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Sustainability Dynamics of Traditional Villages: A Case Study in Qiannan Prefecture, Guizhou, China

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Abstract: Rapid urbanization has greatly changed traditional villages in rural areas of China. This paper aims to assess sustainability and obtain its spatio–temporal dynamics, analyze the cause of sustainability changing conditions, and offer suggestions on the sustainable development of traditional villages. We integrated human disturbances into a minimum cumulative resistance (MCR) model based on land use, landscape patterns, and ecosystem service (ES) provision in order to evaluate the sustainability dynamics of traditional villages between 1995 and 2015 in the Qiannan Prefecture, China. The results showed that pronounced declines in sustainability were limited to the northern and eastern regions, where the degradation of forest ecosystems and the rapid increase in construction land have resulted in landscape fragmentation and ES decline. We suggest that scientific land use development plans and ecological restoration should be implemented to protect the ecosystem and improve the sustainability of traditional villages in Qiannan Prefecture.

Keywords: sustainability assessment; landscape pattern; ecosystem services; human disturbance

1. Introduction

China's traditional villages have maintained their special architectural art and folk customs for thousands of years, which are the result of long-term interactions between humans and nature [1]. However, many traditional villages are at risk of being destroyed or even disappearing due to the accelerating process of urbanization [2]. Balancing urbanization and the protection of traditional villages has become a vital issue for decision makers. Researchers have focused on the spatial distribution characteristics of traditional villages [3] and culture protection development [4], which simply provide basic data on the social and geographical states of traditional villages. However, few studies have paid attention to the sustainability assessment of traditional villages [5]. A sustainability assessment offers quantified spatial results as a reference that can be utilized for land use plans and policy making [6]. It also provides approaches for protecting traditional villages and maintaining sustainable development. Since the adoption of Agenda 21 [7] in 1992, scientists have proposed a multitude of sustainability assessment methods. The methods can be broadly classified into three categories: Indicators and indices [8,9], product- or production-focused assessment methods, and integrated methods that commonly involve dynamic models [10]. In the past 20 years, great progress has been achieved, particularly in terms of sustainability indicators and dynamic models. For example, Threshold 21 (T21) is a system dynamics model that assesses the sustainability of developments on a national scale and can be used in policy analysis [11]. Covering economic, social, and environmental aspects of national sustainable development, it has been successfully applied in more than twenty countries [12]. Recently, the minimum cumulative resistance (MCR) model has been applied to assess sustainability. The MCR model originated from a study by Knaapen on the diffusion processes of species [13]. The model describes the difficulty of an object in crossing the resistance surface from a source. In this work, Chen proposed that human disturbance of the source will encounter resistance in the process of diffusion [14]. Resistance is hindrance to the spread of human disturbance due to different landscapes and ecosystems. Chen also proposed that resistance can reduce the impact of human disturbance on the environment and the minimum accumulation resistance is positively correlated with regional sustainability [14]. In this model, human disturbance and resistance can be measured by different indicators. According to the research of Bartlett [15], population and gross domestic production (GDP) are part of the human activities that put stress on a system, and can be selected for measuring human disturbance. Renetzeder proposed that topography, land use type, and landscape pattern are important factors influencing the expansion of human disturbance and also evaluated the resistance value of these factors [16]. Ecosystem services (ES) directly reflect the human wellbeing obtained from an ecosystem and are important for human life and sustainability [17]. Dick [17] and Jørgensen [18] evaluated sustainability based on land use data using ES as indicators. Wu proposed that the regulation services provided by ecosystems represent the buffering effect of ecosystems on human disturbances [19]. The regulation services can be used as resistance in the MCR model to evaluate sustainability. Some researchers have combined various factors and established a methodology for sustainability assessment. For example, Estoque evaluated the sustainability of Baguio city based on land use data by using landscape and ES as indicators [20]. Wu used the MCR model to combine land use, landscape pattern, ES, population, economy, and topography in discussing urban ecology and sustainability [21].

In this study, the MCR model was utilized to integrate dynamics of land use, landscape pattern, ES, GDP, population, and topography in sustainability assessment. First, we studied the dynamics of land use change. Second, we selected three main regulation ES according to ecosystem problems such as stony desertification, soil erosion, and water resource lack in Qiannan [22]. Finally, we put the data of land use, landscape pattern, ES, topography as resistance and GDP, and population density as human disturbance into the model to assess sustainability of traditional villages in Qiannan Prefecture, Western China, from 1995 to 2015 (Figure 1).

The objective of this paper is to reveal the spatio–temporal dynamics of sustainability in traditional villages of Qiannan Prefecture, analyze the cause of sustainability change, and provide some suggestions for the sustainable development of traditional villages.

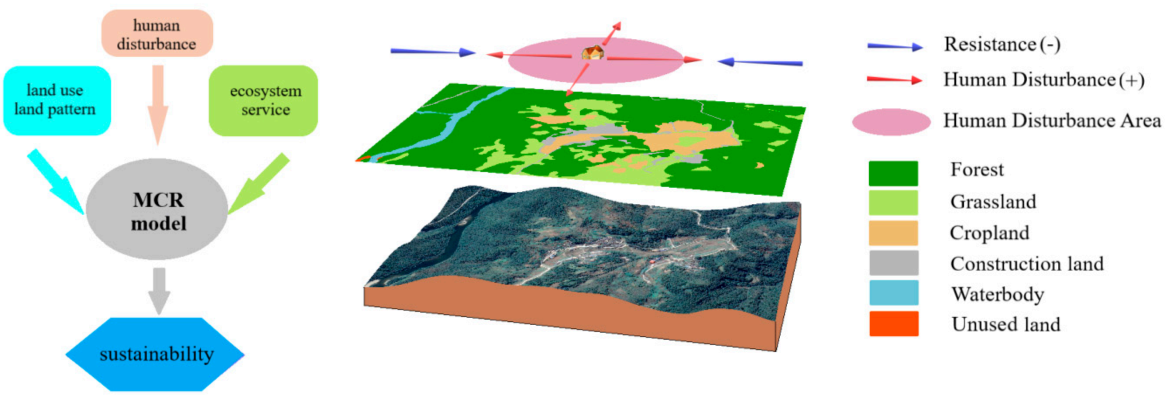

Figure 1. The framework diagram of assessment in this study.

2. Materials and Methods

2.1. Study Area

This study was conducted in the Qiannan Buyi and Miao Autonomous Prefecture. This prefecture is located in the southern part of Guizhou Province, southwest of China. The prefecture has a complex topography, with five distinct settlement zones: Libo-Dushan, Moyang-Luokun, and Duyun-Changshun valleys, Yizhou-Kedu Canyon, and Wengan-Guiding Mountain Basin area. A total of 117 small- and medium-sized rivers dissect the karst landform in these areas. Karst landform is mainly composed of limestone, highly sensitive to external changes, and at high risk of desertification, restricting land resource exploitation [23].

In recent years, traditional villages in the Qiannan Prefecture have experienced rapid urbanization, resulting in an increasing intensity of human disturbance on the surrounding environment. Moreover, traditional villages in the Qiannan Prefecture with its karst landform and fragile ecosystem face challenges in maintaining sustainability with intensive human activities [24].

The study area covered all 12 local counties, autonomous counties, and cities (Figure 2), in which the levels of sustainability were assessed in the form of 63 representative traditional villages [25] of varying elevation and slope (Figure 3).

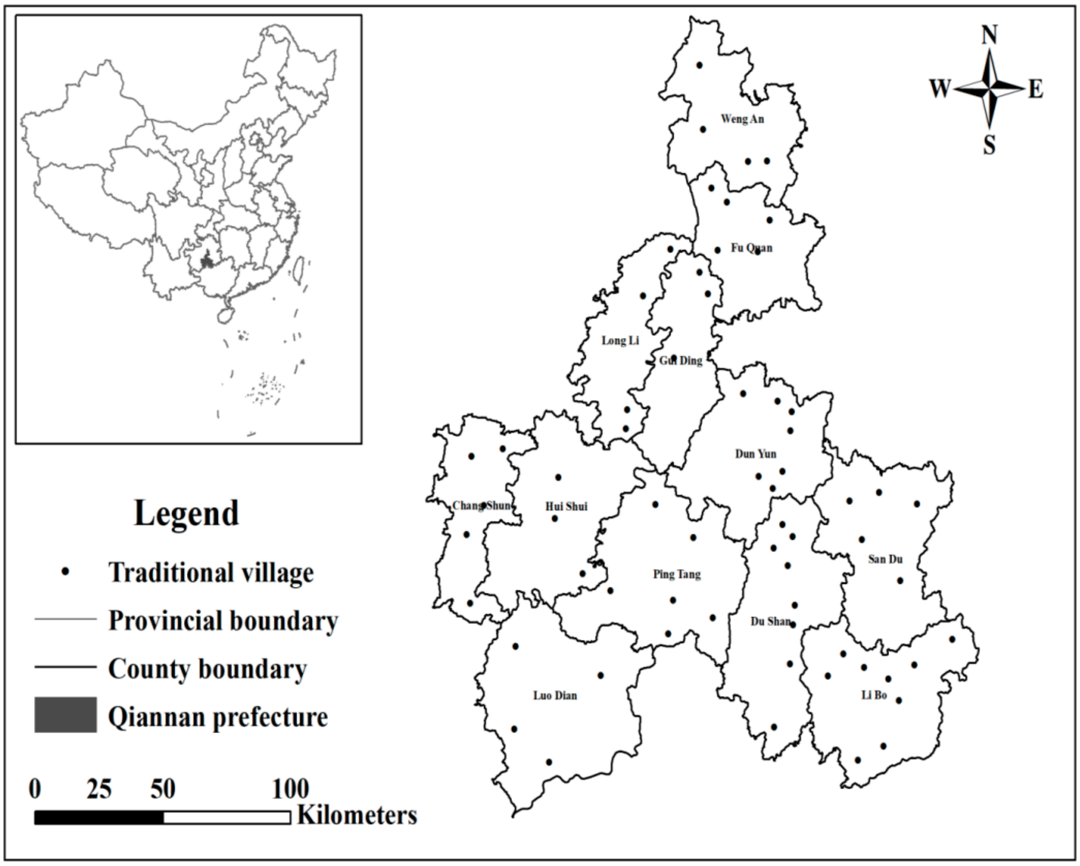

Figure 2. Study areas in the Qiannan Buyi and Miao Autonomous Prefecture.

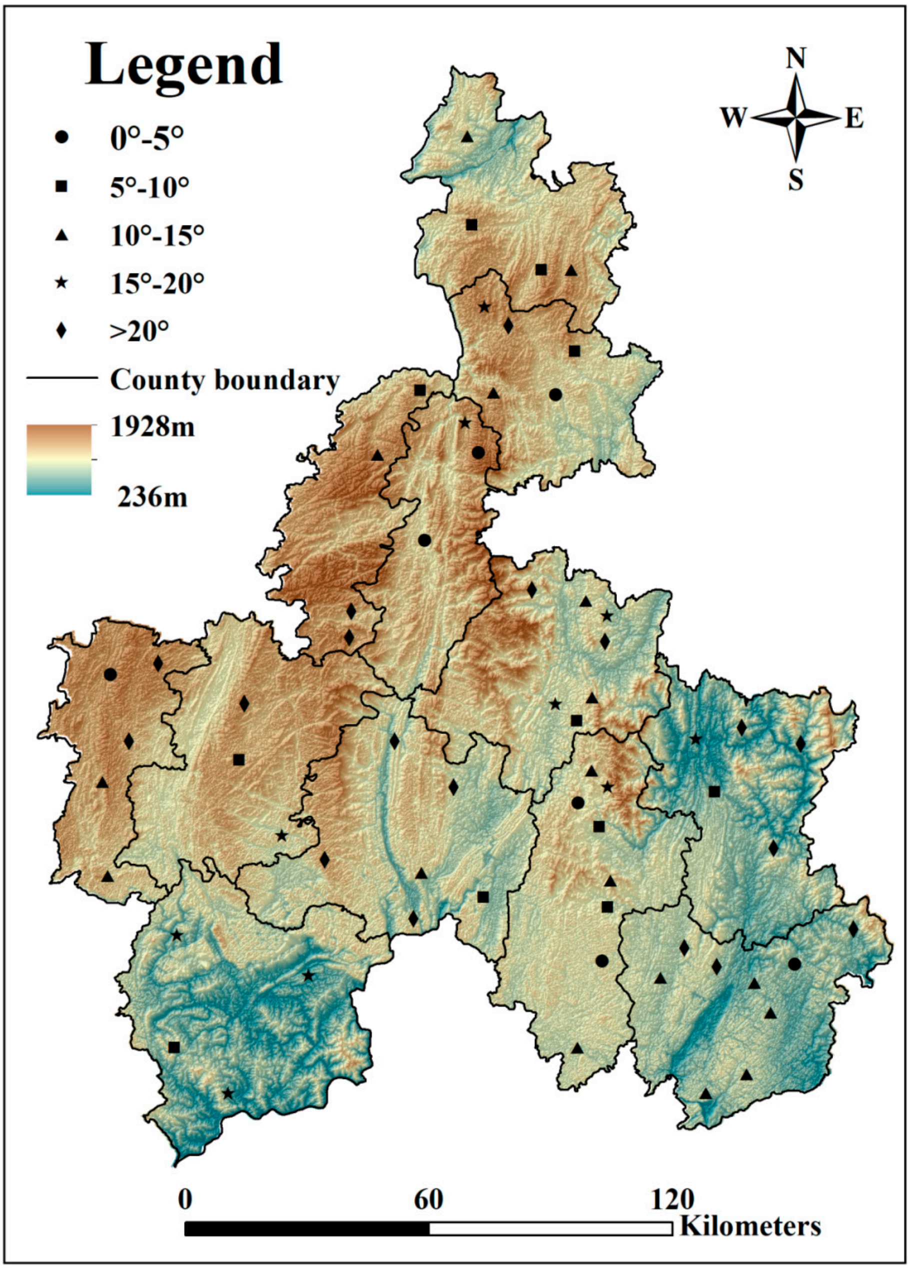

Figure 3. The elevation and slope of the traditional villages investigated in this study.

2.2. Data Source

We obtained Landsat remote sensing images in 1995, 2000, 2005, 2010, 2015, and the digital elevation model (DEM) data (100 m × 100 m resolution) from the Geospatial Data Cloud, Chinese Academy of Sciences [26]. The images were pre-processed by ENVI 5.1 software to calibrate the radiation, correct the geometry, and clip the images. We classified these images into six land use types, including cropland, forest, grassland, construction land, waterbody, and unused land (100 m × 100 m resolution). The kappa coefficients of these land use grid data were greater than 0.85 to ensure the classification has high reliability. Average precipitation grid data (100 m × 100 m) and the annual actual evapotranspiration grid data (100 m × 100 m) in 1995, 2000, 2005, 2010, and 2015 were obtained from the National Meteorological Information Centre. Soil data (100 m × 100 m) were obtained from the Soil and Terrain Database (SOTER) Program. Gross domestic production (GDP) density grid data (100m × 100 m) and population density grid data (100 m × 100 m) in 1995, 2000, 2005, 2010, and 2015 were obtained from the National Geometrics Centre of China [27] and the Guizhou Provincial Statistics Bureau, Guiyang, China [28].

2.3. Data Analysis

2.3.1. The Dynamics of Land Use (LUC) and Landscape Patterns

Land use change includes land resources, land use spatial, and future land resource demand dynamics [29]. Land use change can be quantified by cross-tabulation matrix, in which each row is a land use category at time t_0, each column is a land use category at a subsequent time t_1, and each entry is the area experiencing land cover change or persistence during the interim between t_0 and t_1. The matrix is widely used to facilitate map comparison [30–32].

In this study, we mapped land use of Qiannan in 1995, 2000, 2005, 2010, and 2015 at 100 m resolution using ArcGIS 10.5 software and remote sensing data. We used the raster data statistics tool and spatial analyst tool in ArcGIS 10.5 to obtain the cross-tabulation matrix and analyzed distribution dynamics of six land use types between 1995 and 2015.

The landscape pattern dynamics were quantified by landscape index changes [33–36]. We used Fragstats 4.2 software [37] to calculate the landscape indices and then analyzed landscape pattern dynamics between 1995 and 2015. According to the classification of the landscape indices in Fragstats 4.2 software [37], we divided the nine indices into four groups.

(1) Patch size and density: Patch density (PD) [38] usually represents the number of patches per unit area and the largest patch index (LPI) [39] represents the proportion of the largest patch in the entire landscape. The range of the landscape division index (DVI) [40] is from 0 to 1 and a high DVI value indicates that the landscape is deeply divided into small patches.
(2) Patch scattering and ductility: The aggregation index (AI) [40] ranges from 0 to 100, and the higher the value, the more aggregated the patches are. The interspersion and juxtaposition index (IJI) [40] reflects the distribution characteristics of patches. The higher the IJI value is, the closer the patches are. With regard to the contagion index (CONTAG) [40], a high value indicates that the dominant patch type in the landscape forms a good connectivity.
(3) Patch distribution balance: Shannon's landscape evenness index (SHEI) [41,42] ranges between 0 and 1. A high value indicates that the patch types in the landscape are evenly distributed. The higher the Shannon's diversity index (SHDI) value is [41], the more abundant the land use is and the higher the degree of fragmentation in the landscape is.
(4) Complexity of patches: The landscape shape index (LSI) reflects the complexity of patches [40]. The larger the LSI is, the more complex the shape of the patches is.

2.3.2. Changes in Ecosystem Service (ES) Provision

The ES changes were assessed in 5-year intervals between 1995 and 2015.

(1) Carbon storage

Carbon storage was assessed by calculating the amount of carbon currently stored in the landscape through a combination of land use data and the four carbon pools in the integrated valuation of ecosystem services and trade-offs (InVEST) model [43–47]. The four carbon pools include carbon density in the aboveground biomass (C_{above}), belowground biomass (C_{below}), soil (C_{soil}), and dead matter (C_{dead}) [48]. The four carbon pool data (100 m × 100 m, grid) from 1995 to 2015 were obtained from the National Ecological Environment Decade Change Remote Sensing Survey and Evaluation Project [49]. The formula is as follows:

$$C = C_{above} + C_{below} + C_{soil} + C_{dead}. \quad (1)$$

(2) Water conservation

Water conservation was assessed based on the Budyko [50–52] hydrothermal coupling equilibrium assumption and annual average precipitation data using the following formula [53]:

$$Y_i = \left(1 - \frac{AET_i}{P_i}\right) P_i \tag{2}$$

where Y_i represents the annual water yield in grid unit i; AET_i represents the annual actual evapotranspiration of a grid unit i; and P_i represents the annual precipitation amount of that grid unit i.

Then, a topographic index (TI) [54], saturated hydraulic conductivity of soil ($Ksat$), and flow velocity (V) were used to correct the water yield (Y_i) and obtain the water conservation (WC_i) value using the formula [54]

$$WC_i = \min\left(1, \frac{249}{V}\right) \times \min\left(1, \frac{0.9 \times TI}{3}\right) \times \min\left(1, \frac{Ksat}{300}\right) \times Y_i \tag{3}$$

where TI was calculated based on DEM data, $Ksat$ was calculated using neuro theta [54] based on soil data, and V was obtained from Bao [54].

(3) Soil retention

The soil retention capacity represents the soil loss avoided by the current land use compared to bare land. The formula for this is as follows:

$$SR_i = R_i \cdot K_i \cdot LS_i (1 - C_i \cdot P_i) \times SDR_i \tag{4}$$

where SR_i represents soil retention in the grid unit i; R_i is rainfall erosivity; K_i is soil erodibility; LS_i is a slope length gradient factor; C_i is a crop management factor; P_i is a support practice factor; and SDR_i is the sediment delivery ratio [55,56].

In this study, R_i was obtained by calculating rainfall data; K_i was obtained from the SOTER programme; LS_i was calculated based on DEM data; C_i, P_i and SDR_i were calculated based on land use data.

2.3.3. Sustainability Assessment

The sustainability of traditional villages was assessed by the MCR model. The formula is as follows [57]:

$$MCR = f min \sum_{j=n}^{i=m} (D_{ij} R_i) \tag{5}$$

where f is a function reflecting the positive correlation between the minimum resistance of any point in space and its spatial distance to all sources and features of the landscape base [58]; D_{ij} is the spatial distance between the influence of any human disturbance at its source j to any spatially explicit grid unit i in the landscape [59]; and R_i represents the resistance at grid unit i in terms of the influence of human disturbance [59].

R_i is calculated as follows:

$$R_i = \sum_{x=1}^{x=k} (W_x \times F_{xi}) \tag{6}$$

where x represents the code of factors and k is the number of factors. F_{xi} represents the resistance factor in the grid unit i. The resistance factor of the MCR model is selected from the intrinsic properties and the external properties. Intrinsic properties include topography, land use types, landscape pattern indices, and ES. External properties include economy and population [60]. We set economy and population as human disturbance. According to its direction of spread, we marked it as "+". Ecological resistance represents the hindrance of ecosystems to human activity and was marked as "−". W_x represents the respective weighting of each index in the model. In this study, we set rank and weightings of F_{xi} according to "HJ19-2011: Technical Guidelines for Environmental Impact Assessment: Ecological Impacts" [59,61]. The raster data on the factors were calculated so as to obtain R_i using the raster calculator tool in ArcGIS 10.5. The resulting values and attributes of F_{xi} are displayed in Table 1.

Table 1. Resistance classification of the traditional villages in the Qiannan Prefecture.

	Rule	Factors	W_x	F_x	A	Criteria				
Ecological Resistance	Land use resistance 0.193	Land use type	0.193	F_1	−	Construction land	Unused land	Cropland and Waterbody	Grassland	Forest
	Ecosystem service resistance 0.182	Carbon storage/t·ha^{-1}	0.059	F_2	−	≤30	30–60	60–90	90–120	>120
		Water conservation/m^3·ha^{-1}	0.061	F_3	−	≤5000	5000–10,000	10,000–15,000	15,000–20,000	>20,000
		Soil retention/t·ha^{-1}	0.062	F_4	−	≤3000	3000–6000	6000–9000	9000–12,000	>12,000
	Landscape pattern resistance 0.175	SHDI	0.045	F_5	−	≤1.00	1.0–1.01	1.01–1.02	1.02–1.03	>1.03
		CONTAG	0.044	F_6	−	≤61	61–62	62–63	63–64	>64
		PD	0.043	F_7	−	≤0.7	0.7–0.8	0.8–0.9	0.9–1.0	>1.0
		LSI	0.043	F_8	−	≤151	151–152	152–153	153–154	>154
Human Disturbance	Topography resistance 0.219	Elevation /m	0.075	F_9	−	≤400	400–800	800–1200	1200–1600	>1600
		Slope/°	0.073	F_{10}	−	≤5	5–10	10–15	15–20	>20
		Topography	0.071	F_{11}	−	plain	hill	basin	valley	mountain
	Social and economic impetus 0.231	GDP density/yuan·km^{-2}	0.125	F_{12}	+	≤250	250–500	500–750	750–1000	>1000
		Population density/person· km^{-2}	0.106	F_{13}	+	≤200	200–400	400–600	600–800	>800
	Resistance classification of traditional villages					I Lowest	II Low	III Middle	IV High	V Highest
	Evaluation					10	15	20	25	30

A: We marked the spread direction of $\mathbf{F_x}$ as "+" or "−"; SHDI: Shannon's diversity index; LSI: Landscape shape index; CONTAG: Contagion index; PD: Patch density.

There are many ways for human disturbance to expand outwards. The MCR was applied to calculate the optimal path for human disturbance to expand to any patch in the surroundings. The minimum cost distance method was then used in ArcGIS 10.5 to calculate the accumulated resistance for each pathway. The higher the resistance was, the more difficult it was for human disturbance to develop into patches.

The resulting resistance image data were classified according to the accumulated raster values and attributes. The results were divided into five ranges: 0%–20%, 20%–40%, 40%–60%, 60%–80%, and 80%–100% (Table 2). We then visualized the results through ArcGIS 10.5. Finally, we obtained the sustainability partitions of the villages.

Table 2. Division and definition of cumulative resistance value intervals.

Name	Accumulated Resistance Range (%)	Description
Lowest sustainability zone	0%–20%	Human disturbance has highest impact on ecosystem and landscape; sustainability is lowest.
Lower sustainability zone	20%–40%	Human disturbance has higher impact on ecosystem and landscape; sustainability is lower.
Ordinary sustainability zone	40%–60%	Human disturbance has ordinary impact on ecosystem and landscape; sustainability is ordinary.
Higher sustainability zone	60%–80%	Human disturbance has lower impact on ecosystem and landscape; sustainability is higher.
Highest sustainability zone	80%–100%	Human disturbance has lowest impact on ecosystem and landscape; sustainability is highest.

3. Results

3.1. Landscape Dynamics

3.1.1. Land Use Changes

The spatial distribution of land use in the Qiannan Prefecture from 1995 to 2015 is shown in Figure 4. The area of two of the six land use classes used in this study increased substantially between 1995 and 2015 (Figure 5). The largest proportional increase was observed in construction land, which increased by 304.29% from 5581.26 ha in 1995 to 22,564.98 ha in 2015 (Table 3). The land use with the second largest proportional increase over time was waterbodies. Here, the area increased by 170.82%, from 2898.27 ha in 1995 to 7849.35 ha in 2015 (Table 3).

As the second most important land use class in terms of overall area covering the Qiannan Prefecture, the area of cropland also increased from 590,158.71 to 606,309.75 ha between 1995 and 2015 (Table 3). There was a large increase in the overall cropland area over the first 10 years, reaching a peak in 2005 when cropland covered 619,511.67 ha, followed by a strong decreasing trend toward the current value. If this trend persists, the cropland area will soon drop below the value recorded in 1995. Grassland area also increased from 507,434.31 to 523,081.89 ha between 1995 and 2015 (Table 3), although there was a sharp decrease in grassland area in 2005. The area of unused land almost completely disappeared between 1995 and 2015, with a decrease from 1346.22 to 524.88 ha (Table 3).

The overall gains reported for most of the land-cover types were chiefly associated with decreases in forest area (Table 3). Forest was the most important land use in terms of overall area coverage, but the area of forest decreased by almost 3.5% (52,910.08 ha) from 1.51 million to 1.50 million hectares over the study periods. There was a sharp decrease in forest area in 2000, followed by a rapid re-establishment in 2005.

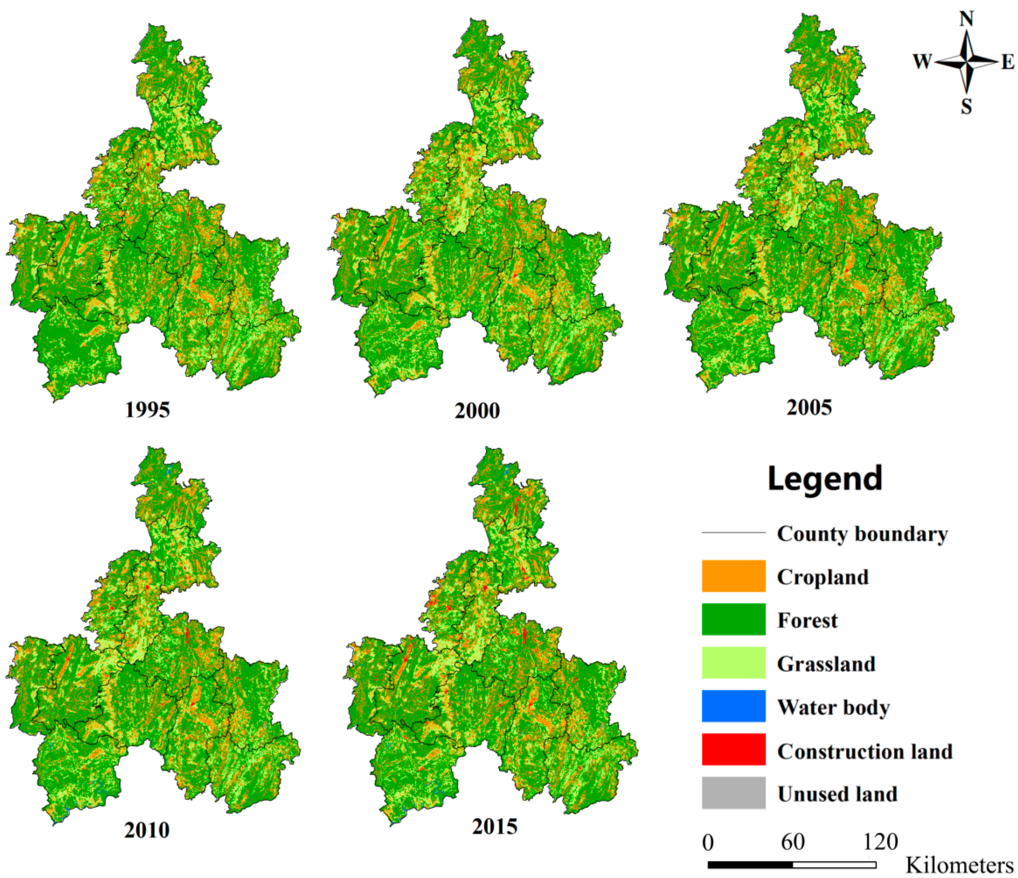

Figure 4. Land use in Qiannan Prefecture from 1995 to 2015.

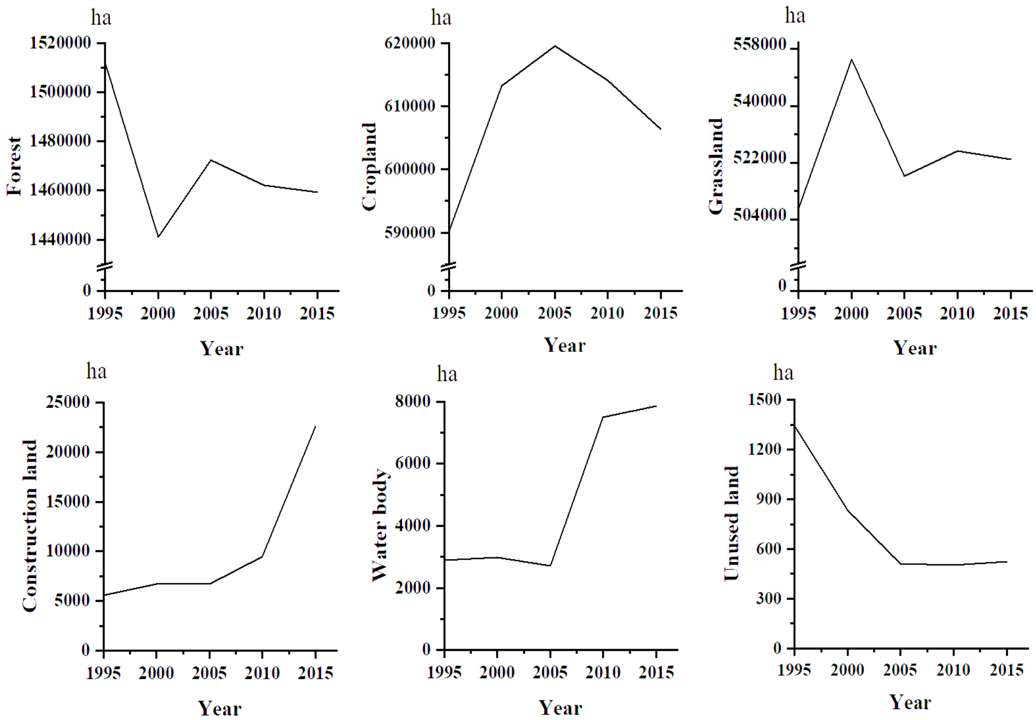

Figure 5. Land use changes in the Qiannan Prefecture.

Table 3. Cross-tabulation of land use in Qiannan from 1995 to 2015 (unit: ha).

2015 \ 1995	Cropland	Forest	Grassland	Waterbody	Construction Land	Unused Land	Total
Cropland	560,146.68	28,444.23	17,625.96	28.98	47.88	16.02	606,309.75
Forest	13,599.45	1,393,722.00	51,013.35	37.62	69.66	801.09	1,459,243.17
Grassland	5117.94	82,620.63	435,085.38	7.65	247.95	2.34	523,081.89
Waterbody	1309.50	3223.62	463.95	2824.02	21.06	7.20	7849.35
Construction land	9964.17	4141.44	3240.00	0.00	5194.71	24.66	22,564.98
Unused land	20.97	3.33	5.67	0.00	0.00	494.91	524.88
Total	590,158.71	1,512,155.25	507,434.31	2898.27	5581.26	1346.22	2,619,574.02

3.1.2. Dynamics in the Landscape Pattern

(1) Changes in patch size and density

The measured PD increased slowly from 1995 to 2015. By contrast, the LPI value decreased sharply while the DVI value increased (Figure 6). These results showed that the landscape patches became smaller and that landscape fragmentation was increasing.

(2) Patch scattering and ductility changes

The AI and the CONTAG values both decreased from 1995 to 2015 while the IJI values increased (Figure 6). The results showed that the same types of patches were more dispersed, and that landscape fragmentation was increasing.

(3) Patch distribution balance changes

The SHDI and SHEI values increased in the Qiannan Prefecture from 1995 to 2015 (Figure 6). These results indicated that the distribution of patches became more balanced while the degree of landscape fragmentation increased. Different land uses became more abundant.

(4) Changes in the complexity of patches

The LSI values increased from 1995 to 2015, indicating that the shape of the patches became more complex (Figure 6).

These changes in the values of the landscape pattern indices showed that the landscape of the Qiannan Prefecture displayed a fragmentation trend from 1995 to 2015.

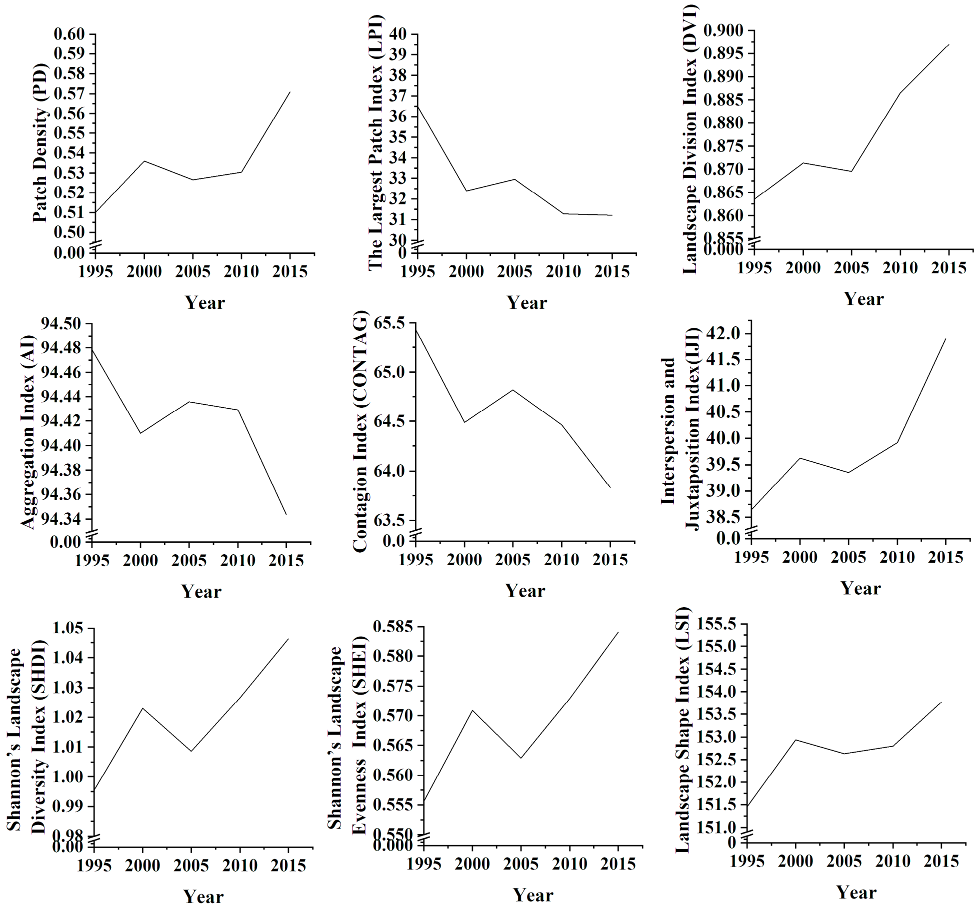

Figure 6. Dynamics of the landscape pattern.

3.2. Changes in Ecosystem Service (ES) Provision

3.2.1. Carbon Storage

From 1995 to 2015, the total carbon storage in the Qiannan Prefecture decreased by 26.13 million tons (from 67.63 to 41.50 million tons). The distribution of carbon storage capacity in the whole state is shown in Figure 7. The largest decrease in carbon storage capacity per unit area in the four counties occurred in the northern and eastern regions, with the largest decrease being 131.65 t ha^{-1}. There was a slight increase in the western regions.

3.2.2. Water Conservation

From 1995 to 2015, the total volume of water conserved in the Qiannan Prefecture was reduced by 66.623 billion m^3 (from 77.68 to 11.06 billion m^3). The distribution of the conserved water in the whole state is shown in Figure 7. The water conserved per unit area declined most rapidly (60,474.71m^3 ha^{-1}) in the eastern and southern regions while increasing slightly in the northern and western regions.

3.2.3. Soil Retention

From 1995 to 2015, the total soil retention of the Qiannan Prefecture decreased by 17.03 million tons (from 4374.43 million tons to 4357.40 million tons). The distribution of the soil retention capacity in the whole prefecture is shown in Figure 7. The soil retention per unit area decreased most in the eastern regions, with a maximum value of 10,795.95 t ha^{-1}.

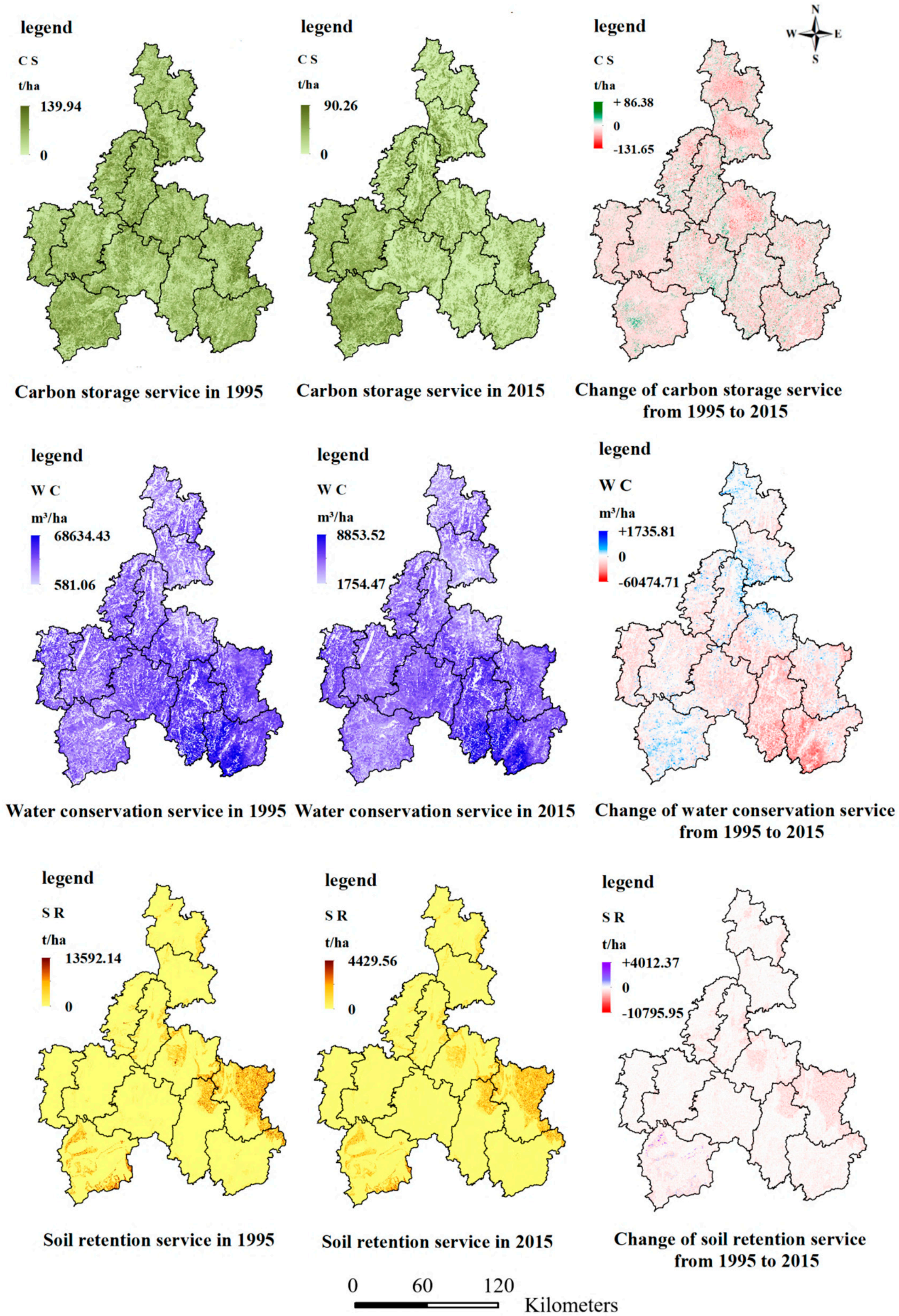

Figure 7. Changes of ecosystem services.

3.3. Assessment of Sustainability

Overall, there was a very clear spatial differentiation of the sustainability levels of traditional villages in Qiannan Prefecture (Figure 8). Traditional villages in the eastern and northern regions of the prefecture generally had much lower levels of sustainability than those in the western and southern regions. These results clearly indicate that, over time, the levels of sustainability in the northeastern lower-sustainability zone further decreased and transformed to the lowest-sustainability zone, resulting in the merging and expansion of the lowest-sustainability zone in this part of the study region. The sustainability levels of the western and southern regions remained stable, thus further enhancing the strong divisions in the sustainability levels of traditional villages in Qiannan Prefecture.

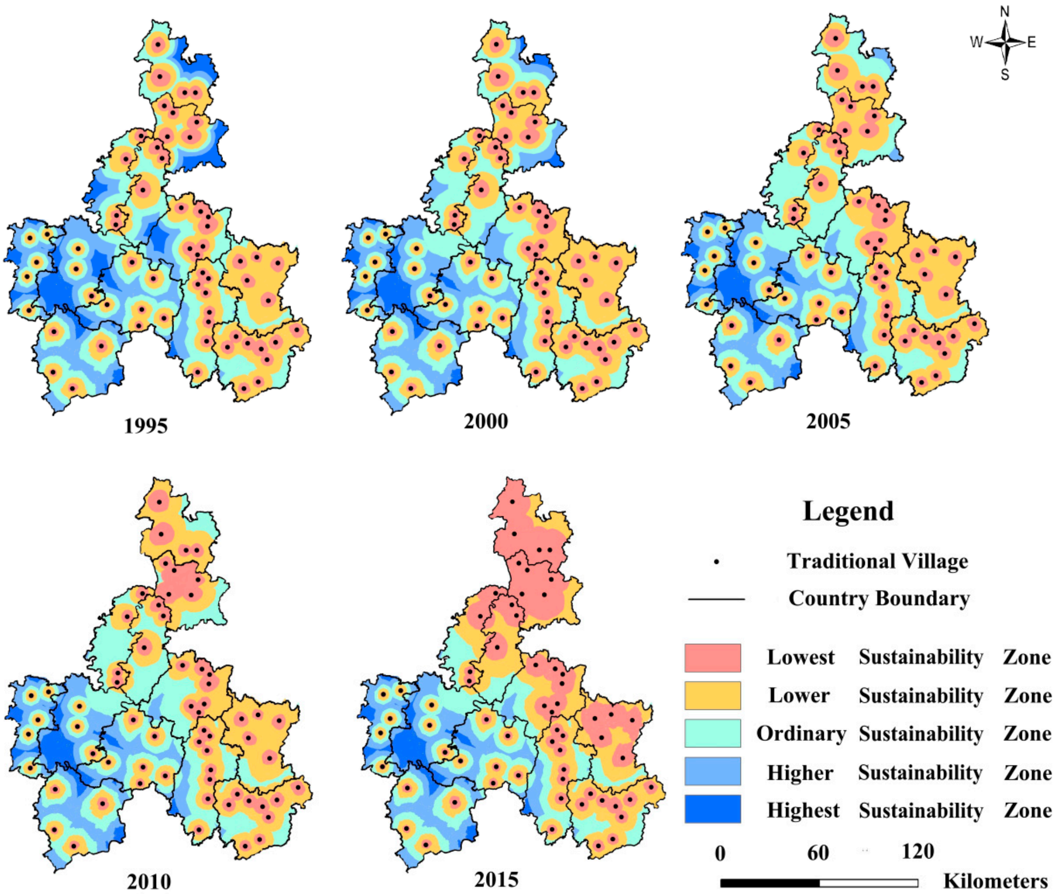

Figure 8. Sustainability partitions of the traditional villages in the Qiannan Prefecture.

4. Discussion

4.1. The Cause of Sustainability Change

The decrease of sustainability in the eastern and northern traditional villages of Qiannan Prefecture resulted from the change of land use, landscape fragmentation, and ecosystem service decline. Forest is the main land use in the Qiannan Prefecture. However, the forest decreased sharply by 52,910.08 ha from 1995 to 2015 in Qiannan. Large forest patches in the eastern and northern regions were transformed into small grass patches, cropland patches, and construction land patches. Massive land exploitation activities have occurred in Qiannan, with 163 land exploitation programs conducted from 2006 to 2014 [62]. Land utilized for houses, roads, and construction accounted for 13,359.70 ha [62]. Hydraulic projects [63] led to the expansion of waterbodies. Therefore, the area of construction land and waterbodies around the traditional villages in the eastern and northern regions expanded rapidly. The cropland near the villages has been converted into construction land and waterbodies. Therefore, residents had to turn the forest land into cultivated land in the suburbs. This has led to more serious landscape fragmentation in the eastern and northern regions. It also led to fewer ES provided by the forest. The decline in ES (carbon storage, water conservation, and soil retention) resulted in a decline of ecosystem regulation capability in the eastern and northern regions. Decline of ecosystem regulation capability may lead to more ecological issues such as soil erosion [64]. If these trends go on, the traditional villages in northern and eastern areas may shrink and become unsustainable in the future, or perhaps may even disappear. On the contrary, the Grain for Green Project was implemented in the western and southern part of Qiannan Prefecture [62]. This project aims to convert cropland with poor farming conditions into forest. From 2005 to 2014, the total area of forest transferred from cropland in western and southern regions was 5550.18 ha [62]. The increase in forest area resulted in recovery of the ecosystem and ES improvement. The ES offset the negative impact of urbanization in these regions, and the sustainability of traditional villages in these regions remained steady from 1995 to 2015.

4.2. Improving Sustainability and a Strategy for Land Use Planning

Sustainable development of traditional villages needs population and economic growth to coordinate with ecosystem conservation. However, rapid urbanization in the eastern and northern regions of Qiannan resulted in fragmentation of the forest and the decline in ecosystem regulation capability, which constrained the sustainability of traditional villages. In order to achieve sustainable development, a reasonable land use development plan and ecological restoration is required. First, in the lowest-sustainability zones of northern Qiannan, urbanization development activities should be prohibited to protect existing forest. At the same time, ecological restoration, such as forest re-establishment, should be implemented to enhance the ability of ES provision. Second, in the lowest-sustainability zones of eastern Qiannan and the whole lower-sustainability zones, it is essential to limit the expansion of construction land and improve land use efficiency. Moreover, the infrastructure construction should try to avoid segmenting natural landscapes and ecosystems. Afforestation could be implemented to repair forest fragmentation around traditional villages. Finally, for zones with ordinary level sustainably and other zones (Figure 8), small-scale urbanization activities are allowed. The distribution of cultivated land and construction land should be optimized. The Grain for Green Project should be conducted in areas with poor farming conditions to maintain areas of forest.

Spatial configuration of land use in sustainable studies of traditional villages was the main topic but surrounding environmental impacts on ecosystem and land use changes were lacking [3–5]. We provided a new approach for improving sustainability of traditional villages that was both optimizing land use pattern and protecting surrounding ecosystems, and suggested that more attention should be paid to ecosystems around traditional villages.

5. Conclusions

Traditional villages in China are facing the challenges of land use change and ecosystem protection under rapid urbanization. Studying the sustainability of traditional villages is important for their protection and development. Our study assessed the sustainability of 63 traditional villages in Qiannan Prefecture from 1995 to 2015 integrating land use data, landscape indices, and ecosystem services (ES) as indicators. The results showed traditional villages in eastern and northern regions had much lower levels of sustainability than those in western and southern regions of the Qiannan Prefecture, Guizhou Province. The reasons for this were forest area decrease, construction land expansion, and landscape fragmentation in eastern and northern regions.

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