Journal of Rural Studies 47 (2016) 622–629

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Adaptive capacity of mountainous rural communities under restructuring to geological disasters: The case of Yunnan Province

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ARTICLE INFO

Article history:
Received 23 October 2015
Received in revised form
2 May 2016
Accepted 4 May 2016
Available online 13 May 2016

Keyword:
Adaptive capacity
Geological disaster
Rural community
Principal component analysis
Socio-economic data
Yunnan Province

ABSTRACT

Understanding the relationship between adaptive capacity and natural disasters plays a crucial role in mountainous rural development planning in the context of rapid urbanization and the increasing risk of natural disasters in China. Previous studies have examined the adaptive capacity while ignoring the differences between surrounding environments. We analysed the adaptive capacity while incorporating a variety of geological disaster susceptibilities in prefecture-level cities in the mountainous rural Yunnan Province by using socio-economic data from the Yunnan Statistical Yearbook 2014 and geological disaster data from 2000 to 2014. In addition, the major socio-economic determinants and correlation between the adaptive capacity and geological disaster susceptibility were further explored. The results demonstrate the following: (1) 90.2% of geological disasters were primarily distributed in mountainous rural areas, and nearly 70% of prefecture-level cities had moderate, high or very high geological disaster susceptibility; (2) the adaptive capacity was generally higher in south-eastern Yunnan Province, and only 25% of the prefecture-level cities had high or very high adaptive capacity; (3) although the major factors that affected the adaptive capacity varied between cities, the economic conditions were the most important; and (4) although no significant correlation existed between the adaptive capacity and geological disaster susceptibility, cities with high geological disaster susceptibility but low adaptive capacity required more attention to prepare for geological disasters and improve their adaptive capacity. Both the socio-economic background and natural disaster conditions should be considered when evaluating the adaptive capacity. Therefore, determining the local adaptive capacity and then implementing targeted measures to improve the adaptive capacity is more realistic.

1. Introduction

Rural China, which has been affected by rapid urbanization, has experienced far-reaching transformations in land-use spatial patterns, demographic structures and living standards (Long et al., 2011; Long, 2014). At the same time, rural China has faced increasing risk from natural disasters that are caused by changing climate. The adaptive capacity of rural China, especially that in mountainous rural areas, draws our attention because of this dual dynamic. Mountainous rural regions face stagnant economic and social development compared to plain rural regions because of underdeveloped traffic conditions. Furthermore, mountainous environment frequently experiences geological disasters, such as landslides, debris flows and torrential floods, which seriously threaten the lives and properties of farmers.

The concept of adaptation originated in the natural sciences, primarily in the field of ecology and evolutionary biology (Winterhalder, 1980). The term “adaptation” has been used widely in these fields because global climate change and natural disasters have evolved into pressing issues. Regardless of the differences between definitions of adaptation, adjusting systems to improve

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http://dx.doi.org/10.1016/j.jrurstud.2016.05.002
0743-0167/

their capacity to adapt to dynamic environments has been emphasized in previous studies (Pielke, 1998; IPCC, 2001; Smit et al., 2014). Adaptation involves two important concepts: vulnerability and resilience. The vulnerability of any system is a function of exposure, sensitivity and adaptive capacity (IPCC, 2001). Exposure and sensitivity can fall at decreasing rates with higher adaptive capacity (Yohe and Tol, 2002). High adaptive capacity can also reinforce resilience, which reflects the ability of systems to return to a previous status after facing stresses (Engle, 2011).

Many studies have investigated rural adaptation (Pittman et al., 2011; McManus et al., 2012; Whittaker et al., 2012; Boon, 2014). In particular, studying the adaptability of rural communities to natural hazards is one of five key challenges for rural areas in the early 21st century (Woods, 2012). Adaptive strategies and policies have been researched in the mountains of Southwest China (Urgenson et al., 2010; Su et al., 2012). These studies focused more on the vulnerability and resilience of small individual communities, climate change, resources and production. Nevertheless, rural adaptive capacity has garnered less attention. Our ability to evaluate adaptive capacity, however, is limited by a lack of understanding how adaptation occurs (Berrang-Ford et al., 2011). Currently, evaluating adaptive capacity is primarily based on socioeconomic determinants, which depend on the study region and scale (Brooks et al., 2005; Vincent, 2007; Posey, 2009). Determinant-based assessments facilitate comparing the adaptive capacities of different cities, provinces and countries.

Because the adaptive capacity of rural areas plays an important role in dealing with challenges from urbanization and global climate change, identifying the districts that exhibit the weakest adaptive capacity and improving their adaptive capacity is crucial in development schemes. Therefore, we aim to analyse the adaptive capacity to geological disasters in the mountainous rural Yunnan Province. Yunnan Province was selected as the study area for two reasons. First, approximately 94% of the study area is mountainous, which leads to numerous geological disasters. More than 2000 geological disasters occurred in Yunnan Province from 2010 to 2014, causing 577 deaths. Second, the rural population comprises 58.27% of the total population, which has experienced a high risk of geological disasters. Thus, the research objective is to analyse the adaptive capacity of mountainous rural communities under restructuring to geological disasters.

2. Study area

Yunnan Province, which is located in south-western China (Fig. 1), consists of 16 prefecture-level cities and covers an area of approximately 394,000 km^2. The mountainous regions in this province comprise approximately 94% of the total area.

Yunnan Province can be divided into eastern and western districts by terrain. Low mountains, hills and karst landforms comprise the majority of the eastern region, which is called the Yunnan Plateau and has an average elevation of approximately 2000 m. The western region belongs to the Hengduan Mountains and is characterized by steep mountains and deep valleys, which provide the essential geographical conditions for landslides, debris flows and other geological disasters. The study area experiences a low-latitude plateau monsoon climate. The average annual precipitation is distinctly seasonal and varies from 600 mm to 1700 mm, with 75% of the precipitation concentrated between May and September (Thomas, 1993). Because of this unique natural environment, Yunnan Province experiences some of the most serious geological disasters in China.

Yunnan Province has progressed significantly in terms of its society and economy because of evolving urbanization. Many farmers migrated to cities, and the per capita gross domestic product has persistently increased. According to the Yunnan Statistical Yearbook from 2001 to 2014, 4.607 million people moved to cities, and the per capita gross domestic product increased from 4770 Yuan to 25,083 Yuan. However, certain barriers to rapid development exist. The development level of Yunnan Province's population is still low, especially in remote mountainous regions, because of the lack of education and medical services (Xiao et al., 2011). Moreover, the contradiction between the limit of the total available areas and the growth of urban land demands has been aggravated because of the migration of farmers and urban development, which decreased the degree of land use sustainability (Yang et al., 2008).

3. Methods

3.1. Geological disaster susceptibility index

Similarities exist in the locations of geological disasters, and the same locations likely experience geological disasters more than once (Corominas et al., 2013). Therefore, the density of geological disasters is a reasonable proxy for geological disaster susceptibility. A higher density indicates a higher susceptibility, meaning more occurrences of future geological disasters.

Geological disaster data were collected from the National Debris Flow and Landslide Event Data and Spatial Distribution Datasets of Mountain Disasters (Debris Flow, Landslide) in the Whole and Southwest of China, which were provided by the Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn/), and the Map of Geological Disasters in Western China and Map of Collapse, Landslide and Debris Flow in China, which were supported by the National Geological Data Center (http://www.ngac.org.cn/). A total of 595 geological disaster events were gathered from 2000 to 2014, including 443 landslide events, 124 torrential flood events, 25 debris flow events and 3 mixture type events. A spatial distribution map of geological disasters in Yunnan Province was produced. As shown in Fig. 2, the spatial distribution of geological disasters shows remarkable regional disparities. The geological disasters are mainly distributed throughout the northern and western regions of the study area. In contrast, the southeastern region has few geological disasters.

The kernel density method was used to quantify the geological disaster susceptibility of prefecture-level cities. This method has been used to evaluate volcanic susceptibility (Bartolini et al., 2013). Kernel density analysis could be used to estimate the weighted moving average density per unit area over all geological disaster spots in a circular window, which is moved over the entire study region (Berke, 2005). The kernel density of geological disasters was calculated by the ArcGIS 10.2 software. Then, the mean of the standardized density was measured statistically, indirectly representing the Geological Disaster Susceptibility Index (GDSI) of a prefecture-level city. A higher GDSI indicates higher geological disaster susceptibility.

3.2. Index system of adaptive capacity

Determinant indicators of the adaptive capacity were divided by the IPCC into economic resources, technology, information and skills, infrastructure, institutions, and equity (IPCC, 2001). Indicators of the adaptive capacity should reflect rural development and must be easy to access and update. Based on previous studies and principles, the selected indicators are shown in Table 1. The population data were collected from the Yunnan Census 2010, which is the latest and official statistical dataset. Other socioeconomic data were collected from the Yunnan Statistical Yearbook 2014.