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Evaluation and Tradeoff of Ecosystem Services in Jiaozuo

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Abstract

With the continuous development of the economy and society, the demand for land space for human survival has also increased, which means that the pressure on ecosystem services has also been unprecedentedly high, leading to serious problems such as ecological environment deterioration and system function decline, resulting in fierce conflicts between ecological environment protection and human social development. Therefore, the relationship between ecosystem services and economic and social development has become a hot research topic in the field of land ecology. Jiaozuo City is also facing the problem of ecological degradation. In order to achieve coordinated development of ecology, society, and economy, this article analyzes the spatiotemporal changes in land use/cover in Jiaozuo City from 1995 to 2020. The InVEST model is used to evaluate four types of ecosystem services in Jiaozuo City: water production, carbon storage, soil conservation, and nutrient output; Summarize and summarize the spatiotemporal distribution characteristics and evolution laws of ecosystem services, and explore the trade-off and synergistic relationships between ecosystem service functions and their driving factors. The research results indicate that: (1) The main types of land use/cover in Jiaozuo City are arable land (64.5%), forest land (approximately 9.9%), grassland (1.1%), water area (0.6%), and construction land (23.8%). The changes in land use types are relatively small. (2) From 1995 to 2020, the biomass and spatial distribution evolution of the four ecosystem services in Jiaozuo City varied. There are significant interannual differences in water production services, and the spatial distribution of water production in the western region is lower than that in the eastern region. The southern region is lower than the northern region. The interannual variation of nutrient (phosphorus) output is relatively small, and the spatial distribution pattern varies greatly, showing a high and low value clustering distribution pattern. The interannual difference in soil conservation is relatively small. The interannual differences in carbon storage are small, and the annual spatial distribution is irregular. (3) Each ecosystem service is influenced by different natural and social influencing factors, and the contribution rate of natural factors is higher than that of social factors. There is a significant difference in the output capacity of ecosystem services among different land uses/covers, which directly affects the total amount and spatial distribution of ecosystem services. The ecological status of Jiaozuo City is worrying. In the future socio-economic development process, reasonable planning of land use should be carried out to vigorously ensure the parallel and healthy development of social economy and ecological environment.

Keywords: land use change, ecosystem services, weigh the synergy, drivers

1. Introduction

Ecosystems are the space in which humans live and the prerequisite environment for social development and progress (Wang Rongyao, Zhao Junsan, Chen Guoping, Lin Yilin, Yang Anran & Cheng Jiaqi, 2022). They not only provide the physical space for human survival, but also supply the resources necessary for human life, and they can also play a role in being responsible for absorbing the production and living waste produced by humans (Huang Chong, Zhang Chenchen & Li He, 2022). Ecosystem services are the natural environmental conditions and utilities that ecosystems create and maintain on which humans depend for survival, providing all the benefits humans receive directly or indirectly from ecosystems. Ecosystem services are the natural environmental conditions and products of the natural environment on which humans depend to survive and sustain ecosystems and ecological processes (Zhong Cheng, Bei Yiming, Gu Hongliang & Zhang Pengfei, 2022). Ecosystem services provide us with the necessities of life and the environmental conditions for living things to survive. The study of ecosystem services is of great importance to the conservation of the ecological environment as a result of the predatory exploitation of the earth's natural resources, which has resulted in major changes to the landscape and consequent damage to the ecological environment due to increased human demand of all kinds. Global and regional environmental, ecological and resource problems are at odds with the reality of economic growth, resulting in a dramatic increase in economic material wealth and a sharp decline in total natural capital, increasing environmental pollution, a growing ecological crisis and a rapid decline in the services of natural ecosystems. The degradation of ecosystem services in turn affects human well-being and socio-economic development, ultimately posing a direct threat to the ecological basis of sustainable human development. This paper is based on an analysis of land-use cover changes in resource-based cities during the transition period and an assessment of the resulting changes in the biomass of ecosystem services, and a comprehensive analysis of the dynamic changes in the biomass of ecosystem services, as well as the types of expression and mechanisms of ecosystem service trade-offs and synergies, in order to provide a reference for the ecological construction of similar cities during the transition process (Gashaw Temesgen, Worqlul Abeyou W., Dile Yihun T., Sahle Mesfin, Adem Anwar A., Bantider Amare, Teixeira Zara, Alamirew Tena, Meshesha Derege T. & Bayable Getachew, 2022).

2. Study Area and Research Methodology

2.1 Study Area

This paper takes Jiaozuo city as the study area, which is located in the northwestern part of Henan province, on the northern bank of the Yellow River and the southern foot of the Tai hang Mountains, at the throat of North China, East China and Central China leading to the northwest, with geographical coordinates between 35º10′-35º21′ North latitude and 113º4′-113º26′ East longitude (Zhao Yanqi, Yang Ying, Leszek Sobkowiak & Wang Xinyi, 2021). The city is 102.05 kilometers long from east to west and 75.43 kilometers wide from north to south, with a total land area of 4,000.89 square kilometers (Zhang Yongling, Li Xin, Kong Nana, Zhou Miao & Zhou Xiaobing, 2022). It has four administrative districts, namely Shanyang District, Jiefang District, Zhongzhan District, Mamura District and a high-tech economic development zone, four counties, namely Boai County, Wuzhi County, Xiuwu County and Wen County, and two county-level cities, Qingyang and Mengzhou. It is adjacent to Huijia County, Huixian City and Yuanyang County in Xinxiang City to the east, Zhengzhou City and its Xingyang County, Gongyi City and Yanshui County and Mengjin County in Luoyang City to the south across the Yellow River, Jiyuan City to the west and Jincheng City in Shanxi Province to the north.

2.2 Research Methodology

The InVEST model (Integrated Valuation of Ecosystem Services and Trade-offs) is a free and open-source model developed by Stanford University, The Nature Conservancy (TNC) and the World Wildlife Fund (WWF) as part of the Natural Capital Project to measure a wide range of ecosystem services (e.g., carbon sink capacity, biodiversity, soil conservation, water purification, water retention, etc.). The InVEST model is a free and open-source model for quantifying a wide range of ecosystem services (e.g., carbon sink capacity, biodiversity, soil conservation, water purification, water harvesting, etc.) developed as part of the Natural Capital Project. This article uses the InVEST model to evaluate the spatiotemporal changes in water production services, soil conservation services, carbon sink capacity services, and water quality purification services during the 1995s-2010s and 2010s-2020 time periods using basic climate, land use, and other data.

3. Research Findings

3.1 Land Use Change

From 1995 to 2020, the land use types in Jiaozuo City were mainly divided into six categories: arable land, forest land, grassland, water area, construction land and unused land, and because of its location in a grain-producing area, the main land use type in the city was arable land, which accounted for more than 60% of the total area of the study area. The proportions of land use types in Jiaozuo are, in descending order, arable land, construction land, forest land, grassland, water area and unused land (Table 1). The analysis of land-use change has led to the following:

In 1995, the area of arable land in Jiaozuo was 29276.63 hm², accounting for 73.74% of the total area of Jiaozuo, followed by construction land 5193.06 hm², forest land 4064.07 hm² and grassland 890.14 hm², accounting for 13.08%, 10.24% and 2.24% of the total area of Jiaozuo respectively; the area of water area was smaller at 275.14 hm². The area of unused land is the smallest at 0.09 hm², which is negligible compared to the total area of Jiaozuo.

In 2010, the area of arable land in Jiaozuo was 26796.75 hm², a decrease of 2479.87 hm² compared to 1995, followed by construction land of 7605.54 hm², forest land of 4269.64 hm² and grassland of 751.65 hm², an increase of 2412.47 hm², 205.56 hm² and a decrease of 138.49 hm² respectively compared to 1995. From 1995 to 2010, the area of arable land, grassland and water area decreased, while the area of forest land, construction land and unused land increased.

In 2020, the area of arable land in Jiaozuo will be 25,630.76 hm², 1,165.98 hm² less than in 2010; followed by construction land of 9,446.19 hm², forest land of 3,938.95 hm² and grassland of 431.64 hm², respectively 1,840.65 hm² more, 330.68 hm² less and 320.01 less than in 2010; the area of the watershed is smaller at 250.54 hm², 21.66 hm² less than in 2010; and the area of unused land is the smallest at 1.05 hm², 2.31 hm² less than in 2010. The area of arable land, forest land, grassland, watershed and unused land decreases from 2010 to 2020, and the area of land for construction increased significantly.

The changes in the overall area of land use types in Jiaozuo from 1995 to 2020 are more prominent, with a significant decrease in the area of arable land, forest land, grassland, water and unused land and an increase in the area of construction land. The area of arable land decreased from 29276.63 hm² in 1995 to 25630.76 hm² in 2020, a decrease of 12.45%; the area of forest land decreased from 4064.07 hm² in 1995 to 3938.95 hm² in 2020, a decrease of 3.08%; the area of grassland decreased from 890.14 hm² in 1995 to the area of water decreased from 275.14 hm² in 1995 to 250.54 hm² in 2020, a decrease of 8.94%; the area of built-up land increased from 5,193.06 hm² in 1995 to 9,446.19 hm² in 2020, an increase of 81.9%; and the area of unused land increased from 0.09 hm² in 1995 to 0.9 hm² in 2020. The area of unused land increased from 0.09 hm² in 1995 to 1.05 hm² in 2020, an increase of 96.36%.

Table 1. Area and change by land use type in Jiaozuo City, 1995-2020

Unit: hm²

	1995	2010	2020	1995-2010	2010-2020
Arable land	29276.63	26796.75	25630.76	-2479.87	-1165.98
Woodland	4064.07	4269.64	3938.95	205.56	-330.68
Grassland	890.14	751.65	431.64	-138.49	-320.01
Water area	275.14	272.20	250.54	-2.94	-21.66

Building	5193.06	7605.54	9446.19	2412.47	1840.65
Unused land	0.09	3.36	1.05	3.26	-2.31

3.2 Ecosystem Services Assessment

The InVEST model was used to assess water production, carbon storage, soil conservation and nutrients in Jiaozuo in 1995, 2010 and 2020 respectively, and spatial statistics were applied to obtain data on the spatial distribution of ecosystem services in Jiaozuo and to analyses changes in its spatial and temporal patterns.

3.2.1 Spatial and Temporal Evolution of Water Yield in Jiaozuo City

In this study, the InVEST model was used to simulate water production under different climatic and land use conditions in 1995, 2010 and 2020 respectively. The total annual water production in Jiaozuo in 1995, 2010 and 2020 was 3.03×10^8 m^3, 5.51×10^8 m^3 and 7.29×10^8 m^3 respectively. The average annual water production in Jiaozuo between 1995 and 2020 was 76.56 mm, 139.00 mm and 184.19 mm, with an increasing trend over time. The highest water production was in 2020 and the lowest in 1995. The water production in 2010 increased by 2.48×10^8 m^3 or 81.8% compared to 1995, and the water production in 2020 increased by 1.78×10^8 m^3 or 32.3% compared to 2010. The water production in the region in 2020 was basically 2-3 times that of 1995. Overall, from 1995 to 2020, the total water production in the basin increased by 4.26×10^8 m^3, with an average annual water production of 107.63 mm. The multi-year average water production was 5.28×10^8 m^3, with an average multi-year water production of 133.25 mm. The spatial distribution of water production in Jiaozuo from 1995 to 2020 shows that the spatial distribution of water production in Jiaozuo is the spatial distribution of water production in Jiaozuo is uneven and varies greatly from year to year. The spatial distribution characteristics show that the average depth of water production in Jiaozuo is highest in 2020 and lowest in 1995. The distribution across Jiaozuo is characterised by lower water production in the south than in the north and in the west than in the east, with the highest water production in the central core of the city. The municipal spatial distribution of water production is as follows (Unit: mm):

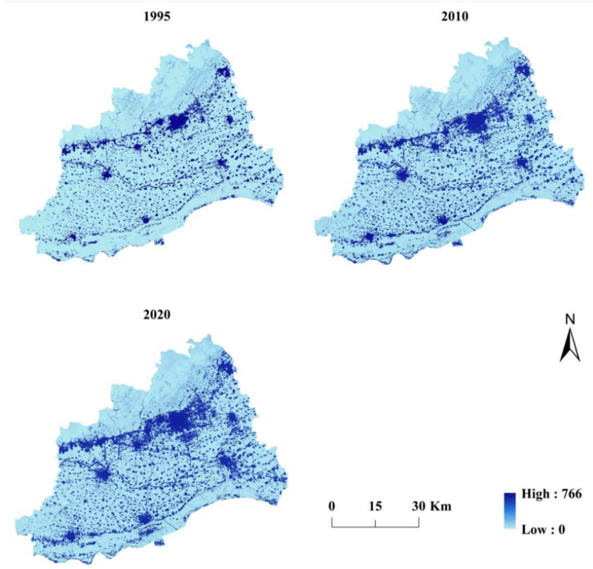

Figure 1. Distribution of water production in Jiaozuo City from 1995 to 2020

3.2.2 Spatial and Temporal Evolution of Soil Conservation in Jiaozuo City

Soil retention in Jiaozuo City was 9.07×10^8 t, 11.56×10^8 t and 13.95×10^8 t in the three study periods. The variation in soil retention within the region was small and showed a gradual increase over time, with an increase of 2.49×10^8 t in the fifteen years from 1995 to 2010. The highest soil retention was produced in 2020 and the lowest in 1995. In terms of the individual counties within Jiaozuo City, the variation and distribution of soil retention in Jiaozuo City show a small inter-annual variation, but the differences between counties are more obvious. The highest soil retention in Jiaozuo City is in Xiuwu County, where the average soil retention from 1995 to 2020 reached 547.09 t, 663.25 t and 820.03 t respectively, followed by Zhongzhan District, where the average soil retention from 1995 to 2020 reached 487.43 t, 606.87 t and 738.86 t respectively, while other districts and counties have very low soil retention. The distribution of soil conservation in Jiaozuo City between 1995 and 2020 shows that the distribution of soil conservation in Jiaozuo City has a small inter-annual variation, with large differences in spatial distribution between counties and districts within the city. From the whole of

Jiaozuo City, the high values of soil conservation in Jiaozuo City are mainly distributed in the northern and eastern parts of Jiaozuo City in these urban centres. Soil retention in these areas exceeds 100 t. Soil retention in Jiefang District, Macun District and Shanyang District is very high, with soil retention in these areas exceeding 110 t, 200 t and 280 t from 1995 to 2020, while soil retention in other areas is generally low, mostly remaining at 100 t or less. The spatial distribution of soil retention in the municipality is as follows (Unit: t):

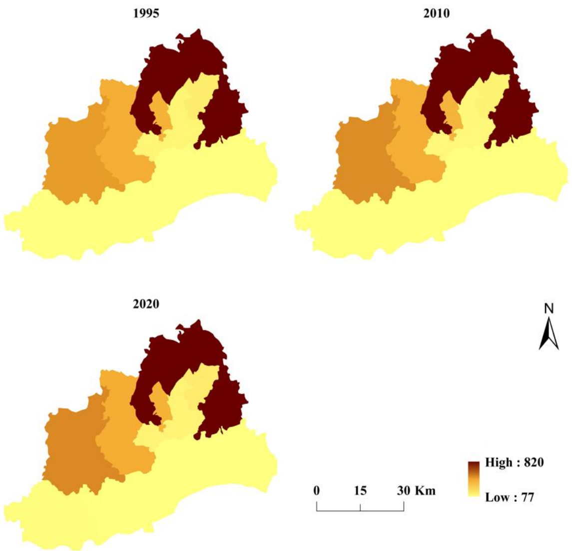

Figure 2. Distribution of Soil Conservation County in Jiaozuo City from 1995 to2020

3.2.3 Spatial and Temporal Evolution of Carbon Storage in Jiaozuo

The reality of carbon storage in Jiaozuo City in 1995, 2010 and 2020, as shown in the figure, was analysed for spatial and temporal variation. After the statistics, the total carbon storage in the study area is 1995 (2.63×10^7 t), 2010 (2.81×10^7 t) and 2020 (3.45×10^7 t), the carbon storage is continuously increasing during the twenty-five years, relative to 1995, the total carbon storage in Jiaozuo City in 2010 has increased (0.18×10^7 t), relative to 2010, the 2020 Jiaozuo's total carbon stock has increased and carbon sequestration resources have been preserved to some extent. The carbon density (average carbon storage per hectare) of each district and county fluctuates relatively steadily over the study period. In terms of the average carbon density of each district and county, Mengzhou City has the highest carbon density at 84.36 t, followed by Wen County at 82.12 t, Wuzhi County at 80.24 t, Qingyang City at 73.98 t, Boai County at 73.22 t. These five districts and counties all have a carbon density of over 70 t. Between 1995 and 2020, carbon stocks showed a large interannual spatial and temporal distribution. From a municipal perspective, the areas with the highest carbon density from 1995 to 2010 are located in the southern and central plains of Jiaozuo City, with large interannual variation and an increasing trend in carbon density; from 2010 to 2020, the average value of carbon density continues to increase, and the areas with low carbon density show a trend of expansion from the previous urban construction land to the surrounding areas.

The overall spatial distribution of carbon storage services varies over time, with the period 1995-2010 showing strong carbon sequestration capacity and high carbon intensity values in the southern and central plains; the period 2010-2020 shows a significant change, with the carbon sequestration capacity continuing to strengthen and the areas with high carbon intensity values increasing more than in 1995-2010. The northern mountains and the central and southern parts of Jiaozuo City are the main carbon storage service areas of Jiaozuo City. The spatial distribution of carbon stocks in the municipality is as follows (Unit: t):

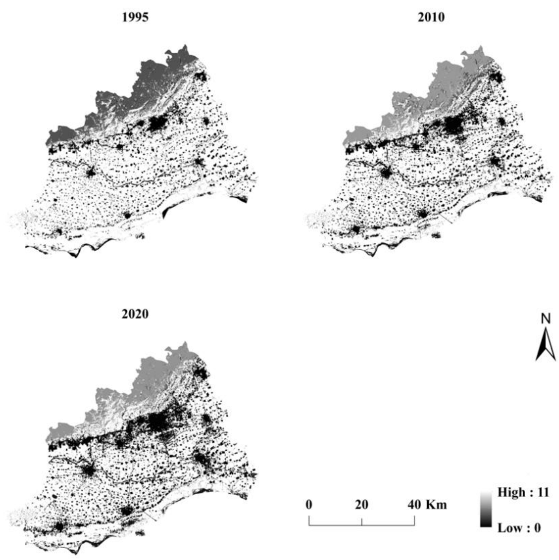

Figure 3. Distribution of carbon storage in Jiaozuo City from 1995 to 2020

3.2.4 Spatial and Temporal Evolution of Nutrient Output in Jiaozuo

The total phosphorus output in Jiaozuo City was

4.79×10^4 t, 4.46×10^4 t and 4.31×10^4 t in the three years from 1995 to 2020, respectively. The average annual growth rate of phosphorus nutrient output was -8.19 kg/ha from 114.98 kg/ha in 1995 to 106.79 kg/ha in 2010, and -3.47 kg/ha from 106.79 kg/ha in 2010 to 103.32 kg/ha in 2020, but the growth rates of different time periods showed significant differences. Analysing all districts and counties in Jiaozuo as a whole, six districts and counties had a phosphorus output of more than 120 kg/ha in 1995, with the highest to lowest outputs being Mengzhou, Wen, Boai, Wuzhi, Macun and Shanyang districts, with 146.84 kg, 132.45 kg, 131.74 kg, 131.33 kg, 129.94 kg and 128.29 kg, respectively. The districts with lower output were Jiefang District, Xiuwu County and Zhongzhan District, with less than 115 kg of phosphorus output per hectare. four districts and counties with phosphorus output exceeding 120 kg per hectare in 2010 were Mengzhou City, Wen County, Wuzhi County and Boai County. the districts and counties with lower phosphorus output in 2010 were Jiefang District and Xiuwu County, both with less than 100 kg. in 2020, the districts with phosphorus output exceeding 120 kg from in 2020, the districts with phosphorus output of more than 120 kg were Mengzhou and Boai counties, and the districts with phosphorus output of less than 100 kg per hectare in 2020 were Jiefang, Macun and Shanyang districts.

In terms of the three-year average, the top four districts and counties in terms of nutrient output are Mengzhou City, Wen County, Wuzhi County and Boai County, with the trend being that nutrient output is lower in the mountains than in the plains. As it is the better the water quality of a certain area, the smaller the value of its nutrient output. Therefore, from the above analysis of the nutrient output values in Jiaozuo, it can be concluded that the water quality in the mountainous areas of Jiaozuo is better than that in the plains. This indicates that the water purification function of mountainous ecosystems in Jiaozuo is stronger than that of the plains.

The spatial distribution of nutrient phosphorus output in Jiaozuo from 1995 to 2020 is characterized by large intra-annual spatial distribution differences and small inter-annual differences. From the following map of the spatial distribution of nutrient phosphorus output in Jiaozuo, it can be seen that the areas with high phosphorus output in Jiaozuo are mainly located in the central, southern and southwestern plains and scattered locations in the northern mountainous areas. In terms of administrative districts, the Mengzhou city region has values of 130-150 kg/ha of phosphorus output, which is the highest in the Jiaozuo city region. Overall, the values for phosphorus output in the northern and northwestern mountainous areas are lower than those in the southeastern and southern plains, indicating that the mountainous ecosystems of Jiaozuo City function better than the plains in purifying water and that water quality is better within the mountainous areas of Jiaozuo City. (Unit: kg)

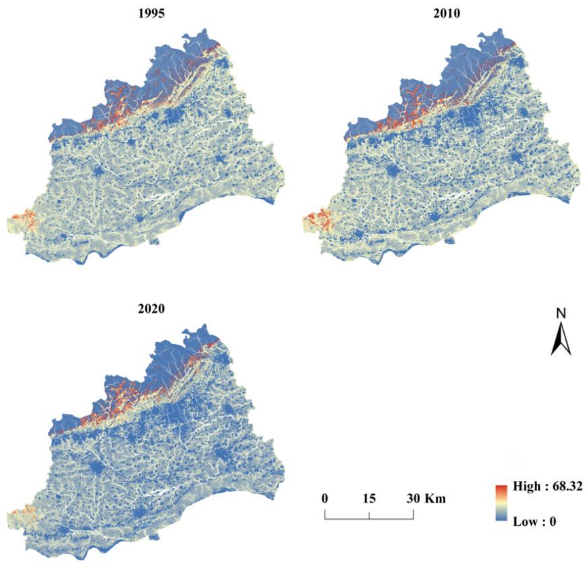

Figure 4. Distribution of Nutrient Output in Jiaozuo City from 1995 to 2020

3.3 Ecosystem Service Trade-Offs

The correlation between ecosystem services, in roll-out situations, generally manifests itself as synergy or interaction between individual ecosystem services in a complex way, with some relationships manifesting themselves as a trade-off and others as a mutually reinforcing relationship, that is, as one ecosystem service increases in change, another ecosystem service produces a decrease in change, or one of the types of ecosystem services increase while another exhibits an increase in another ecosystem service, which can lead to trade-offs or synergistic expressions between ecosystem services. This study calculated the interrelationships between the ecosystem services based on Pearson correlation analysis.

Table 2. Interrelationships between ecosystem services

	AWY	CS	SDR	NDR
AWY	1			
CS	-0.857**	1		
SDR	-0.587**	0.756**	1	
NDR	-0.102**	-0.042	-0.066*	1

Based on the results of the study, it was shown that there was a significant negative correlation between water production and carbon storage (r = -0.857**, p<0.01), a significant negative correlation with soil retention (r = -0.587**, p<0.01) and a significant negative correlation with nutrient output (r = -0.102**, p< 0.01); areas with high water production values corresponded to low values of carbon storage and nutrient export in the region.

There is a significant positive correlation between carbon storage and soil retention (r = 0.756**, p<0.01). When carbon storage is high in the region, soil retention is also relatively high, and when carbon storage decreases in the region, soil retention services also decrease accordingly. The correlation between carbon storage services and nutrient export services was not significant in this study.

There is a negative correlation between soil conservation and nutrient export (r = -0.066*, p<0.01), which means that when soil conservation services increase in an area, the corresponding nutrient export services in the area also increase. The areas with high values of soil conservation and nutrient export services are mountainous and hilly areas. These areas are mostly woodlands and grasslands with a high proportion of green vegetation. Due to their high vegetation occupancy, these green plants can, through their own characteristics, contain water, reduce soil erosion, adsorb and fix carbon in the atmosphere, and effectively mitigate the greenhouse effect in Jiaozuo. Areas with good soil conservation can increase the amount of soil carbon stored in the area and reduce carbon emissions to the air, based on functions such as soil chemical stabilisation mechanisms. In turn, the increased ability of the soil itself to purify water can contribute to an increase in the organic carbon and organic matter content of the soil, thereby reducing soil erosion and loss. Thus, soil conservation services and nutrient export services show a mutually supportive relationship.

The relationships between ecosystem services are not isolated from each other but rather show interdependence and checks and balances. Based on the above analysis of the relationships between ecosystem services in this study, it is concluded that water production services and carbon storage services in Jiaozuo City show a trade-off relationship, i.e., areas with a high production value of water have a low production value of carbon storage. Woodlands and grasslands, with their high vegetation cover, have a high capacity for water storage and carbon sequestration due to the nature of the plants in the area, and therefore, under the same climatic conditions, woodlands and grasslands, which are the two types of use, have a low production value of water production services and a high production value of carbon storage. Thus, the trade-off between water production services and carbon sequestration services appears to be a combination of factors that influence each other. A negative trade-off is shown between nutrient export and soil conservation, indicating that a decrease in the function of soil conservation services in a given area is accompanied by an increase in nutrient export services in that area and vice versa. Soil conservation services and carbon storage services are negatively correlated, with a trade-off between them showing mutual inhibition. There is a significant positive correlation between nutrient export and carbon storage, which is the reason why when Jiaozuo City adopts measures to increase the supply of one ecosystem service, it can also have an increasing effect on the other, thus doubling the gain in the ecosystem services in Jiaozuo City.

4. Conclusion

Taking Jiaozuo City as the study area, its administrative divisions were divided into 10 sub-units. According to the development characteristics of Jiaozuo City in different historical periods, the period 1995-2020 was divided into two study periods, 1995-2010 and 2010-2020, and the land use/cover types, landscape patterns and their characteristics of Jiaozuo City in these two periods were studied respectively. The InVEST model was applied to assess the ecosystem services in Jiaozuo City and to explore their spatial and temporal distribution, summarise and summarise the evolutionary patterns of ecosystem services, analyse the combined influence of multiple factors on ecosystem services, the characteristics of spatial cold hotspot aggregation and distribution, as well as the detailed detection of trade-offs and driving factors among ecosystem services, in order to provide a basis for the regional. This paper provides a basis for the scientific development of the regional ecological economy in the process of urban transformation and development in Jiaozuo City. The main conclusions of this paper, based on the above experiments and data analysis, are as follows:

(1) With the increase in population, rapid economic development and urbanisation in Jiaozuo, the area of built-up land increased by 4,253 hectares between 1995 and 2020, an increase of 81.9%, and the increase in built-up land came mainly from arable land, while the area of arable land, forest land, grassland and water areas continued to decrease rapidly and were mostly converted into built-up land. Despite the dramatic changes in the values of each land use/cover area, the spatial distribution of each land use type remains relatively stable, with most of the increase in built-up land being the result of the expansion of urban centres into the surrounding area.

(2) Natural climatic factors have a great influence on water production, especially the value of precipitation is very important for annual water production, due to the large inter-annual variation of precipitation and the complex topography of Jiaozuo leads to uneven distribution of precipitation, so there are obvious spatial and temporal differences in annual water production. The spatial and temporal distribution of water production is generally lower in the south than in the north, lower in the west than in the east, and highest in the central core of the city, with an average water production depth of 100 mm. And the eastern part of these urban centres. Soil retention in these municipalities exceeds 100 t. Soil retention in Jiefang, Macun and Shanyang districts is very high, with soil retention in these areas exceeding 110 t, 200 t and 280 t from 1995 to 2020, while soil retention in other areas is generally low, with most remaining at around 100 t. The multi-year average soil retention in the counties with higher soil retention production values compared to those with lower values of soil retention production values is about an order of magnitude worse. The values for the nutrient phosphorus export service show little interannual variation, while the spatial distribution pattern is high; in the overall region of Jiaozuo, the areas with high phosphorus export are mainly located in the central, southern and south-western plains and in scattered locations in the northern mountainous regions. There is little inter-annual variation in carbon storage, and the distribution of carbon storage in Jiaozuo is irregular, with areas of high carbon storage values concentrated in the Mengzhou, Wenxian and Wuzhi County regions, and a trend for areas of low carbon density to expand in all directions from previously urban construction sites. The average value of the areas with high carbon storage values is about 1.8 times higher than that of the areas with low carbon storage.

(3) The correlation between water production and carbon storage, soil conservation and nutrient phosphorus export is a trade-off, with soil conservation and applied material phosphorus export showing a trade-off and soil conservation and carbon sequestration showing a synergistic relationship, mainly as a result of the unevenness of the areas in which the land-use types in the study area are located and the different evolutionary relationships between their ecosystem services. Ecosystem services are sensitive to changes in natural factors under a combination of factors. Water production is mainly influenced by the correlation between precipitation, building land use rate and arable land cover, with building land use rate and precipitation positively correlated and arable land cover negatively correlated; building land cover, precipitation and grassland cover are negatively correlated with nutrient phosphorus export; precipitation, woodland and grassland cover are the main positive influences on soil conservation; temperature and arable land cover are positively correlated with carbon storage. Socio-economic factors as a whole are negatively correlated with ecosystem services, i.e., ecosystem service functions are suppressed by socioeconomic development. Therefore, there should be an integrated and coordinated development between socio-economic development and ecological protection.

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