Journal of 山地科学学报(英文)
Mountain Science
Springer

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View online: https://doi.org/10.1007/s11629-020-6236-7

J. Mt. Sci. (2021) 18(3): 749-763 e-mail: jms@imde.ac.cn http://jms.imde.ac.cn
https://doi.org/10.1007/s11629-020-6236-7

Original Article

Impacts of land use change on landscape patterns in mountain human settlement: The case study of Hantai District (Shaanxi, China)

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Citation: Wang L, Wu L, Zhang W (2020) Impacts of land use change on landscape patterns in mountain human settlement: The case study of Hantai District (Shaanxi, China). Journal of Mountain Science 18(3). https://doi.org/10.1007/s11629-020-6236-7

Abstract: Mountain area is an important geographical unit of land, and its ecology is sensitive and fragile. Over the past few decades, human activities have caused dramatic changes in land use in mountainous areas, which caused changes in landscape patterns and impacts on the ecological environment. It is unknown how the mechanism of land use affects the landscape pattern at different scales. The Hantai District, a typical human settlement in the mountain area in Shaanxi, China, was chosen as the study area. Based on the remote sensing images, the mathematical models and landscape indexes were adopted to evaluate the impact of land use change from 1998 to 2017 on the landscape pattern at different scales, and its main driving forces were analyzed. The results showed that the urbanized land expanded largest from 15.39% to 24.30%, and cultivated land experienced the largest decline from 43.54% to 35.35%. Changes in land use have made the patch morphology of most land types developed from a natural random to a sawtooth shape, and its spatial pattern evolved from a ruleset to a fragmented expansion. This reflects the continuous strengthening of human intervention in the process of regional development. Under the jurisdiction of Hantai District, the biggest change in landscape pattern is in Hanzhong City and Qili Town. The improved economy and increasing population and urbanization rate were the main factors that cause these changes. This research could provide necessary information for understanding the evolution mechanism of land resources in mountainous human settlements for mountainous areas with significant geomorphic differentiation.

Keywords: Land use change; Land cover change; Landscape pattern evolution; Transition trend; Driving force; Mountain regions; Hantai District

Received: 29-May-2020
Revised: 28-Oct-2020
Accepted: 26-Nov-2020

1 Introduction

Land is the material basis for human survival and the carrier of regional economic development (Liu 1999). With the rapid development of economy and population, the expansion of construction land has become an important feature of urbanization. Some ecological problems gradually emerge, such as problems related to the heat island effect (Alexander and Wu 2010), a loss of biodiversity (Kevin 2002), and environmental pollution (Li et al. 2018). Nowadays, the land use/cover change (LUCC) has aroused increasing attention in the research fields of global ecosystem balance (Grimm et al. 2008; Jaarsveld et al. 2005). Landscape pattern is a spatial system formed by the spatial distribution of various landscape elements (Liu et al. 2010), and it is an important indicator of the tension between the socio-economic system and the natural ecosystem (Monica 1990; Mcgarigal and Marks 1995). It can reflect the rationality of land use to a certain extent. Research on the interaction mechanism between land use and landscape pattern evolution will help us understand the impact of social development on natural ecosystems (Klaus and Jeroen 2006), and provide a scientific basis for regional development of ecological civilisations and sustainable land planning strategies.

In the study of regional land resource changes, LUCC, landscape pattern evolution and driving forces are the main directions at present. First, LUCC has received wide attention as a basic means of monitoring regional development and becoming a hotspot issue in current global change research (Wang and Bao 1999). The spatial distribution of landscape elements can be visualized by 3S analysis, which uses a combination of three systems, geographic information, global positioning and remote sensing systems (Matthias et al. 2005). The combination of historical map and geographic information technology could effectively analyze the long-term change of land resource. By manually digitizing the 1986 paper map of the region near Chancellorsville, USA and combining it with modern aerial imagery, Liu et al. (2018) obtained the 147 years fine scale land use history in this area. Picuno et al. (2019) based on GIS software processing, used historical cartography, aerial photos and orthophotos as basic data to reveal the 138 years of land use changes in the Basilicata region (southern Italy). Similar studies have also been done by Kroczak et al. (2018) based on cadastral and orthophoto maps. With the development of remote sensing technology, multi-temporal remote sensing data has become an effective method for identifying short-term land use changes (Weber 2003). Using Landsat satellite imagery, Betru et al. (2019) studied LUCC in the main land use types in western Ethiopia over 38 years and find that forest lands, shrub lands, and grasslands were frequently converted to agricultural land. In addition, Elagouz et al. (2019) investigated LUCC of the Nile River Delta in Egypt from 1987 to 2015 based on remote sensing and used a geographic information system to assess the effect of urban expansion on land cover change.

Next, more and more scholars have began to focus on landscape pattern quantitative analysis and scale effects in recent years. In terms of quantitative analysis, the relationship between landscape pattern change and water system in Beijing was analyzed by Wang et al. (2019). The results showed that the water system tends to expand continuously and provide services for new areas, while the overall shape of the landscape patch becomes regular. The spatial changes in the landscape pattern of oil palm plantations in the Kuala Langat area of Malaysia were simulated by Nourqolipoyr et al. (2015) based on a CA-Markov model, and the evolutionary trend was predicted. In terms of scale effect, Xia et al. (2012) took Baiyangdian Basin in Hebei, China from 2002 to 2007 as an example to analysis landscape pattern changes under the scale of River basin. They find that the fragmentation of anthropogenic landscapes decreased and spatial extent of natural landscapes increased. Furthermore, some investigations have conducted on the regional scale (Feng et al. 2018a, b). The change of the landscape pattern also has an obvious dependence on time scale. It is often limited by data sources, and the time scale has mostly been about 10-40 years (Chan et al. 2016; Bai et al. 2013). However, there is also a small amount of research time spanning more than 50 years (Campagnaro et al. 2017).

Sorting out the driving factors of changes in land resources is conducive to better completion of regional land use policies and improvement of the human settlement environment. Some scholars have done related research in this aspect. Peña-Angulo et al (2019) investigated the physical and artificial driving forces of diversity of land cover in abandoned fields of Mediterranean mountainous areas. The results show that climate and altitude affect the geographic location of secondary forests, and human management also plays an important role in its secondary succession. Kamal et al. (2018) investigated the Kohi Safid Mountains of north-western Pakistan and found that the increased energy demand caused by population growth was the main reason for shrinking green plants. In addition, Luo et al. (2015) showed that the growth from industry and services are the actual drivers leading to a fragmented landscape pattern in China. By the investigation of the drivers of global agricultural land use changes, Alexander et al. (2015) indicated that the increase in human population serves as the greatest driver while changes in diet is an important and growing driver of change.

Based on the above discussion, most of the studies on the evolution of land resources are based on the analysis of land conversion or landscape pattern at the single scale. Changes in land use under the background of urbanization will transform the regional landscape pattern (Salvati et al. 2018), and have a profound impact on ecological, social and economic systems (Tischendorf and Walz 2014). However, most recent studies have ignored the interaction relationship between the land use pattern and landscape pattern. Moreover, recent studies have mainly concentrated on large cities, and there is less research on mountain regions. China has vast mountainous areas that occupy two-thirds of the country's land area, and have obvious geomorphic differentiation characteristics. It has formed loess landform, Danxia landform and karst landform and other landscape elements with different shapes. The spatial differences of landscape elements have shaped different landscape archetypes, such as archetype of branched shape river-valley formed by river water erosion; the archetype of the high-density settlement plain formed by the river alluvium; and the archetype of reticulated agricultural landscape closely integrated with the water system, etc. These landscape archetypes are important elements for the protection of national cultural heritage and biodiversity (Hreško et al. 2015). Therefore, it is necessary to pay more attention to the human settlement of mountain regions. The economy in small cities and towns of mountainous areas has developed rapidly since China's reform and opening up, but economic development and population growth led to land tension in the region. In this paper, we have studied how LUCC affects landscape patterns at different scales in this kind of ecologically sensitive areas in mountain regions. The main problems to be solved are as follows: (1) The characteristics of land use change of the mountain human settlement and their impact mechanisms on the landscape pattern at the regional and town scales. (2) The main driving forces influencing land resources evolution in the mountain human settlement. This study will benefit our understanding of the relationship between regional spatial land use patterns and ecological processes and provides a reference for regional sustainable development and government decision-making.

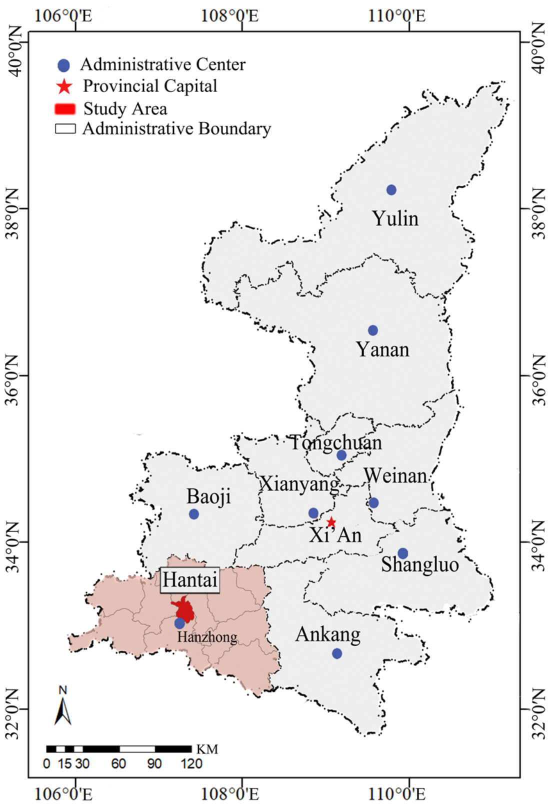

Fig. 1 Geographical location of the study area of Shaanxi Province: showing the political subdivisions and administrative centers.

2 Study Area and Dataset

2.1 Study area

Hantai District (33°07'N, 107°02'E) is located in Hanzhong City, it's a municipal district of Shaanxi Province, China (Fig. 1). Hantai is the core area of the Qinling and Bashan Mountains, and it's an important watershed that influences the climate of China. Moreover, Hantai District is one of the most developed and densely populated mountainous human settlements which is located on the southern edge of the Qinling Mountains. The District has a relatively good geographical location where national management policies have been strongly supported in recent years. It has rapidly developed into the political, economic, and cultural center of the Hanzhong City, having great significance on the economic development of Shaanxi Province and the ecological security of China.

Hantai District has 11 towns under its jurisdiction covering an area of about 556 km² at an elevation of 460 – 2620 m (Fig. 2). The topography of Hantai District has obvious differentiation, and the

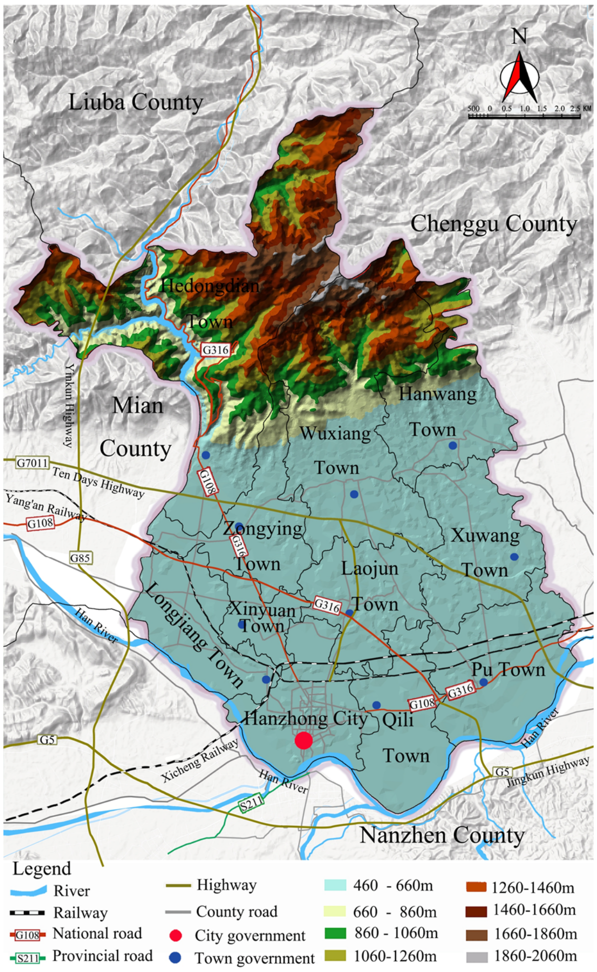

Fig. 2 Map of the administrative division of Hantai District in Shaanxi province, which shows transportation corridors, political boundaries, and elevation.

topography can be divided into alluvial plains, shallow hills and high mountains. The density of population had been reached 1017 people per km² in 2017. In recent years, the economic growth has driven urbanization, but a degree of conflict exists between human need and the provision of land resources. This conflict is mainly characterized by landscape dysfunction and spatial structure disorders under the influence of human activities. Therefore, this is a suitable area to evaluate the impacts of LUCC on landscape pattern, and the driving forces of it.

2.2 Spatial datasets

This study was based on data from the Geospatial Data Cloud that was used to acquire remote sensing images of Hantai District acquired in 1998, 2008 (Landsat 4-5 Thematic Mapper imagery), and 2017 (Landsat 8 Operational Land Imager-Thermal Infrared Sensor imagery). The spatial data employed a Universal Transverse Mercator Projection (UTM), and the coordinate system was WGS84. The images were classified into six land use types including: forest land, cultivated land, water area, grassland, urbanized land, and unused land. Fig. 3 shows the visual maps with land use classification for each of the three time periods. According to the global positioning system field survey, the random point method was used to verify the accuracy of the classification results. The results show that the Kappa index was 0.85 in 1998, 0.85 in 2008, and 0.83 in 2017. It reached the accuracy of the allowable precision at 0.7 (Corcoran et al. 2013). The landscape types were divided into four categories corresponding to related land use types and shown in Table 1 (Olaf 2000). In addtion, the socio-economic data in Hantai Distirct come from Statistical Yearbooks of Hantai District from 1998 to 2017.

3 Methodology

3.1 Analysis of the dynamic evolution of land use

3.1.1 LUCC trajectory

Table 1 Landscape classification of Hantai District

Landscape type	Features	Elements	Land use type
Natural landscape	Primitive landscapes with minimal disturbance from human activities	Han River and its tributaries	Open water
		Barren land	Unused land
Management landscape	The landscape is relatively undisturbed by human activities and is often managed by humans	Forest land, shrub bush, farmland shelter forest	Forest land
		Grassland	Grassland
Farming landscape	Farmland landscape with extensive human use	Dry land, crop, flower, and vegetable fields, orchards	Cultivated land
Anthropogenic landscape	A landscape created by human activities that did not exist in nature.	Residential, rural settlements National, provincial, county, and village transportation corridors Industrial and mining land, tourism and recreation land, special land	Urbanized land

This study took the land use data of 1998, 2008 and 2017 overlapped and summarized their change trajectory into three patterns: (1) early change type: land use type changed only in 1998-2008; (2) late change type: land use type changed only in 2008-2017; (3) continuous change type: land use type changed twice during 1998-2017.

3.1.2 Land use transfer matrix

This study used a land use transfer matrix (Liu and Zhu 2010) to analyze LUCC between 1998 and 2017 in Hantai District of Shaanxi (Table 2).

3.1.3 LUCC characterization

The dynamic process of land use can also be represented by quantitative factors such as net changes (Feng et al. 2011), total changes (Pontius et al. 2004), and states (Luo et al. 2008). Among them:

$$N_c = \frac{U_b - U_a}{U_a} \times 100\% = \frac{\Delta U_{in} - \Delta U_{out}}{U_a} \times 100\% \quad (1)$$

$$T_c = \frac{\Delta U_{in} + \Delta U_{out}}{U_a} \times 100\% \quad (2)$$

$$P_s = \frac{N_c}{T_c} = \frac{\Delta U_{in} - \Delta U_{out}}{\Delta U_{in} + \Delta U_{out}} \quad (3)$$

$$(\Delta U_{in} + \Delta U_{out} \neq 0, -1 \leq P_s \leq 1)$$

where N_c and T_c represents net change and total change in land use type, respectively; U_a and U_b refer to the area of a land use type at the beginning and end of the research period, respectively; ΔU_{in} indicates the area of other land types converted to a certain type; and ΔU_{out} indicates that a certain land use type is converted to another land use type.

P_s refers to the trend of change and state of land use types. When $0 < P_s \leqslant 1$, it indicates that land use types are developing in the direction of scale growth. The closer the P_s is to 0, the more the land is growing Hantai District at a slow rate, and the transition is in a two-way equilibrium state, but the amount of area being transferred out is slightly smaller than the area

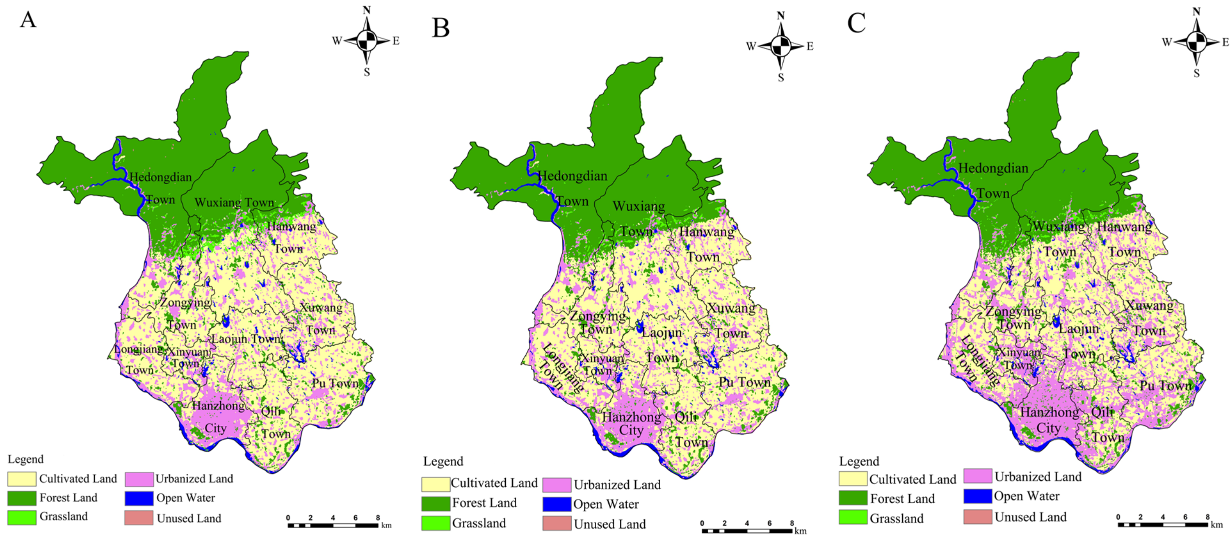

Fig. 3 Land use/cover type map of Hantai District in (A) 1998, (B) 2008, and (C) 2017.

Table 2 Land use transfer matrix

		T_2				P_{i+}	Reduction
		A_1	A_2	…	A_n		
T_1	A_1	P_{11}	P_{12}	…	P_{1n}	P_{1+}	$P_{1+}-P_{11}$
	A_2	P_{21}	P_{22}	…	P_{2n}	P_{2+}	$P_{2+}-P_{22}$
	…	…	…	…	…	…	…
	A_n	P_{n1}	P_{n2}	…	P_{nn}	P_{n+}	$P_{n+}-P_{nn}$
P_{+j}		P_{+1}	P_{+2}	…	P_{+n}	1	
Increase		$P_{+1}-P_{11}$	$P_{+2}-P_{22}$	…	$P_{+n}-P_{nn}$		

Note: rows indicate the land use type at time T_2, and columns indicate the land use type at time T_1. P_{ij} represents the percentage of land type *i* converted to land type *j* as a percentage of total area at time T_1–T_2. P_{ii} represents the area percentage of land use type that remains unchanged at time T_1–T_2. P_{i+} represents the percentage of land type *i* at the time of T_1. P_{+j} represents the percentage of land type *j* in total area at T_2. $P_{i+}-P_{ii}$ is the percentage reduction of the land type *i* during T_1–T_2; $P_{+j}-P_{jj}$ is the percentage increase of land type *j* during T_1–T_2.

Table 3 Landscape pattern indices

Scale	Name	Formula	Meaning
Class Metrics	Patch Density	$PD=N/A$	The larger the value, the higher the spatial heterogeneity of the landscape.
	Mean Proximity Index	$MPI=(\sum_{j=1}^{n}\sum_{s=1}^{n}\frac{a_{ijs}}{h_{ijs}^{2}})/n_i$	The larger the MPI value, the higher the proximity between plaques of the same type.
	Mean Patch Fractal Index	$MPFD=\frac{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}2\ln(\frac{0.25p_{ij}}{\ln a_{ij}})\right]}{N}$	MPFD value range [1,2]. The closer the MPFD is to 1 or 2, the simpler or more complex the land use polygon shape, respectively.
	Mean Shape Index	$MSI=\sum_{j=1}^{n}\left[\left(\frac{0.25p_{ij}}{\sqrt{a_{ij}}}\right)\cdot\left(\frac{a_{ij}}{\sum_{j=1}^{n}a_{ij}}\right)\right]$	An increase in MSI indicates the land use polygon shape becomes more complicated and irregular.
Landscape Metrics	Shannon's Evenness Index	$SHEI=\left[-\sum_{i=1}^{n}(p_i\cdot\log p_i)\right]/\log n$	SHEI∈[0,1], The closer the SHEI is to 0, the more uneven the proportion of different land use polygon types in the landscape.
	Shannon's Diversity Index	$SHDI=1-\sum_{i=1}^{n}p_i^2$	SHDI≥0. The larger the SHDI, the higher the degree of landscape diversity.
	Fragmentation Index	$FN=(N_p-1)/N_c$	FN∈[0,1]. If FN is 0 or 1, this means the landscape has no fragmentation or is completely fragmented, respectively.

Note: N/N_p is the number of patches in the landscape; p_i is the proportion of the area occupied by landscape i; m is the number of landscape types; n is the number of patches in a certain type of landscape. N_c is the ratio of total area to minimum land use polygon area; p_{ij} and a_{ij} are the perimeter (m) and area (m²) of land use polygon ij; a_{ijs} and h_{ijs} are the area of the land use polygon ijs (m²) and its closest distance to the same type of land use polygon (m).

transferred in. The closer P_s is to 1, the more the land type conversion is in an unbalanced state and is dominated by a one-way transfer in to land uses.

When $-1 \leqslant P_s \leqslant 0$, the land use type is developing in the direction of a scale decrease. The closer P_s is to 0, the more the land type is decreasing at a slow rate, showing a two-way conversion trend, but the amount of area being transferred out is slightly larger than that transferred in. The closer P_s is to -1, the more the land type conversion is in an unbalanced state and is dominated by a one-way transfer out of that land type.

3.2 Models of landscape pattern change

A landscape pattern index can highly enrich the regional landscape pattern information and quantitatively express the landscape pattern's spatial configuration (Fu et al. 2011). In this study, the typical landscape pattern indicators at the regional scale and the scales of towns under the jurisdiction were analyzed (Table 3).

3.3 Driving force analysis

The factors affecting the change of land resource can be divided into environmental and anthropogenic elements. There are obvious differences in landform in Hantai area, the main part is alluvial plain, and is also the area with the most significant land use change. Some environmental variables are stable (such as topography and slope, etc.) in the alluvial plain area in a short time and space. As pointed out by Kleemann et al. (2017) and Demise's et al. (2017) research, human activities and policy changes are the main factors causing land use changes. Hantai District has received support from national development policies in recent years, and the population of surrounding towns has also flowed in. Therefore, the present investigation mainly analyzed the effects of anthropogenic factors and the most important environmental factors on the evolution of land resource. This paper selected ten indicators that may affect land resource changes based on the 1998–2017 Statistical Yearbooks of Hantai District. The selected factors are as follows: X1, population (people); X2, X3, X4, and X5, annual total (dollars), primary industry (dollars), secondary industry (dollars), and tertiary industry economic outputs (dollars), respectively; X6, annual fixed asset investments (dollars); X7, total amount of annual grain production (ton); X8, annual investment in real estate development (dollars); X9, afforestation area (ha); X10, level of urbanization (%). Principal component analysis by SPSS 21 revealed the correlation between various indicators and changes in land resources.

4 Result and Discussion

4.1 Analysis on LUCC and evolution trends

From the perspective of the spatial distribution of land use change in Hantai District (Fig. 4), it has spatial agglomeration and is closely related to human activities. The change areas were mainly concentrated in the southern and central parts of the region where human activities are relatively frequent. In the northern part of the region, land use development was restricted due to the topography restrictions and ecological conservation. The land use types were mainly cultivated land and grassland, with little change. In terms of time series, the land use change trajectory in Hantai District was mainly late changes, supplemented by early changes, and the proportion of continuous changes was the smallest. This also showed that the economic construction of Hantai District has made remarkable development since 2008.

The results of landscape type change from 1998 to 2017 can be visualized in Fig. 5. The main landscape type of Hantai District during 1998 and 2008 was farming (214.29 km² and 209.83 km²). By 2017, managed landscape became the main type (211.56 km²). The natural landscape was always the smallest landscape type. The anthropogenic landscape had developed rapidly during 1998-2017 and changed from were 85.57 km² to 135.10 km².

According to the analysis result of land use change trend (Table 4), from 1998 to 2017, the land use type in Hantai District showed a two-way transition trend. During 1998-2008, the N_c indices of forest, cultivated, and urbanized lands showed a growing trend; meanwhile, the P_s indices were 0.81, 0.16, and 0.75, respectively. These indices suggesting that the corresponding land types developed in the direction of scale growth. The cultivated expanded land most slowly, and experienced two-way transitions with other land use types. Meanwhile, forest and urbanized land mainly experienced one-way transitions, and the forest land expanded fastest.

Fig. 4 Spatial distribution of land use change in Hantai District from 1998 to 2017.

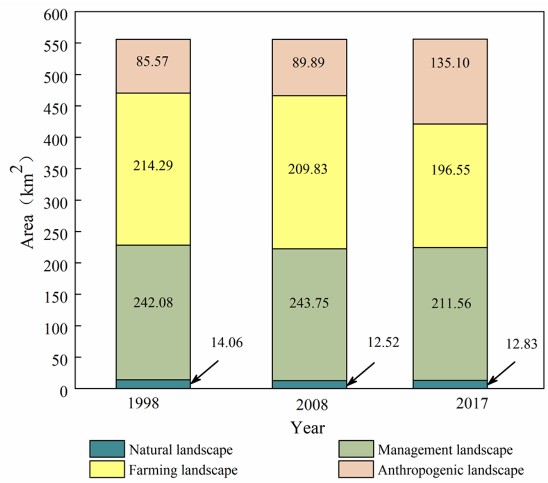

Fig. 5 Areas of different landscape types in Hantai District in three time points.

The N_c indices of open water, unused land, and grassland deceased during this period. The P_s of open water was -0.57 and relatively closes to 0, indicating that area was being lost but only at a very small rate, and there is a tendency to a dynamic balance between open water and other land-use types. The P_s indices of grassland and unused land were -0.98 and -0.81, respectively, which was falling and close to -1, indicating that the conversion of grassland is dominated by a one-way transfer out and is in an extremely unbalanced state.

From 2008 to 2017, the N_c indices of open water, grassland, forest land, and urbanized land showed a growing trend (Table 4). The P_s indices for those same areas were 0.28, 0.65, 0.12, and 0.93, respectively, which indicates that the corresponding land types developed in the direction of scale growth decreased. The P_s of open water and forest land were 0.28 and 0.12 which is relatively close to 0, indicating that the land types were growing at a slow rate and in a two-way equilibrium state. The conversions of grassland and urbanized land were mainly represented by one-way transitions. In particular, the P_s of urbanized land was close to 1, indicating the land use type transition is extremely imbalanced. The N_c of unused and cultivated lands decreased during the study period. The P_s of the unused land was -0.40, which indicates that unused land was losing very slowly, and the trend is toward a dynamic balance. The cultivated land P_s was -0.95, which indicates that cultivated land was rapidly converted to other land use types.

Reviewing the land use transfer matrix (Table 5) showed that from 1998 to 2017 the open water was mainly converted into forest or used for urbanization and cultivation. Unused land was mainly converted into forest land. Forest land is mainly converted into urbanized, cultivated, and grasslands. Grassland was mainly converted into cultivated or urbanized land, and cultivated land was mainly converted into urbanized land and grassland. Meanwhile, a small amount of urbanized land was mainly converted into forest or cultivated lands. From the perspective of landscape types, the natural and cultivated landscapes were both mainly transformed into anthropogenic landscapes during 1998 to 2017. Farming landscapes that were converted into anthropogenic landscapes accounted for 93.4% of lost farmland, and the transition from natural into anthropogenic landscapes accounted for 79.1% of lost natural landscapes. Management landscapes were mainly transformed into farming landscapes, accounting for 68.1% of its transfer out.

4.2 Analysis of LUCC impacts on the landscape pattern

4.2.1 LUCC impacts on the landscape pattern at regional scale

Table 4 Land use change in Hantai District from 1998 to 2017

Years	Variables	Open Water	Unused land	Grassland	Forest land	Cultivated land	Urbanized land
1998	Area (km²)	13.73	0.33	9.79	204.50	242.08	85.57
	Proportion (%)	2.47	0.06	1.76	36.78	43.54	15.39
2008	Area (km²)	12.40	0.12	4.61	205.22	243.8	89.90
	Proportion (%)	2.23	0.02	0.83	36.91	43.84	16.17
2017	Area (km²)	12.73	0.10	5.67	205.9	196.6	135.1
	Proportion (%)	2.29	0.02	1.02	37.02	35.35	24.30
1998-2008	N_c (%)	-9.69	-63.64	-52.91	0.35	0.69	5.06
	T_c (%)	16.53	78.79	53.73	0.43	4.32	6.79
	P_s	-0.57	-0.81	-0.98	0.81	0.16	0.75
2008-2017	N_c (%)	2.66	-16.67	22.30	0.33	-19.36	50.30
	T_c (%)	9.60	41.67	34.49	2.66	20.42	54.06
	P_s	0.28	-0.40	0.65	0.12	-0.95	0.93

Note: N_c and T_c represents net change and total change in land use type, respectively; P_s refers to the trend of change and state of land use types.

Table 5 Land us transfer matrix of Hantai District from 1998 to 2017 (Unit: %)

Land use type		2017 Open Water	Unused land	Grassland	Forest land	Cultivated land	Urbanized land	Total	Decrease
1998	Open water	2.09	0.00	0.00	0.03	0.02	0.33	2.47	0.38
	Unused land	0.00	0.01	0.00	0.03	0.01	0.01	0.06	0.05
	Grassland	0.05	0.00	0.79	0.03	0.83	0.06	1.76	0.97
	Forest land	0.02	0.01	0.09	36.37	0.11	0.18	36.78	0.41
	Cultivated land	0.09	0.00	0.12	0.40	34.24	8.69	43.54	9.30
	Urbanized land	0.04	0.00	0.02	0.16	0.14	15.03	15.39	0.36
Total		2.29	0.02	1.02	37.02	35.35	24.30	100	
Increase		0.20	0.02	0.23	0.65	1.11	9.27		

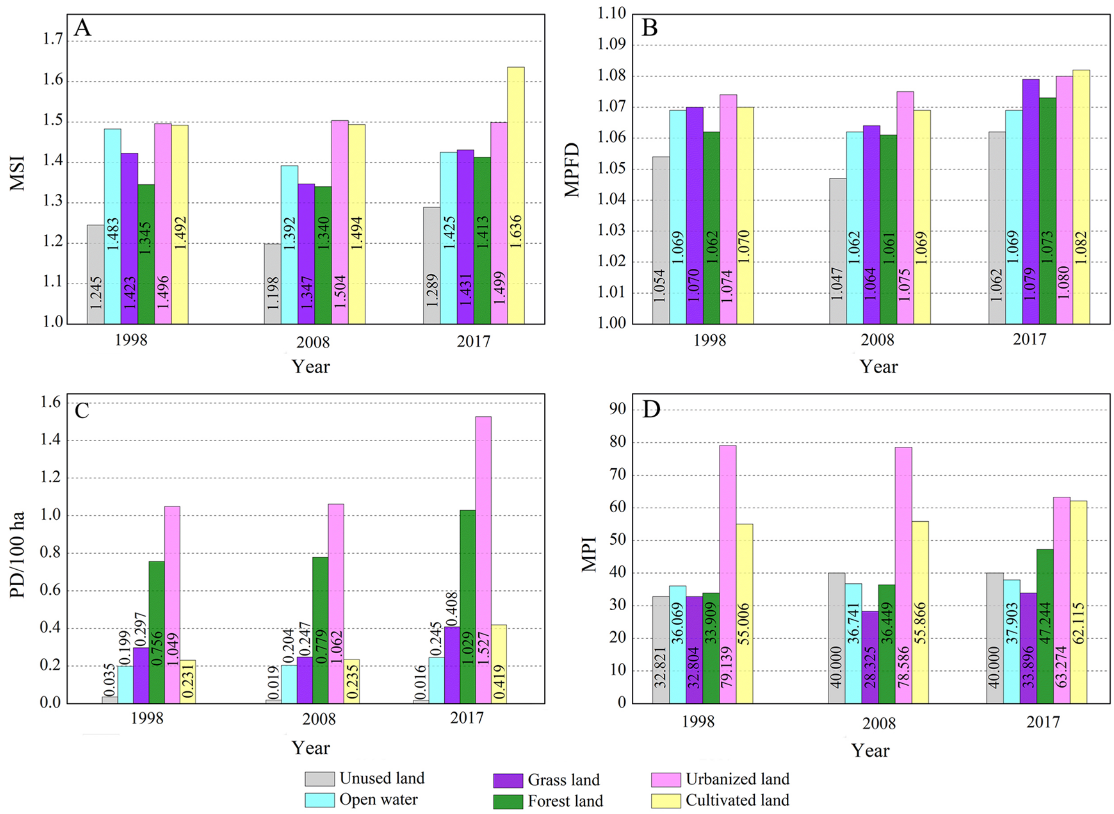

Fig. 6 The value of landscape indexes in Hantai District for three time points: A. Mean Shape Index (MSI), B. Mean Patch Fractal Index (MPFD), C. Patch density (PD), D. Mean proximity index (MPI).

This paper analyzes the changes in landscape pattern from the aspects of land use patches morphology and spatial patterns. The Mean Shape Index (MSI) and Mean Patch Fractal Index (MPFD) were used to analyze the changes of land use patches morphology. The MSI is best used to describe the macroscopic morphology of a land use patches, while MPFD is used to describe the complexity of land use patches boundaries. The Patch Density (PD) and Mean Proximity Index (MPI) were used to analyze the changes of spatial patterns. The PD reflects the degree of fragmentation and heterogeneity of the landscape, and MPI reflects the connectivity of land use patches in the same landscape type.

Results for MSI and MPFD changes in Hantai District from 1998 to 2017 can be visualized in Figs. 6 A and B. The MSI and MPFD of unused land was the smallest among all land types indicating that unused land patches are most regular and have simple border in shape. The MSI and MPFD of cultivated land and urbanized land were higher among all land types with a significant increasing trend especially from 2008 to 2017. This indicates that the corresponding the land patches has a significant change in morphology, and the shape of their boundary became more complex, this trend is more obvious after 2008. The MSI and MPFD of forest land are most stable, indicating that forest land is less affected by humans and with the least change. By comparing MSI and MPFD could found that the trends of the two indicators in each land type are the same. It means that when the land type morphology is simple, the boundary is also relatively smooth; the land type morphology tends to be complicated; the boundaries of land use patches tend to develop in a saw tooth shape.

The PD and MPI changes in Hantai District can be seen in Figs. 6 C and D. From 1998 to 2017, the PD is highest in urbanized land, indicating that it is most fragmented patches. The lowest patches fragmentation is unused land. The PD of all land use type except unused land showed an increasing trend. This indicates that most land types are moving towards fragmented. In terms of landscape connectivity, the MPI of urbanized land showed a decreasing trend while other land use type increased slightly. Although the landscape connectivity of urbanized land is the highest, it is decreased year by year. By comparing PD and MPI, we can see that there is no obvious regularity in the changes of these two indicators. The impact of the fragmentation of land use patches on proximity depends on the distribution of patches in the region.

Comparing the landscape pattern evolution with LUCC process in the Hantai District, we can find that the change of each land use type directly affects its landscape pattern. The relationship between the MSI, MPFD, and its area was investigated. The results revealed that the patch shape of unused land in the study area becomes relatively complex with the decrease of an unused area. Under the influence of forest protection policies, the area of forest land has changed little from 1998 to 2008, with the most stable MSI and MPFD, and the least human interference to patch shape. The MSI and MPFD of cultivated land and urbanized land increased depends on the large amount of urbanized land occupied by the cultivated land, which causes the land patches to become more scattered. Investigation of the relationship between the PD of the urbanized land and its area revealed that the PD in the study area increased with the increased in urbanized land. This indicated that the patches of urbanized land tend to be fragmented during the expansion process. The PD of unused land decreased with the decreased of its area, indicating that the unused land patches develop towards aggregation during conversion. The PD of other land type increased with their area decreased. This is mainly as a result of the scattered expansion of construction land, various types of land have been invaded, fragmenting the overall landscape pattern of the region. The relationship between the MPI of the urbanized land and its area revealed that the MPI decreased obviously with the increased of its area. It indicated that the connectivity between patches reduced while the area is fragmented. In addition, the MPI of other land type increased with their area decreased. The connectivity of these land types ascends slowly. However, this trend is not obvious.

Overall, the landscape pattern of Hantai District was obviously influenced by LUCC, the morphology of land use patches has become more complex, which evolved from natural random growth to an anthropogenic saw tooth shape (Fig. 7). The spatial pattern of land use patches has evolved from a ruled concentration to a fragmented expansion (Fig. 8).

4.2.2 LUCC impacts on the landscape pattern under the jurisdiction of Hantai District

LUCC have caused varying degrees of landscape pattern impact on towns under the jurisdiction of Hantai District. We discussed the impact of the LUCC on the landscape uniformity, diversity, and fragmentation in each town through Shannon's Evenness Index (SHEI), Shannon's Diversity Index (SHDI), and Fragmentation Index (FN) (Table 6). SHEI can reflect the degree to which landscape type controls the overall landscape. From 1998 to 2017, the SHEI of Wuxiang, Laojun, Puzhen, Qili, and Longjiang Towns were showing an increasing trend. It means that all kinds of landscape patches developed into a balance trend. The SHEI of Xuwang Town, Xinyuan Town, and Hanzhong City increased from 1998 to 2008, then decreased from 2008 to 2017. Meanwhile, SHEI of the towns of Hedongdian, Hanwang, and Zongying declined from 1998 to 2008. However, from 2008 to 2017, the growth of the

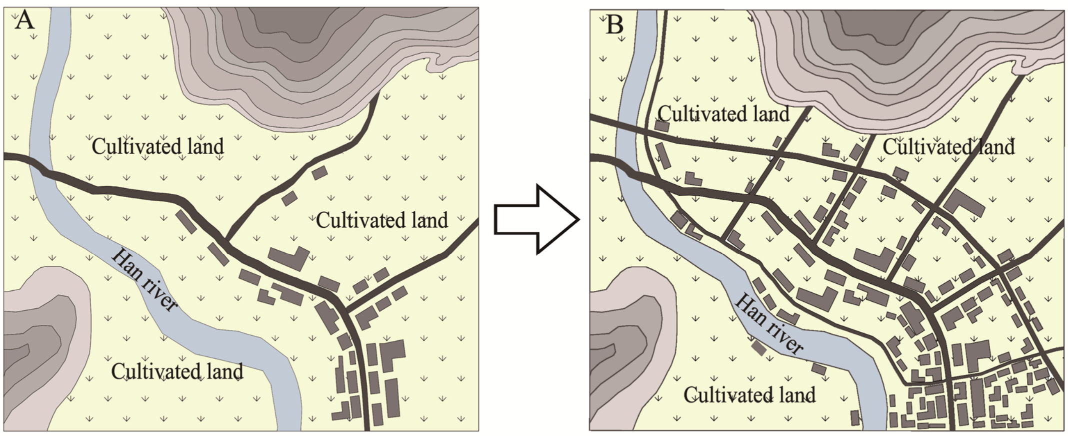

Fig. 7 Schematic diagram of the evolution of land use polygon morphology of landscape patches in Hantai District: A. the natural and regular land use morphology; B. the morphology tends to be an anthropogenic saw tooth shape.

anthropogenic landscape made the overall landscape become more balanced between different land types.

SHDI can reflect the complexity and variability of landscape patches as well as the proportion of different landscape types in the overall landscape. The SHDI of Hanzhong City decreased from 1998 to 2017, the landscape diversity reduced. The SHDI of Qili and Xinyuan towns showed an increasing trend, the landscape heterogeneity increased. The SHDI of the towns of Hedongdian, Wuxiang, Hanwang, Zongying, Pazhen and Longjiang decreased from 1998 to 2008, then increased from 2008 to 2017. In addition, from 1998 to 2008, the SHDI of Xuwang and Laojun towns showed an increasing trend. The small increase in forest land there made the landscape development tends to be diverse. However, due to the reduction in cultivated land from 2008, the SHDI declined.

FN can reflect the degree of landscape fragmentation and the complexity of its structure. From 1998 to 2017, the FN of Hanwang Town showed a decreasing trend, with landscape patches were tending to gathering. The FN of Qili and Xinyuan towns showed an increasing trend, the landscape patches were tending to be fragmented. The FN of Wuxiang, Zongying, Laojun, and Longjiang towns decreased from 1998 to 2008. However, the FN increases during 2008 to 2017. The FN of Hedongdian, Xuwang, and Puzhen towns as well as Hanzhong City increased from 1998 to 2008 and decreased from 2008 to 2017.

It can be seen from the analysis of the landscape pattern changes of the towns under the jurisdiction of Hantai District. The largest decrease in SHEI, SHDI and FN from 1998 to 2017 was both in Hanzhong City, indicating that the area proportion of each patches develops in a most unbalanced trend, the most significant decline in landscape patches diversity, and the landscape fragmentation has been most

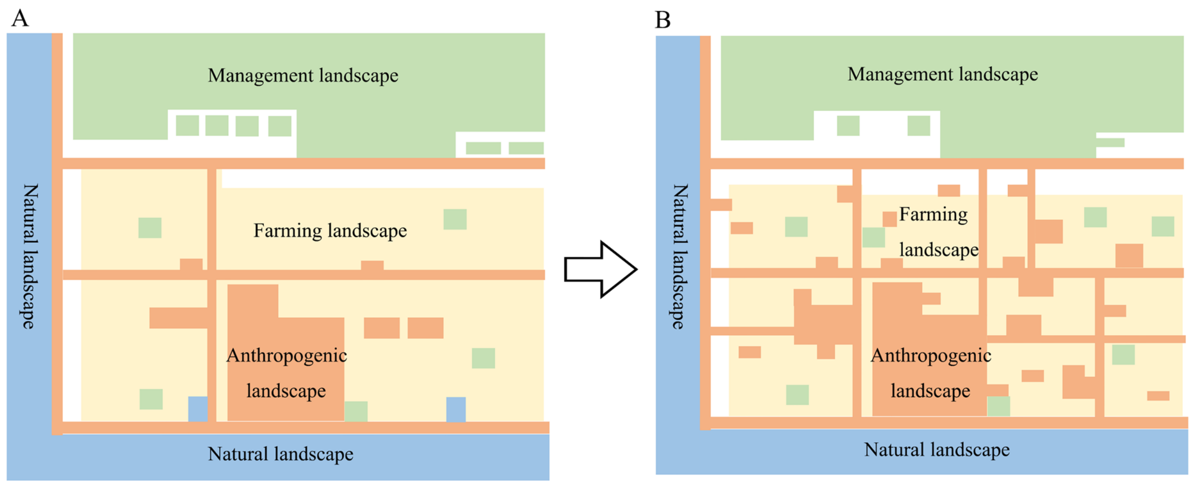

Fig. 8 Schematic diagram of the spatial pattern evolution of landscape patches in Hantai District: A. the concentrated pattern; B. the fragmentation of landscape polygon.

Table 6 Landscape pattern indices of various towns in 1998, 2008 and 2017 in Hantai District

Town	SHEI			SHDI			FN		
	1998	2008	2017	1998	2008	2017	1998	2008	2017
Hedongdian Town	0.358	0.354	0.361	0.697	0.689	0.098	0.001	0.002	0.001
Wuxiang Town	0.568	0.586	0.615	1.105	1.051	1.101	0.01	0.006	0.007
Hanwang Town	0.742	0.687	0.713	1.329	0.987	1.277	0.007	0.006	0.003
Zongying Town	0.615	0.573	0.623	1.102	1.027	1.116	0.009	0.006	0.016
Xuwang Town	0.463	0.586	0.539	0.829	1.051	0.965	0.012	0.013	0.009
Laojun Town	0.440	0.452	0.559	0.708	0.727	0.899	0.021	0.019	0.017
Puzhen Town	0.480	0.511	0.602	0.934	0.916	1.074	0.013	0.025	0.013
Qili Town	0.460	0.513	0.602	0.895	0.920	1.078	0.004	0.004	0.014
Xinyuan Town	0.539	0.646	0.599	0.868	0.900	0.965	0.013	0.016	0.016
Longjiang Town	0.497	0.531	0.595	0.967	0.951	1.066	0.011	0.004	0.008
Hanzhong City	0.574	0.606	0.510	1.117	1.086	0.914	0.017	0.019	0.006

Note: SHEI, Shannon's Evenness Index; SHDI, Shannon's Diversity Index; FN, Fragmentation Index.

significantly improved. This phenomenon is mainly driven by the implementation of the Hanzhong City Master Plan (2009-2020) in 2009. The construction of various transportation and infrastructure made urbanized land has experienced a rapid expansion and became the main land use type in this area. The areas of cultivated land, forest land, open water, and unused land decreased correspondingly, this extremely unbalanced land change trend made uniformity and diversity of the landscape significantly reduced. The large-scale anthropogenic landscape enhanced the connectivity between landscape patches dominated by anthropogenic landscape, which significantly reduced the phenomenon of landscape fragmentation.

The largest increase in SHEI, SHDI and FN from 1998 to 2017 was both in Qili Town, which means that during this period the proportion of different landscape patches tend to be balanced, landscape towards diversification and the trendency of landscape towards fragmentation were most obvious. In the 1990s, Qili Town focused on the development of industrialized agricultural economy, with cultivated land being the main land type; after 2000, township enterprises such as Chongqing Glass Factory and Power Tool Factory gradually developed, forming a market town business economy. The continuous growth of urbanized land has replaced part of the cultivated land to increase the overall landscape uniformity and diversity. But the aggregation was low, the sporadic urbanized land cuts the integrity of the farmland matrix which led to fragmentation of landscape patches.

The most stable SHEI, SHDI and FN from 1998 to 2017 were both in Hedongdian town, the landscape uniformity, diversity and fragmentation changed little. The central and northern parts of Hedongdian Town are mainly hilly areas of the Qinling Mountains; forest land was the main land type. Under the influence of forest land protection and the policy of returning farmland to forest, the human activities are minimally, which created stable landscape pattern.

Overall, the LUCC changes of the Hantai District had different degrees of impact on the landscape pattern of each town. The expansion of urbanized land played a key role in promoting the change of landscape pattern. Among them, the most significant changes in the landscape pattern are Hanzhong City and Qili Town. However, these two areas are at different stages of development. It indicates that in the initial development of towns and cities, landscape uniformity, diversity and fragmentation increased. After development occurs to a certain extent, a single landscape type continues to expand with corresponding decreases in landscape uniformity, diversity, and fragmentation. The most stable landscape pattern is Hedongdian Town.

4.3 Driving force analysis of landscape pattern evolution

Principal component analysis was carried out on 10 selected indicators by SPSS22 software. The two principal components that were extracted contributed 86.78% of the cumulative variance. The first principal component was primarily correlated with economic development, real estate development and urbanization level, so it summarizes social and economic factors. The second principal component is summarized as a policy factor, which is related to the grain output (Table 7), meanwhile the adjustment of urban, rural, and land use planning is also related to it.

4.3.1 Social and economic factors

The development of economic and urbanization are important factors affecting the changing landscape patterns in Hantai District. The total gross domestic product of Hantai District was 319.51

Table 7 Principal component load

Indicators	First principal component	Second principal component
X1 Population	0.949	-0.254
X2 Annual total economic output	0.994	0.080
X3 Primary industry economic output	0.991	0.132
X4 Secondary industry economic output	0.973	0.193
X5 Tertiary industry economic output	0.889	0.133
X6 Annual fixed asset investment value	0.974	0.198
X7 Total amount of annual grain production	-0.510	0.853
X8 Annual investment in real estate development	0.994	0.100
X9 Afforestation area	0.945	-0.280
X10 Urbanization level.	0.990	0.134

million USD (2.25 billion yuan) in 1998, while it reached 4048.57 million USD (28.74 billion yuan) in 2017. The urbanization rate of Hantai District has increased from 43% in 1998 to 59% in 2017. The abandonment of farming landscapes under the development of urbanization is a worldwide problem that affecting mountain areas. The environmental conflict of abandoned farmland in mountain areas is mainly manifested in the replacement of traditional mountain arable land with tourism facilities, roads and hotel related construction. (Săvulescu et al. 2019). In Hantai district, the economic growth has led to increased demand for housing, transportation and infrastructure. Therefore, part of the cultivated land is occupied as urbanized land. Meanwhile, the mechanization of agriculture and the rapid development of manufacturing industries have brought about an improvement in production methods and a transformation from low to high yield industries. This also promotes the reduction of cultivated land. The urbanized area of Hantai district expanded from 85.57 km^2 in 1998 to 135.11 km^2 in 2017, and the overall landscape pattern tends to be fragmented. This coincides with Liu et al. (2014) investigation on the spatiotemporal characteristics in China since the late 1980s. Their results indicated that with the acceleration of urbanization in China, the conflict between urbanization and cultivated land conservation is becoming increasingly prominent. The use of cultivated land for construction is the main reason for cultivated land loss. In addition, human activities have also increased the level of overall landscape fragmentation and promoted the transition from water area, unused land, and grassland to urbanized lands.

4.3.2 Policy factor

Human management has a strong influence on land resources evolution (Peña-Angulo et al. 2019), government intervention and implementation of land policies will lead to changes in the landscape pattern. Since 2004, the establishment of the interest compensation mechanism, and the improvement of rural land contracting policies have all changed the landscape of the study area. These policies have enabled the maximization of food production in the face of shrinking arable land. Long-term agricultural activities also tend to fragment cultivated land and promote change in the overall landscape pattern.

In addition, the urban and rural planning, as well as in land use planning, have affected the landscape pattern of Hantai District. For example, the urbanization of areas used for the Hanzhong High-speed Railway Station, Hanzhong Chenggu Airport, Xihan and Shitian Expressway has promoted the transition from cultivated land to urbanized land. Under the guidance of the *Hanzhong City Land Use Plan*, *Hanzhong City Master Plan*, *Hanzhong City Town System Plan*, and relevant plans of various towns and villages in Hantai District, the Hantai District has developed and become more urbanized so that the structure of the landscape pattern changed.

5 Conclusions

Based on the quantitative method, this study analyzed the impact of LUCC on landscape patterns at different scales in typical mountain human settlement of Shaanxi, China. Based on the principal component analysis, the leading factors of land resources evolution were analyzed. The main conclusions are as follows:

(1) In Hantai District, the urbanized land from 1998 to 2017 expanded most rapidly, with the proportion increasing from 15.39% to 24.30%. Cultivated land was lost most rapidly with the proportion falling from 43.54% to 35.35%. This reflects the human increasing demand for land in mountainous areas, which transforms farming landscapes into anthropogenic landscapes.

(2) LUCC has caused a significant change in the landscape pattern. The expansion of urbanized land played a key role in promoting the change of landscape pattern. At the regional scale, the patch morphology of most land types tends to be complicated, and the degree of fragmentation increases. Patches morphology developed from a natural random to a sawtooth shape and its spatial pattern evolved from a ruleset to a fragmented expansion. This reflects the region is in the early stage of urbanization, the urbanized land is mosaiced into other land types, but it's not large-scale. Under the jurisdiction of Hantai District, the biggest change in landscape pattern caused by LUCC is in Hanzhong City and Qili Town.

(3) Of the driving factors of this change, the improvement in economy and increases in population and urbanization rate are the main driving forces causing the transformation of farming landscapes into

anthropogenic landscapes. In addition, under the influence of regional policies such as urban and rural planning, adjustment of land use planning, direct food subsidies for people in rural areas, and establishment of interest compensation mechanisms has also promoted changes in the landscape pattern.

This investigation improves our understanding of the land resources evolution process and mechanism in mountain region settlements and provides theoretical guidance for reviewing local development. This method is also applicable and can be used to analyze other regions. Future research will focus on the ecological effects of land use changes in mountain region settlements, and in-depth analysis of the simulated predictions of land changes to delineate reasonable spatial control boundaries.

Acknowledgements

This study was funded by Natural Science Foundation of China (51378067), the Natural Science Foundation of Shaanxi (806215594019).

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