

Transformation of Rural Landscape Patterns in Southwest China's Mountain: A Case Study Based on the Three Gorges Reservoir Area

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Research Article

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Abstract

Since the 21st century, China's rural areas have experienced far-reaching social and economic transformation. Studying the evolution and transformation of rural land use landscape pattern under this background is of great significance to reveal the evolution of human-land relationship in China's mountains and explore the rural revitalization path. Based on the study of land use change and transition, we put forward the theoretical framework of landscape pattern transition, and establish the rural landscape pattern transformation model of mountain area in southwest China by use of high resolution remote sensing images and field investigation. The results show that: (1) The focus of landscape pattern transformation in the case region is mainly embodied in the reduction of cultivated land, the expansion of orchard and the restoration of woodland. There are obvious differences in landscape pattern transition among different terrain areas in the case region. (2) From 2000 to 2018, the landscape types in the valleys of the study area were gradually diversified, there was a concentration of intensive land use types, and the landscape types in mountainous and hilly area were gradually simplified, and forest land was restored. (3) On the whole, the landscape pattern of the study area has changed from production-oriented landscape pattern to eco-economic landscape pattern and eco-regulatory landscape pattern. The results of case study show that the rural landscape pattern in the mountainous areas of Southwest China has undergone a transformation under the background of land use transformation, which has its own particularity, and verifies the theoretical hypothesis proposed in this paper, so it is necessary to conduct a systematic and in-depth study on this. The theories and methods of this paper are helpful to understand the process of landscape pattern transition in mountainous areas, and provide reference value for the rational use of land resources, ecological management and rural revitalization in similar mountainous areas.

1. Introduction

Land use is the most prominent landscape symbol of the Earth's surface, human survival and development can't be separated from the land (Long 2007). Land use transition is a process when regional land use morphology changes from one form to another in a period corresponding to the transition of socioeconomic stages (Long 2012). The basic characteristics of land transformation are land use change and intensification (Richter 1984), and the rapid land use transformation caused by agricultural, industry and population urbanization has a huge impact on the ecological environment (Zhang et al. 2010). Land use change and landscape processes are interrelated and form a complex multi-scale system under the influence of various biological, physical and socio-economic drivers (Claessens et al. 2009). Land use change will directly affect the change of landscape pattern (Long et al. 2009; Ruiz and Domon 2009; Foley et al. 2005; Lambin and Meyfroidt 2010), and is considered to be a major factor affecting landscape structure and biodiversity patterns, particularly in regions with long-term anthropogenic disturbances and habitat fragmentation (Hernandez et al. 2015). The change of landscape pattern is the most prominent symbol of land use change (Jiang et al. 2018). Of course, land use change is highly dynamic in landscape structure change and its impact on ecosystem

services supply (Baude et al. 2019). The changes in landscape composition and structure are the result of changes in the interaction between humans and the environment, and are also the driving force of global environmental change (Verburg et al. 2013).

The change of land use and landscape pattern can be divided into five stages, such as land reclamation, subsistence agriculture, gradual intensive agriculture and intensive agriculture (Foley et al. 2005). Influenced by history, socioeconomic conditions and ecological background, different regions of the world are in different stages of land use transformation (DeFries et al. 2004). Landscape transition shows that both productivist agriculture and land abandonment can coexist in a spatially differentiated pattern (Zomeni et al. 2008). In other areas, however, there has been a reverse shift, with market-oriented intensive agricultural production systems replacing ecologically oriented extensive traditional agricultural systems, resulting in rapid changes in the agricultural landscape (Amjath-Babu and Kaechele 2015).

The land use adjustment of different artificial processes (such as industrialization) and the abandonment of land due to the reduction or transfer of agricultural activities are driving the agricultural landscape from production services to regulation services (Zhao 2004; Vigl et al. 2016). Some scholars have illustrated how the development associated with globalization and growing urban markets are reshaping rural areas (Robinson and Song 2019). For example, most changes in rural areas have been found to point to cash crops and to highlight socioeconomic differences between different farmers (Vanwambeke et al. 2007). The transformation of agricultural land use in rural areas is characterized by the substantial decrease of farmland, cultivated land and sown land and the increase of fallow land, natural grassland and pasture (Kaz'min 2016). In order to improve the ecological management of the miombo woodlands in southwestern Tanzania, the implement of sustainable land management and diversified livelihood strategies could reduce dependence on tobacco cultivation and contribute to the future sustainable development of this ecological zone (Jew et al. 2017). The number of settlements in high-altitude areas (above 1400 m) has decreased, forest coverage has increased, and agricultural land, shrubs and grasslands have decreased (Bhawana et al. 2017). The dynamics of land cover at both the regional and local scales indicate that the landscape shows a trend of homogeneity (Garcia-Llamas et al. 2019). Of course, the expansion of man-made activities has also occurred in some mountainous areas. For example, in Brazil, especially near rivers and woodlands or on steep slopes with sufficient rainfall, pastures and sugarcane plantations have shown a significant expansion trend (Molin et al. 2017).

Since 1989, China's land use intensity has been declining, leading to the return of large areas of cropland to grassland (Feurdean et al. 2016), and a forest transition has already occurred in China and that the turning point took place in the 1990s (Wang et al. 2019). The Grain to Green Program, launched in 1999, is the most effective measure to significantly improve the ecological and socioeconomic status of the Loess Plateau in China (Cao et al. 2018). In recent years, China's mountainous areas have gradually formed a sustainable spatial pattern of "ecology-production". Abandoned lands have shown the characteristics of "spreading" development, and settlements and cultivated land have gradually moved from high altitudes to the valley flats (Cao et al. 2019). Presently, rural China is undergoing a transition from "traditional grain production stage" to "market-oriented comprehensive agricultural development

stage” (Ge et al. 2019). Human assets and transport facilities are the most important factors in improving the livelihood strategies of rural Chinese households (Zhang et al. 2019). Combining ecological restoration with measures to provide sustainable livelihood for residents in the project areas can achieve the win-win goal of ecological restoration and poverty alleviation (Cao et al. 2020). The rapid urbanization, with a large increase in construction land area, is the core dynamic mechanism of the landscape structure change of farmland landscape system (Jiang et al. 2018).

In a word, in the background of rapid socioeconomic development and land use transformation, great changes have taken place in rural China in recent decades. Therefore, how does rural landscape pattern evolve, especially, how does the landscape pattern in mountain area transform and evolve is an important issue worth studying. However, there are few studies on the evolution of rural landscape pattern under the background of land use transition.

Three Gorges Reservoir Area (TGRA) is a typical mountainous area in Southwest China, which has an important ecological status. Once it has also been a region with a large population pressure and the intense slope land reclamation (Zhang et al. 2012). The land use/land cover of TGRA has changed significantly (Zhang et al. 2009), land consolidation project and returning farmland to forest projects are the main reasons for the change of landscape pattern (Zhang et al. 2020). Therefore, it is of great significance to discuss whether the rural land use changes have led to changes in rural landscape pattern under the background of multiple changes in this region. This study first defines the transformation of landscape pattern, then puts forward its theoretical framework of landscape pattern transformation, and takes Caotangxi watershed, a typical watershed in the TGRA, as the study area. The object of this paper is to deeply explore whether the landscape pattern has undergone corresponding transformation, the focus of landscape pattern transformation, the spatial difference of transformation and the transformation mode under the background of rural land use transformation in mountain areas with the high-definition remote sensing images combined with field investigation as the data source, and reveal the driving mechanism and its practical significance that affect the transformation of landscape pattern. The research results will provide scientific basis for the future landscape pattern optimization in typical mountainous areas such as the TGRA, and also provide an important reference for future ecological construction of a similar special geographical environment.

2. Research Ideas

2.1 Research hypothesis

Land use transition is the result of the land use change evolving to a certain stage (Grainger 1995a; Grainger 1995b; DeFries et al. 2004). The trend transition of land use patterns in different spatial scales will inevitably lead to changes in landscapes and patterns of different spatial scales, from land use transition to landscape transition, and then to landscape pattern transition. In the 1980s, the land use pattern changed and entered the forest transition stage. The pattern of land use in mountainous areas of China has gradually changed from the expansion of cultivated land and the reduction of forest land to

the reverse trend of the reduction of cultivated land and the expansion of forest land (Zhang et al. 2019; Wang et al. 2019). The ecological environment has changed from overall deterioration to overall improvement (Barbier et al. 2010; Li and Zhao 2011). Under the background of land use transition and forest transition, in order to meet their own economic needs, in the mountainous area, the farmer's livelihood diversifies. Mountain farmers change the planting direction or leave the slope farmland uncultivated, which has transformed agricultural production methods and land use patterns (Figure 1). At present, the relationship between man and land in the mountainous areas of southwest China has gradually shifted from the traditional agricultural system to the non-agricultural and new agricultural systems, and the landscape pattern has also changed from the traditional single agricultural landscape to an ecological economic landscape (Liang et al. 2020).

In summary, the author believes that the background of socioeconomic development and land use transition has promoted the transformation of land use and the diversification of farmers' livelihoods in mountainous areas, which has led to changes of landscape patterns in mountainous areas. Therefore, based on the theories of forest transition, land use transition and agro-ecosystem transition, this paper puts forward the hypothesis of rural landscape pattern transition in mountainous areas of China, deconstructs the changing characteristics of various elements in the evolution of rural landscape pattern in mountainous areas from the perspective of landscape dynamic changes and its interaction mechanism, and emphasizes the differences between landscape pattern transition and land use transition and landscape pattern evolution.

2.2 Definition of landscape pattern transformation

Land use transition causes the change in the spatial and temporal distribution of landscape elements. Such changes accumulating to a certain extent will inevitably lead to the change of landscape patterns from quantitative to qualitative. Therefore, the landscape pattern transformation can be defined as a fundamental change in the type, quantity, spatial distribution and configuration of landscape components caused by long-term cumulative changes or abrupt changes in land use and land cover. It evolved from one pattern form to another pattern form, from one landscape function to another landscape function, and the evolutionary trend of landscape spatial pattern also changed in a turning way. The transformation of landscape pattern is the result of the combination of land use, land cover and landscape structure, such as from forest to city, or from cultivated land to forest, etc., it is the result of the balance change among social consumption, environmental protection and production and the result of changing occupation pattern (Theo et al. 2019).

3. Methods

3.1 The study area

The Caotangxi watershed, a first-class tributary on the north bank of the Yangtze River in the hinterland of the TGRA, located in the northeast of Fengjie County, Chongqing, China, is selected as the study area.

This watershed is 33.3km long and covers a total area of approximately 191.5 km² (Figure 2). The main landform types of it are mainly low mountains and valleys or middle-low mountains, the area of slope >15° accounts for 86.6% of the study area, 500~1500m elevation range up to 77.38% (Liang and Li 2019). It is a typical mountainous area with high population density and serious reclamation of sloping farmland. Therefore, this watershed is representative of the southwest mountain area. In recent years, a large number of navel orange and other fruit forests have been planted in the study area, resulting in a gradual transition from sloping farmland to fruit forests, and the land use patterns has changed, as well as the landscape pattern.

3.2 Data Sources

In this study, the series of remote sensing image data in 2000, 2010 and 2018 are from Google Earth (with a resolution of 2.5m), and the reference image data periods are 2000-11-08, 2010-01-04 and 2018-07-26. The 1:50000 digital elevation model (DEM) of the study area is taken from the geospatial data cloud platform. Using ArcGIS 10.2 software to fine-tune remote sensing images, the land use type maps of three periods in the study area were obtained by human-computer interaction interpretation, and the interpretation results were verified by combining the field investigation data, and the map interpretation accuracy reached 90%. According to China's "Classification Standard for Land Use Status" (GB/T21010-2017) and combined with the actual situation of the study area, the land use types are divided into 11 categories, such as sloping farmland, unused land, road, economic fruit forest land, woodland, grassland, water area, construction land (Airport, industrial and mining construction land, ecological industrial park), shrub land, settlement (Town and rural settlements) and abandoned farmland.

3.3 Transect selection and analysis

3.3.1 Basis for selection of study transects

The effects of topography and geomorphology, urbanization level and socioeconomic environment on the land use pattern and landscape pattern are considered. The changes of physical and geographical environment in the Caotangxi watershed are mainly manifested in the longitudinal gradient along the upper, middle and lower reaches of the river and the transverse gradient perpendicular to the river flow direction. That is to say, the valley on both sides of the river is relatively flat. From the upper, middle and lower reaches of the watershed, there are various types of land use and diverse landscape. With the increase of the distance from the river, the altitude and the slope increase, and the land use types from the foot of the mountain to the top of the mountain gradually decrease and the landscape is homogeneous. Therefore, the above-mentioned factors serve as the basis for selecting transactions.

According to the different local landforms and geomorphological characteristics, the areas with obvious transformation from planting to fruit and rapid expansion of construction land and forest land were selectively analyzed, and different transects were extended to the whole study area as far as possible, covering the divided land use types to the maximum extent. When the transect width is large, some important pattern features may be concealed and can not accurately reflect the pattern features of the

transect landscape. If the transect width is small, the number of patches is too small, and the landscape type is not comprehensive, the change of landscape type can not be seen. Therefore, taking all the factors into consideration, it is more appropriate to set the transect width to 200 m. Finally, five representative transects were set up in this study (Figure 2). The transect a and e represent the longitudinal gradient pattern, which are located in the river valley area, while transect b, c and d represent transverse gradient pattern in mountainous and hilly area. The length of transects a and c are 15 and 14.2 km respectively, and that of transects b, d and e are 7 km.

3.3.2 Transect gradient analysis

The transect gradient refers to the landscape features along the dominant driving factors, which gradually changes regularly in the terrain gradient (Fonnan 1995; Kamada and Nakagoshi 1997; Hahs and Mcdonnell 2006), it can reveal the spatial difference of different land use types in transect, and reflect the spatial distribution difference of landscape patterns in watershed (Kong and Nobukazu 2006; Weng 2007). A square window of 200m×200m is set up in each transect, which is manually operated and moved from south to north, one window at a time is moved and it is transformed into 1m×1m raster data. Then, the landscape index values of each window is calculated by Fragstats 4.2 software, and the distance of each window is marked from the starting point to quantitatively analyze the landscape pattern of different topographic gradient transects.

3.4 Landscape pattern index

The landscape index can highly concentrate the information of landscape pattern, quantify landscape, and reflect some aspects of its structural composition and spatial configuration characteristics (Solon 2009; Buyantuyev et al. 2010). According to the principles of landscape ecology, the aims of this study and the characteristics of the watershed, four indicators were selected at the landscape level, namely the patch density (PD), the landscape shape index (LSI), the largest patch index (LPI) and the Shannon diversity index (SHDI) (Table 1). These indicators can better reveal the landscape pattern change characteristics of the Caotangxi watershed in general and different direction transects from 2000 to 2018. The calculation methods and ecological significance of each index are shown in the literature (Wu 2007).

Tab. 1 Landscape metrics used in this study

Category	Landscape metrics	Calculation formula	Description
DENSITY	Patch Density (PD)	$PD=N/A$	The number of patches in per unit area, $NP \geq 1$.
AREA	Largest Patch Index (LPI)	$LPI = \frac{Max(a_1, a_2, \dots, a_n)}{A} \times 100$	The percentage of the landscape comprised by the largest patch of the corresponding patch type, $0 < LPI \leq 100$.
SHAPE	Landscape Shape Index (LSI)	$LSI = \frac{0.25E}{\sqrt{A}}$	A perimeter-to-area ratio that measures the overall geometric complexity of the landscape, $LSI \geq 1$.
DIVERSITY	Shannon Diversity Index (SHDI)	$SHDI = - \sum_{i=1}^n [P_i \times \ln(P_i)]$	Reflect the richness and complexity of landscape types, $0 \leq SHDI < 1$.

4. Results

4.1 The overall land use and landscape pattern transformation

From 2000 to 2018, there were three types of land use change in the study area: 1) Relatively stable type: including road, water body, settlement, unused land and grassland, which are mainly located in low altitude areas and have little change of area; 2) Decreasing year by year: the area of sloping farmland decreases year by year and becomes orchard and woodland; 3) Fluctuating growth type: including the increase of economic fruit forest land, forest land, construction land and abandoned land. The area of the economic fruit forest land and construction land increased year by year. The economic forest land has mainly expanded from the valley flat area in the central and western regions to the northeast and northwest areas with higher altitude and steep slope, and the forest coverage rate has increased (Figure 3).

From 2000 to 2018, the land use in the Caotangxi watershed changed significantly, which was mainly manifested in the transformation between sloping farmland, woodland, grassland, economic fruit forest land and abandoned farmland. As can be seen from Figure 4, the transformation of cultivated land to orchard in Caotangxi watershed from 2000 to 2010 was mainly concentrated in the valley area. From 2010 to 2018, it gradually moved to the high altitude area of 500-1000 m, and the economic fruit forest land dominated the low altitude areas on both sides of the river. The cultivated land at high altitudes areas has been transformed into forests or abandoned. The spatio-temporal changes of these land use types show that from 2000 to 2018, farmers' livelihood were diversified and the landscape pattern changed obviously.

From 2000 to 2018, the valley area in the Caotangxi watershed was mainly transformed from sloping farmland to economic fruit forest land, and the mountainous and hilly area was transformed from forest

and grassland to woodland and abandoned land.

4.2 Land use and landscape pattern transformation in transect

4.2.1 Land use and landscape pattern transformation in the valley area

The landscape pattern and land use change in the different directions of the Caotangxi watershed during 2000-2018 are significant (Figure 5). Transects a and e mainly distribute in the flat area of the river valley. Most of the water body, the settlement, the road and the construction land are distributed in the low-altitude areas of the valley.

In 2000, the landscape was mainly cultivated land, with a few fruit trees scattered in the southwest river valley area and the area below 500m in the northern part of transect e. In the northwest of transect e and the northeast of transect a, the slope gradient is relatively low, and there were many rural settlements and the area of sloping cultivated land increased from 2000 to 2010. In 2010-2018, due to the rapid development of economy, settlements in high altitude areas have been demolished, and sloping farmland has been transformed into orchards and shrubbery land, the cultivated land landscape was gradually replaced by fruit trees. The area of the original orchard expanded and gradually shifted to an altitude of 500-1000 meters. The orchard dominated the low-altitude areas on both sides of the river and became a major feature of the study area.

4.2.2 Land use and landscape pattern transformation in mountainous and hilly areas

Transects b, c and d locates in the upper, middle and lower reaches of the study area. In 2000, the main landscape matrix types of transects b, c and d were cultivated land and shrub woodland (Figure 5). With the acceleration of urbanization, the area of sloping farmland in the middle and high altitude area decreased rapidly from 2010 to 2018, and was transformed into orchard and shrub woodland, with obvious expansion of woodland. Orchards are mainly distributed in the gentle slope area in the north of transect b, in the valley within 5km from the starting point of transect d, and on both sides of the river in transects c. Shrub and forested land are mainly distributed in the southeast and northwest of transect c, the middle and high altitude area in the northwest of transect d, and in the whole eastern region of transect b.

From the perspective of overall landscape characteristics, the cultivated land and shrub forest land in 2000-2010 were the main landscape matrix type in various transects. The richness of land use types is increased, and the landscape is relatively fragmented, showing the characteristics of discrete distribution. In 2010-2018, the increased area of forest land and shrub forest land was the most, followed by the orchard, and the landscape distribution on each transect was concentrated and distributed in agglomeration. This change is not only related to the mountainous terrain of the study area, but also closely related to the transformation of cultivated land use in recent years, which promotes the change of other landscape types.

4.3 Topographic difference of landscape pattern index change

4.3.1 Changes of landscape pattern index of transect in valley area

The variation of values of PD, LPI, LSI and SHDI values of transect a and e with the topographic gradient is shown in Figure 6. From 2000 to 2018, the landscape indices of transect a decreased year by year, the patch density of landscape types decreased, the landscape fragmentation degree decreased and the landscape heterogeneity decreased, the landscape shape and types tend to be simple from low altitude to high altitude. Within 8 km from the starting point, at an altitude of 500m, the landscape of transect a changed from cultivated land in 2000 to construction land and orchard, and the landscape within 8-15 km was mainly forestland, with a small amount of sloping farmland. The southwest part of the transect a is located in the lower reaches of the watershed, with low and flat terrain, distributed with roads, rivers, settlements, orchards, construction land and cultivated land, and the sloping cultivated land in its northeast is transformed into orchard and shrub land, which leads to the change of diversity index.

The transect e is located on the tributary of the study area, with low altitude and gentle terrain. Within 3 km from the starting point of transect e, the land use types changed from cultivated land to orchard and construction land, the landscape types were diverse, the patches were fragmented, and the corresponding values of SHDI, LSI and PD showed basically consistent changes. In the range of 3-5 km from the starting point, the woodland landscape was dominant, and within the range of 5-7 km, the sloping farmland gradually changed to orchard and shrub land, the landscape type was single, and the LPI value of the landscape reached the maximum, while the values of PD, SHDI and LSI were opposite. The change of landscape index in transect a was larger than that in transect e, which indicated that the degree of land use transformation in transect a was accelerated. From the time scale, the index value of the largest patch of the land near the river decreased, while the index value far away from the river increased, which indicates that the traditional landscape pattern dominated by cultivated land in the study area was being broken up gradually, the transformation of cultivated land use shown a coexistence pattern of various land use landscapes.

4.3.2 Changes of landscape pattern index of transect in mountain and hilly area

The variation of PD, LPI, LSI and SHDI of transect b, c and d with the topographic gradient is shown in Figure 7. With the increase of the distance from the starting point of the transect, the landscape indices of b, c and d showed repeated wave-like changes as a whole, and the landscape indices of these transects decreased year by year with the change of time. For example, from 2000 to 2018, the PD values of the three transects gradually decreased, which indicated that the landscape fragmentation degree decreased and the landscape homogeneity degree increased. Moreover, all the three transects pass through the river, and the diversity index of river valley on both sides of the river is higher, and the diversity decreases with the increase of distance from the river. Forest land and shrub land are mainly distributed in the areas with high altitude at both ends of the three transects, so the landscape fragmentation at both ends of the transect is small, the dominant types are obvious, and the diversity index is lower than that in the middle part near the river. Generally speaking, the overall fluctuation range of landscape index in the north of the

transect c is more severe than that in the south, while the overall landscape sequence of transects b and d is relatively continuous.

4.4 The transformation model of landscape pattern in the study area

(1) The change of land use in Caotangxi watershed are mainly reflected in the retreat of sloping farmland to orchards and woodlands, the expansion of economic fruit forest area and its gradual shift to 500-1000 m altitude, the increase of abandoned farmland area and woodland area, and the obvious increase of forest canopy. The reason lies in the downward movement of human activities in the study area and the coexistence of increasing and decreasing land intensive use, so, the landscape type tends to be unitary. Therefore, the landscape pattern transformation in the study area can be summarized into the following modes.

(1) On the whole, the landscape pattern has changed from production type to ecological economy type and ecological regulation type.

(2) In the valley areas with higher urbanization level and better topographic conditions, the landscape diversity has increased, and the landscape pattern has changed from the traditional farming landscape to the coexistence of multiple landscape type.

(3) In the mountainous and hilly area with high altitude and complex terrain, the intensity of human activities and the diversity of landscape decreased, and the landscape pattern has changed from coexisting multiple landscapes to forest landscapes.

(4) The focus of landscape transformation is mainly reflected in sloping farmland, economic fruit forest and woodland landscape (Figure 8).

5. Discussion

5.1 Theoretical value of research on landscape pattern transition

Studies have shown that China and India are leading the greening of the earth, which is mainly due to the grain for green in China and the intensive agriculture of the two countries (Chen 2019). The abandonment of cultivated land is changing the rural landscape around the world (Queiroz 2014). For example, about 90% of the land in southern France was abandoned before 1940 (Sluiter et al. 2007). In the range of 600-900m above sea level, the cultivated land area changes the most (Wang et al. 2020). On the local scale, the rate of abandoned farmland increases exponentially with the distance from the settlement, which is mainly distributed in the area 500 m away from the settlement (Chen et al. 2018). The conclusion of this paper is consistent with the above research.

Through a case study, this paper found that in the mountainous areas of Southwest China, the transformation of rural land use under multiple backgrounds has caused the transformation of rural landscape pattern, which verifies the theoretical hypothesis suggested by this paper, that is, driven by the

transformation of land use in mountainous areas, the mountain landscape pattern has undergone transformation and evolution. Related studies have confirmed this point. The theoretical value of the results of this study is as follows: (1) It provides micro case verification for greening in China. (2) It reveals the topographical differences of the evolution of the mountainous landscape in Southwest China. (3) It is found that the ecological-economic win-win land use system can solve the problems of ecological and economic development in mountainous areas and guide the transformation of landscape pattern.

The successful model of China's mountainous areas provides a reference for similar regions in other developing countries in the world. Based on the empirical results of this paper, the author also made some policy recommendations with reference to the research of other scholars, such as the transformation of the agricultural development mode for a less demand in rural labor, increasing the inputs of agricultural technique and capital instead of labor, improving the comparative benefit of agriculture to attract young rural labor for farming, cultivation of professional farmers, establishing of an agricultural supporting system and developing circulative agriculture (Liu et al. 2016).

5.2 Driving Mechanism of Landscape Pattern Evolution in Research Areas and Its Practical Significance

The study area, located in the heart of the TGRA, is responsible for the ecological security of the TGRA and the middle and lower reaches of the Yangtze River, but at the same time, it is also a region with a fragile ecological environment (He et al. 2016). As a combination of mountain area, reservoir area and rural area, the transformation of the landscape pattern of the study area is the behavior of the farmers' collective abandoned cultivated land and large-scale planting of economic fruit forests, it is also the result of the government's support for the development of forestry and fruit industry and the incentive policy of ecological conversion of farmland (Hui et al. 2015).

Natural factors, such as topography and landforms, also determine the agricultural production mode to a great extent, affecting the landscape pattern in rural areas, and forming various types of land use. In areas with high altitude and steep slope, human activities move down, cultivated land is abandoned, and farmers' livelihood is diversified. The farmers' family is less dependent on cultivated land, and the abandoned land has already evolved into forest and grassland. Overall, the evolution of landscape pattern is mainly driven by socio-economic factors and natural factors.

The gradient change of landscape pattern in the study area reflects the mountain land use transition from the traditional single function and extensive management to the modern agricultural society with diverse function and intensive space. In the field investigation, it was found that the transformation of cultivated land use in the study area tended to change from cultivated land to orchard and from grain crops to cash crop, and always aimed at ecological benefits, and the total area of abandoned cultivated land increased with time. Therefore, in the process of land remediation, in order to ensure regional food security, the government still needs to optimize the use and focus on remediation of sloping farmland, which can be planted with both food crops and cash crops, so as to improve the quality of cultivated land, reduce soil erosion, increase farmers' income, and enhance farmers' enthusiasm for land remediation. On the basis of

planting fruit trees, the government should also encourage the development of characteristic agricultural industries, further develop modern agricultural industrial parks such as "Government + Farmers" and "Company + Farmers", improve rural e-commerce service levels, seek product supermarketization and branding, promote characteristic and profitable agriculture, improve the current situation of self-produced and self-sold agricultural products, and realize rural revitalization, agricultural development, and increase farmers' income (Liu et al. 2016). At the same time, the development of economic fruit forests has provided the direction for agriculture transformation in the study area, promoted the adjustment of agricultural planting structure, and improved the land quality and utilization efficiency in mountainous areas, it has certain guiding significance for the sustainable development of modern agriculture and landscape pattern optimization in the study area.

6. Conclusions

This paper proposes the transformation of landscape pattern caused by land use transformation in mountainous areas of China, and defines the transformation of landscape pattern. In this paper, the transformation process of landscape pattern in Caotangxi watershed is analyzed by using landscape pattern index and transect gradient analysis with three period high resolution image data, the evolution of landscape pattern on different gradient zones in the study area was discussed, and the general law of landscape pattern transformation in mountainous rural areas was revealed.

(1) This paper discusses the general rules and spatio-temporal variation characteristics of the impact of land use change on landscape pattern in Caotangxi watershed, and concludes that the landscape pattern in the study area is undergoing transformation with land use and agro-ecosystem transformation. The valley area in the Caotangxi watershed was mainly transformed from sloping farmland to economic fruit forest land, and the mountainous and hilly area was transformed from forest and grassland to woodland and abandoned land.

(2) From 2000 to 2018, the overall landscape of Caotangxi watershed changed from production landscape pattern to eco-economic landscape pattern and eco-regulatory landscape pattern. The landscape pattern in the valley area has changed from the original pattern dominated by the cultivated land landscape to one in which many kinds of landscapes coexist, and the sloping cultivated land landscape has gradually developed into the landscape of economic fruit forests and forests, mountainous and hilly areas have changed from the coexistence of multiple landscapes to a pattern dominated by woodland landscapes.

(3) The results of the case study show that socio-economic development and agricultural policies have led to the transformation of land use in mountainous areas of China, and the rural landscape pattern has also undergone accordingly a transformation in the context of land use transformation. The results provide reference for the rational utilization of land resources, ecological management and rural revitalization in mountainous areas in the future.

Declarations

Declaration of interests

✓ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Figures

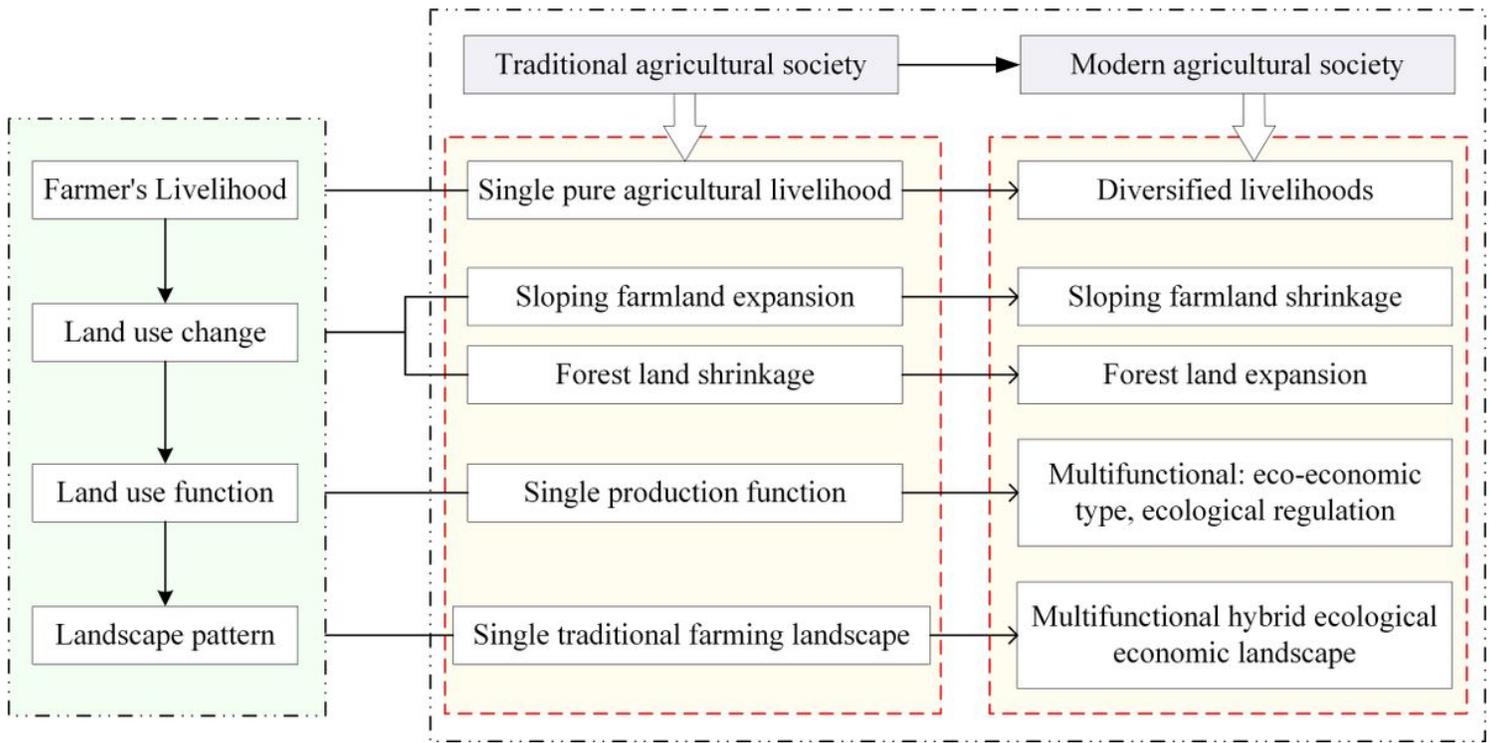


Figure 1

Relationship between land use transition and landscape pattern evolution

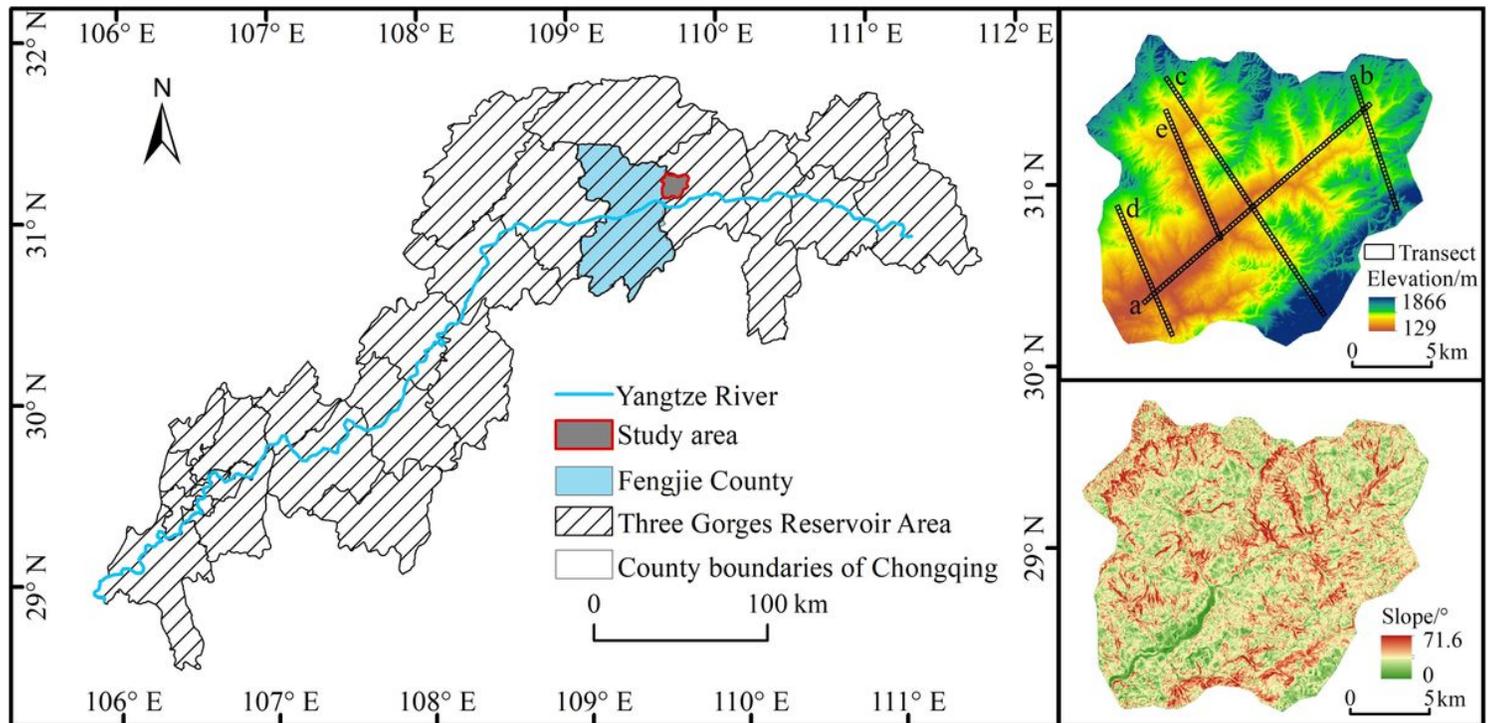


Figure 2

Location of the case area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning

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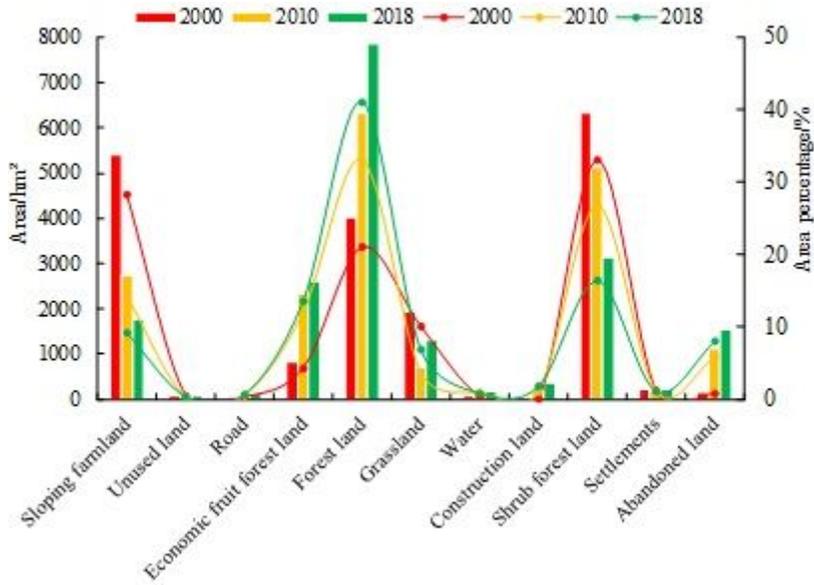


Figure 3

Area of land use types in the study area from 2000 to 2018

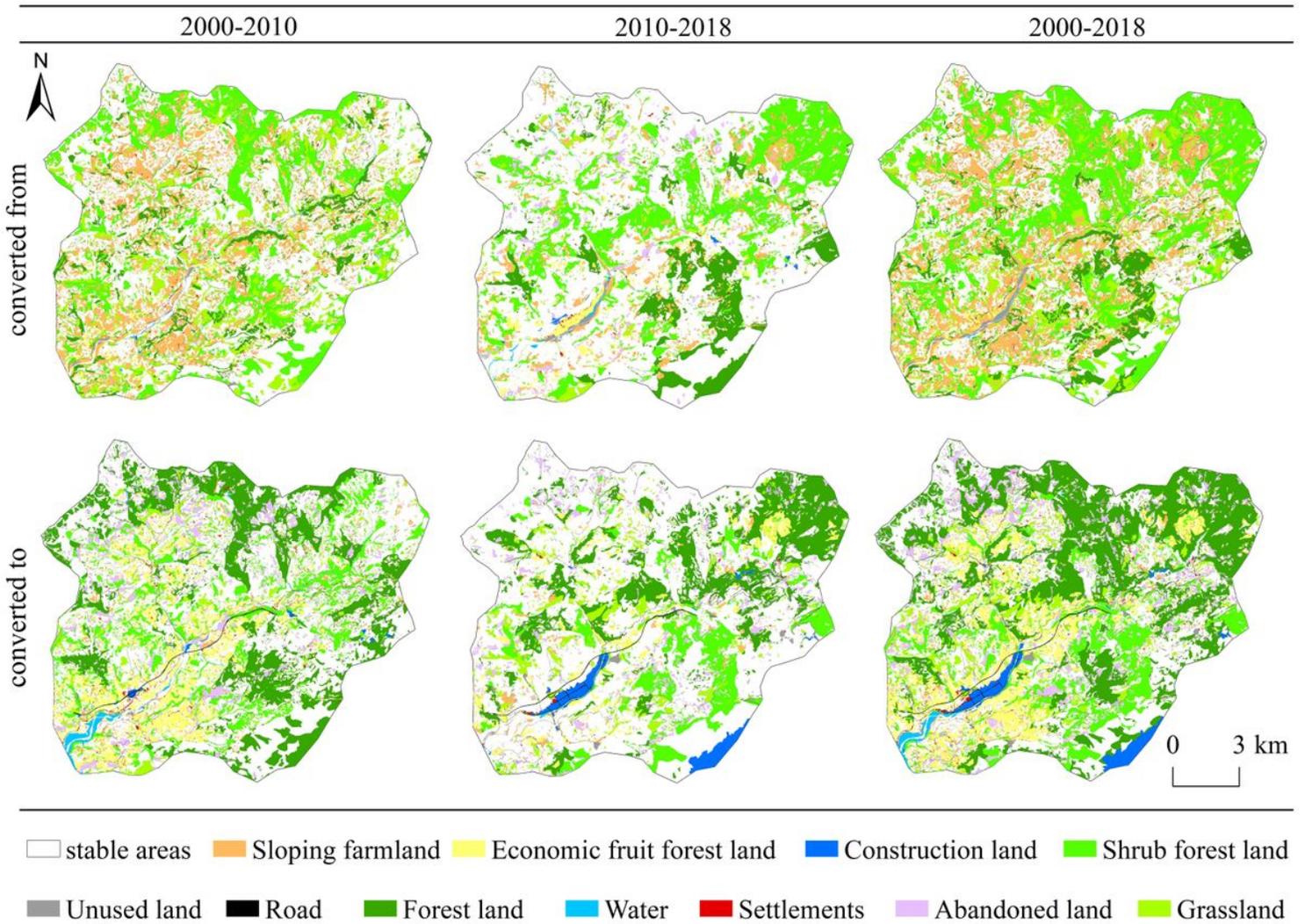


Figure 4

Land use conversions in the Caotangxi watershed during the period 2000-2010, 2010-2018, and 2000-2018. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

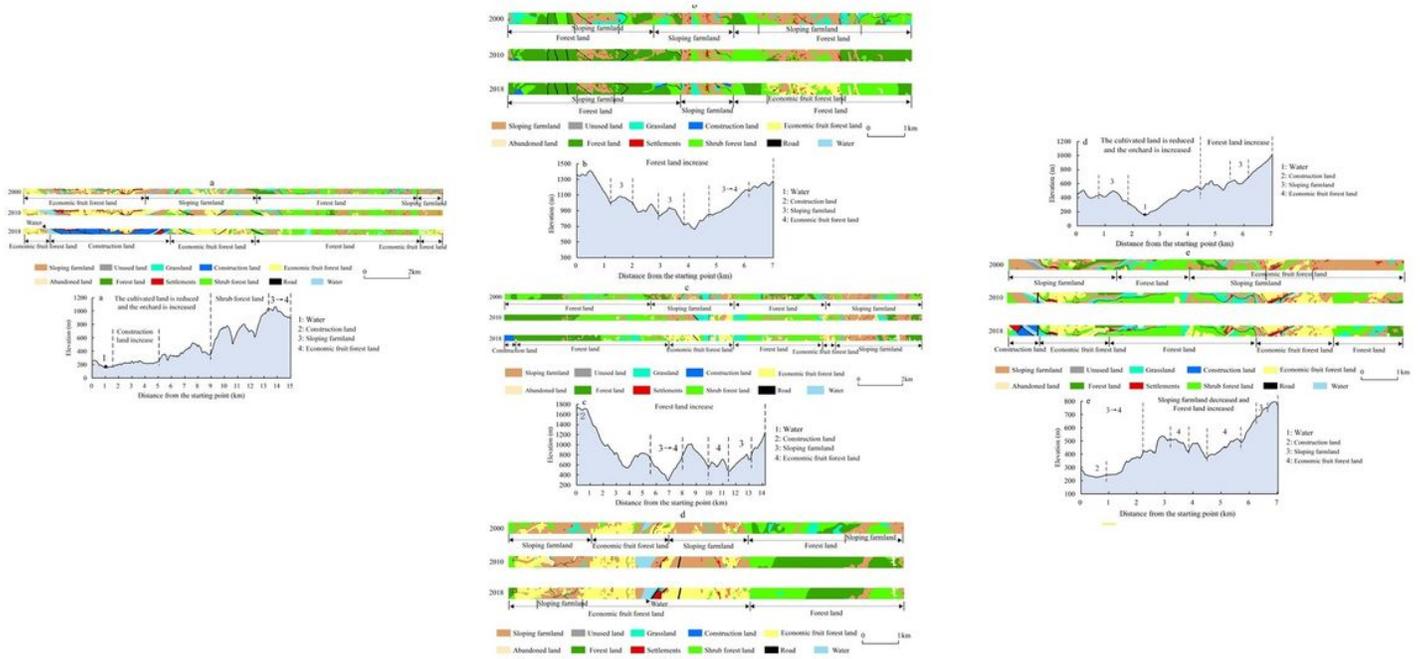


Figure 5

land use landscape of different transects. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

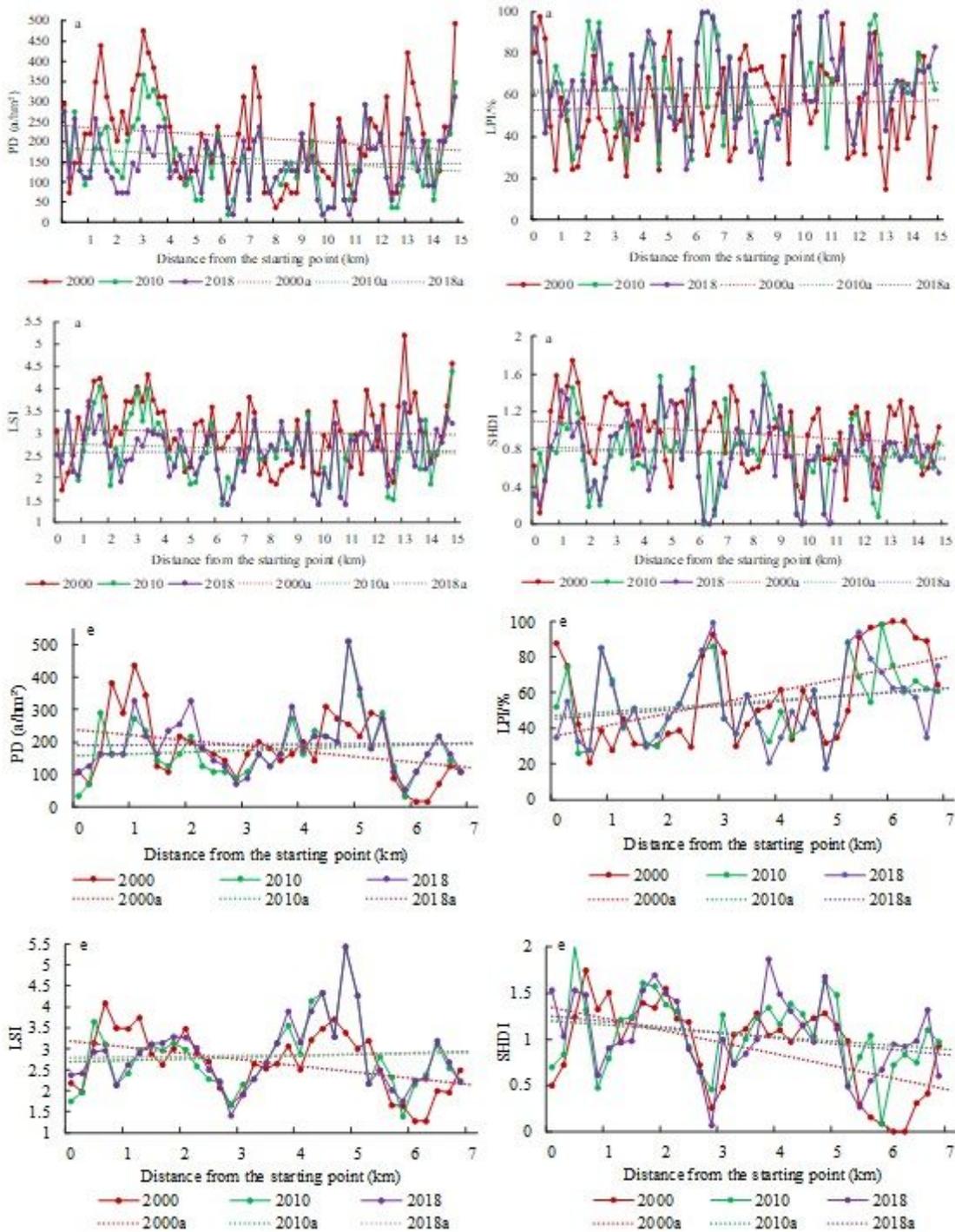


Figure 6

Changes in the landscape-level metrics of transects a and e in the valley area

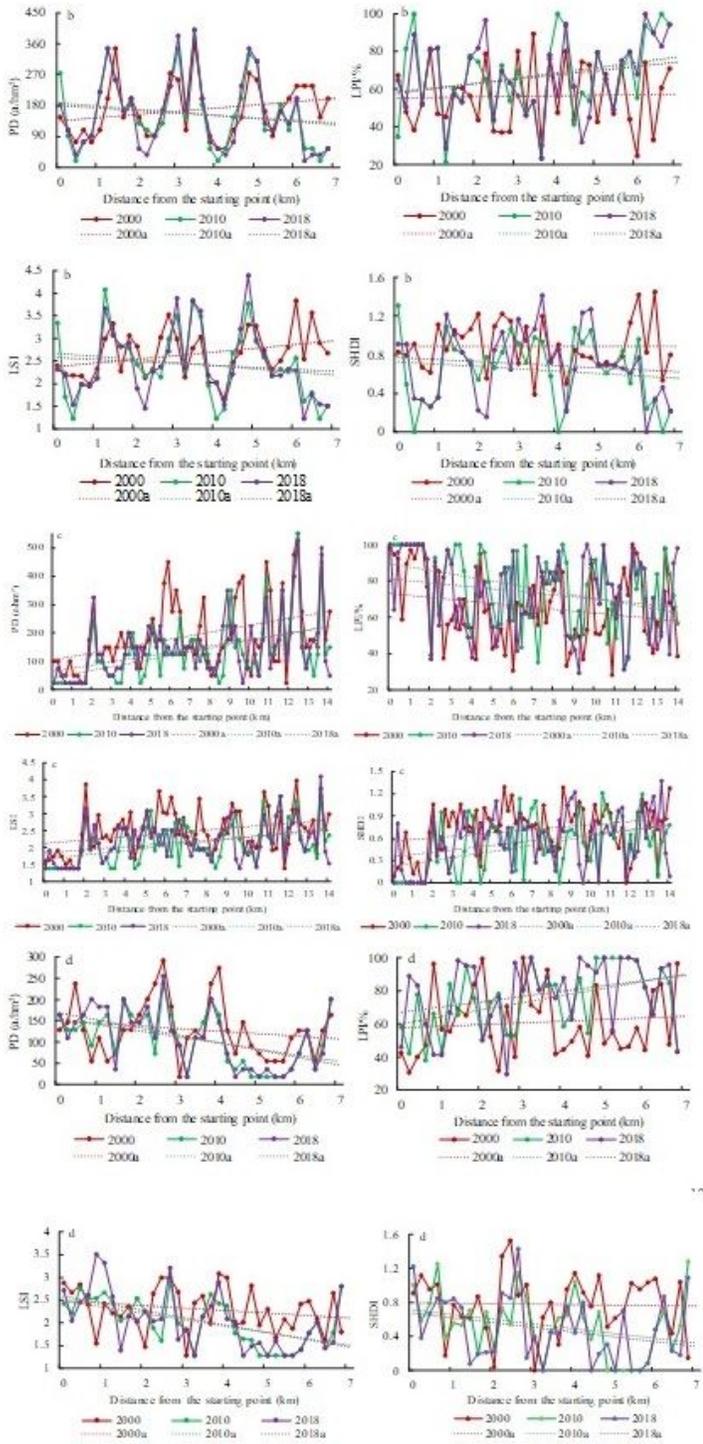


Figure 7

Changes in the landscape-level metrics of transects b, c and d in the mountain and hilly area

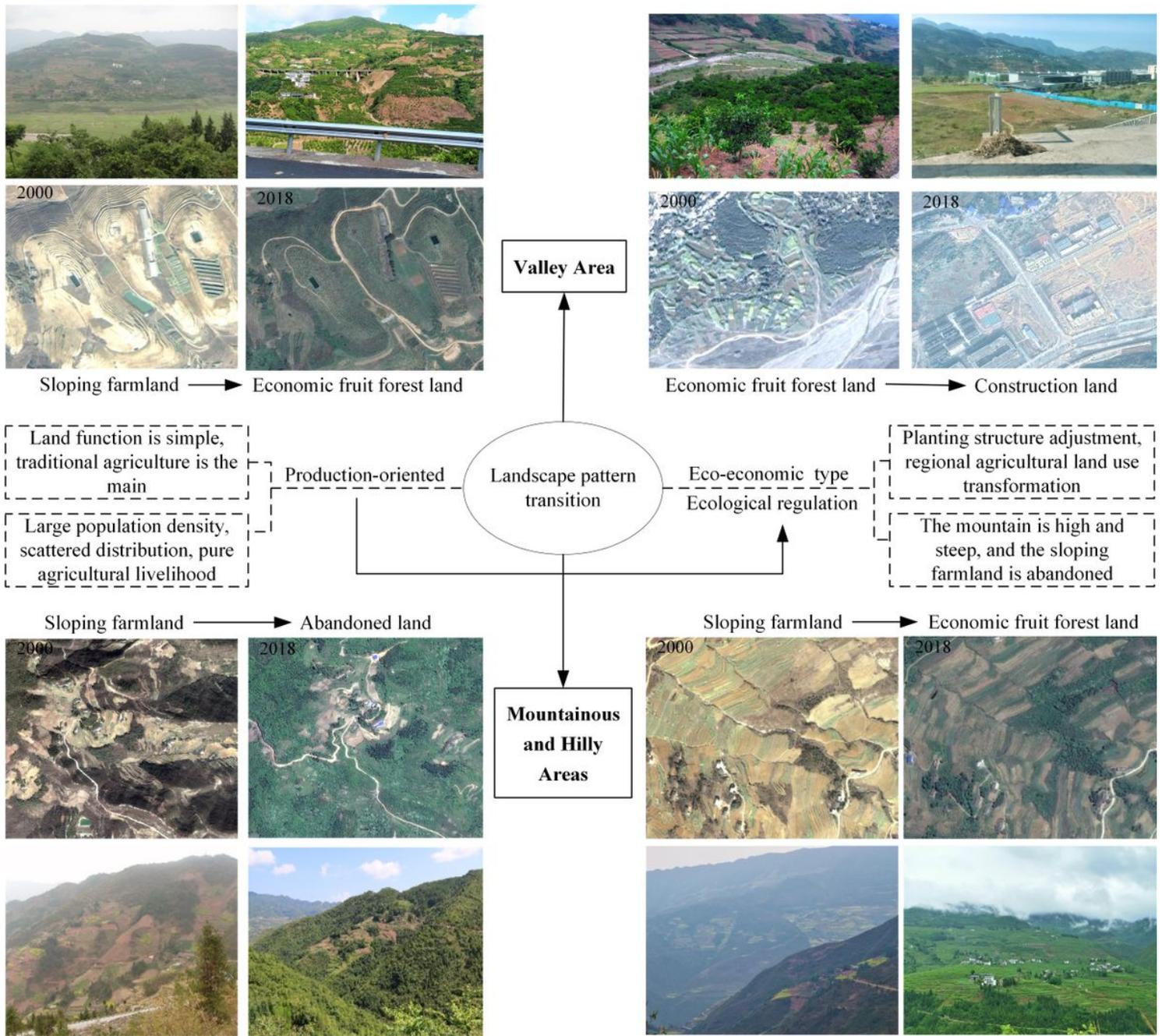


Figure 8

Change models of landscape pattern transformation in the study area (the real pictures were by author in 2010-07 and 2021-05 respectively) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.