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Land Use/Cover Change and Its Relationship with Regional Development in Xixian New Area, China

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Abstract: There is a close relationship between land use/cover change and regional development in new urban areas. In this paper, based on the land-use data before (2010, 2013) and after (2015, 2018) the establishment of Xixian New Area and the economic development data of the corresponding period, with the help of indexes such as the land use transfer matrix, relative change rate/net change rate and the composite index of land use degree, the temporal and spatial differences of land-use change and land use degree in the ten years before and after the establishment of Xixian New Area were analyzed, and the driving factors of land-use change and their relationship with the level of social and economic development were discussed. The results indicate that cultivated land and construction land are the main land-use types in Xixian New Area in the whole studying period. From 2010 to 2018, the area of cultivated land and forest land in the region decreased over time, but the construction land area continuously increased dramatically (increased by 36.5% from 2010 to 2018) and the land-use change corresponds basically to the construction and development process of the New Area. In the spatial transfer of land use, the transformation of cultivated land to construction land was the most evident, and the urbanization construction in the New Area occupied the most cultivated land. The composite index of land use degree in the New Area was generally high and increased with time. Geographical location and policy guidance are the main reasons for the spatial difference of land use degree. The land use benefits in the New Area increased significantly, and the land use degree was positively correlated with the level of regional, social and economic development. The main driving factor of land-use change was human activities guided by policy.

Keywords: land-use change; land use degree; land use benefits; regional development; Xixian New Area

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1. Introduction

Land is a complex system composed of economy, society and ecological environment [1]. Land is the basic natural resource and material basis for human survival and development. The rational use of land is an important guarantee for regional sustainable development [2]. Although urbanization is beneficial to social and economic growth as well as people's livelihoods and wellbeing, it has a negative influence on the local natural environment. [3–5], so it has always been an important topic of academic discussion. Built-up areas are expanding at the expense of natural cover, so urbanization is considered to be "the most drastic form of land-use change leading to irreversible landscape change" [6]. As the largest urbanized country, China's land use pattern has altered dramatically. The

most noticeable change is the fast growth of building land, which has resulted in the encroachment of a considerable amount of high-quality ecological land such as cropland, forest land, orchard, grassland, and water bodies [7]. As an important strategy of regional development in China at the present stage, the new urban area is the reposition of regional development under the background of the development in the new era. The continuous expansion of new urban areas will unavoidably result in land use changes. Since land use is the closest link between man and nature, the regional change of land use has an important impact on ecological environment, climate change and human activities, and even causes global environmental change [8,9]. Therefore, the study of land use change is now one of the important directions of global change research.

In recent decades, many academics have conducted studies on the changes of land use spatial patterns in different regions [10–12], different scales [13–15] and different scenarios [16–19]. Estoque et al. [20] analyzed the relationship between land use, population and social development under the guidance of the United Nations 2030 Sustainable Development Agenda. Ma et al. [21] built a fuzzy multi-objective linear programming (FMLP) model that comprehensively considered the social, economic and ecological benefits of land to guide the land use planning of cities with unbalanced land use structure. Kuwari et al. [22] used remote sensing technology to systematically evaluate the change of the use of urban land caused by the construction of the RasLaffan oil field port in northern Qatar. Chen et al. [23] used the gravity model and other methods to select geographic grid scale indexes to evaluate the land use benefits of the Yellow River Basin from 1995 to 2018 and they believed that regional differences were mainly determined by land transfer and economic level (city size). Scholars have steadily turned their attention to the impact of land-use change on social and economic growth as well as environmental change [24–27]. Rational land use planning should take into account both economic growth and the ecological environment and how to combine ecological preservation and economic development is still the key point of regional development. Previous land use plans mainly focused on economic benefits, resulting in increased pressure on ecosystem protection and low land use efficiency [28]. The ecological environment in western China's arid and semi-arid areas is fragile, with a wide range of land types and distinct regional economic development and land use characteristics. With population growth and economic development, land use has changed dramatically [29], especially with the increase of construction land caused by the continuous expansion of new metropolitan areas.

As the representative of the New Area in the central and western regions in China, Xixian New Area was established on 6 January 2014. It is China's seventh state-level New Area formally authorized by the State Council in document GH (2014) No. 2 and located in the area between Xi'an City and Xianyang City, Shaanxi Province, with a land area of 882 km^2. The development of Xixian New Area is an important part of the national strategy of developing northwest China and also a tentative exploration path of new urbanization construction. It makes use of the strategic role of Xi'an and Xianyang for overall planning to achieve the goal of building a modern new ecological town with Chinese characteristics. With the rapid expansion of the new urban area and the quick development of the social economy, the intensity of land use and development in this area began to increase. Scholars have studied land-use change in this region, but most of these studies focused on change of land-use type, driving factors and ecological effects [30–34], and less are related to quantitative studies on land use degree and social and economic development. Therefore, based on the research of regional land-use change and its driving mechanisms, analyzing the interaction between land-use change and social economic growth is favorable to the region's sustainable development and can give decision-making suggestions for the creation of other new urban districts. In this paper, Xixian New Area was selected as the study object, the process and trend of land-use change of the New Area are reflected by investigating the differences in spatio-temporal distribution of land utilization in two periods: 2010–2013 (before the establishment of the New Area) and 2015–2018 (after the establishment of the New Area). The composite index of land use degree

and land use benefit in different periods are calculated to reflect the dynamic change and spatial difference of land utilization in the New Area; on this basis, the interaction between land use degree and social economic development was investigated, and the driving factors of land use change, as well as its social and economic consequences, are preliminarily explored. This is crucial to understand the evolution law of land use in New Areas, boost the efficient use of regional land resources and foster sustainable economic growth.

2. Study Area and Methods

2.1. Overview of the Study Area

The National New Area is a kind of new development, opening up and reforming metropolitan areas established in China in the early 1990s. It is a multifunctional area approved by the State Council to drive regional development and boost national reform and development. As a key development area supported by the state, the national new area is an important engine of national economic development: according to statistics, in 2016, the national new areas achieved a regional GDP of about 4 trillion CNY, accounting for 5.4% of the country with about 0.2% of the population and area. As one of the two national new areas in Northwest China, Xixian New Area is the core area of the Guanzhong-Tianshui Economic Zone. It has obvious geographical advantages, good economic foundation and a natural ecological environment to accelerate development and plays a positive role in expanding the depth and breadth of China's opening to the West.

Xixian New Area is located between the built-up areas in Xi'an City and Xianyang City in the Shaanxi Province (between 108°31′47″~108°58′19″ E and 34°10′15″~34°33′16″ N). The average altitude of Xixian New Area is about 440 m, covering Jinghe Alluvial Plain, Weihe Alluvial Plain, secondary beach, loess tundra, etc. The climate in the New Area is semi-humid. It is the first national new area dedicated to innovative urban development. The planning area of Xixian New Area is 882 km^2, and the registered population is 1.03 million. Xixian New Area is subdivided into Airport New City, Fengdong New City, Qinhan New City, Fengxi New City and Jinghe New City by administrative region (Figure 1). In 2018, the GDP of Xixian New Area was 38.19 billion CNY with an annual growth rate of 13.3%, ranking first among cities in the Shaanxi Province.

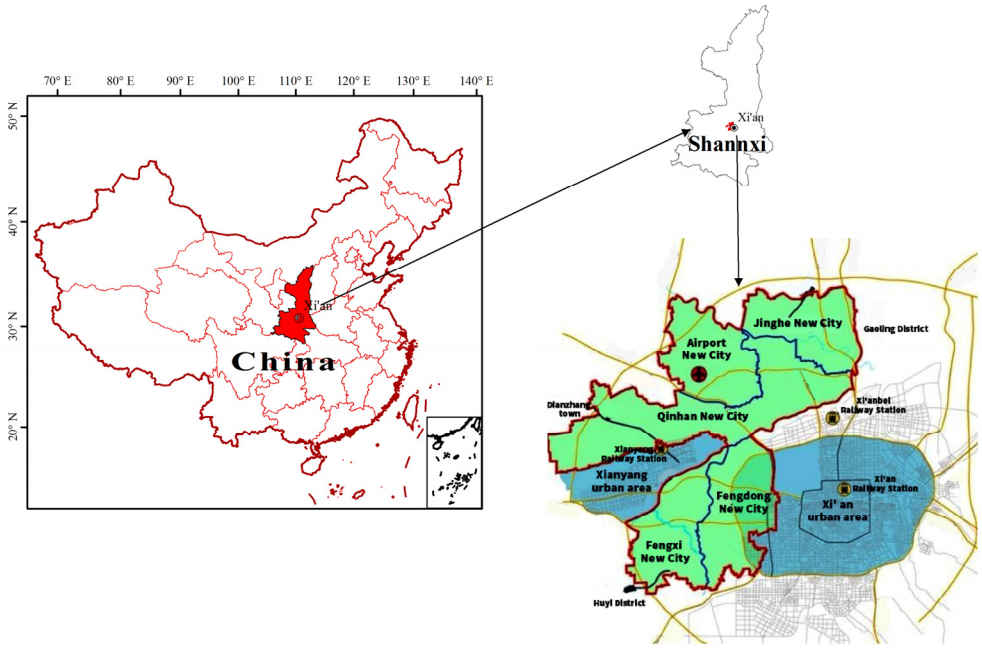

Figure 1. Location and zoning scope of Xixian New Area.

2.2. Data and Preprocessing

Land use data: Based on the establishment time of the New Area, the land-use data of 2010 and 2013 before the establishment of the New Area and 2015 and 2018 after the establishment of the New Area are selected, respectively. The data source is the Resource and Environment Science and Data Center, Chinese Academy of Sciences (http://resdc.cn (accessed on 1 March 2021)), and the resolution is 30 m × 30 m. Based on the current condition and the original classification, the land use in the research region is re-divided into six categories: cultivated land, forest land, grass land, construction land, unutilized land and water body. The social economic data are mainly from the Xixian New Area Bureau of Statistics and the statistical authority of Xi'an and Shaanxi Province.

2.3. Land Use Transfer Matrix

Land use/cover changes through time as a result of natural and human forces, and the amount, direction, and speed of the change for different land use categories varies. The variation of land use is the change of land use spatial characteristics over time. However, the mutual transition between different land use types is affected by their initial state. The land use transfer matrix can well reflect this change. The rows and columns of the usual land use transfer matrix (Table 1) represent the land use types in two different periods (T_1 and T_2), respectively. The values in the matrix (P_{nn}, $n = 1, 2, \ldots, n$) represent the transfer area of different land use types in two periods. With reference to the research on this method by predecessors [35], in order to make it easy to understand and apply, the matrix is slightly modified as follows:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} (i, j = 1, 2, 3 \ldots n) \quad (1)$$

where S_{ij} is the land area transformed from type i land to type j ($i = j$ means the area of land with a certain unchanged land-use type). i and j are the two types before and after transfer. n is the amount of land-use types ($n = 6$ in this study).

Table 1. A general example of the land use transfer matrix.

Period/Land Use Type		**T_2**			
		A_1	**A_2**	...	**A_n**
T_1	A_1	P_{11}	P_{12}	...	P_{1n}
	A_2	P_{21}	P_{22}	...	P_{2n}
	⋮	⋮	⋮	⋮	⋮
	A_n	P_{n1}	P_{n2}	...	P_{nn}

The land use transfer matrix is mainly calculated through overlay analysis using Change Detection Statistics on the ENVI 5.1 platform based on the existing four phases of land-use data.

2.4. Change Rate of Land Use

The change rate of land use area is a concrete expression of the research region's land-use change over time. It can reflect a change rate trend in the study area, which can be subdivided into relative change rate and net change rate [35]. The relative change rate represents the change of land use area compared to the initial stage, and the net change rate is an expression of the average annual change rate. Through the analysis of the relative change rate and net change rate of land use area in the research region, a multi-dimensional systematic analysis result is obtained.

$$N_c = \frac{U_b - U_a}{U_a}, \tag{2}$$

$$R_s = \left[\sqrt[T]{\frac{U_b}{U_a}} - 1 \right] \times 100\%, \tag{3}$$

where N_c is the area relative change rate; R_s is the net change rate; U_a and U_b are the areas at the initial stage and at the end of the study period; T is the research time span. The changed areas involved here are all net change areas, regardless of the mutual transfer in and out for all types.

2.5. Composite Index of Comprehensive Land Use Degree

The composite index of land use degree is used to characterize the intensification degree of land use reflected by all land use types in a specific year. Through the classification of land use degree, the composite index quantifies the impact of human activities on the land system and quantitatively describes the integral level and variation trend of land use, so it is a crucial metric for assessing the state of land usage.

In this section, with reference to the composite index proposed by Zhuang et al. [36], the degree of land use is classified into four grades, and the corresponding value is assigned to each level (Table 2). The cascade index is mainly determined based on the change of land compared with the natural state, which also includes some human activities and eco-environmental factors. A large index means a high degree of land use, that is, a more intense man-made transformation with little consideration of the ecological environment [37]. The composite index of land use degree includes both regional economic development information (construction land area) and certain ecological environment information (forest and grassland area). Therefore, it can serve as a theoretical foundation for regional sustainable development.

Table 2. Graded value of different land use types.

Land-Use Type	Unutilized Land	Forest Land, Grass Land and Water Body	Cultivated Land	Construction Land
Graded value	1	2	3	4

Based on the graded index and land use area statistics, the land use degree in the study area at different stages is evaluated by figuring out the composite index. The detailed calculating procedure is as follows:

$$\mathrm{L} = 100 \times \sum_{i=1}^{4} \mathrm{A}_i \times \mathrm{C}_i, \tag{4}$$

where L is the composite index; A_i is the graded value for types in level i; C_i is the area proportion corresponding to A_i.

Compared with other land types, unutilized land has less input from human activities and also less output. The land use types except unutilized land are extracted to create the adjusted composite index, which eliminates the influence of an excessive amount of unutilized land on the land use degree index.

3. Results

3.1. Land-Use Change

Figure 2 depicts the spatial distribution of land usage in the Xixian New Area over time. The area and the proportions of different land use types in the studying periods are shown in Table 3 and Figure 3. The percentage of cultivated land is the highest, indicating that cultivated land is the major type in the region. The second is construction land, accounting for the smallest proportion. The decreasing order of land area is: cultivated land, construction land, grass land, water body, forest land and unutilized land. As depicted

in Figure 3, the proportion of cultivated land in 2010, 2013, 2015 and 2018 reached 72.57%, 71.38%, 67.38% and 65.56%, respectively, showing a state of decreasing with age. Contrary to the cultivated land, the proportions of construction land in the four periods were 20.64%, 22.03, 25.90% and 28.21%, respectively. The proportion of unutilized land was only 1.16%, 1.10%, 1.32% and 1.13%, respectively.

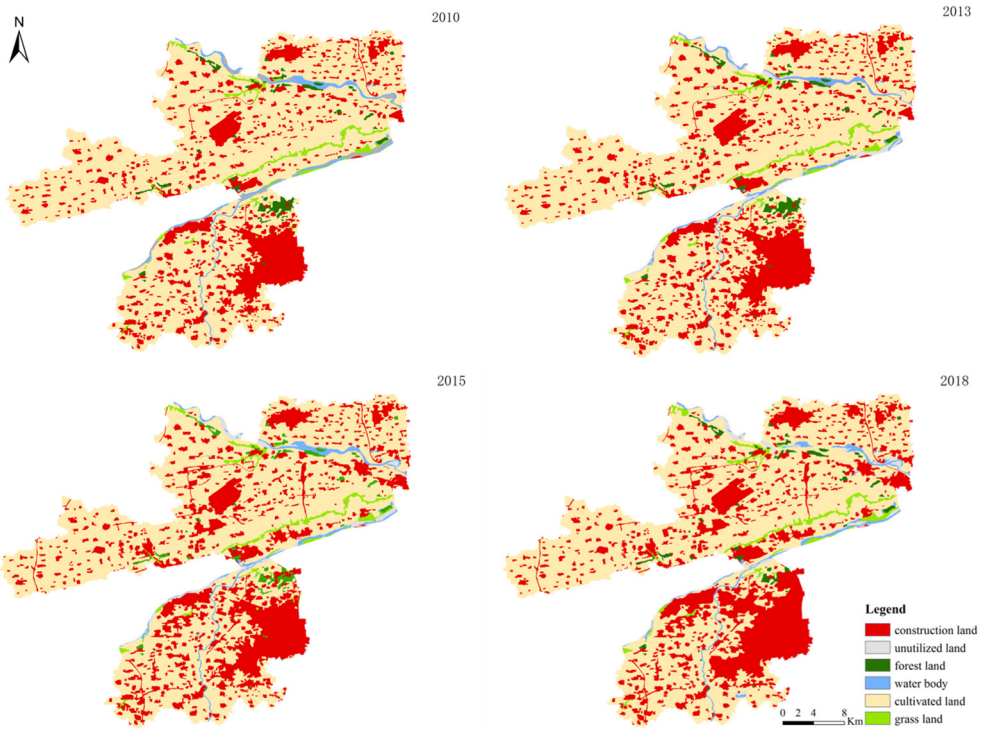

Figure 2. Spatial pattern map of land use in Xixian New Area from 2010 to 2018.

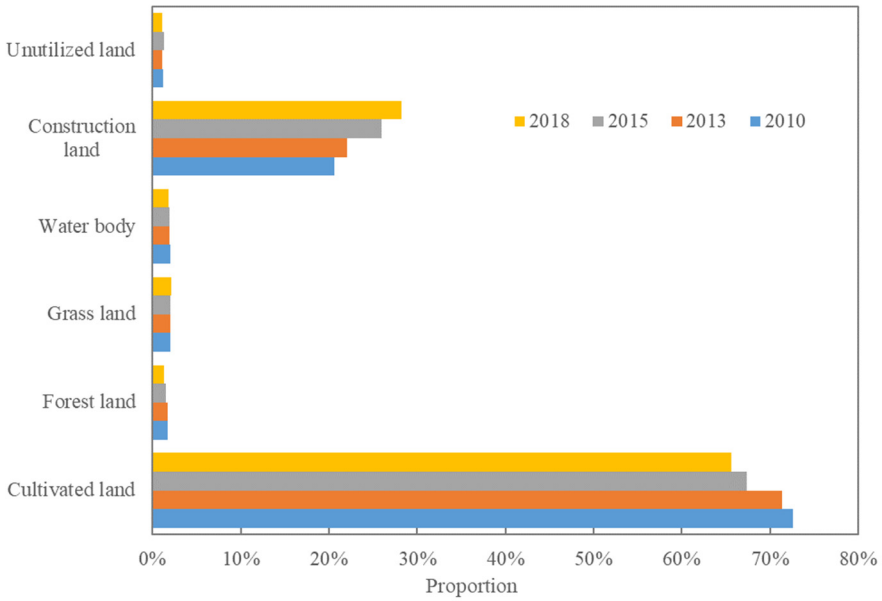

Figure 3. Land use proportions in different periods.

Table 3. Land use area in Xixian New Area in different periods (km^2).

Year	Cultivated Land	Forest Land	Grass Land	Water Body	Construction Land	Unutilized Land
2010	638.36	14.60	17.55	17.37	181.60	10.19
2013	627.89	14.57	17.33	16.41	193.80	9.68
2015	592.71	13.35	17.27	16.85	227.87	11.63
2018	576.70	11.09	18.38	15.40	248.15	9.91

Table 3 also reveals that, since 2010, the cultivated land and forest land area in Xixian New Area have shown a decreasing trend, of which the decreasing degree of cultivated land area is more obvious; the construction land area has shown an obvious increasing trend; the grass land and unutilized land area have been fluctuating. Table 4 displays the calculated results of the change rate for all types across various time periods. From 2010 to 2013, the area of cultivated land, forest land, grass land and water body decreased, of which the cultivated land area decreased most obviously with the area of 10.47 km^2, followed by water body, and the forest land decreased the least, which was by only 0.03 km^2. By eliminating the influence of the area base of each land-use type, it can be seen from the relative change rate and net change rate that the relative change rate and net change rate of water body areas were the largest, which were −5.11% and −1.87% respectively. The relative change rate and net change rate of the unutilized land area was close to that of water body areas. On the contrary, the construction land area increased by 12.20 km^2, and the relative change rate and net change rate of construction land were also the largest, which were 6.72% and 2.19%, respectively. From 2015 to 2018, the area of most types remained at the same change trend as the previous stage except for grass land, which showed the opposite trend from the previous stage. The area of grass land changed from a decrease to an increase. Compared with 2010–2013, the net change rate of all land use types in 2015–2018 has increased, of which the net change rate of the forest land area changed most obviously, 81 times that of the previous period. Similarly, the relative change rate of 2015–2018 is also higher than that of 2010–2013, and the forest land increases the most. Notably, for the period of 2013–2015, containing the establishment of Xixian New Area, the most prominent change is the reduction of cultivated land area and the increase of construction land area. From the perspective of change rate, both the net change rate and relative change rate of the two land types at this period are explicitly higher than those in 2010–2013 and 2015–2018.

Table 4. Change for various land-use types in Xixian New Area from 2010 to 2018.

Time Interval	Index	Cultivated Land	Forest Land	Grass Land	Water Body	Construction Land	Unutilized Land
2010–2013	Area variation (km^2)	−10.47	−0.03	−0.23	−0.96	12.20	−0.52
	Relative change rate (%)	−1.64	−0.22	−1.29	−5.51	6.72	−5.08
	Net change rate (%)	−0.55	−0.07	−0.43	−1.87	2.19	−1.72
2013–2015	Area variation (km^2)	−35.18	−1.22	−0.06	0.44	34.07	1.95
	Relative change rate (%)	−5.60	−8.35	−0.36	2.68	17.58	20.17
	Net change rate (%)	−2.84	−4.27	−0.18	1.33	8.43	9.62
2015–2018	Area variation (km^2)	−16.01	−2.26	1.11	−1.45	20.28	−1.72
	Relative change rate (%)	−2.70	−16.93	6.44	−8.59	8.90	−14.76
	Net change rate (%)	−0.91	−6.00	2.10	−2.95	2.88	−5.18
2010–2018	Area variation (km^2)	−61.67	−3.51	0.82	−1.96	66.55	−0.28
	Relative change rate (%)	−9.66	−24.03	4.68	−11.31	26.82	−2.76
	Net change rate (%)	−1.26	−3.38	0.57	−1.49	3.98	−0.35

In the whole research period, the cultivated land and forest land area declined, the area of cultivated land and forest land continued to decrease, the area of construction land increased, the grass land area increased as a whole, and the area of unutilized land

fluctuated. On the whole, the net change rate from high to low is: construction land, forest land, water body, cultivated land, grass land and unutilized land.

3.2. Spatial Transfer of Land Use

In order to analyze the transfer between different land-use types in Xixian New Area from 2010 to 2018, the land use transfer matrices of 2010–2013, 2013–2015, 2015–2018 and 2010–2018 are calculated, respectively (Tables 5–8). During 2010–2013 (Table 5), the reduced cultivated land was transferred into the other land use types, of which the area transferred into construction land was the largest, accounting for 95.73% of the total transfer-out area. The majority of forest land has been converted to cultivated and construction land, with the ratio of 63.56% and 25.10%. The remaining four land use types were mainly transferred to cultivated land, accounting for 63.08%, 86.69%, 95.56%, 58.63% of the total transferred out area, respectively.

Table 5. Land use transfer matrix of Xixian New Area from 2010 to 2013.

Land-Use Type		2013					
		Cultivated Land	**Forest Land**	**Grass Land**	**Water Body**	**Construction Land**	**Unutilized Land**
2010	Cultivated land	552.81	0.49	0.67	1.21	71.87	0.83
	Forest land	1.02	12.96	0.06	0.10	0.40	0.02
	Grass land	1.34	0.05	15.20	0.42	0.08	0.23
	Water body	2.59	0.02	0.07	13.42	0.10	0.21
	Construction land	19.63	0.34	0.40	0.06	173.26	0.12
	Unutilized land	0.99	0.01	0.04	0.62	0.02	7.99

Table 6. Land use transfer matrix of Xixian New Area from 2013 to 2015.

Land-Use Type		2015					
		Cultivated Land	**Forest Land**	**Grass Land**	**Water Body**	**Construction Land**	**Unutilized Land**
2013	Cultivated land	496.19	0.22	0.72	3.59	90.53	1.46
	Forest land	0.16	10.88	0.02	0.02	2.27	0.01
	Grass land	0.46	0.03	15.08	1.30	0.18	0.21
	Water body	0.34	0.02	0.13	12.65	0.02	3.69
	Construction land	30.66	0.16	0.06	0.38	196.21	0.39
	Unutilized land	0.26	0.00	0.01	2.24	0.01	9.10

Table 7. Land use transfer matrix of Xixian New Area from 2015 to 2018.

Land-Use Type		2018					
		Cultivated Land	**Forest Land**	**Grass Land**	**Water Body**	**Construction Land**	**Unutilized Land**
2015	Cultivated land	491.36	0.57	2.44	5.73	70.67	4.44
	Forest land	0.19	8.03	0.02	0.01	2.83	0.00
	Grass land	1.08	0.01	15.87	0.06	1.27	0.06
	Water body	4.79	0.02	0.31	9.86	0.03	0.23
	Construction land	31.04	0.47	0.29	0.49	215.23	0.20
	Unutilized land	2.07	0.00	0.62	1.01	0.04	6.05

Table 8. Land use transfer matrix of Xixian New Area from 2010 to 2018.

Land-Use Type		2018					
		Cultivated Land	**Forest Land**	**Grass Land**	**Water Body**	**Construction Land**	**Unutilized Land**
2010	Cultivated land	456.77	0.33	1.40	3.67	110.27	2.78
	Forest land	0.16	7.34	0.02	0.00	3.55	0.00
	Grass land	0.85	0.01	15.62	0.91	0.85	0.12
	Water body	4.26	0.02	0.28	8.34	0.04	2.31
	Construction land	31.65	0.51	0.29	0.74	213.92	0.62
	Unutilized land	2.18	0.00	0.65	2.06	0.03	4.87

For 2013–2015, which spans the establishment of the new area, the transferred area from cultivated land to construction land further increased, reaching 90.53 km^2, accounting for 93.79% of the total transferred out area. Forest land was also mainly transferred to construction land, and the transformed area was much higher than other land use types. Grass land was mainly transformed into water body, but the transfer out area is generally small. The variation of water body and unutilized land areas was mainly reflected in the mutual transformation between them.

From 2015 to 2018, the transfer between various land-use types in the region became more active, and the dynamic change of land use was significantly more complex than in the previous periods. Specifically, cultivated land was transferred to the other five land-use types, of which the area transferred to construction land was the largest, accounting for 84.28% of the total transfer-out area, followed by water body, accounting for 6.83%, and the area transformed into forest land was the least. Forest land and grass land were mainly transferred to construction land, accounting for 92.79% and 51.21% of the total transfer-out area, respectively, and in this period, part of the grass land was transformed into cultivated land at the same time. The water body was mainly transformed into cultivated land with an area of 4.79 km^2, accounting for 89.03%. Construction land became the main input of cultivated land with 31.04 km^2 of construction land transformed into cultivated land, accounting for 95.54% of the total transfer-out area. The reduced unutilized land was also mainly transformed into cultivated land.

In terms of the whole research period, the reduced areas of cultivated land and forest land were mainly transformed into construction land, of which the former transformed area was up to 110.27 km^2, while grass land was mostly converted to cultivated land, water body and construction land, accounting for 31.02%, 33.21% and 31.02% of the total transfer-out area, respectively. The reduced water body and construction land areas were chiefly converted to cultivated land, and the unutilized land was primarily shifted to cultivated land and water body areas. Above all, the transfer in and transfer out of construction land is at least one order of magnitude higher than other types.

3.3. Land Use Degree

Compared with other land types, unutilized land has less input from human activities and also less output. In order to exclude the impact of unutilized land on the land use degree index, two scenarios were divided according to whether the unutilized land was included or not, that is, before and after the adjustment, and the composite index of land use degree before and after adjustment was calculated, respectively. The results are displayed in Table 9. The composite index of regional land use degree in the four periods was about 320, which was much higher than the composite index of the Shaanxi Province calculated by Su et al. [38] (226.57 in 2010 and 232.25 in 2018), indicating that the overall land use degree in the new area was at a high level.

Table 9. Composite index of land use degree in Xixian New Area.

Land Use Degree Index	2010	2013	2015	2018
Unadjusted	312.70	314.34	317.86	320.84
Adjusted	315.19	316.91	320.78	323.37

Before and after the adjustment, the composite index of Xixian New Area increased with time. Although the reduction of cultivated land and forest land area could lead to the reduction of the composite index to a certain extent, the rapid increase of construction land area made the regional composite index increase generally. Comparing the two scenarios, the composite index of the whole region has improved due to excluding unutilized land.

In order to better reflect the impact of natural and social factors on land use change, the spatial distribution of comprehensive land use status is analyzed by ArcGIS10.2 (Figure 4). Obviously, the area with a low composite index of land use degree (less than 200) is small, which was mainly distributed along Weihe River and Jinghe River running through the New Area. The area with the index in the range of 200–300 was the most widely distributed. In addition to scattered areas, there were a few concentrated areas with high land use (greater than 300), namely, the northwest of Jinghe New City in the north of the New Area, Xi'an/Xianyang International Airport in Airport New City, and most of Fengdong New City in the southeast of the New Area, among which the area with a high land use index in Fengdong New City was the largest. The main reason is likely to be that Fengdong New City is closest to the main urban area of Xi'an in Xixian New Area and its urban construction and land use were greatly affected by Xi'an, which generally leads to the high land use degree. From the perspective of time, a few concentrated areas with high land use were expanding over time. Due to the different industry guidance policies of the five new cities in the New Area, there are some differences in the composite index of land use degree in each new city. In the same region, under basically the same land conditions, the policy guidance also played a vital role in the degree of land use.

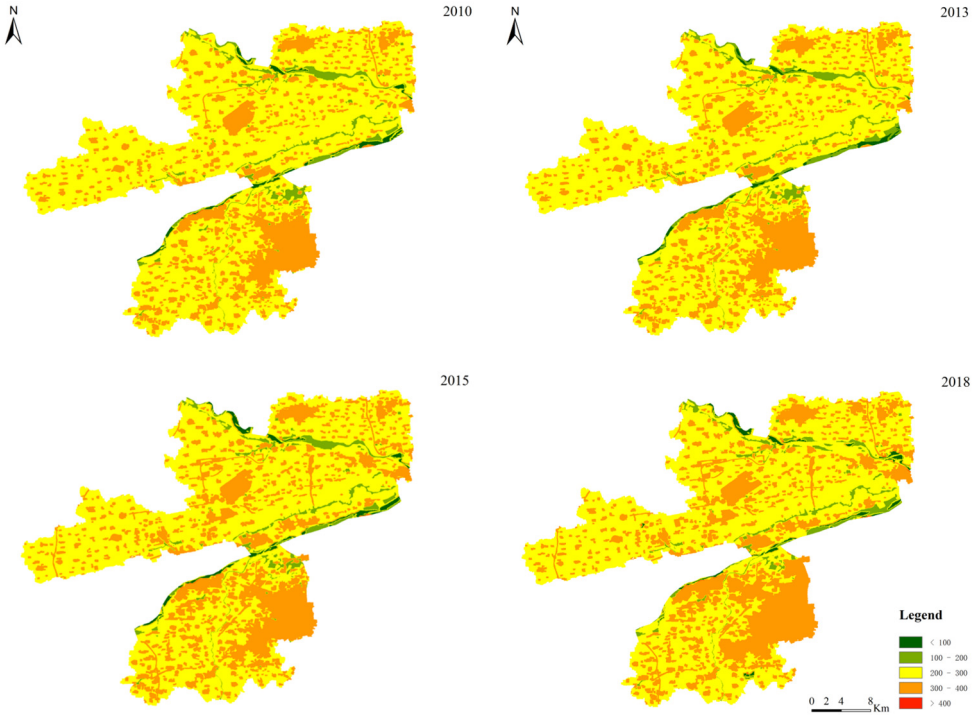

Figure 4. Composite index of land use degree in Xixian New Area from 2010 to 2018.

3.4. Land Use Benefits

GDP per unit area is selected as the assessment index to analyze the change of land use benefits in Xixian New Area. In order to improve the rationality of the comparison between years, GDP is converted into comparable prices based on 2010. The land use area is analyzed by two scenarios: the total area of the region (before adjustment) and the area excluding unutilized land (after adjustment). With the establishment of Xixian New Area, the regional land use benefits increased obviously (Table 10). By calculating the growth rate (Table 11), it can be seen that there was little difference in the growth rate in all periods. By comparing the results at all periods, it is found that the growth rate of land use benefits in the study area was the highest (114.92%) in the whole study period (2010–2018), indicating that land use benefits in 2018 more than doubled compared with the initial year. The growth rate of land use benefits in 2013–2015 was only about 19.52%, lower than 42.55% in 2010–2015 and 26.15% in 2015–2018.

Table 10. Land use benefits in Xixian New Area.

Year	Per Capita GDP (10 Thousand)	GDP per km^2 (10 Thousand/km^2)	
		Unadjusted	Adjusted
2010	1.52	1692.09	1711.92
2013	3.35	2412.13	2438.94
2015	4.72	2882.95	2921.58
2018	5.09	3636.71	3678.36

Table 11. Change rate of land use benefits in Xixian New Area.

Time Interval	Unadjusted	Adjusted
2010–2013	42.55%	42.47%
2013–2015	19.52%	19.79%
2015–2018	26.15%	25.90%
2010–2018	114.92%	114.87%

4. Discussion

4.1. Relationship between Land Use and Regional Sustainable Development

The research on regional sustainable development includes three levels: conceptual form, economic and social systems, and science and technology [39]. Land use research belongs to sustainable development research on the level of science and technology [40]. Therefore, for quantifying the direct association between land use degree and regional economic development level, GDP per unit area was used to characterize the regional economic development, the urbanization index (the proportion of construction land) was selected to characterize the urbanization level, and the composite index was selected to characterize the regional land use degree. Similarly, two scenarios, namely before adjustment (total area of the region) and after adjustment (excluding unutilized land area), were used for analysis. The indexes of Xixian New Area in the corresponding periods under the two scenarios were calculated (Table 12) Obviously, the most remarkable feature of land use change in the New Area is the continuous growth of the construction land area and the continuous reduction of the cultivated land area, which is also reflected in the urbanization index and the comprehensive index of land use degree. In other words, the characteristics of land use change in the New Area during the study period reflect the rapid development of the regional economy. Urbanization (the increase of construction land area) is the leading reason for the increase of land use degree in the New Area, which also promotes the regional economic development. Due to the small proportion of unutilized land in the region, the internal coupling connection between land use degree and regional development before and after adjustment did not change significantly. The formal establishment of Xixian New Area in 2014 promoted urbanization, accompanied by the increase of the composite index of land use degree and the improvement of the economic development level.

Table 12. Land use and economic development indicators of Xixian New Area.

Year	GDP per Unit Area (10 Thousand/km^2)	Spatial Urbanization Index	Composite Index of Land Use Degree
		Before Adjustment	
2010	1692.09	0.21	312.70
2013	2412.13	0.22	314.34
2015	2882.95	0.26	317.86
2018	3636.71	0.28	320.84
		After Adjustment	
2010	1711.92	0.21	315.19
2013	2438.94	0.23	316.91
2015	2921.58	0.26	320.78
2018	3678.36	0.29	323.37

Taking the establishment of the New Area as the time node, the land use change in different periods was analyzed (Table 13). In 2010–2013, the urban area was not constructed, so the regional economic development was slow, and the composite index of land use degree is the smallest of the four periods. The growth rate of the spatial urbanization index and the composite index of land use degree is also the lowest. In 2013–2015, with the formal establishment of the New Area, the expansionary growth was more prominent, and the composite index also increased significantly. During the new urban construction period, the government guided an increase in infrastructure construction and increased construction investment, but the implementation of many policies and institutions were not perfect, resulting in the rapid increase of construction land area and the spatial urbanization index [28]. The growth rate of the spatial urbanization index and composite index in 2013–2015 is much higher than that in 2010–2013 and 2015–2018. During 2015–2018, after a few years of rapid development, the government appropriately adjusted the regional development orientation and operation mode, switching from actively developing infrastructure construction to developing an innovative city, following the development path of intensive resources, industrial agglomeration, concentrated talents and eco-civilization, paying attention to improving land use efficiency, making efforts to coordinate scientific and technological resources, actively developing ecological agriculture, adjusting the industrial structure, and promoting industrial upgrades with innovation as the driving force. Therefore, the spatial urbanization index and the composite index of land use degree are lower than those in the previous stage, but they are still higher than those in 2010–2013 before the establishment of the new area. Similarly, the growth rate of the spatial urbanization index and comprehensive land use index in 2015–2018 is higher than that in 2010–2013. That is, the establishment of the New Area had a substantial impact on regional land use, and the degree of land use increased.

Table 13. Change of land use degree in different periods.

Studying Periods	Spatial Urbanization Index		Composite Index of Land Use Degree	
	Variation	Variation Ratio (%)	Variation	Variation ratio (%)
2010–2013	0.01	6.57	1.64	0.53
2013–2015	0.04	18.18	3.52	1.12
2015–2018	0.02	8.90	2.97	0.94

Notably, Tables 10 and 11 show that the land use benefits of the New Area show a continuous growth trend throughout the study period. However, comparing the growth rate of per capita GDP in the two time periods before and after the establishment of the new area (2010–2013, 2015–2018), it is found that the latter is lower than the former. The main reason is that the change of population and its long-term dividend have not been shown.

The population decreased by 146,100 in 2013 compared with 2010, while the population increased by 108,200 in 2018 compared with 2015. The reduction of population in the previous stage is one of the main reasons for the high growth rate of per capita GDP. In addition, after the completion of the New Area, it not only attracted a large number of people, but also had more government policies and planning guidance for its own development, and the development mode changed significantly compared with the previous stage. The advantages of the labor force and creativity brought by rapid population growth are gradually emerging, and the GDP growth rate of the New Area slowed down temporarily. Undoubtedly, the establishment of the New Area has advantageously promoted regional development, and its positive effect on the speed and quality of regional development will be more and more significant.

As the key carrier of the interaction between humans and nature, land use systems play an important role in the process of regional sustainable development. Land as a resource is the basis of regional sustainable development. At the same time, land use change directly affects the regional ecological environment, and then affects the regional social economy development. (1) Impact on regional agricultural production. The loss of cultivated land will put the regional food supply at risk. Due to the influence of economic progress, population increase, motorization, the cultivated land in Xixian New Area is significantly reduced and more land is being turned to development land in both the city and the countryside. Regarding the changes of regional GDP and population in the same period, the clear decline of cultivated land in this stage is closely tied to large-scale construction, and the rise of urban and rural residential land is also closely linked to expansion during this time. The decline of farmland will shatter the foundations of regional development. (2) Regional environmental consequences. Different terrestrial ecosystems are carried via land. Different ecosystem kinds, locations, and spatial distribution patterns alter when land use patterns change. The variety and intensity of ecosystem services are directly affected by great land use changes [41]. Xixian New Area is a development zone with rapid economic growth. The change of the land use structure caused by economic activities reduces the area of the ecological area, while the proportion of industrial and mining, transportation and construction land in the artificial system continues to rise, which hinders the exertion of the service function of the natural ecosystem. From 2010 to 2018, the forest land and water body areas in Xixian New Area were decreasing, which weakens the ecological and natural purification function. The felling of trees greatly reduced the conservation function of water resources and directly accelerated the shrinkage of rivers. The reduction of the wetland area and serious pollution result in the degradation of the ecosystem, especially the decline of water storage capacity. Therefore, the change of land use mode will destroy the regional ecological environment and pose a threat to regional sustainable development. (3) Impact on regional social economy development. The deterioration of the regional ecological environment will restrict the development of social economy and cause a situation of double lag of social economy and ecological environment [42]. As a rapidly developing area, Xixian New Area should especially avoid this vicious circle. Therefore, it is necessary to establish a sustainable land use model and lay a good foundation for regional sustainable development.

4.2. Analysis on Driving Factors of Land-Use Change

Land-use change is affected by both natural and human activities, in which human activities have an increasing impact on land-use change [43–45], including population [43–45], policy [43,44,46], social economy [43,45] and other factors [46]. (1) Population is the most dynamic driving factor of land-use change. The increase of population will inevitably lead to the increase of residential areas and urban land. In 2010 and 2013 before the establishment of Xixian New Area, the population was 779, 500 and 633, 400, respectively. After its establishment, the population increased to 915, 000 and 1.0232 million in 2015 and 2018, respectively, with average growth rates of 37.18%. (2) Xixian New Area is located in the economic core area of Guanzhong. It is the starting city of the New Silk Road

and shoulders the important task of "building greater Xi'an, leading greater Guanzhong and radiating the northwest China". As the first state-level new area with the theme of innovative urban development, its development orientation is: an important fulcrum of the Silk Road Economic Belt, an important hub of China's opening to the west, a pilot area of national innovative urban development, an example of new urbanization with Chinese characteristics, a new engine of Western Development, and a demonstration area of eco-civilization construction and Chinese culture. Therefore, the development of Xixian New Area will inevitably be accompanied by industrial agglomeration, accelerated infrastructure construction, accelerated urban-rural integration and other activities [47], which will lead to rapid changes in regional land use. The most obvious characteristic is that the area of construction land increased rapidly in all periods. (3) As a modern new area, Xixian New Area has integrated a lot of ecological and landscape measures during urban construction, such as bioretention ponds and other LID facilities used in the construction of a sponge city, which has increased the area of water body and grass land areas in the region to a certain extent [48,49]. (4) The impact of urbanization on climate and regional runoff is also the driving factor of land-use change. The urbanization process is accompanied by the change of underlying surface, which has an important impact on the spatial distribution and runoff yield and concentration of regional precipitation. Similarly, the changes of the spatial distribution of precipitation and runoff will also affect the spatial pattern of land use in the basin. For example, precipitation will affect vegetation growth, and the change of runoff yield and concentration will affect the water body areas in the region.

5. Conclusions

Based on the three phases of land-use data and socio-economic data from 2010 to 2018 before and after the completion of Xixian New Area, the land-use change in the region and its relationship with socio-economic development were analyzed, concluding the following:

(1) Cultivated land and construction land are the two main land-use types in Xixian New Area, and their area accounts for more than 90% of the whole region. From 2010 to 2018, the area of cultivated land, forest land and water body in the region decreased, among which the area of cultivated land decreased most significantly, and the proportion decreased from 72.57% to 65.56%; the area of construction land continued to increase, increasing from 20.64% to 28.21%. The land-use change was basically consistent with the construction and development process of the New Area. The New Area's establishment and growth had a significant influence on regional land use and raised the land use degree.

(2) The spatial transfer of land use is mainly reflected in the mutual transfer-in and transfer-out between cultivated land and construction land, and the area of cultivated land converted into construction land is larger, which is directly related to the urbanization of the New Area. The urbanization of the New Area occupies the most cultivated land. The new metropolitan area will inevitably go through a large-scale infrastructure construction process, in which the protection of cultivated land could not be ignored.

(3) The composite index of land use degree in Xixian New Area was generally high and increased with time. In terms of space, the land use degree in the southeast of the New Area is higher than that in the northwest. The radiation effect of big cities caused by geographical location and policy guidance are the main reasons for the spatial difference of the land use degree.

(4) During the study period, the land use efficiency in Xixian New Area increased significantly, more than doubling from 2010 to 2018. The land use degree is positively correlated with the regional economic development level. The completion of the New Area has a significant impact on land use change and land use change could reflect the regional economic development of the new area. The main driving factor of land-use change is policy-guided human activities, that is, policy-guided urbanization construction and other human activities enhance the land use degree in the region.

Land-use change and regional development cannot only characterize each other, but also restrict each other.

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