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Analysis of Changes in Ecological Patterns in the Upper Reaches of the Minjiang River One of Typical Disaster Prone Area of China

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Abstract. Mountain torrents and debris flows are rapid transport processes for soil and water materials in small watersheds in mountainous areas. They have a strong destructive power and often result in devastating natural disasters. Natural ecosystems can regulate natural disasters, reduce the risk of damage, increase the stability of disaster-prone environments and reduce the vulnerability of downstream areas. The upper reaches of the Minjiang River (URM) in Sichuan Province, China is a typical area prone to flood and debris flow disasters. An established scientific model was used to analyze land cover change in the URM to discover the optimum land use pattern. Based on the analysis of the pattern of temporal and spatial changes of ecosystems in the URM, the results showed that the amount of ecosystem change in the URM was small, and the overall change rate of ecosystems was only 1.7%. There was an obvious trend of landscape fragmentation in the whole URM region, and the change of ecosystems had clear regional differences. Human economic activities were the main reason for the changes in the spatial pattern of ecosystems from 1985 to 2013.

1. Introduction

Mountainous areas have steep terrain and plentiful sedimentary material. High intensity rainfall or rapid snow melt can lead to disastrous flash floods and debris flows [1]. The simultaneous occurrence of mountain floods and debris flow (MFDF) will magnify the corresponding hazards of each single process, which is of particular concern [2]. For effective disaster early warning, it is essential to identify typical areas prone to MFDF so that the distribution and pattern of temporal and spatial changes to ecosystems can be analyzed. Yang et al. developed comprehensive index values to evaluate the landscape ecological security of Maoxian County in Sichuan Province in 2000, 2007 and 2015, using changes of ecological pattern over time from multi-stage remote sensing images [3]. Based on remote sensing data from 2000, 2005, 2008 and 2013, Zhao Weiquan analyzed the evolution of landscape patterns in the Chishui River Basin [4]. Normalized difference vegetation index (NDVI) data have been used to study both long-term and large-scale trends of change in land ecosystem vegetation health and growth, and short-term changes in land distribution patterns in local areas [5-6]. Previous research has used a range of scientific theories and models to analyze land resources, improve the ecological security coefficient and explore the values of ecosystem services [7-8]. In this paper, we analyzed the distribution and pattern of ecosystems and their temporal and spatial changes in the URM as a case study of a typical disaster-prone area to optimize the land use pattern and reduce the occurrence of MFDF.

2. Materials and Methods

2.1. Study Area
The URM was selected as a typical disaster-prone area for MFDF. The URM includes six counties with an area of 25,470 km^2. It is located in the north of Sichuan Province (Figure 1). Previous research has provided information on ecological service functions, disaster risk assessment and zoning in the URM [9-11].

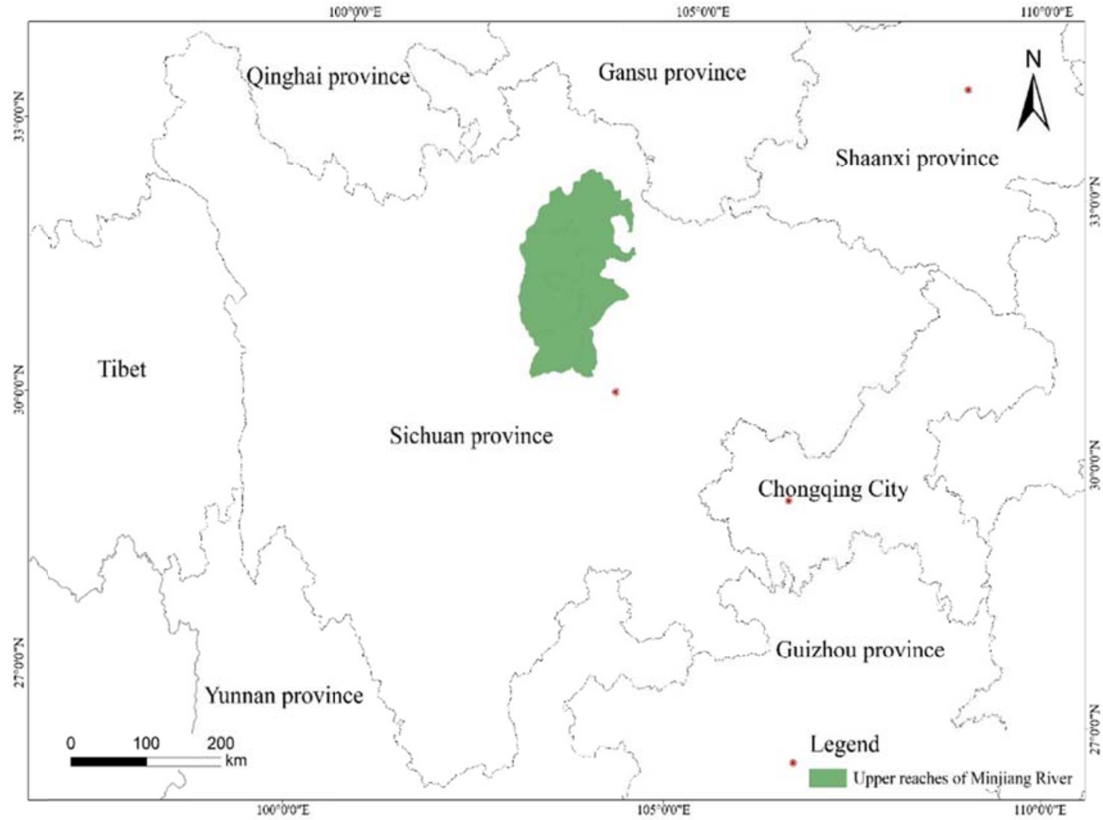

Figure 1. Location of the upper reaches of the Minjiang River Basin

2.2. Data Sources
The study used ecosystem classification data interpreted from remote sensing images for 1985, 2000 and 2013 to assess the URM ecosystem patterns. The characteristics of vegetation types were used to design the land cover classification system. The land cover classification had two levels. Level 1 had 6 categories and the level 2 classification had 38 categories. These reflected the dynamic monitoring of ecosystem types in the URM and allowed us to extract important indicators of ecosystem structure. The types of land cover met the needs of ecological environment protection and management.

2.3. Evaluation Index for Ecosystem Pattern Change
The distribution and pattern of ecosystems in the URM and their temporal and spatial changes were analyzed based on data for land use and land cover in 1985, 2000 and 2013. The types, distribution, proportion and spatial pattern of terrestrial ecosystems were evaluated, and the characteristics of transformation between various types of ecosystem were analyzed. The ecosystem pattern and change evaluation index is shown in Table 1. The index was used to examine the spatial distribution, allocation and proportion of different ecosystem types and analyze the temporal and spatial changes in ecosystems in the URM from 1985 to 2013.

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Table 1. Ecosystem pattern and change evaluation index

Evaluation content	Evaluating indicator
Composition of ecosystem	Ecosystem area Proportion of ecosystem composition
Changes in ecosystem composition	Change rate of ecosystem type area
Characteristics and changes of landscape pattern in ecosystem	number of patches(NP) Mean patch size(MPS) Mean patch size of type(MPST) Edge Density (ED)(m/hm^2) contagion index(CONT) (%)

3. Results and Discussion

3.1. Changes in Ecosystem Composition

3.1.1. The range of natural ecosystem change
The change in forest and grassland was relatively small at less than 2%. The net decrease of forest area was 91.3 km^2, with a decrease rate of 0.6%, and an average annual decrease of 3.3 km^2 in the URM from 1985 to 2013. The grassland area increased by 43.5 km^2, with an average annual increase of 1.6 km^2, and an increase rate of 0.7%. In general, the areas were relatively stable. The area of other natural ecosystem types increased by 161.0 km^2, with an average annual increase of 5.8 km^2, accounting for 6.0% of the total, and the total area also remained stable. Wetland areas increased rapidly by 13.4 km^2 in area and 10.9% in proportion.

3.1.2. The range of artificial ecosystem change
Artificial surface area increased significantly by 84.5 km^2, an average of 3.0 km^2 per year, with an increase rate of 601.5%. However, there was a large net reduction in cultivated land area of 211.0 km^2, with an average annual reduction of 7.5 km^2, accounting for 21.5% of the total in the URM from 1985 to 2013. This shows that the area of cultivated land decreased significantly in the URM.

3.2. Intensity of Ecosystem Change

3.2.1. The intensity of ecosystem change
From the perspective of changes in level 1 ecosystem types, the overall change rate of ecosystems from 1985 to 2000 was 0.1%, or 23.1 km^2. The rate of conversion in the second half of the study was much larger, with 413.7 km^2 (1.6%) of level 1 classified ecosystems being converted. Over the whole period 1985–2013, the overall change rate of ecosystems was 1.7% (436.1 km^2) in the URM (Table 2).

In the level 2 classification of ecosystem types, the overall change rate of the ecosystem was 0.2% from 1985 to 2000, with 38.4 km^2 of different ecosystem types being converted. Between 2000 and 2013, the rate of change was 2.4% (614.9 km^2). Over the period 1985–2013, the overall change rate of ecosystems was 2.6% or 653.7 km^2 in the URM (Table 2).

Table 2. Comprehensive change rate and conversion intensity of ecosystems in the URM

classification	indicator	1985~2000	2000~2013	1985~2013
Level 1 classification	EC(%)	0.09	1.62	1.71
	LCCI(%)	-0.05	-1.55	-1.60
Level 2 classification	EC(%)	0.15	2.42	2.57
	LCCI(%)	-0.06	-2.01	-2.07

3.2.2. The stages of ecosystem change
The main changes occurred from 2000 to 2013 in the URM. According to the change of ecosystem types of the level 1 classification, the comprehensive change rate of the ecosystem was 1.7% from 1985 to 2013, 1.6% from 2000 to 2013, and 0.2% from 1985 to 2000. According to the change of ecosystem types of level 2 classification, the comprehensive change rate of ecosystem was 2.6% from 1985 to 2013, 2.4% from 2000 to 2013, and 0.2% from 1985 to 2000 in the URM.

3.3. Change of Ecosystem Pattern

3.3.1. Fragmentation of the regional landscape
The trend of landscape fragmentation was obvious, and the distribution of landscape types became more scattered in the URM. The number of patches increased from 42,232 to 44,447, an increase of 5.2% while the average patch area decreased from 60.3 ha to 57.3 ha, a decrease of 5.0%. The boundary density increased from 35.8 m/ha to 36.9 m/ha and the aggregation index decreased from 64.6% to 64.1% from 1985 to 2013 (Table 3). The four indicators show a clear trend of fragmentation of landscape types.

Table 3. Landscape pattern characteristics and changes in level 1 ecosystems in the URM

year	NP	MPS(ha)	ED(m/ ha)	CONT(%)
1985	42232	60.3	35.8	64.6
2000	42356	60.1	35.9	64.5
2013	44447	57.3	36.9	64.1

3.3.2. Changes in fragmentation patterns
The fragmentation of wetlands and artificial surfaces decreased, the fragmentation of cultivated land and other ecosystem types increased, and the fragmentation of forest and grassland remained stable from 1985 to 2013. The area of wetland patches in the URM increased from 6.7 ha to 7.5 ha (11.9%), while the area of artificial surface patches increased from 24.6 ha to 42.3 ha (72.0%). In contrast, the area of cultivated land patches decreased from 15.0 ha to 11.6 ha (22.7%) and the area of other types of patches decreased from 61.0 ha to 50.6 ha. The area of forest patches decreased by 1.3% from 208.3 ha to 205.6 ha; the area of grassland patches decreased by 2.6% from 27.4 ha to 26.7 ha.

3.4. Regional Differences of Ecosystem Changes

3.4.1. Extension along the main rivers and valleys
The overall rate of ecosystem change in the URM was mainly characterized by extension along both sides of the large river valley from 1985 to 2013. The change of ecosystem types was most obvious along the main stream of the Minjiang River and its tributaries, such as the Xiaoxinggou and Weilong Rivers, especially in some reaches of the main stream of the Minjiang River.

3.4.2. The change of ecosystem types in the vicinity of main urban settlements

The ecosystem types of the URM changed most rapidly around the main towns and surrounding areas. In the small watersheds around Dujiangyan, Wenchuan, Maoxian, Heishui and Songpan, the overall change rate of ecosystems was significantly higher than that of the surrounding areas from 1985 to 2013.

4. Conclusion

The intensity of ecosystem change in the URM was relatively small, and the overall rate of ecosystem change was only 1.7% from 1985 to 2013. Changes in ecosystems showed clear stages: the major changes occurred between 2000 and 2013, with conversion of forest to other types, and the conversion of cultivated land to forest land and artificial surfaces. The overall landscape fragmentation trend of the URM was obvious and the distribution of landscape types was more scattered. The fragmentation of wetlands and artificial surfaces landscapes was reduced, the fragmentation of arable land and other ecosystem types increased, and the fragmentation of forest and grassland was generally stable. Human economic activities in the URM were the main reason for the change of ecosystem spatial patterns. Around 60.4% of ecosystem conversion was related to the changes in the cultivated land and artificial surface ecosystems from 1985 to 2013.

5. Acknowledgement

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