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Rural Landscape Vulnerability Assessment Method Incorporating Human Disturbance Factors: The Case of a Autonomous Prefecture in Southwestern China

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Key words: Landscape pattern, spatial and temporal evolution, driving forces, landscape vulnerability index(LVI), landscape adaptability index (LAI), landscape sensitivity index(LSI), population pressure index(PPI).

Abstract:

This study Addressed the inadequacy of traditional landscape vulnerability measurement methods in considering human disturbance factors, added the population pressure index, to constructs a rural landscape vulnerability measurement model of "landscape sensitivity index (LSI) - landscape adaptability index (LAI) - population pressure index (PPI)" by combining rural landscape vulnerability characterization.Based on the land use cover data from 2005 to 2015 in Liangshan Yi Autonomous Prefecture,we constructed a rural landscape vulnerability evaluation system and took empirical analysis. we found that :(1) the evaluation model has good feasibility to portray the vulnerability of rural landscape in the study area, and the research findings reflect the actual situation to a certain extent, which can provide a reference for the study of rural landscape vulnerability measurement. (2) During the period of 2005-2015, the unevenness of rural landscape vulnerability in each district and county of the study area is significant, showing the characteristics of circles; the spatial structure of landscape vulnerability level changes significantly, the area of high vulnerability area has experienced the process of first increasing and then decreasing, and gradually changing to medium and low vulnerability areas, and the overall situation of landscape vulnerability has been optimized. (3) Natural environmental factors have a continuous influence on the fragility of rural landscape, while socio-economic and urban-rural construction and other anthropogenic disturbance factors have a transformative influence on the spatial and temporal differentiation of rural landscape fragility, and administrative force is another major influencing factor.

1. INTRODUCTION

In the process of transformation from "rural China" to "urban-rural China", the rapid socio-economic development has led to significant changes in the rural landscape pattern. Faced with the dual pressure of rapid urbanization and ecological environmental protection, the rural landscape in China shows obvious vulnerability in the natural environmental landscape, economic landscape, settlement landscape, and human landscape (YU.et al., 2019). In particular, unreasonable human activities have led to the emergence of ecological vulnerability problems (Ren. et al., 2018). It is important to carry out the study of rural landscape vulnerability measurement for integrating rural human and land resources and improving the coordination between human and ecological environment (Leng. et al., 2018). With the promotion of the implementation of strategies such as rural revitalization and ecological civilization construction, rural landscape vulnerability has attracted great attention from academia and relevant departments, especially in ecologically sensitive and fragile areas, rural landscape vulnerability research has important urgency and practicality.

At present, the research on rural landscape vulnerability in China is still at the stage of exploration and development. Leng. et al. (2018) first proposed the concept of "Rural Landscape Vulnerability" and pointed out that rural landscape vulnerability research is a natural extension of landscape vulnerability research in the rural area . Zou. et al. (2018) proposed that rural landscape vulnerability is divided into two levels, material and immaterial, from the perspective of traditional village conservation . Lin. et al. (2018) constructed an ecological vulnerability evaluation index system for key villages in Fujian Province based on the "cause - result" model. Li. et al. (2018) constructed a rural ecological vulnerability evaluation system from three dimensions: exposure, sensitivity and adaptability . The above-mentioned studies have laid the theoretical foundation and research framework for the study of rural landscape vulnerability, however, most of the above studies focus on tourism-oriented villages, and the attention to the study of rural landscape vulnerability measurement in ecologically fragile areas is slightly insufficient; secondly, the data of the indicator layer of the above evaluation system mostly come from statistical yearbooks, and the attribute characteristics of landscape types are not considered.

Located in the southwestern part of Sichuan Province, Liangshan Yi Autonomous Prefecture belongs to the ecologically fragile area of interlocking agriculture and animal husbandry in the southwestern part of China, and is an important part of the ecological barrier in the upper reaches of the Yangtze River. The ecological vulnerability is manifested by the undulating terrain, complex geological structure, obvious vertical changes in water and heat conditions, incomplete development of soil layers and sparse vegetation; the strong influence of anthropogenic activities has resulted in obvious regional ecological degradation. Currently, rural construction is in full swing, human activities are increasingly disturbing the ecosystem, and the fragmentation and homogenization of the rural landscape are prominent; coupled with soil erosion and natural geological disasters in recent years, the ecosystem imbalance is more serious, which restricts the sustainable development of the countryside (Zhang. et al., 2020). With the acceleration of poverty eradication and urbanization process, rural landscape will face more serious challenges. How to ensure the safety of rural landscape pattern and integrate the contradiction of rural human and land resources is one of the important issues of rural landscape at present. The clarification of the

spatial and temporal evolution of the fragility of rural landscape and the influencing factors is the primary premise of rural landscape pattern optimization.

In view of this, the paper selects the ecologically fragile Liangshan Yi Autonomous Prefecture as the study area, and constructs a landscape vulnerability evaluation index system from three dimensions: landscape sensitivity index (LSI), landscape adaptability index (LAI) and population pressure index (PPD) based on land use data for three periods from 2005 to 2015, and uses spatial analysis methods to analyze the spatial and temporal evolution characteristics and influencing factors of rural landscape vulnerability in the study area, and proposes strategies and suggestions to provide reference for rural landscape planning in ecologically fragile areas.

2. LITERATURE REVIEW

Landscape pattern vulnerability reflects the vulnerability as well as the response and adaptive capacity of landscape ecosystems under the influence of external disturbances (Tian. et al, 2019) , and is one of the important indicators to characterize regional ecological security (Xu. et al., 2018) . Currently, landscape vulnerability research at home and abroad has become mature, mainly focusing on ecology and geography, covering multi-dimensional scales such as mining areas, watersheds, provinces, and cities, with diversified research contents.

For the measurement of landscape vulnerability, there is no unified standard in the academic field. The reasons for this are that there are various causes of landscape vulnerability, and different regions have different landscape vulnerability performance situations (Wu. et al., 2012 ,Wang. et al., 2005). At present, the field of landscape ecology mainly constructs the landscape vulnerability index (LVI) evaluation system from landscape sensitivity index (LSI) and landscape adaptability index (LAI) through landscape pattern index, and further studies show the spatial and temporal evolution, driving mechanism, response of human activities, and regulatory countermeasures of landscape vulnerability index (Fu. et al., 2020). There are fewer studies on landscape vulnerability in the field of urban and rural planning, Yu., et al. (2019), based on the concept of vulnerability, argued that rural landscape vulnerability is attributed to ecological and environmental vulnerability, land use vulnerability, and socioeconomic vulnerability, and constructed a rural landscape vulnerability evaluation index system at the county scale from three levels: exposure, sensitivity, and adaptation .

In recent years, with the gradual deepening of vulnerability research, some scholars have realized the limitations of simply relying on the landscape pattern index to evaluate landscape vulnerability, ignoring the perturbation effect of external factors. For example, Tian. et al. (2019) took the bay in the East China Sea region as an example and proposed that natural and anthropogenic factors jointly influence landscape vulnerability, and the influence of natural factors dominates on long spatial and temporal scales; while on short spatial and temporal scales, the influence of anthropogenic factors is more obvious. Zhang. et al. (2019) proposed a new method for landscape pattern vulnerability index evaluation, adding the population pressure index to the traditional landscape sensitivity index and landscape adaptation index, and further pointed out that human activities have a

significant influence on the landscape pattern index through empirical analysis .

In general, the current measurement of ecological vulnerability is mainly evaluated by constructing a comprehensive factor system, and the weights of each factor are assigned by principal component analysis, hierarchical analysis, entropy value method, comprehensive evaluation method, artificial neural network method, etc. The construction of landscape ecological vulnerability index by landscape pattern index has significant advantages, and the combination of regional ecological environment sensitive factors to measure is the mainstream trend in the current academic field(Zhang. et al., 2020).

3. MATERIALS AND METHODS

3.1 Methods

This paper aims to construct a rural landscape vulnerability measurement model by landscape pattern index, and spatially visualize it by spatial analysis method to clarify the spatial and temporal evolution characteristics and influencing factors. The traditional methods of landscape vulnerability evaluation Landscape Sensitivity Index (LSI) and Landscape Adaptation Index (LAI) construct the Landscape Vulnerability Index (LVI) evaluation model. The paper is based on the study of Zhang. et al. (2019), which introduced the population pressure index (Formula 4) and modified it (Formula 5) by combining the current characteristics of Liangshan Yi Autonomous Prefecture.

$$\mathrm{LSI} = \sum_{i}^{n} U_i \times V_i \quad (1)$$

$$\mathrm{U}_i = a\mathrm{F}N_{\mathrm{i}} + b\mathrm{F}D_{\mathrm{i}} + cDO_{\mathrm{i}} \quad (2)$$

$$\mathrm{LAI} = PRD \times \mathrm{SHDI} \times SHEI \quad (3)$$

$$\mathrm{PPD} = x * P\mathrm{C} + y * PID \quad (4)$$

$$\mathrm{PID} = (\mathrm{S_C} + \mathrm{S_A}) \ /\mathrm{S_S} \quad (5)$$

$$\mathrm{PC} = P_{\mathrm{A}} / P_{\mathrm{S}} \quad (6)$$

$$\mathrm{LVI} = \mathrm{LSI} \times (1 - LAI) \times PPD \quad (7)$$

(1) LSI is the landscape sensitivity index. n is the number of landscape types, i is the landscape type. ui is the landscape disturbance index, FNi, FDi, DOi, respectively, represent the landscape fragmentation index, the inverse of the landscape sub-dimension, landscape dominance, the weights a, b, c refer to the above-mentioned literature and combined with the study area landscape characterization, in order to take the value of 0.5, 0.3, 0.2, landscape dominance using the maximum patch index (LPI) to measure (Wu, et al., 2012). Vi denotes the landscape vulnerability index, and according to the results of previous studies, generally the unused land is the most sensitive, and the built-up land and water bodies are more stable, so the

vulnerability of built-up land, water, forest land, grassland, cropland and unused land are assigned as 1, 2, 3, 4, 5 and 6 respectively.

(2) LAI is landscape adaptability index, SHDI is Shannon diversity index, PRD is patch abundance density index, and SHEI is Shannon evenness index. The landscape pattern indices were calculated by software Fragstats 4.2.

(3) PPD is the population pressure index, PC is the proportion of rural population and permanent population, PID is the population disturbance index, S_C, S_A, and S_S the area of construction land, the area of agricultural land, and the total area of the study area, respectively. p_A and p_S represent the number of rural population and the number of permanent population, respectively. The weights x and y are set to 0.4 and 0.6, respectively.

(4) LVI is the landscape vulnerability index. the higher the LVI value, the more serious the vulnerability of the landscape ecosystem.

3.2 Study area

Liangshan Yi Autonomous Prefecture (26°03′N-29°18′N, 100°03′E-103° 52′E) is located in the southwestern part of Sichuan Province, bordering Ya'an City and Ganzi Prefecture from the Dadu River in the north to Jinsha River in the south and Yunnan Province, Zhaotong City in Yunnan Province and Leshan City in Yibin City in Sichuan Province in the east, and Panzhihua City and Lijiang City in Yunnan Province in the west. Yunnan Lijiang City. The area under the jurisdiction of the state is 60,423 square kilometers, with 1 city and 16 counties (Figure 1). Due to the regional dry and hot river valley zone, the heterogeneity and sensitivity of ecological environment is high, coupled with the long-term unreasonable development and utilization of resources such as mining, hydropower, forestry and agriculture and animal husbandry, resulting in its ecological barrier function not only failing to give full play, but instead making it a region with prominent ecological and environmental problems, which seriously restricts the sustainable development of the region .

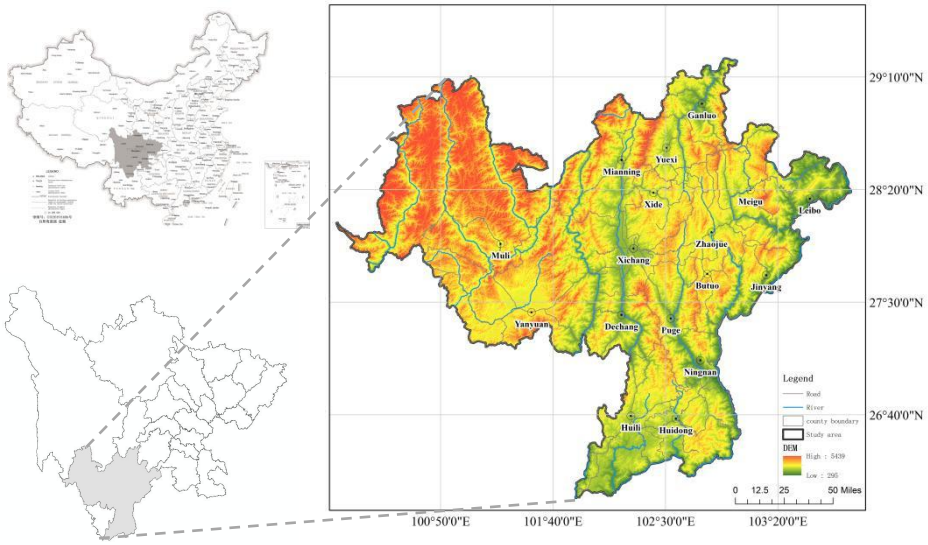


Figure 1. Study area

3.3 Data and processing

The data involved in the study are mainly the land use cover data of 3 periods from 2005 to 2015, and the data are obtained from the National Geographic Information Resource Catalogue Service , and a total of six types of arable land, grassland, forest land, water, construction land, and unused land were obtained by collation (Figure 2). The socioeconomic data such as rural population and the number of resident population were obtained from Sichuan Statistical Yearbook, Liangshan Prefecture Statistical Yearbook, and government official reports.

It is worth noting that the study aims to measure the vulnerability of rural landscapes in each district and county, analyze their spatial and temporal evolution characteristics and influencing factors, and propose corresponding response strategies and suggestions. Therefore, we did not use the grid analysis method, but took the 17 county administrative divisions as the research units.

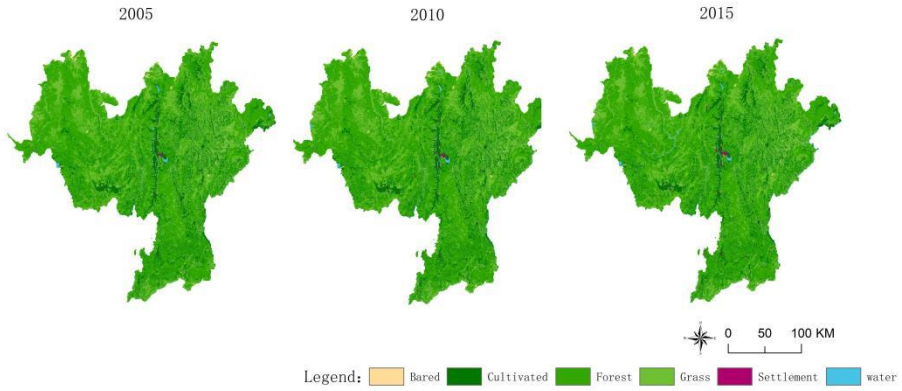


Figure 2. Land use cover of study area

4. RESULTS

4.1 Vulnerability characteristics and typology of rural landscapes

By calculating the landscape fragility index for each district and county through equations 1-7, taking into account the comparability of data in the time dimension, and after continuous revision, the landscape fragility was finally divided into a total of five classes, namely low fragility zone ($LVI \leq 0.02$), lower fragility zone ($0.02 < LVI \leq 0.028$), medium fragility zone ($0.028 < LVI \leq 0.032$) , higher vulnerable ($0.032 < LVI \leq 0.037$), and high vulnerable ($0.37 < LVI$).

Table 1. Typology of rural landscape fragility

Year	LVI Classification	county	amount
2005	Lowest Zones	Puge. Xide. Zhaojue.	3
	Lower Zones	Butuo. Ganluo. Jinyang. Ningnan. Xichang. Yuexi.	6
	Moderate Zones	Dechang. Mianning. Muli.	3
	Higher Zones	Meigu. Yanyuan.	2
	Highest Zones	Huidong. Huili. Leibo.	3
2010	Lowest Zones	Puge. Xide. Zhaojue.	3
	Lower Zones	Butuo. Jinyang. Mianning. Ningnan. Xichang. Yuexi.	6
	Moderate Zones	Dechang. Muli. Meigu.	3
	Higher Zones	Leibo.	1
	Highest Zones	Ganluo. Huidong. Huili. Yanyuan.	4
2015	Lowest Zones	Butuo. Jinyang. Puge. Xichang. Xide. Yuexi. Zhaojue.	7
	Lower Zones	Dechang. Mianning. Muli. Ningnan.	4
	Moderate Zones	Huili. Leibo. Meigu. Yanyuan.	4
	Higher Zones	Ganluo. Huidong.	2
	Highest Zones	—	0

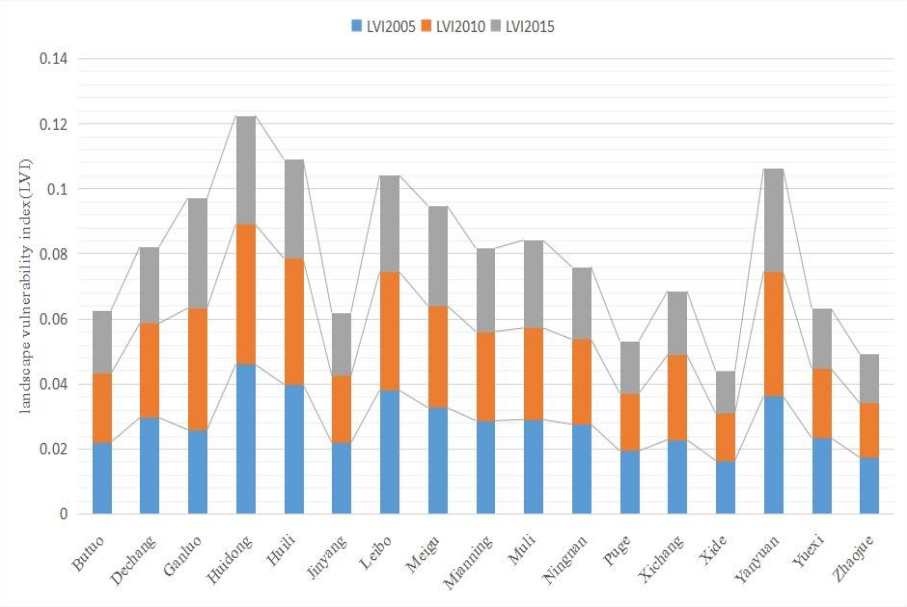
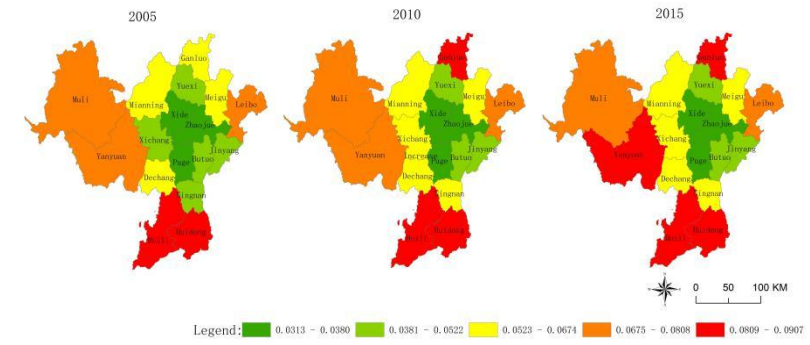
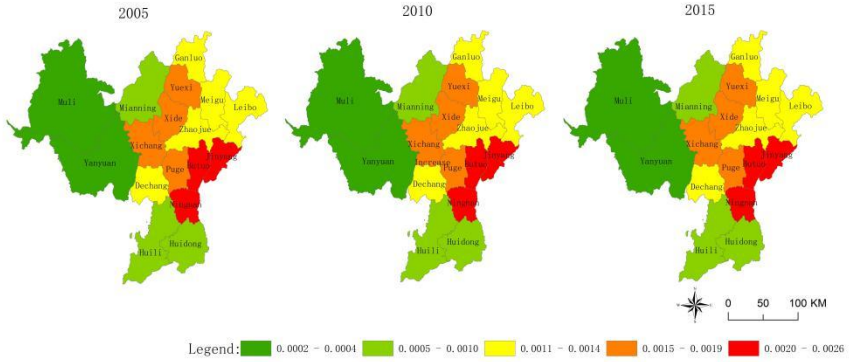


Figure 3. landscape vulnerability index(LVI)

From the calculation results in Figure 3 and Table 1, the number of research units in the low vulnerability area showed a significant increase from 2005 to 2015, from 3 in 2005 to 7 in 2015; the number of research units in the lower vulnerability area showed a small downward trend, from 6 in 2005 to 4 in 2015; the medium vulnerability area and higher vulnerability area did not change much; the number of research units in the high vulnerability area experienced an increase and then a decrease, and the number of research units in the high vulnerability area was 0 in 2015. In general, there is a clear shift from higher to lower values.



(a)



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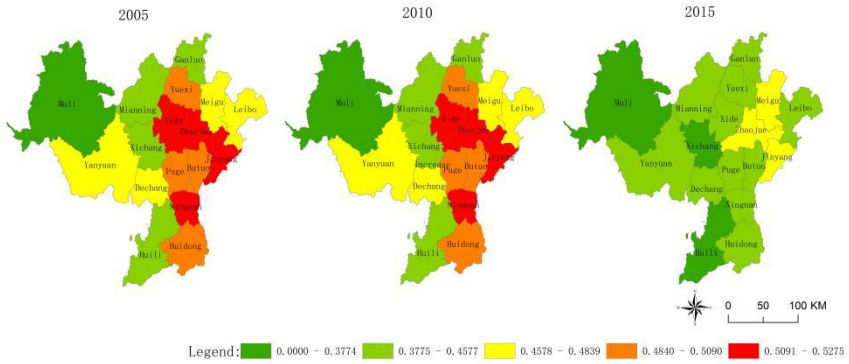

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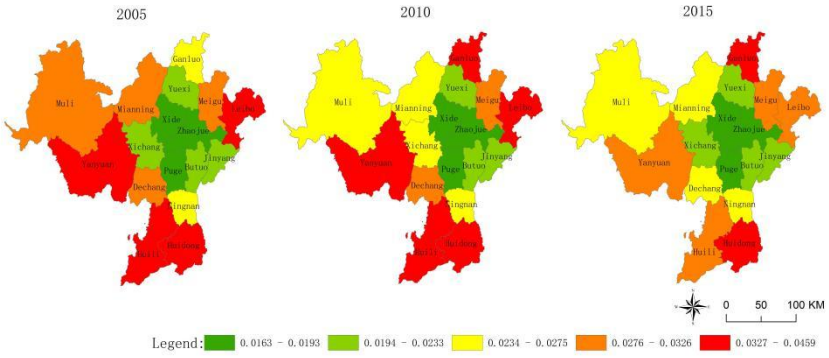

(d)

Figure 4. LSI,LAI, PPI and LVI

(a) landscape sensitivity index (LSI), (b) landscape adaptability index (LAI), (c) population pressure index (PPI), (d) landscape vulnerability index(LVI)

4.2 Spatial and temporal distribution characteristics and evolution patterns of rural landscape fragility

According to the results in Figure 4 and Figure 5, in general, the unevenness of rural landscape fragility across the study area was significant and showed a circling characteristic during the period 2005-2015. The spatial structure of landscape vulnerability levels has changed significantly, and the overall landscape vulnerability has been optimised. The area of high vulnerability zones experienced a trend of first increasing and then decreasing, gradually changing to medium and lower vulnerability zones.

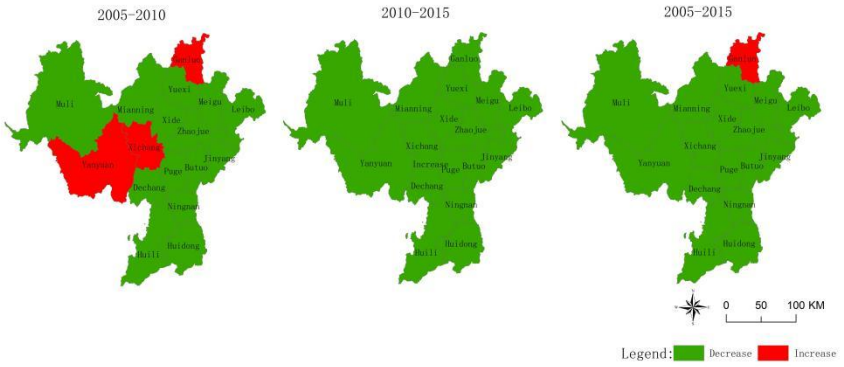

Figure 5. Spatial and temporal evolution of LVI

From 2005 to 2010, the main changes in the spatial pattern of rural landscape vulnerability are as follows: in terms of spatial distribution, the high vulnerability areas are mainly clustered in Leibo County, Huidong County, Huili County and Ganluo County, which have a high level of urbanisation and strong anthropogenic disturbance. Construction land and arable land have increased significantly and are more concentrated. Secondly, the socio-economic development model, which is based on the concept of "industrial strengthening of counties", has a significant impact on the fragility of the rural landscape. The low vulnerability areas are mainly in Xide, Zhajue, Puge, Butuo and Jinyang counties in central Liangshan. Although the population density is concentrated, the anthropogenic disturbances are relatively calm and the overall landscape adaptation is strong. The overall change is characterised by a significant expansion of the high value range, with Ganluo, Leibo and Yangyuan counties shifting from more and moderately vulnerable to highly vulnerable areas. The results of the study further illustrate the direct impact of urban and rural construction and human activities on the vulnerability of rural landscapes.

From 2010 to 2015, the hierarchical structure of rural landscape vulnerability changed significantly, with a more pronounced circle feature. The high-vulnerable areas show a clear decrease, with Ganluo, Yangyuan, Huili and Huidong counties shifting from high-vulnerable to medium- and low-vulnerable areas, with only Ganluo and Huidong counties being higher-vulnerable areas, while the range of low-vulnerable areas seems to remain blocky, but the area shows a more obvious expansion, indicating an overall trend of improvement in the fragility of the rural landscape. The reason for this is that Liangshan Prefecture is one of the three major forest areas in Sichuan Province, and a key area in the country and the province that took

the lead in launching the Retreat to Forestry Project. Since the 1990s, Liangshan Yi Autonomous Prefecture has been implementing the policy of returning farmland to forest, and in 2013, it responded to the national call to start a new round of the Returning Farmland to Forest project, with increased measures to promote a good optimisation of the landscape fragility situation.

4.3 Factors influencing the spatial and temporal evolution of the vulnerability of rural landscapes

The drivers of landscape pattern vulnerability have been analysed, and related research further suggests that the spatial and temporal evolution of landscape vulnerability is the result of a combination of factors. In general, areas with high landscape vulnerability are mainly concentrated in areas with active human activities and intersecting landscapes. The research methods are divided into qualitative and quantitative studies, with qualitative studies focusing on socio-economic, ecological, natural environment and land use types, while quantitative analyses are mostly geographical probes and grey correlation analyses, with each method having its own advantages and disadvantages. It is worth clarifying that rural landscapes have important territorial characteristics and the factors influencing the spatial and temporal differentiation of landscape vulnerability have different influences depending on their representations.

4.3.1 Influence of natural environmental factors

The natural environment is a direct influence on the vulnerability of rural landscapes and has a continuous impact on them. The landscape in Liangshan Yi Autonomous Prefecture is complex and varied, with a complex geological structure; mountains, deep valleys, plains, basins and hills are intertwined, and the ecological environment is very fragile, and natural disasters such as geology, earthquakes and floods and secondary disasters are frequent. Generally speaking, the fragility of the rural landscape in Liangshan Yi Autonomous Prefecture is high, and the unevenness of the fragility of the rural landscape in the study area is significant due to the influence of topography and natural environmental factors.

4.3.2 Influence of socio-economic factors

Socio-economic, urban and rural construction and other anthropogenic disturbance factors have a transformative influence on the spatial and temporal variation of rural landscape fragility. Socio-economic factors have a two-way effect on the vulnerability of rural landscapes. The positive effect is mainly manifested in that socio-economic development provides technical conditions and economic support for the optimisation of rural landscape patterns; the negative effect is manifested in that the development of rural economies will, to a certain extent, consume natural resources and cause certain disturbances to the landscape ecology. From the results of the above landscape fragility analysis, Xide County, Zhaoge County, Puge County, Butuo County and Jinyang County in the central part of Liangshan Prefecture are low fragility areas. Although the population density is concentrated, the anthropogenic disturbances are relatively calm and the overall landscape adaptation is strong. The results of the study further suggest that there is no purely linear relationship between the two.

4.3.3 The influence of administrative forces

Administrative forces are another major influence on the spatial and temporal variation of rural landscape fragility. According to the results of the above analysis, the overall situation of rural landscape vulnerability in the study area showed a decreasing trend during the period 2010-2015. On the one hand, this is attributed to the fact that the Liangshan Yi Autonomous Prefecture has made tremendous achievements in such initiatives as "returning farmland to forest", "natural forest protection", "returning grazing to grass" and "comprehensive management of stone desertification". The great achievements made in initiatives such as "returning farmland to forest", "natural forest protection", "returning pasture to grass" and "comprehensive management of stone desertification". On the other hand, during the 12th Five-Year Plan period, Liangshan Yi Autonomous Prefecture responded to national policies, actively promoted ecological construction and transformed its development model. However, administrative force elements are difficult to analyse quantitatively due to their uncertain characteristics, and can be explored in future studies based on comparative analysis methods.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The paper takes Liangshan Yi Autonomous Prefecture, a typical ecologically fragile area in southwest Sichuan Province, as an example. Based on the results of previous research, the paper attempts to improve the traditional method of measuring landscape vulnerability in the field of ecology by introducing a population pressure index to measure the vulnerability of rural landscapes in each district and county in the study area. The main findings of the study are.

(1) The "Landscape Sensitivity Index (LSI)-Landscape Adaptation Index (LAI)-Population Pressure Index (PPD)" rural landscape vulnerability evaluation model is feasible for portraying the vulnerability and spatial and temporal evolution characteristics of rural landscape in the study area, and the findings of the study reflect the actual situation to a certain extent, which can provide reference for rural landscape vulnerability research.

(2) During the period of 2005-2015, the unevenness of rural landscape vulnerability among the districts and counties in the study area is remarkable, showing the characteristics of circles; the spatial structure of landscape vulnerability levels changes significantly, with the area of high vulnerability zones experiencing an increase and then a decrease, gradually changing to medium and low vulnerability zones, and the overall situation of rural landscape vulnerability has been optimized.

(3) Natural environmental factors have a continuous influence on the fragility of rural landscapes, administrative forces are another major influencing factor on the spatial and temporal variation of rural landscape fragility, and anthropogenic disturbances such as socio-economic and urban-rural construction have a transformative influence on it.

5.2 Recommendations

Based on the above findings, the following recommendations are made:

(1) Focus on the innovation and appropriateness of the methodological system for evaluating the fragility of rural landscapes. Some scholars have noted the urgency and importance of rural landscape vulnerability research, however, there are relatively few relevant studies at present. The study is based on the existing literature on rural landscape vulnerability, the introduction of landscape ecology methods to explore the analysis, there are certain limitations. The reason is that the above approach is mainly used at the macroscopic scale of provinces, watersheds and cities to explain the vulnerability characteristics of the landscape from the perspective of landscape pattern indices, ignoring the production and life attributes of rural landscapes, which are the special features of rural landscapes in comparison with urban landscapes and regional landscapes. The current rural production and lifestyle has changed rapidly, and its impact on the rural landscape pattern cannot be ignored. In view of such recognition, the future should strengthen the relevant exploration and research .

(2) rational guidance of rural planning and construction, and strengthen the intervention of rural landscape ecological protection in rural planning. With the vigorous promotion of the strategy of poverty eradication and rural revitalisation, rural planning and construction will usher in a large volume of renewal; secondly, the rapid development of rural tourism and the enhancement of man-made disturbance factors, the landscape pattern of rural settlements will face a more serious challenge. With the in-depth promotion of territorial spatial planning, the construction of rural landscape ecological network is the key to reducing landscape vulnerability and bringing into play ecological service functions.

(3) Actively build a rural landscape security pattern. As it is located in the middle and high mountain valley area, the ecological environment is very fragile, geological, earthquake, floods and other natural disasters and secondary disasters are frequent, causing huge losses to the local rural society and economy, and the people's life safety and housing security are also under serious threat.

The study mainly constructs the measurement model based on the landscape pattern index, and the interpretation of the production, living and cultural attributes of the rural landscape is still lacking consideration and still needs further research.

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