A regional strategy for ecological sustainability: A case study in Southwest China

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HIGHLIGHTS

• A zoning method considering environment and development simultaneously was applied.
• Study area was classified into four development strategy zones using this method.
• Conflict zone could be identified and further subdivided.
• In Southwest China, 9.04% of nature reserve areas belong to Conflict zones.

GRAPHICAL ABSTRACT

ABSTRACT

Partitioning, a method considering environmental protection and development potential, is an effective way to provide regional management strategies to maintain ecological sustainability. In this study, we provide a large-scale regional division approach and present a strategy for Southwest China, which also has extremely high development potential because of the "Western development" policy. Based on the superposition of 15 factors, including species diversity, pattern restriction, agricultural potential, accessibility, urbanization potential, and topographical limitations, the environmental value and development benefit in the region were quantified spatially by weighting the sum of indicators within environmental and development categories. By comparing the scores with their respective median values, the study area was divided into four different strategy zones: Conserve zones (34.94%), Construction zones (32.95%), Conflict zones (16.96%), and Low-tension zones (15.16%). The Conflict zones in which environmental value and development benefit were both higher than the respective medians were separated further into the following 5 levels: Extreme conflict (36.20%), Serious conflict (28.07%), Moderate conflict (12.28%), Minor conflict (6.55%), and Slight conflict (16.91%). We found that 9.04% of nature reserves were in Conflict zones, and thus should be given more attention. This study provides a simple and feasible method for regional partitioning, as well as comprehensive support that weighs both the environmental value and development benefit for China's current Ecological Red Line and space planning and for regional management in similar situations.

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1. Introduction

Regional ecological sustainability is influenced profoundly and typically negatively by local development, as well as various anthropogenic
activities such as road construction (Jaeger et al., 2007; Huang et al., 2013), mining exploration (Lei et al., 2016), hydropower exploitation (Ouyang et al., 2009) and urban expansion (York et al., 2003). To address these issues, spatial zoning designed to regulate disruptive activities has been considered an effective approach to ecological protection, and has attracted great attention. Essentially, zoning is a partition method based on regional socioeconomic or ecological characteristics. Based on zoning results, governments can apply different types of zones that correspond to policies intended to optimize spatial distribution, improve the efficiency of resource utilization, and promote ecological protection and sustainable development (Xie et al., 2015; Xu et al., 2016).

Much research about ecological spatial zoning has been conducted with different purposes. For example, marine spatial zoning that included the identification of critical habitat was used to minimize the environmental risks caused by marine industries (Martin et al., 2015; McWhinnie et al., 2015). Terrestrial protected area zoning was used to balance various land uses by evaluating the degree of ecological suitability and the priorities of conservation areas (Hajehforooshnia et al., 2011; Freudenberger et al., 2012). In China, ecological zoning also has been an important method of ecological management. In 2001, Ecological Function Zoning based on the importance of local ecosystem services and current ecological status was implemented to maintain ecosystem health, and focused largely on ecological sensitivity, including biodiversity, vegetation, and landscape pattern factors (Cai et al., 2010; Wang and Pan, 2017). In 2012, the new Ecological Red Line policy, an ongoing project, was designed by the government to constrain human activities in regions with high ecological vulnerability. This project is considered to be an integrated management system to control the intensity of human activities, and establish environmental admittance standards for industrial development and a system to evaluate ecological status (Lin et al., 2016; Hong et al., 2017).

Researchers have suggested many methods to achieve more scientific zonings and develop a single target evaluation, such as multi-criteria evaluation (MCE: Wang and Pan, 2017), principal component analysis (Chen et al., 2016a), and various optimization model methods (Montgomery et al., 2016; Fei et al., 2017; Liu et al., 2017b). The quantitative evaluation of ecological suitability is the most common approach in spatial zoning, and GIS-based MCE is the method most widely (Malczewski, 2006a,b). Based on the integrated ecological resistance model, Peng et al. (2016) provided an ecological suitability assessment of mountainous areas. Their study developed an index system based on structural and functional dynamics theory that emphasized ecological processes. Liu et al. (2014) analyzed the land use suitability distribution of Beijing and compared the difference between two MCE methods. The ecological importance of different regions can be evaluated by using the methods above, which focus largely on assessing a particular objective. However, the conflict between ecological protection and social development cannot be identified, which is an unavoidable and long-standing social phenomenon (Lin and Li, 2016).

Because of the inevitability and pervasiveness of such conflict, zoning that combines social development and ecological protection has become an urgent priority. To adapt to the needs of ecosystem management, some researchers have attempted to emphasize the conflict in zoning. Jojá et al. (2014) identified spatial land use conflict based on a multi-criteria analysis. Ten conflict criteria were assigned weights by the Analytical Hierarchy Process (AHP) and overlaid to obtain the degree of conflict. However, they determined only the degree of conflict, which is a single target evaluation, and cannot reflect additional zoning information (Jojá et al., 2014). Lin and Li (2016) proposed a method to obtain a spatial zoning scheme that includes a conflict zone based on game theory, a theory of decision-making that simulates a negotiation process. In their methods, the conflict between urban expansion and eco-protection obtained a good trade-off in the game models, but the only indicator of social development they considered was urban expansion.

Currently, China is launching a new round of space planning pilot work that divides the entire country into ecological, agricultural, and urban space (Space planning China, 2017). In the division process, conflict between environmental protection and development benefit is inevitable. Therefore, if Conflict zones can be identified, better and more targeted management measures can be achieved. Our study provided a regional strategy for a so-called “key ecological security region” in China. In this region, the topography is complex and the ecosystems are extremely sensitive and fragile (Sun et al., 2008). Moreover, there also are many compact communities of ethnic minorities and impoverished population. To promote economic development, the government has implemented the “Western development” policy since 2000, which has been accompanied by many construction activities. As a result, long-term and intensive human activities have caused serious damage to the local ecosystems (Liu, 2016). Therefore, environmental value and development benefit should be considered simultaneously and their conflict taken seriously.

In our study, we provided a large-scale regional division approach as a strategy for regional development and ecological sustainability. In the regional strategy, we can identify zones with high environment value and low development benefit where future high-intensity development activities should be avoided if possible, and vice versa. More importantly, Conflict zones in which construction activities can provide considerable benefit, but also will have a serious environmental cost, may be identified and classified. Our main objectives included the following: 1) quantifying the environmental value and development benefit of the study region for zoning, and 2) generating a partition map and conducting an in-depth analysis of the conflict zone. The results of this research can provide comprehensive support for China’s current Ecological Red Line and space planning implications.

2. Materials and methods

2.1. Study area

The study area is located in Southwest China (83.9°–112° E, 21.2°–36.5° N), and has a high percentage of mountains, hills and plateaus with an elevation ranging from −8 to 7403 m. The total area is 2,330,000 km², approximately a quarter of China’s total area, and include the Yunnan, Guizhou, Sichuan, Chongqing, western Tibet, and southwestern Qinghai provinces (Fig. 1). This area is known as the ecological barrier of China and represents a very important ecological niche because of its abundant ecological diversity, complex natural environment and ecological structure. Characteristically, this area has great value in the protection of water sources and biodiversity while protecting these resources is hugely challenging.

For the protection of water sources, the Three-River Source Region (TRSR) is the most important representation; the TRSR covers an area of 350,000 km² and includes the upper reaches of three Asian rivers and provides these rivers a large amount of water. The TRSR supplies 25%, 49% and 15%, respectively, of the total water to the Yangtze River, the Yellow River and the Lancang River (the Mekong River) (Zhang et al., 2012). The TRSR is called the China water tower, and it is also the world’s largest water system, which directly or indirectly affects approximately 40% of the global population (Liu et al., 2017a). In the TRSR, the vegetation and soil have an important water conservation service. With the degradation of vegetation in recent decades, the regional ecosystem health and water conservation declined, which resulted in a great threat to the ecological security of this and the downstream areas (Zhang et al., 2016).

In biodiversity conservation, the “Mountains of Southwest China” is known as the global center of biodiversity hotspots (Myers et al., 2000). Representatively, the southern part of Yunnan is an important member of the Greater Mekong Subregion Biodiversity Corridor Program, which aims to ensure connectivity between nature reserves in the Mekong River Basin. Over the past 60 years, the region has experienced
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