



# Transition of rural landscape patterns in Southwest China's mountainous area: a case study based on the Three Gorges Reservoir Area

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## Abstract

China's rural areas have experienced far-reaching social and economic transformation since the twenty-first century. Studying the rural landscape pattern (RLP) transition under this background is significant in revealing human–land relationship evolution and exploring the rural revitalization path in China's mountains. In this paper, we put forward the theoretical framework of landscape pattern transition and establish the RLP transition model of mountainous areas in Southwest China by using high-resolution remote sensing images and field investigation. The results show that the RLP transition in the case region is mainly embodied in sloping farmland reduction, orchard expansion, and woodland restoration. Moreover, there are obvious differences in landscape pattern transition among different terrain areas. From 2000 to 2018, the landscape types in valleys have gradually diversified, and there is a spatial concentration of intensification land-use types, and the landscape types in mountainous and hilly areas have gradually simplified, and forest land has been restored. Overall, the regional RLP has changed from production-oriented to eco-economic and eco-regulatory landscape patterns. The RLP in the mountainous areas of Southwest China has undergone a transition different from regular land-use transition, and the process verifies the theoretical framework proposed in this paper. The theories and methods of this paper are helpful to understand the RLP transition process in mountainous areas and to provide a reference value for rational land resource use, ecological management, and rural revitalization in similar mountainous areas.

**Keywords** Transition · Rural landscape pattern · Driving mechanism · Mountain · Three Gorges Reservoir Area · Southwest China

## Introduction

Land use is the most prominent landscape symbol of the Earth's surface (Long et al. 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 transition characteristics are land-use change and intensification (Richter 1984), and the rapid land-use transition caused by agriculture, industrialization, 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 socioeconomic 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 it 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

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et al. 2018). Naturally, 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).

Landscape pattern change can be divided into five stages, including land reclamation, subsistence agriculture, gradual intensive agriculture, and intensive agriculture (Foley et al. 2005). Generally, regions are in different land-use transition stages influenced by history, socioeconomic conditions, and ecological background (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. Specially, market-oriented intensive agricultural production systems replace 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 land abandonment due to the reduction or transfer of agricultural activities are driving the agricultural landscape from production services to regulation services (Zhao et al. 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 transition 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 southwestern Tanzania, sustainable land management and diversified livelihood strategies could reduce dependence on tobacco cultivation and contribute to improving the ecological management of the Miombo woodlands (Jew et al. 2017). Presently, rural China is undergoing a transition from the "traditional grain production stage" to the "market-oriented comprehensive agricultural development stage" (Ge et al. 2019). The rapid urbanization, with a large increase in construction land area, is the core dynamic mechanism of the landscape structure change of the farmland landscape system (Jiang et al. 2018). Human assets and transport facilities are the most important factors in improving the livelihood strategies of rural Chinese households (Zhang et al. 2019a, b). Combining ecological restoration with measures to provide a sustainable livelihood for residents in the project areas can achieve the win-win goal of ecological restoration and poverty alleviation (Cao et al. 2020).

Previous researches have proved that 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). Besides, man-made activities have expanded in some mountainous areas. For example, Brazil' 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). The contrasting biophysical conditions along the altitudinal gradient gave rise to distinct spatiotemporal patterns of ecosystem service provision in a mountainous region (Gomes et al. 2020). In the 1980s, the land-use pattern changed and entered the forest transition stage, and the ecological environment has changed from overall deterioration to overall improvement (Barbier et al. 2010; Li and Zhao 2011). Since 1989, China's land-use intensity has been declining, leading to the large-area returns from cropland to grassland (Feurdean et al. 2016), and a forest transition has occurred in China (Wang et al. 2019a, b). China's Grain to Green Program, launched in 1999, is the most effective measure to significantly improve the ecological and socioeconomic status of the Loess Plateau (Cao et al. 2018). The landscape pattern in mountainous areas of China has gradually changed from the expansion of farmland and the reduction of forest land to the reverse trend of the reduction of farmland and the expansion of forest land (Zhang et al. 2019a, b; Wang et al. 2019a, b). 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). Limited school access and a demand for high-quality education have directly led to the substantial abandonment of mountain settlements (Wang et al. 2019a, b). So, satellite images show that China is turning green (Macias-Fauria 2018). In a word, the landscape pattern in mountainous areas is undergoing transition. China's mountainous areas (including mountains, hills, and plateaus) account for 69.1% of its territorial area (Liang et al. 2020a, b, c), integrating ecological barriers, climate-sensitive, and ecologically fragile areas. Therefore, how does the rural landscape pattern (RLP) in mountainous areas transform and evolve is an important issue worth studying.

The 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 large population pressure and intense slope land reclamation (Zhang et al. 2012). The land use/land cover of TGRA has changed significantly (Zhang et al. 2009); land consolidation projects 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 patterns in this region under the background of the dramatic social, economic and ecological changes in China. This study first defines the concept of RLP transition, then conducts a case study based on a typical watershed in TGRA. This paper aims to address the following research questions: (1) explore whether the landscape pattern has undergone the corresponding transition, the focus of landscape pattern transition, the spatial difference of transition, and the transition mode, (2) reveal the driving mechanism and its practical significance that affect the transition of landscape pattern. The research results will provide a 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 restoration of a similar special geographical environment.

## Research framework

### From land-use transition to landscape pattern transition

Land-use transition is the result of the land-use change evolving to a certain stage (Grainger 1995a, b; DeFries et al. 2004). The land-use transition in different spatial scales will inevitably lead to changes in landscapes and patterns of different spatial scales, from the evolution process of land-use transition to landscape transition, and then to landscape pattern transition. Under the background of land-use transition and forest transition, farmers' livelihood in mountainous areas is gradually diversified to meet their own economic

needs, such as changing the planting direction or abandoning the sloping farmland, which has transformed agricultural production mode and land-use mode (Fig. 1). Presently, 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 eco-economic landscape (Liang et al. 2020a, b, c).

Summarily, socioeconomic development and land-use transition have promoted the diversification of farmers' livelihoods in mountainous areas, leading to a series of changes in landscape patterns in mountainous areas. Therefore, based on the theories of forest transition, land-use transition, and agro-ecosystem transition, this paper defines the concept of RLP transition in mountainous areas of China, reveals the changing characteristics of various elements of RLP in the transition process in mountainous areas from the perspective of landscape dynamic changes and its driving mechanism, and emphasizes the differences between landscape pattern transition, land-use transition, and landscape pattern evolution.

### Definition of landscape pattern transition

Land-use transition causes the spatial–temporal distribution change 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 transition can be defined as a fundamental change in the type, quantity, spatial distribution, and configuration of landscape components caused by long-term

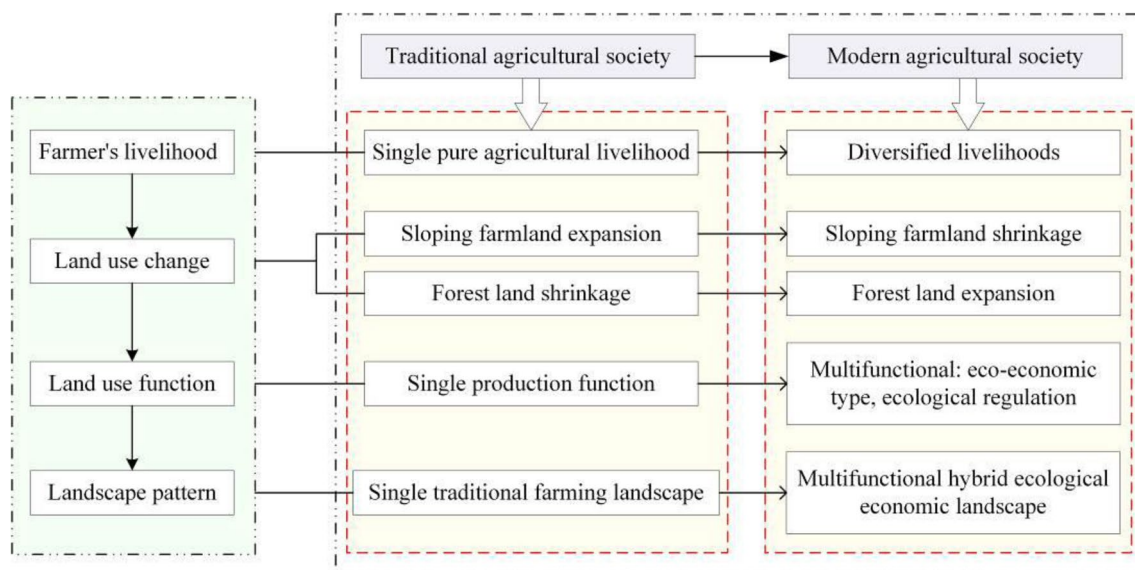


Fig. 1 Relationship between land-use transition and landscape pattern evolution

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 landscape pattern transition is the result of the combination of land use, land cover, and landscape structure, such as from forest to city, or from farmland to forest, etc. Meanwhile, it is the result of the balance change among social consumption, environmental protection, and production and the result of changing occupation patterns (Van der Sluis et al. 2019).

## 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 33.3 km long and covers a total area of approximately 191.5 km<sup>2</sup> (Fig. 2). The main landform types are mainly low mountains and valleys or middle–low mountains, the area of slope > 15° accounts for 86.6% of the study area, and 500–1500 m 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 mountainous area in China. 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 have changed, as well as the landscape pattern.

## Methods

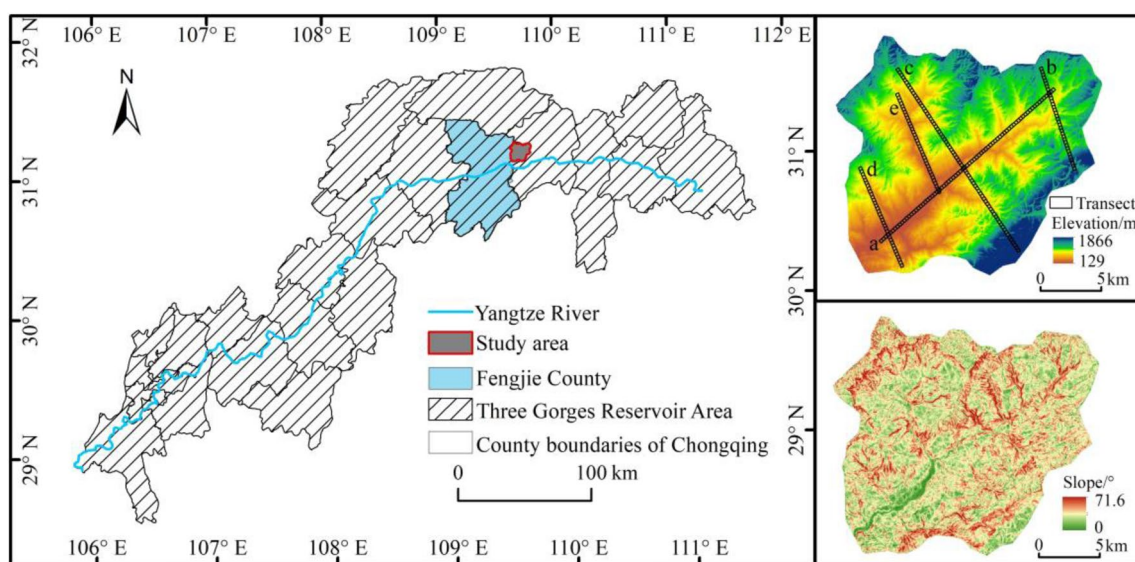
### Data sources

In this study, a series of remote sensing image data with a resolution of 2.5 m were obtained from Google Earth and their dates were 2000-11-08, 2010-01-04, and 2018-07-26, respectively. Furthermore, the 1:50,000 digital elevation model (DEM) of the study area was obtained from the geospatial data cloud platform (<http://www.gscloud.cn/sources/>). After accurate calibration of remote sensing images, the land use type maps of three periods in the study area were interpreted by human–computer interaction interpretation based on the ArcGIS 10.2 software. Lastly, the land-use data have been validated in the field investigation and its accuracy was above 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, forest land, grassland, water area, construction land (airport, industrial and mining construction land, ecological industrial park), shrubland, settlement (town and rural settlements) and abandoned farmland.

### Transect selection and analysis

#### Basis for selection of study transects

The effects of topography and geomorphology, urbanization level, and socioeconomic environment on the land use



**Fig. 2** Location of the case area

and landscape pattern are considered to choose the study transect. The changes of physical and geographical environment in the Caotangxi watershed are mainly manifested along the longitudinal gradient from the upper, middle, to the lower reaches of the river, and the transverse gradient perpendicular to the river flow direction. Namely, the valley on both sides of the river is relatively flat. As a result, there are various land-use types and diverse landscapes from the upper-middle, and lower reaches of the watershed. With the increase of the distance from the river, the altitude and the slope increase, the land-use types gradually decrease from the foot to the top of the mountain, and the landscape is homogeneous. Therefore, the above-mentioned factors are considered as the basis for selecting transactions.

According to the different local landforms and geomorphological characteristics, the areas with obvious transition were selectively analyzed, and different transects were extended to the whole study area as far as possible to include the divided land-use types to the maximum extent. When the transect width is large, some important pattern features may be concealed and cannot accurately reflect the pattern features of the transect landscape. In contrast, if the transect width is small, the number of patches and patch type included in this transect may be too small to reflect the comprehensive changes of landscape type. Therefore, after comprehensive consideration, the transect width is determined to be 200 m. Finally, five representative transects were set up (Fig. 2). Transects a and e, located in the river valley area, represent the longitudinal gradient pattern, while transects b, c, and d represent transverse gradient patterns in the mountainous and hilly areas. The lengths of transects a and c are 15 and 14.2 km, respectively, and that of transects b, d, and e are 7 km.

**Transect gradient analysis**

The transect gradient refers to the landscape features along with the dominant driving factors, which gradually change

regularly in the terrain gradient (Forman 1995; Kamada and Nakagoshi 1997; Hahs and McDonnell 2006). It can reveal the spatial difference of different land-use types in the transect and reflect the spatial distribution difference of landscape patterns in a watershed (Kong and Nobukazu 2006; Weng 2007). A square window of 200 m × 200 m is set up in each transect firstly. Then the landscape index values of each window are calculated by Fragstats 4.2 software. Finally, the distance of each window is marked from the starting point to quantitatively analyze the landscape pattern of different topographic gradient transects.

**Landscape pattern index**

The landscape index can highly concentrate the information of landscape pattern, express the landscape pattern quantitatively, and reflect its structural composition and spatial configuration characteristics (Solon 2009; Buyantuyev et al. 2010). According to the landscape ecology principles, study aims and watershed characteristics, four indicators were selected at the landscape level, including patch density (PD), landscape shape index (LSI), largest patch index (LPI), and Shannon diversity index (SHDI) (Table 1). These indicators could 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).

**Results**

**Overall land use and landscape pattern transition**

From 2000 to 2018, there were three types of land-use change in the study area: (1) relatively stable type. The type includes road, water body, settlement, unused land, and grassland, which were mainly located in low-altitude areas

**Table 1** Landscape metrics used in this study

Category	Landscape metrics	Calculation formula	Description	Unit
Density	Patch density (PD)	$PD = N/A$	The number of patches per unit area. $PD > 0$ . N: number of patches; A: amount of the landscape area	n/ha
Area	Largest patch index (LPI)	$LPI = \frac{Max(a_1, a_2, \dots, a_n)}{A} \times 100$	The percentage of the largest patch area accounts for the total area of the corresponding landscape patch type. $0 < LPI \leq 100$ . n: the amount of the patch, A: amount of the landscape area	Percent
Shape	Landscape shape index (LSI)	$LSI = \frac{0.25E}{\sqrt{A}}$	A perimeter–area ratio that measures the overall geometric complexity of the landscape. $LSI \geq 1$ , without limit. E: Total length of all patch boundaries in the landscape; A: Total landscape area	None
Diversity	Shannon diversity index (SHDI)	$SHDI = - \sum_{i=1}^n [P_i \times \ln(P_i)]$	Reflect on the richness and complexity of landscape types. $SHDI \geq 0$ . Pi: Percentage of landscape patch types	None

and their area remained almost unchanged; (2) continuously decreasing type. The area of sloping farmland decreased year by year and it was being converted into orchards and woodlands; (3) continuously increasing type. The type includes the increase of economic fruit forest land, forest land, construction land, and abandoned farmland. 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 altitudes and steep slopes, and the forest coverage rate has increased (Fig. 3).

Concurrently, the land use in the Caotangxi watershed changed significantly, mainly manifested by the transition between sloping farmland, woodland, grassland, economic fruit forest land, and abandoned farmland. The transition from farmland to orchards was mainly concentrated in the valley area (Fig. 4). It gradually moved to high altitudes of 500–1000 m, and the economic fruit forest land dominated the low altitude areas on both sides of the river. The farmland at high altitude areas has been transformed into forests or abandoned land. The spatiotemporal changes of these land-use types showed that farmers' livelihood was diversified and the landscape pattern changed obviously from 2000 to 2018. Additionally, 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 sloping farmland and shrubs to abandoned land and forest land.

## Landscape pattern transition in the transect

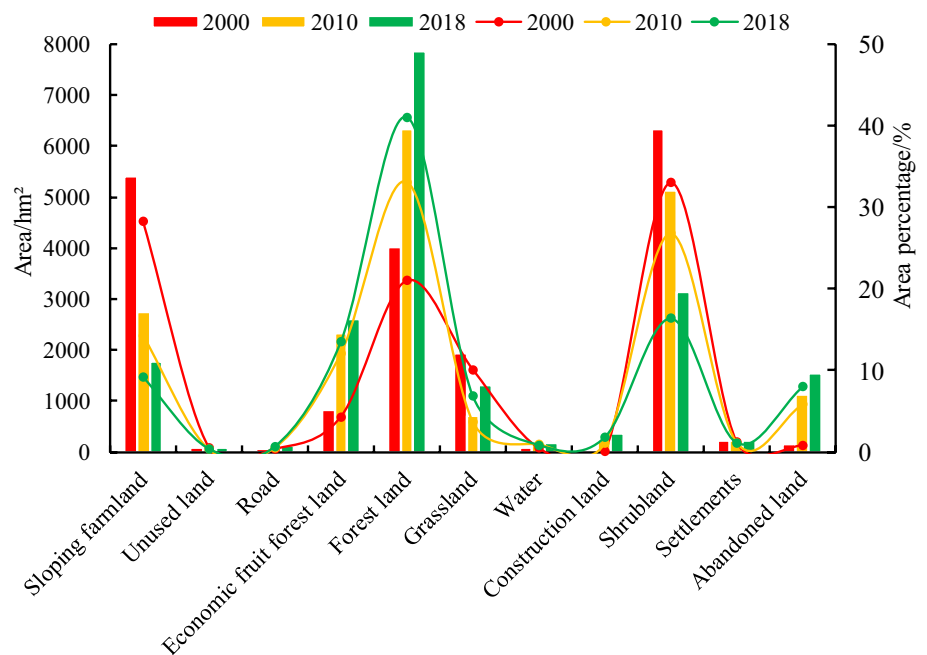
### Landscape pattern transition in the valley area

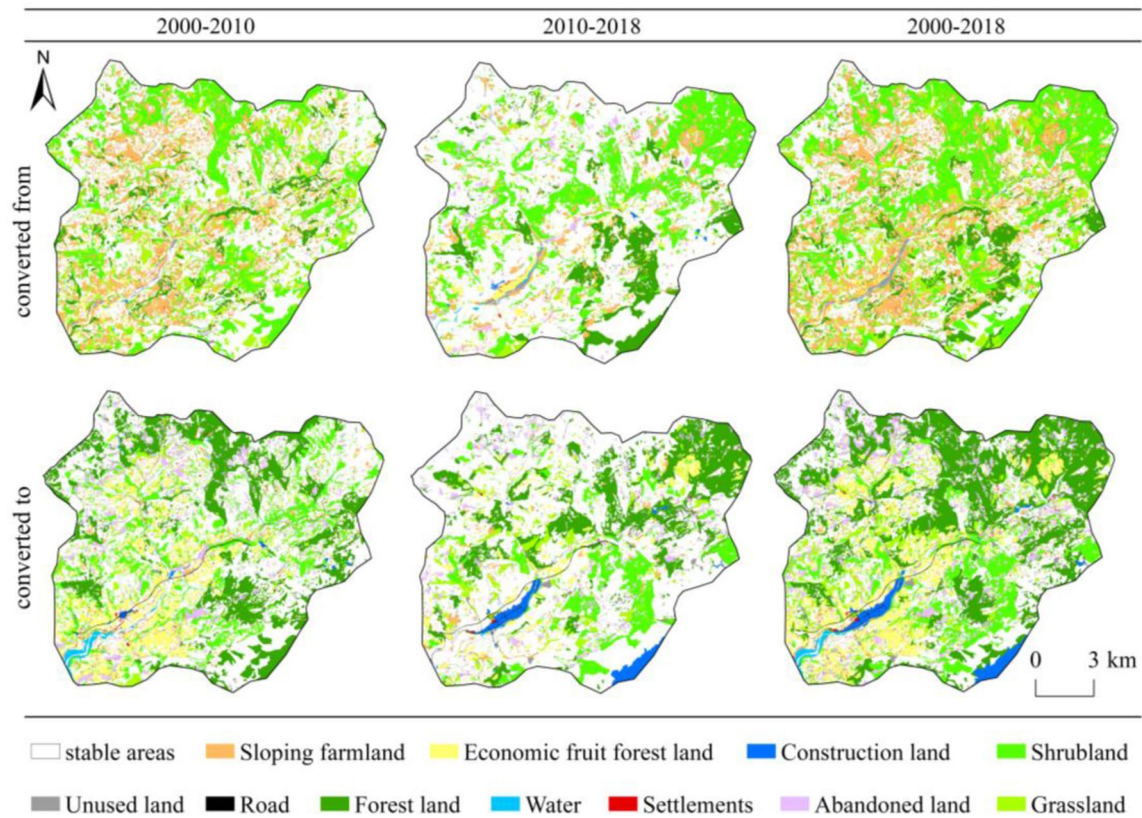
The RLP change in the different directions of the Caotangxi watershed during 2000–2018 is significant (Fig. 5). Transects a and e mainly distribute in the flat area of the river valley, the landscape in 2000 was mainly farmland with a few fruit trees scattered in the southwest river valley area, and the altitude range below 500 m in the northern part of transect e. Instead, the slope gradient is low in the northwest of transect e and the northeast of transect a, and there were many rural settlements, and the area of sloping farmland increased from 2000 to 2010. Due to rapid economic development, settlements in high-altitude areas have been demolished, sloping farmland have been transformed into orchards and shrubland, and the farmland landscape has been gradually replaced by fruit trees. The area of the existing orchard expanded and gradually shifted to an elevation range of 500–1000 m. The orchards dominated the low-altitude areas on both sides of the river and became a major feature of the study area.

### Landscape pattern transition in mountainous and hilly areas

Transects b, c, and d are located in the upper, middle, and lower reaches of the study area, respectively. In 2000, the main landscape matrix of transects b, c, and d were farmland and shrubland (Fig. 5). With the acceleration of urbanization, the area of sloping farmland in the middle- and high-altitude areas decreased rapidly from 2010 to 2018 and was transformed into

**Fig. 3** Area of land-use types in the study area from 2000 to 2018





**Fig. 4** Land-use conversions during the periods of 2000–2010, 2010–2018, and 2000–2018 in the Caotangxi watershed

orchards and shrubland. These show an obvious expansion of forest land. Orchards are mainly distributed in the gentle slope area in the north of transect b, in the valley within 5 km from the starting point of transect d, and on both sides of the river in transects c. Shrub and forest 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 the whole eastern region of transect b.

From the perspective of overall landscape characteristics, the farmland and shrubland during 2000–2010 were the main landscape type in various transects. The richness of land-use types was increased, and the landscape was relatively fragmented, showing the characteristics of the discrete distribution. During 2010–2018, the increased area of forest land and shrubland 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 transition of farmland use in recent years, which promoted the change of other landscape types.

**Topographic difference of landscape pattern index change**

**Changes of landscape pattern index of transect in the valley area**

The variation of PD, LPI, LSI, and SHDI values in transects a and e with the topographic gradient is shown in Fig. 6. From 2000 to 2018, the landscape index values of transect a decreased year by year. The landscape fragmentation degree and landscape heterogeneity decreased, and the landscape shape and types tend to be simple from low altitude to high altitude. At an altitude of 500 m of the transect a, the landscape within 8 km from the starting point changed from farmland in 2000 to construction land and orchard. 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’ flat areas of the watershed, distributed with roads, rivers, settlements, orchards, construction land, and cultivated land. The sloping

**Fig. 5** Land-use landscape of different transects

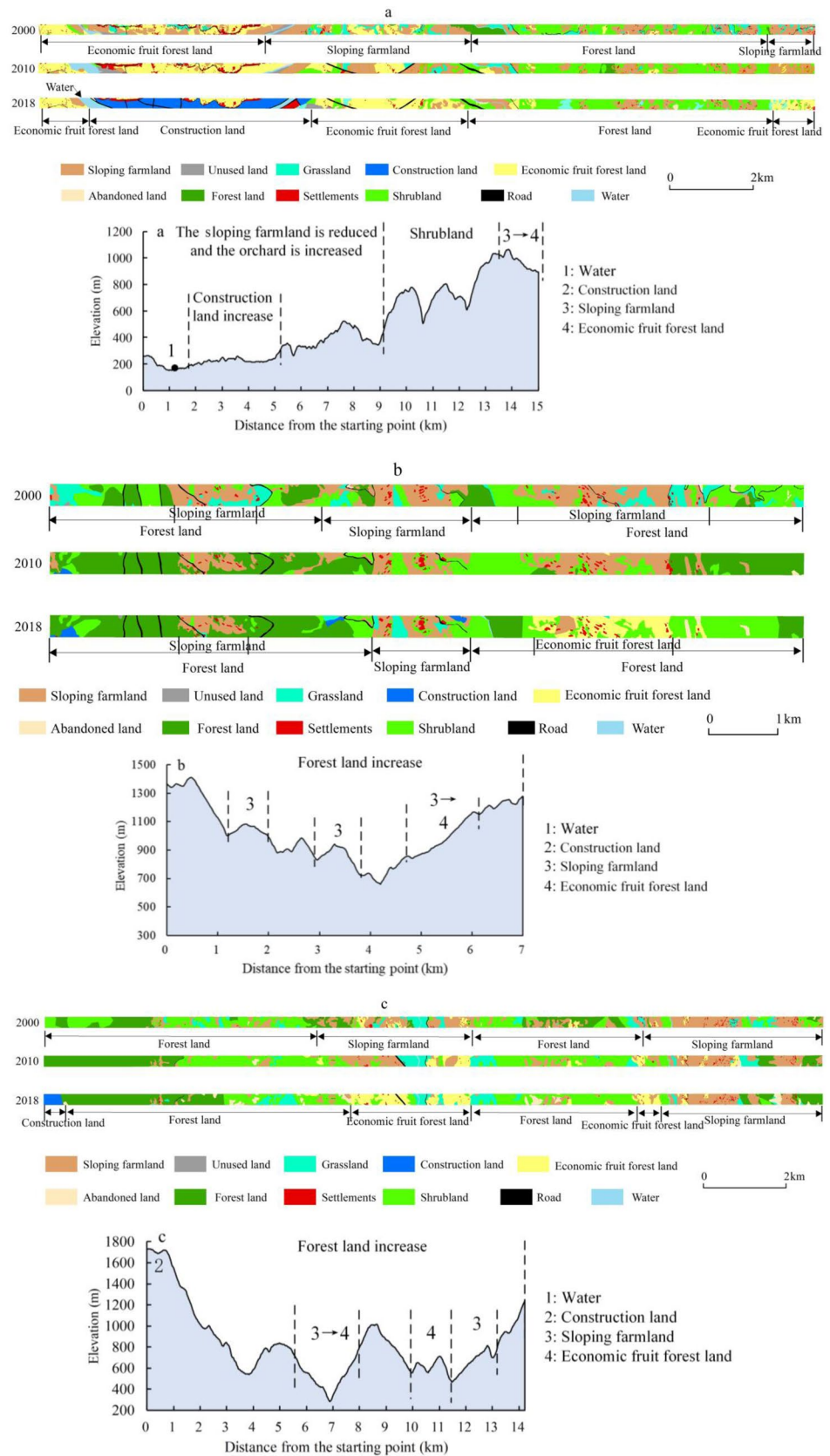
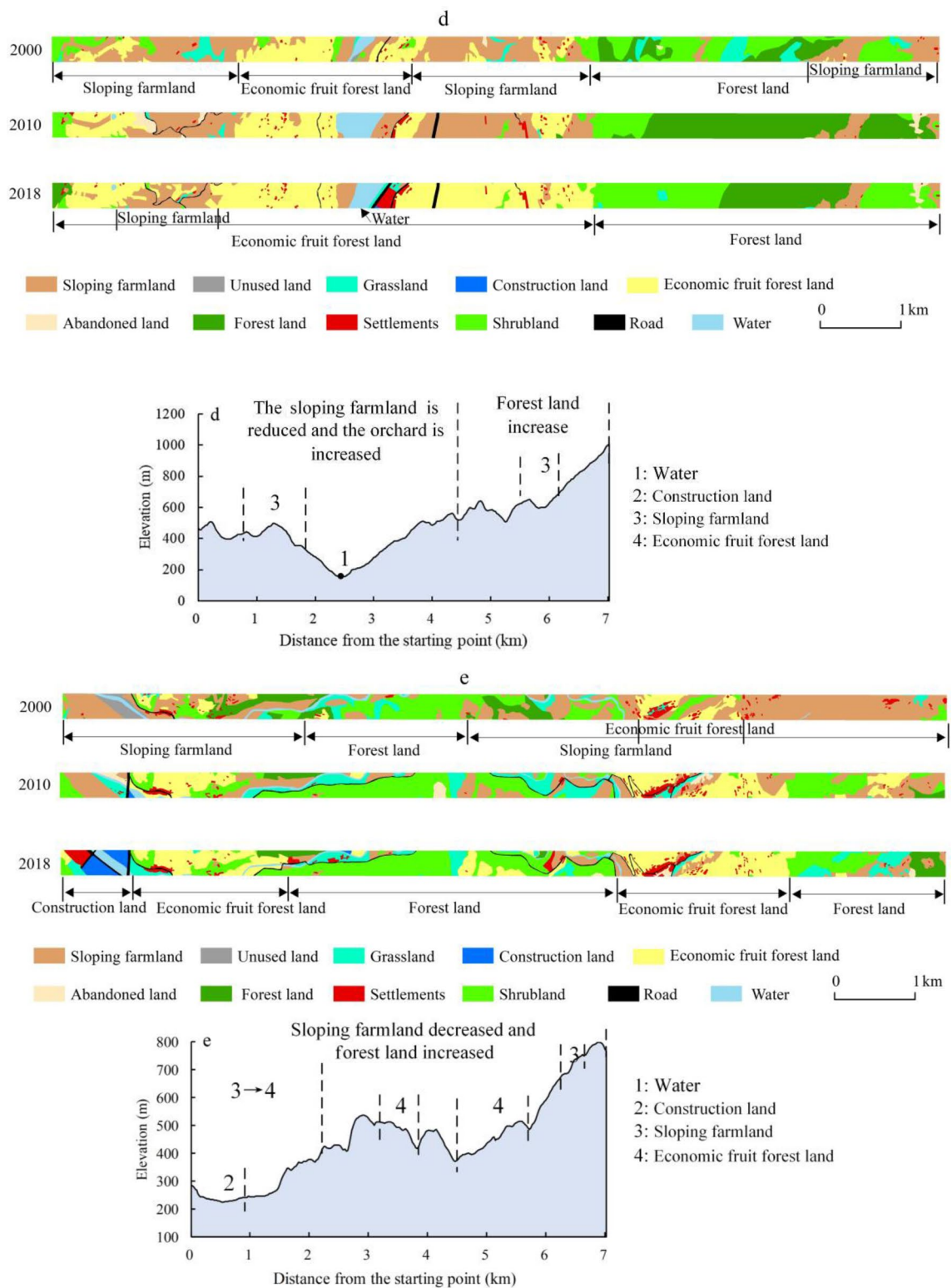




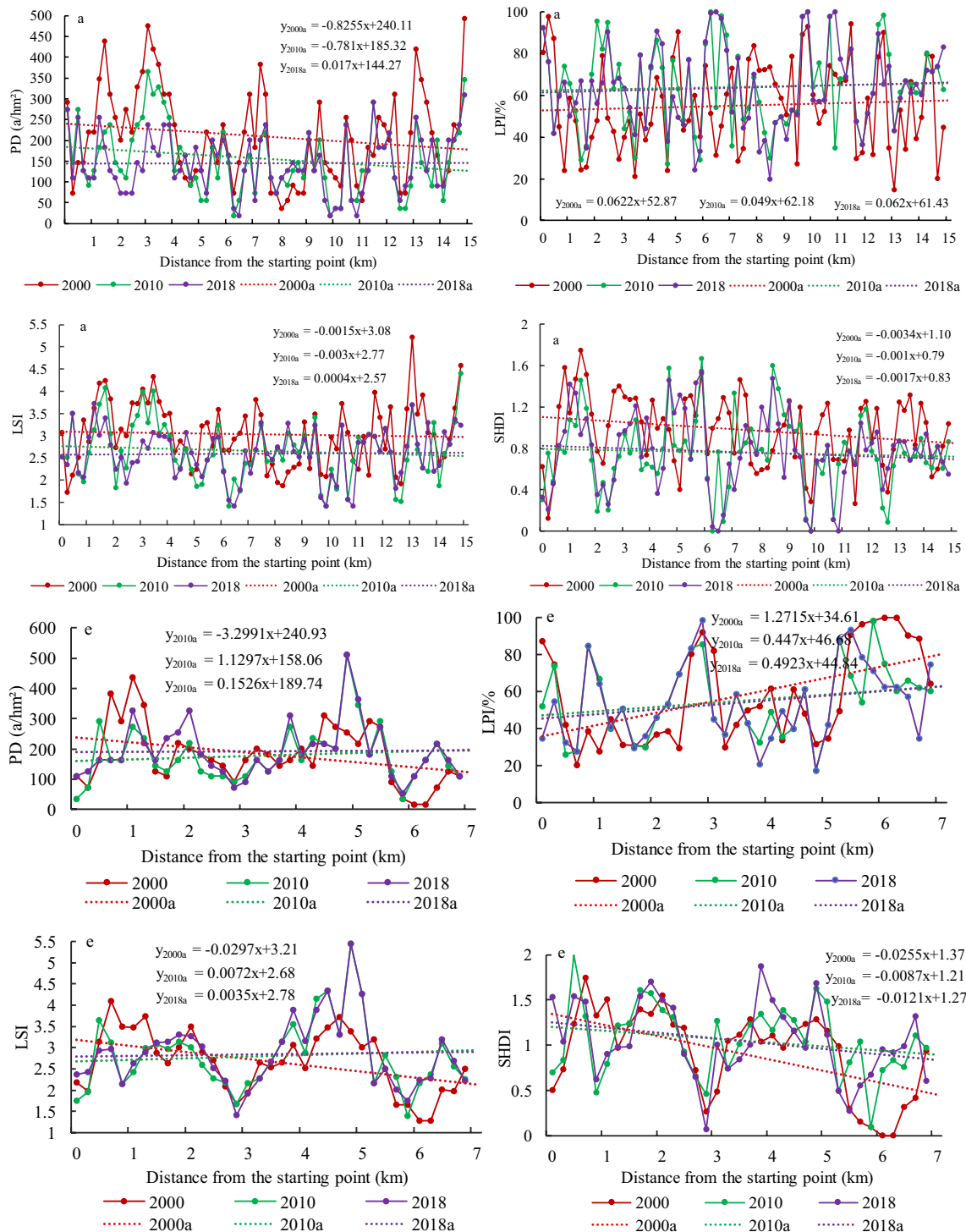
Fig. 5 (continued)



farmland in its northeast is transformed into orchard and shrubland, which led 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 landscape types changed

from farmland to orchard and construction land. The landscape types were diverse, the patches were fragmented, and the corresponding values of SHDI, LSI, and PD showed consistent changes. In the range of 3–5 km from the starting point, the woodland landscape was dominant. Within the



**Fig. 6** Changes in the landscape-level metrics of transects a and e in the valley area

range of 5–7 km, the sloping farmland gradually changed to orchard and shrubland, and the landscape type was single. 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 RLP transition in transect a was accelerated. From the timescale, the LPI near the river decreased, while the index value far away from the river increased. It indicates that the traditional landscape pattern dominated by farmland in the study area was being

altered gradually, and the transition of farmland use shows a coexistence pattern of various landscapes.

### Changes of landscape pattern index of transect in the mountain and hilly area.

The variation of PD, LPI, LSI, and SHDI in transects b, c, and d with the topographic gradient are shown in Fig. 7. With the increase of the distance from the transect's starting point, the landscape indices of transects b, c, and d showed repeated wave-like changes as a whole, and the landscape indices of these transects decreased with the change of time. For example, the PD values of the three transects gradually decreased from 2000 to 2018, which indicated that the landscape fragmentation decreased and the landscape homogeneity increased. The landscape diversity of the three transects was higher in the river valley on both sides of the river than in the rest, and the diversity decreased with increased distance from the river. Forest land and shrubland were mainly distributed in the areas with high altitudes at both ends of the three transects, so the landscape fragmentation at both ends of transects was small because of the obvious dominant types, and the diversity index was lower than that in the middle part near the river. Generally, the overall fluctuation range of landscape index in the north of transect c was more severe than that in the south, while there was relatively little variation across the landscape sequence of transects b and d.

### The transition mode of landscape pattern in the study area

The RLP transition in the Caotangxi watershed was mainly reflected in different characteristics, e.g., returning from sloping farmland to orchards and woodlands, expanded economic fruit forest area, increased abandoned farmland area and woodland area, and obvious forest land area increase. The reasons for this evolution were human activities' downward shift, co-existing intensification and extensification, and landscape types' homogenization trend, etc. Further, the RLP transition in the study area can be summarized into the following modes (Fig. 8).

- (1) On the whole, the RLP has changed from production type to ecological economy type and ecological regulation type.
- (2) In valley areas with higher urbanization levels and better topographic conditions, the landscape diversity has increased, and the RLP has changed from the traditional farming landscape to the coexistence of multiple landscape types.
- (3) In mountainous and hilly areas with high altitudes and complex terrain, landscape diversity decreased with weakening human activities intensity. The landscape

pattern has changed from coexisting multiple landscapes to forest landscapes.

- (4) The focus of RLP transition has been mainly reflected in sloping farmland, economic fruit forest, and woodland landscape.

## Discussion

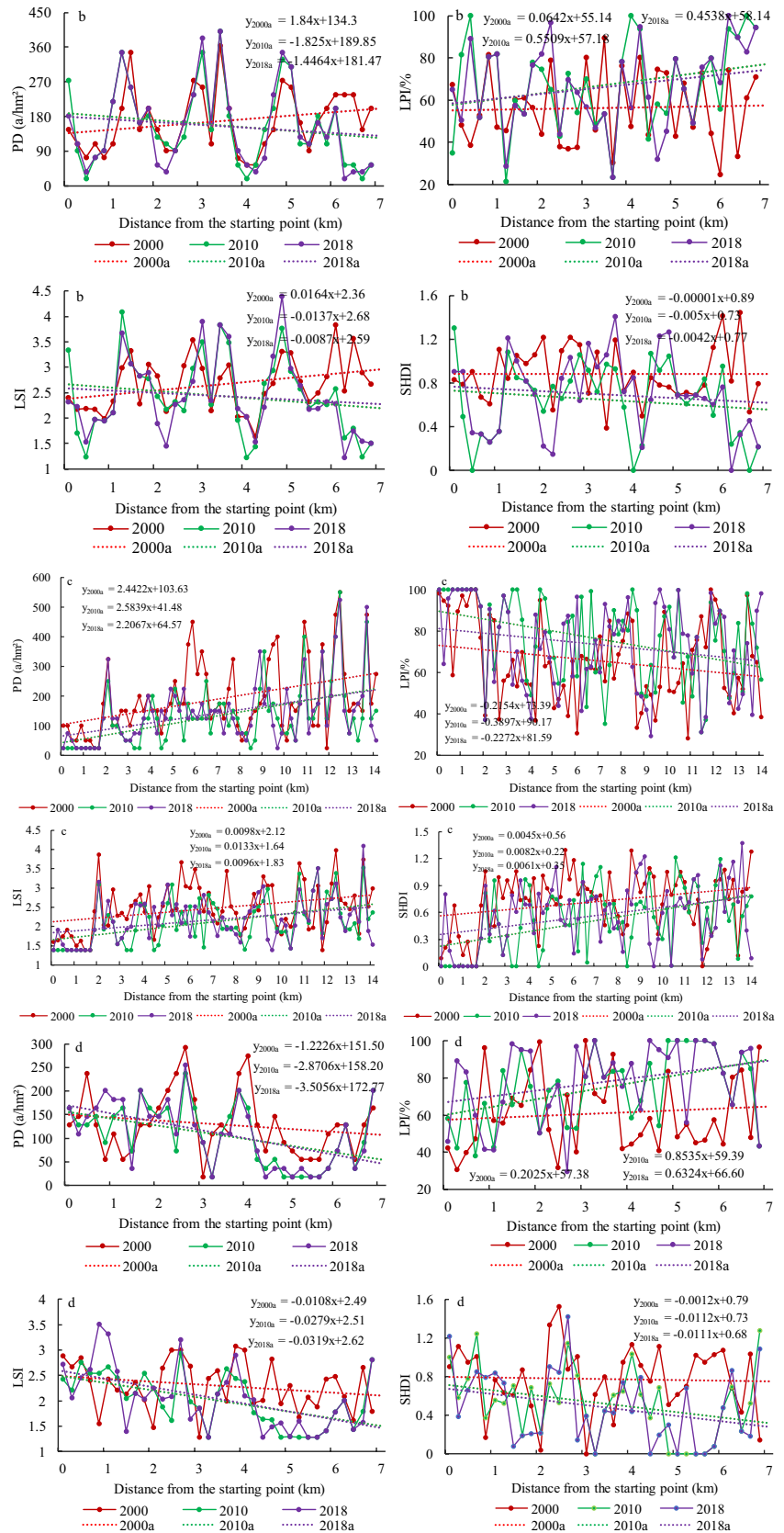
### Theoretical value of research on RLP transition

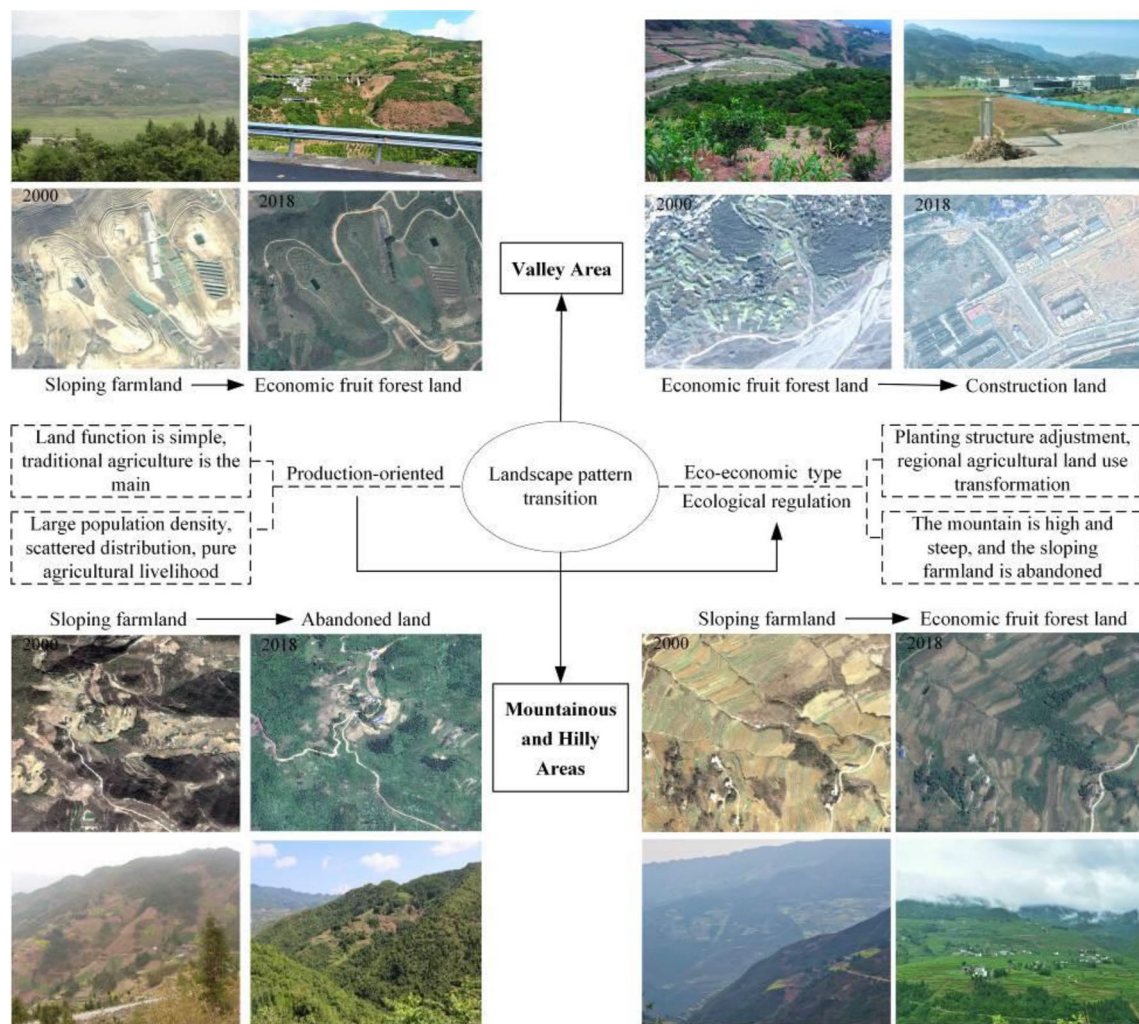
Farmland abandonment is changing the rural landscape around the world (Queiroz et al. 2014). For example, about 90% of the land in southern France was abandoned before 1940 (Sluiter and Jong 2007). In the range of 600–900 m above sea level, the cultivated land area changes the most (Wang et al. 2020). On the local scale, the farmland abandonment rate 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). In recent years, China's mountainous areas have gradually formed a sustainable ecology-production pattern (Jiang et al. 2021). All this changes the landscape pattern, as China is turning green (Chen et al. 2019). The conclusion of this paper is consistent with the above research.

Through a case study, this paper found that rural land-use transition under multiple backgrounds has caused the RLP transition in the mountainous areas of Southwest China. The results verified the hypothesis suggested by this paper, namely, the mountain landscape pattern has undergone transition and evolution driven by land-use transition in mountainous areas. 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 mountainous landscape evolution in Southwest China; (3) it is found that the ecological-economic win-win land-use system can solve the conflicts of ecological and economic development in mountainous areas and guide the RLPs transition.

The successful mode 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, such as the transition of the agricultural development mode for a lesser demand in rural labor, improving the comparative benefit of agriculture to attract young rural labor for farming, increasing the inputs of agricultural technique and capital instead of labor, cultivation of professional farmers, at the same time, establishing of an agricultural supporting system and developing circulative agriculture (Liu et al. 2016).

**Fig. 7** Changes in the landscape-level metrics of transects b, c and d in the mountain and hilly area





**Fig. 8** RLP transition modes in the study area (the real pictures were by the author in 2010-07 and 2021-05, respectively)

**RLP’s driving mechanism in TGRA 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. Simultaneously, it is also a region with a fragile ecological environment (He et al. 2016). As a combination of the mountain area, reservoir area, and rural area, the RLP transition of the study area is the behavior of the farmers' collective abandoned sloping farmland and large-scale economic fruit forest planting. It is also the result of the government's support for the forestry and fruit industry development and the incentive policy of farmland ecological protection (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 altitudes and

steep slopes, human activities move down, farmland 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 patterns is mainly driven by socioeconomic factors and natural factors.

The gradient change of RLP 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 functions and intensive space. In the field investigation, we found that the land-use transition in the study area tended to change from farmland to orchards and from grain crops to cash crops. The transition always aimed at ecological benefits, and the total abandonment area increased with time. Therefore, in the process of land consolidation, the government still needs to optimize the use and focus on sloping farmland to ensure regional food security. A combination of food and cash crops can

be planted to improve the quality of farmland, reduce soil erosion, increase farmers' incomes and improve their motivation to undertake land consolidation (Liang et al. 2020a, b, c). The government should also encourage the development of characteristic agricultural industries based on the planting of economic fruit forests to create modern agricultural industrial parks such as "Government + Farmers" and "Company + Farmers", and realize rural revitalization, agricultural development, and increase farmers' income (Liu et al. 2016). At the same time, the economic fruit forest development in the study area has provided the agriculture transition direction, promoted agricultural planting structure adjustment, and improved the land quality and utilization efficiency in mountainous areas. It has guiding significance for the sustainable development of modern agriculture and the optimization of landscape pattern in the study area.

## Conclusions

This paper proposes and defines the RLP transition caused by land-use transition in the mountainous areas of China. The RLP transition process on different gradient zones in the Caotangxi watershed was analyzed, and the general law of RLP transition in mountainous areas was revealed.

- (1) The landscape pattern in the Caotangxi watershed has undergone a transition with land-use and agro-ecosystem transition. The valley area was mainly transformed from sloping farmland to economic fruit forest land, and the mountainous and hilly area was transformed from sloping farmland and shrubs to abandoned land and forest land.
- (2) From 2000 to 2018, the overall landscape of the Caotangxi watershed changed from production landscape pattern to eco-economic landscape pattern and eco-regulatory landscape pattern.
- (3) Socioeconomic development and agricultural policies have led to the RLP transition in mountainous areas of China. The results provide a reference for the rational land resources utilization, ecological management, and rural revitalization in mountainous areas in the future.

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## Declarations

**Conflict of interest** 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.

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