great ecological value and function in soil formation and protection & waste treatment. The difference between them is that the ecological value coefficient of biodiversity protection of vegetation is higher, and the ecological value coefficient of food production of cultivated land is higher. The ecological value coefficient of bare land is the lowest, which is mainly reflected in biodiversity protection. Generally speaking, the ecological value coefficient corresponding to each land use type in the mining area basically corresponds to its ecological value function.

Table 5
Ecosystem Types and value coefficients of LUCC in Shengli coalfield(yuan·ha^{-1})

Indicators	Vegetation	Cultivated land	Water	Bareland	Constructed land
Gas regulation	248.0	155.0	0.0	0.0	0.0
Climate regulation	279.0	275.9	142.6	0.0	0.0
Water conservation	248.0	186.0	6317.8	9.3	0.0
Soil formation & protection	604.5	452.6	3.1	6.2	0.0
Waste treatment	406.1	508.4	5635.8	6.2	0.0
Biodiversity protection	337.9	220.1	771.9	105.4	0.0
Food production	93.0	310.0	31.0	3.1	0.0
Raw material	15.5	31.0	3.1	0.0	0.0
Entertainment culture	12.4	3.1	1345.4	3.1	0.0
Total	2244.4	2142.1	14250.7	133.3	0.0

According to the ecological value coefficients and land utilization area, the ecosystem service value (Table 6) is calculated in2000,2005, 2010, 2015 and 2020. Between 2000 and 2020, the total change of ecosystem service value of Shengli coalfield was significantly reduced from10.939 billion yuan to9.527 billion yuan, showing a decreasing trend. According to the change rate of the ecosystem service value of the Shengli coalfield (Table 6, Table 7), the value of vegetation ecosystem services was the highest in 2000.

Since 2000, the ecosystem service value of vegetation has decreased year by year, with the highest change of 6.64 billion yuan from 2005 to 2010. The service value of bareland ecosystem increased year by year, with the highest increase of 410 million yuan from 2005 to 2010. The ecosystem service value of cultivated land increased by 165 million yuan from 2000 to 2005. Since 2010, the ecosystem service value has decreased year by year. Until 2020, it rised slightly, the ecosystem service value of water area decreased year by year from 2000 to 2010, increased from 2010 to 2015 and decreased slightly from 2015 to 2020. In general, the ecosystem service value of vegetation in mining area is the highest, followed by cultivated land, and the ecosystem service value of bare land is the lowest.

Table 6
Ecosystem Service Value in Shengli coalfield from 2000–2020 (billion yuan)

Year	Index	Urban	Vegetation	Cultivated land	Bareland	Water	SUM
2000	Value (billion yuan)	0.00	10.675	0.245	0.001	0.018	10.939
	Percentage (%)	0	97.59%	2.24%	0.01%	0.16%	100.00%
2005	Value (billion yuan)	0.00	10.473	0.411	0.002	0.009	10.895
	Percentage (%)	0	96.13%	3.77%	0.02%	0.08%	100.00%
2010	Value (billion yuan)	0.00	9.809	0.366	0.044	0.002	10.22
	Percentage (%)	0	95.98%	3.58%	0.43%	0.02%	100.00%
2015	Value (billion yuan)	0.00	9.374	0.360	0.069	0.014	9.818
	Percentage (%)	0	95.48%	3.67%	0.70%	0.14%	100.00%
2020	Value (billion yuan)	0.00	9.063	0.365	0.087	0.012	9.527
	Percentage (%)	0	95.13%	3.83%	0.91%	0.13%	100.00%

Table 7
ESV change amount per 5 years in Shengli coalfield

Year	Urban	Vegetation	Cultivated land	Bareland	Water
2000–2005	0.00	-2.02	1.65	0.02	-0.09
2005–2010	0.00	-6.64	-0.45	0.41	-0.07
2010–2015	0.00	-4.34	-0.05	0.25	0.12
2015–2020	0.00	-3.12	0.05	0.18	-0.02

4.3 Influence of LUCC on Ecosystem Service Value in coalfield

Through the analysis of the relationship between land use change and ecosystem service value change, we can more intuitively clarify the impact of land use on ecosystem service value. The change of area of different land use types can lead to a large or small change of ecosystem service value. The change of land use area is positively correlated with the change of ecosystem service value. In general, the change range of ecosystem service value is obvious compared with the corresponding land use area. It can be seen that land use change has a significant impact on the change of ecosystem service value. The change rate of cultivated land has decreased year by year since 2005, and the change rate of vegetation has gradually decreased in the same period, and the change range is greater than that of cultivated land. The reason is that in the function of ecosystem service value coefficient, the food production value coefficient of cultivated land is greater than that of vegetation, but the ecological benefit value in the composition of vegetation value coefficient is higher, which is more obvious in the long-term change. It also provides an important reference for the preparation of ecological conservation and restoration planning, long-term follow-up monitoring and effectiveness evaluation in the future.

5. Discussion

The impact of coal resource mining on the ecosystem has the characteristics of a long cycle, wide range and deep degree. The cumulative negative ecological effect intensifies the ecological vulnerability in eastern Inner Mongolia and becomes one of the key factors to reduce the value of ecosystem services(Wu, Z et al., 2020). Aiming at the scientific problem of "temporal and spatial variation law and correlation of land use and ecosystem service value in mining area", taking Shengli mining area, a typical arid and semi-arid vulnerable area in Inner Mongolia, as an example, based on the calculation and analysis of land use types and changes in this area, this study quantitatively evaluates the interaction between land use change and key ecosystem services, The correlation between land use change and temporal and spatial evolution of ecosystem services is revealed. Relevant research results strongly prove the negative impact of open-pit mining on ecosystem services and put forward that mining area ecosystem management should make management decisions from the whole ecosystem, to truly realize the coordination between resource development and environmental protection. In the future government management decision-making, this method can continuously track the evolution of land use patterns and the change of ecosystem services in this area, and try to establish a tracking monitoring and early warning mechanism to appropriately slow down the cumulative trend of ecological negative effects in mining areas.

(1)Usability of the method

This study preliminarily analyzes the impact of open-pit mining on ecosystem services and intuitively analyzes the land use change in the Shengli mining area in recent 20 years by using the land use matrix analysis method and mapping method, which conforms to the characteristics and regularities of mining impact in the mining area. Using the equivalent method, based on the local coefficient correction in Inner Mongolia, the changes of ecosystem services are calculated, which has a certain correlation with the law of land use change. However, the research on the underlying impact mechanism is not deep enough. In addition, this study comprehensively considers the specific situation of the research frontier and the research area, selects 9 kinds of ecosystem services as the research object, and does not calculate all ecosystem services in detail. At present, the relevant conclusions of the research can provide support for the optimal regulation of mining and reclamation projects based on ecosystem services in Shengli mining area, and solve the main contradiction between mining and reclamation and ecological environment protection. However, the research on the impact mechanism of open-pit mining area on ecosystem services and more types of ecosystem services still need to be strengthened.

(2) Implications for the value of ecological services variety

The research on ecosystem service value has been a hot spot since 2000, but most of the research is carried out on the watershed scale, regional scale, or macro scale, and the research objects are mostly natural ecosystems. There is little research on the special natural artificial ecosystem of the open-pit mining area. Under the violent disturbance of human activities, the land use structure and ecosystem service value of open-pit mining areas are bound to change greatly. As the analysis, in 2000–2020, From the regularity of land use change,The area of vegetation, cultivated land and water body in Shengli mining area of Inner Mongolia shows a decreasing trend, while the bare land and construction land show an increasing trend. The largest change in the area proportion is the bare land and the smallest is the water body; From the change of ecosystem service value, the total ecosystem service value in the Shengli mining area decreased from 10.939 billion to 9.527 billion. However, studies by Wang Ning and others show that although the total value of ecosystem services in the Inner Mongolia Autonomous Region changed little from 1990 to 2018, it has been increasing. On the contrary, it can be seen that mining activities have a great impact on the promotion of ecosystem service value.

(3) Consideration of cultural function of construction land and research accuracy

Based on the evolution of land use patterns in Shengli mining area in the recent 20 years, this study analyzes its impact on the change of ecosystem service value and analyzes and summarizes it from the perspective of time and space. However, in the research process, there are still many problems to be solved and worthy of in-depth thinking: first, the consideration of the cultural function of construction land. At present, the research method of calculating ecosystem service function based on the change of land use type is relatively common, but the value equivalent of construction land is often set to 0 in the calculation. In the next step, the equivalent value can be further optimized to be more comprehensive and objective in the calculation of ecosystem service value. Second, due to the availability of remote sensing images, the spatial resolution of the land use classification data of the Inner Mongolia open-pit mining area obtained in this study is not enough to identify and support a more detailed land use and ecological effect assessment of the mining area.

(4) Expand multi-scale research

Expand the space-time scale of research, and carry out multi-scale research on ecosystem services caused by open-pit mining and reclamation. Limited by the available data, the period of this study is 2000–2020, and only one scale of Shengli mining area is considered in the spatial scale. In terms of time scale, it is not refined from the stages of basic construction, mining practices, reclamation and management, and protection according to the implementation characteristics of the project in Shengli mining area. There are problems such as no reclamation after mining, or no timely recovery of a disturbance at the initial stage of reclamation within the research time. The time scale can also be extended for future research to evaluate the change of ecosystem service value comprehensively, systematically Objectively, and conduct simulation evaluation based on the measures taken.

In terms of spatial scale, the project area scale can be selected for future research to deeply explore the impact mechanism of mining and reclamation on ecosystem services, and expand the research system to Xilin Gol League of Inner Mongolia provincial scale to reveal the impact of open-pit mining and reclamation activities on ecosystem services, Based on the characteristics and relationship of the impact of open-pit mining and reclamation on ecosystem services at different scales, a multi-scale coupling model construction can be a new research point in the future.

(5)Construction of multi-scale ecological monitoring system in the mining area

Ecological monitoring, including the monitoring of existing ecological problems and the monitoring of ecological restoration effect, is a very important basic work. Mining areas have caused varying degrees of impact on ecological health all over the world. If various possible impacts can be predicted in advance at less cost and response plans can be formulated in advance, various negative impacts of coal mining on the ecological environment will be greatly reduced. With the increasingly mature 3S technology, it is possible to build a multi-scale mining area ecological monitoring system to control the ecological environment damage caused by coal mining and natural disasters from time to time (Wu Zhenhua, 2020). In the future coal mining in the mining area, based on adhering to the concept of sustainable development and the principles of mining while reclamation, we should build a mining area ecological monitoring system with different precision and multi-dimensional scale. Through monitoring, the mining disturbance law in the mining area is found and the risk is warned. Combined with hyperspectral data, UAV photogrammetry, portable ground object spectrometer and other means to monitor at the same time, compare historical data such as mining and reclamation in the mining area, deeply study the impact of open-pit mining in Shengli mining area and even the whole arid and semi-arid area on ecosystem services, and promote the local government to put forward feasible ecological protection and restoration measures.

(6)Establish a long-term mechanism for realizing the value of ecological products

The mining areas usually have fragile ecological environments. Protecting, maintaining and stably improving the ecosystem service function and value is an important means to improve the well-being of the people and maintain the ecological environment in the mining area. With the publishing of the guidance document on the value realization mechanism of ecological products and the establishment and improvement of relevant mechanisms, people's demand for a better ecological environment is increasing day by day. In recent years, natural resources departments and ecological environment departments have issued typical cases to advocate increasing the supply capacity of ecological products in areas damaged by natural ecosystems through ecological restoration, system governance and comprehensive development, and realizing the value promotion and value spillover of ecological products after ecological restoration by combining with land spatial layout, land use adjustment and industrial policies. To establish a long-term mechanism for realizing the value of ecological products in mining areas with fragile ecological backgrounds, it is necessary to protect the fragile ecological environment of mining areas through unified planning and design, starting from the whole life cycle of mining, and "integrated planning, integrated implementation and integrated effect" of mineral resource mining, ecological protection and restoration, industrial development and improvement and Realization of the value of ecological products.

6. Conclusion

Through the analysis of the relationship between land use change and ecosystem service value, we can more intuitively clarify the impact of land use on ecosystem service value. The results show that: (1) among the different land use types in the Shengli mining area, vegetation is the main land-use type, followed by bare land and cultivated land. From 2000 to 2020, the construction land in the mining area has hardly changed; Vegetation, cultivated land and water body show a decreasing trend, while bare land and construction land show an increasing trend. The largest change in area proportion is bare land and the smallest is water body.(2) Vegetation is mainly transformed into bare land and cultivated land, with transformation areas of 63.66 and 12.36 km^2 respectively; Cultivated land is mainly transformed into bare land and vegetation, with transformation areas of 0.86 and 5.73 km^2 respectively; Bare land is mainly transformed into vegetation, with a transformation area of 0.02 km^2; The water body is mainly transformed into vegetation, with a transformation area of 0.06 km^2 respectively（3) The total ecosystem service value of the mining area decreased from 10.939 billion yuan to 9.527 billion yuan, showing a decreasing trend. Among them, the vegetation ecosystem service value is the highest, followed by cultivated land and water body, and the bare land ecosystem service value is the lowest.（4) From the spatial scale, the total ecosystem service value of Shengli mining area decreases year by year, the bare land ecosystem service value increases year by year, the vegetation ecosystem service value decreases year by year, and the interannual change of cultivated land and water ecosystem service value is irregular.

Declarations

Author contributions Lijia Zhang：Writing original draft&Data processing，reviewing and editing.Xu Zhou：Reviewing，Editing &corresponding.Yan Zhou：Reviewing.Ji Zhou：Reviewing .Jiwang Guo：Data processing&Typesetting.Zihan Zhai：Checking and Other Auxiliary.Yan Chen：Checking and Other Auxiliary.Xiang Yan Su：Checking and Other Auxiliary.Lingxiao Ying：Checking and Other Auxiliary.Liwei Wang：Checking and Other Auxiliary.Ying Qiao：Checking and Other Auxiliary.

Conflict of interest All the authors of this manuscript have approved the article's submission for publication，and there are no conflicts of interest to declare.This paper has not been published previously，in whole or in part，and is not under consideration by another journal.

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Figures

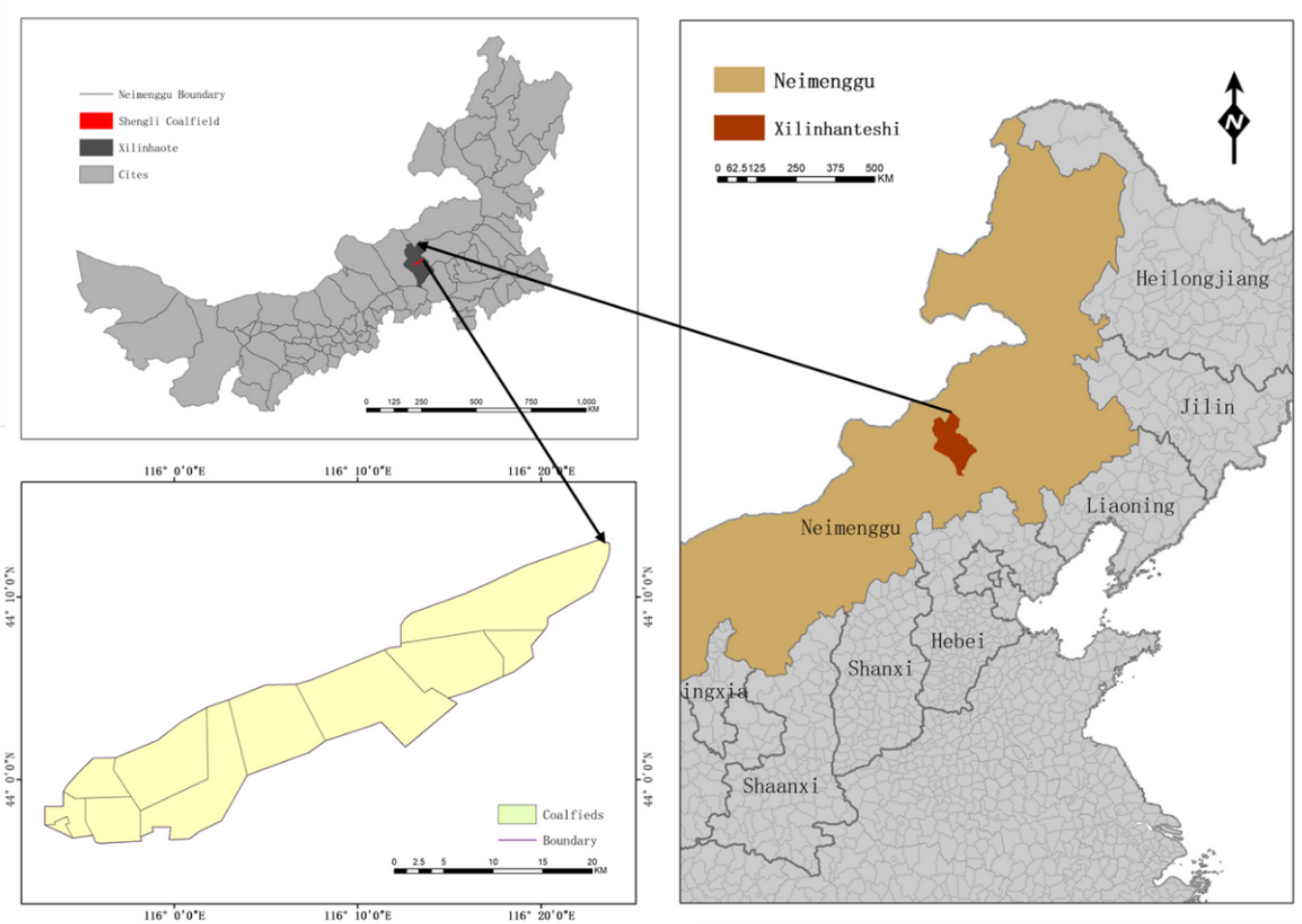

Figure 1

Location of Shengli Coalfield

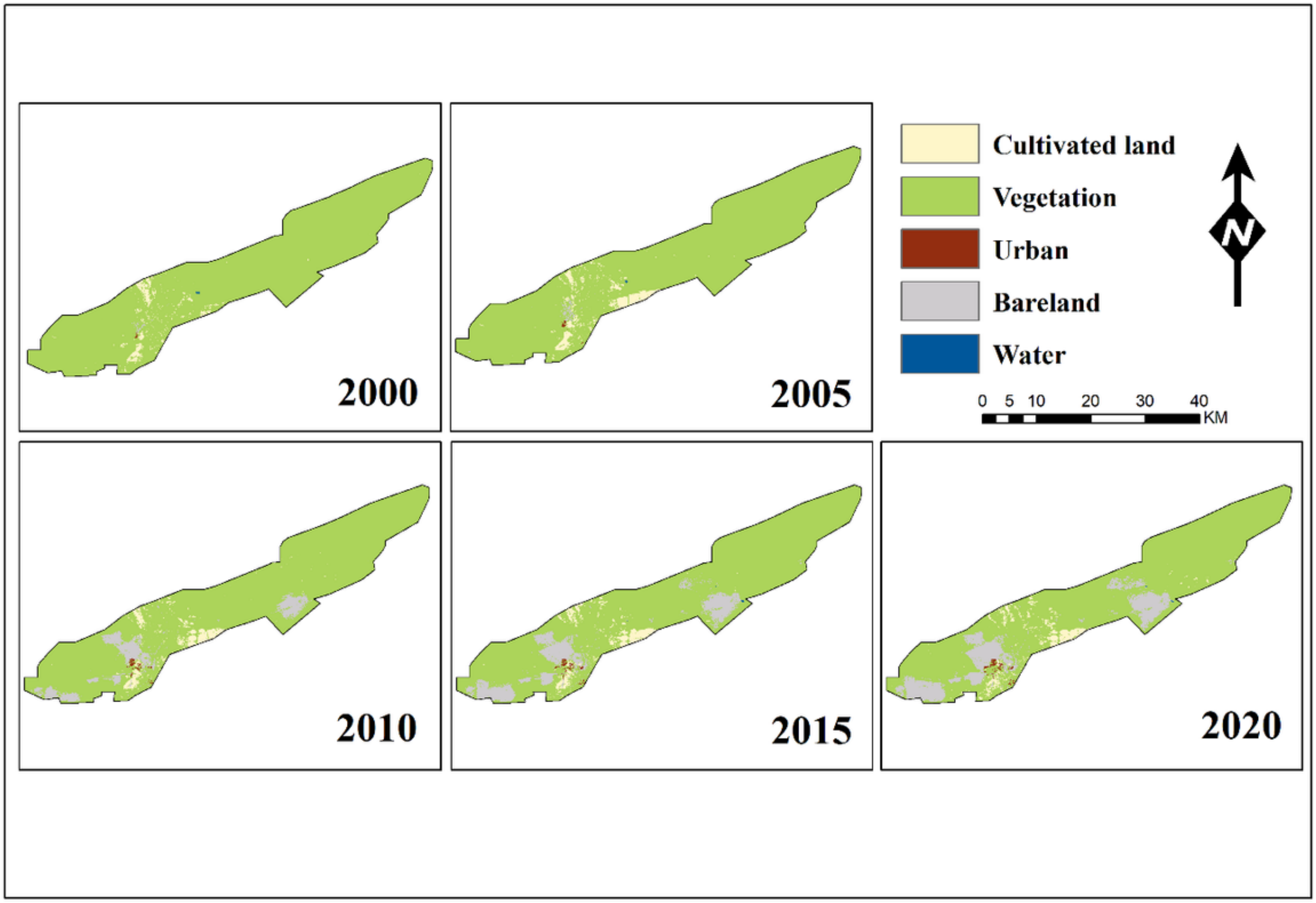

Figure 2

Mining area distribution of land use status in different periods in Shengli Coalfield

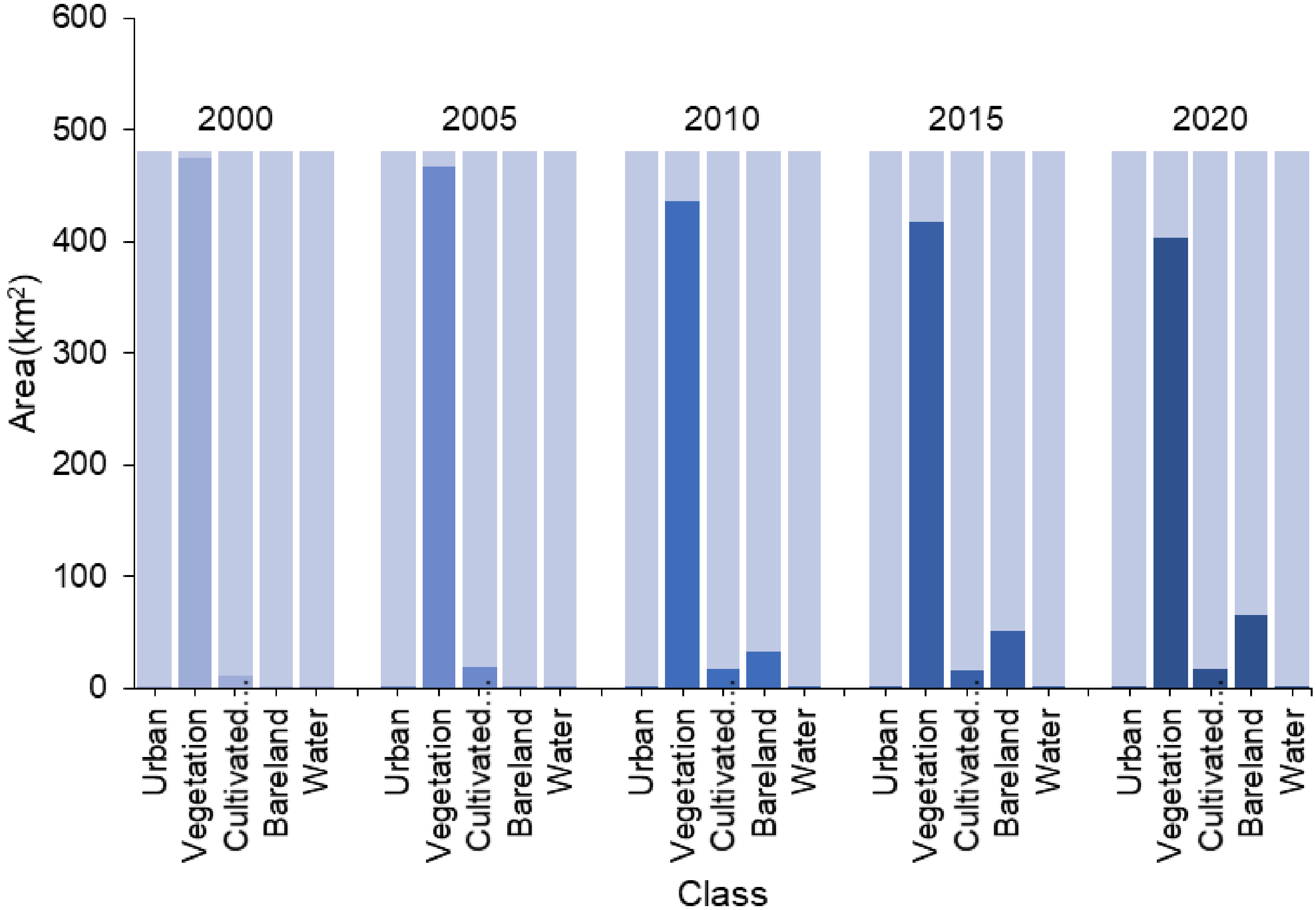

Figure 3

Statistical information of LUCC classification

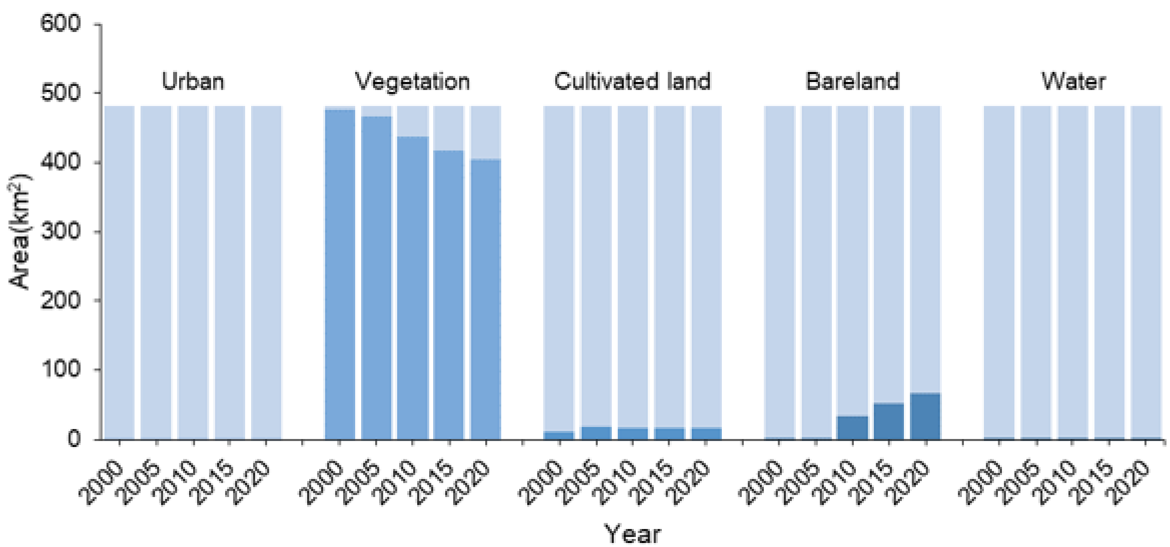

Figure 4

Area of various LUCC change from 2000 to 2020

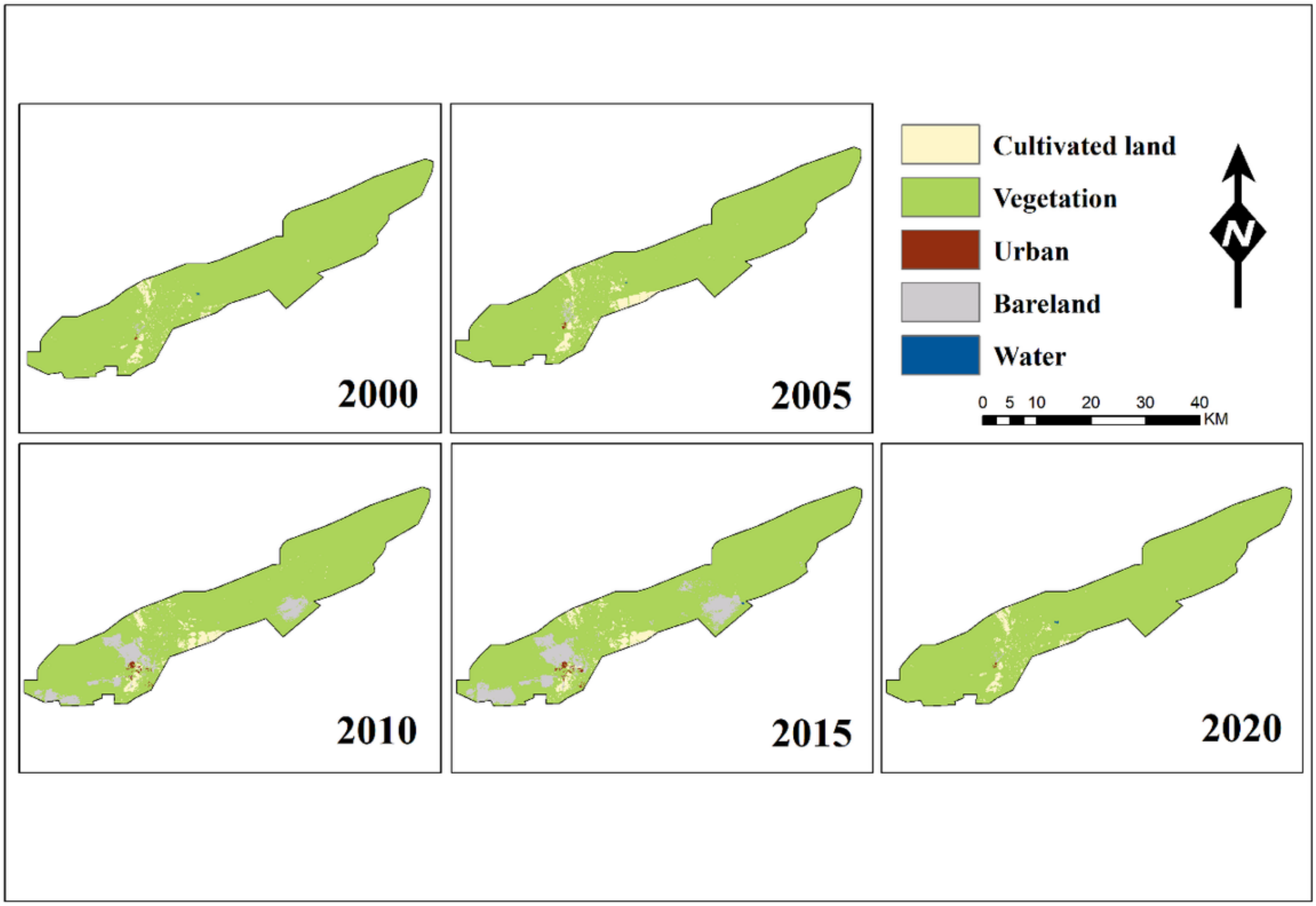

Figure 5

Maps of LUCC change from 2000 to 2020

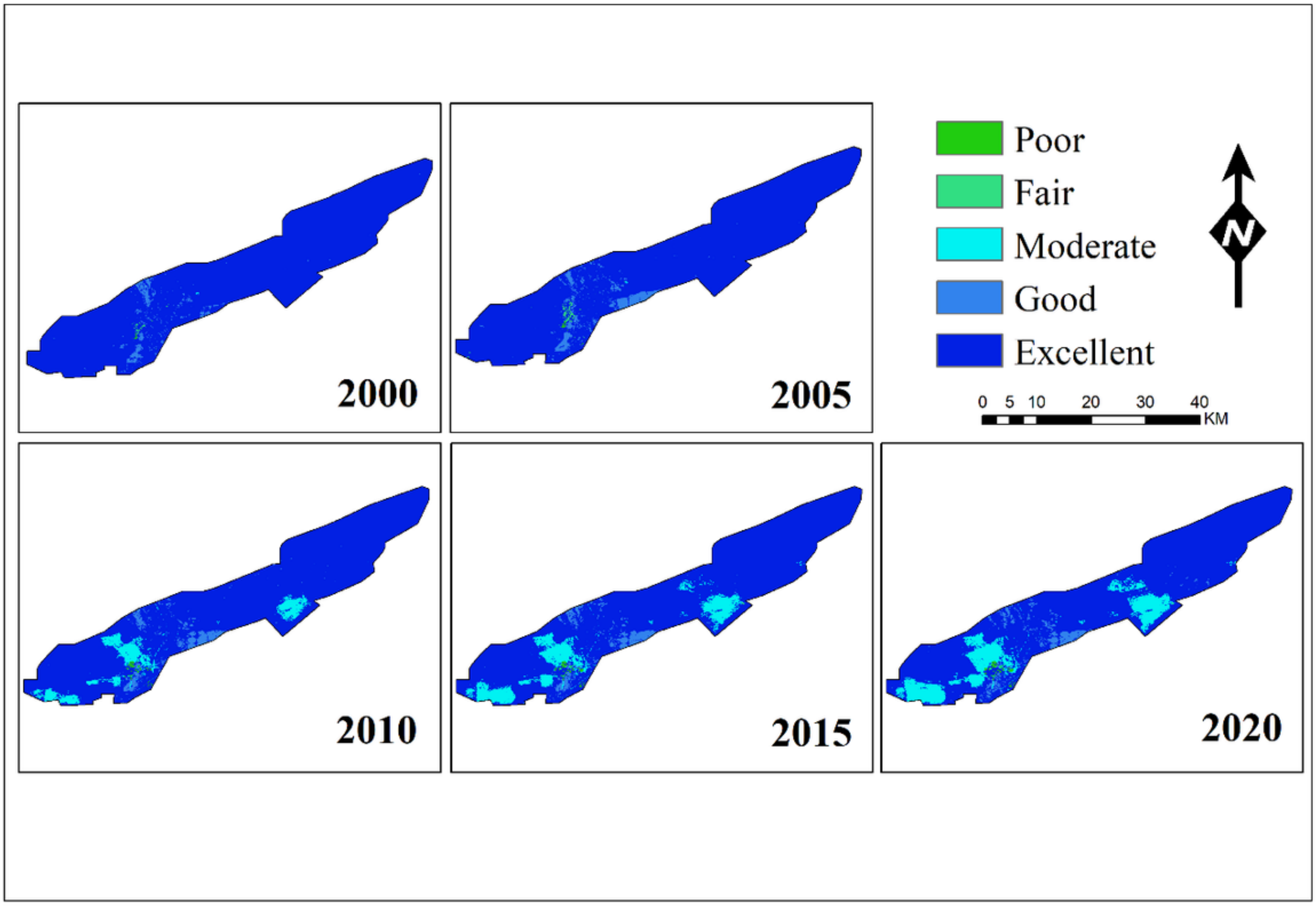

Figure 6

Maps of ESV classification from 2000 to 2020 using natural segment method.

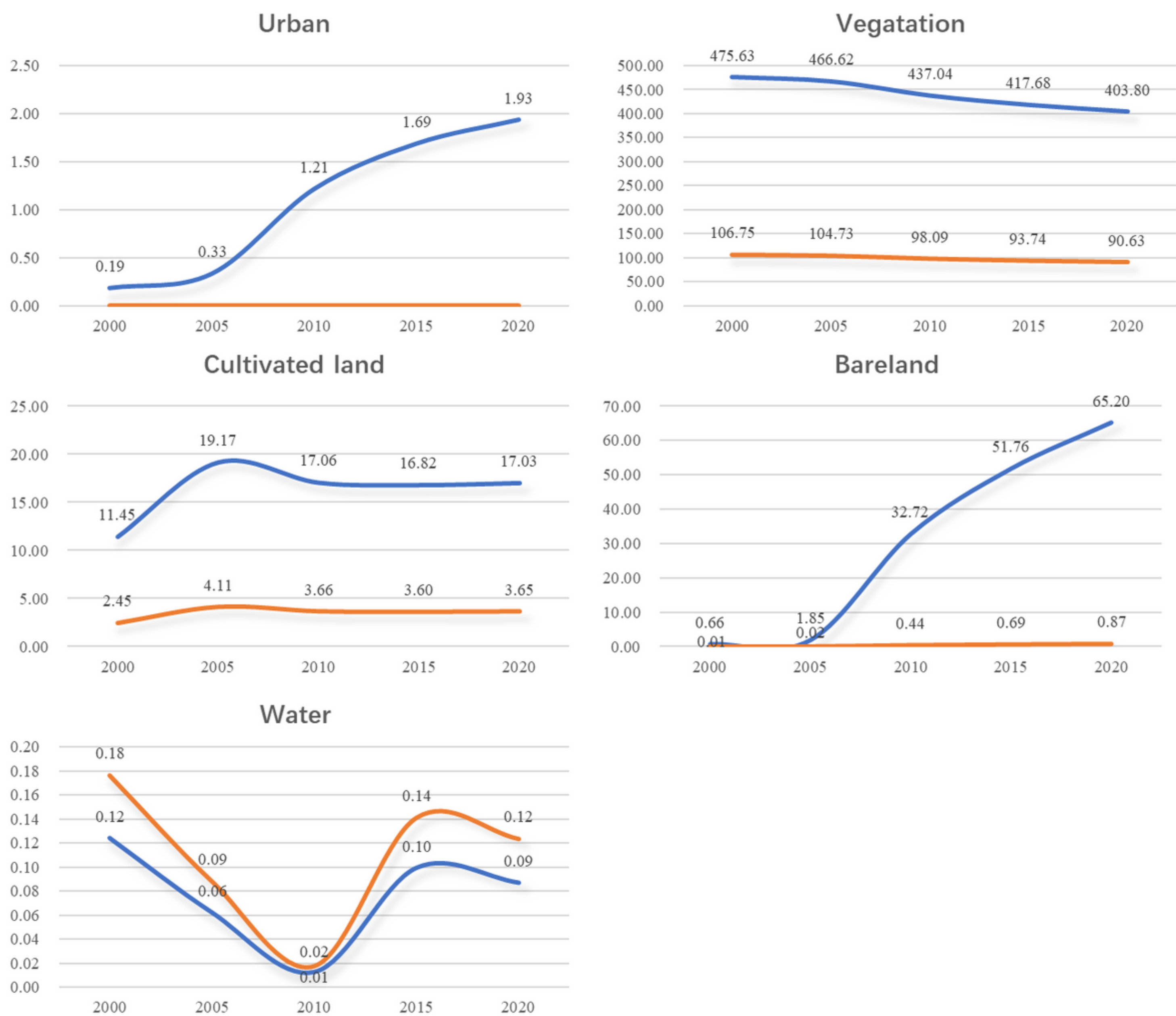

Figure 7

variation of Land use area and ecosystem service value from 2000-2020

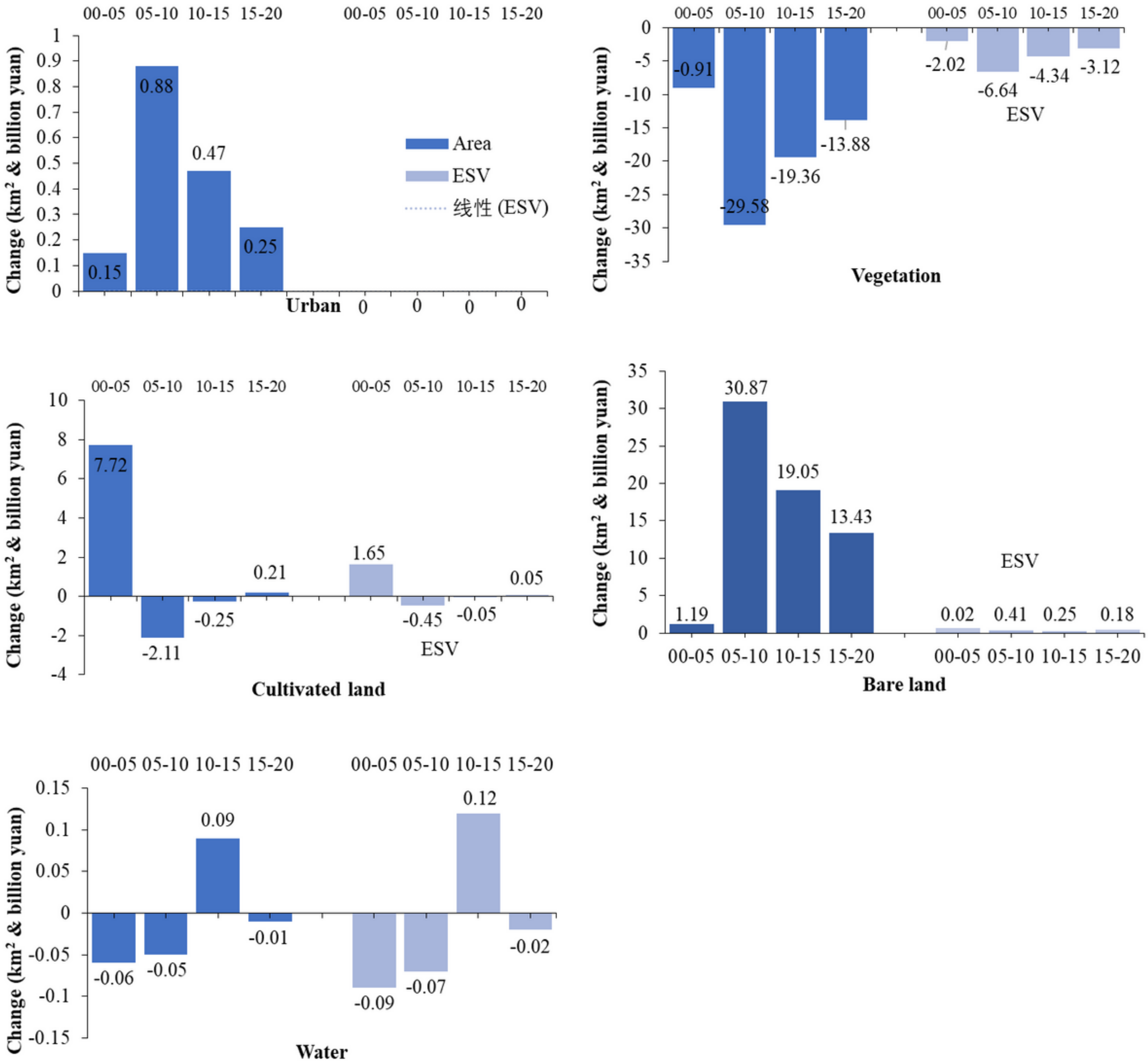

Figure 8

variation of Land use area and ecosystem service value per change period.