Regional Ecological Vulnerability Assessment of the Guangxi Xijiang River Economic Belt in Southwest China with VSD Model

LI Pingxing¹* and FAN Jie²

1 Nanjing Institute of Geography and Limnology, CAS, Nanjing 210008, China;
2 Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China

Abstract: The interactive effects of natural and human factors on ecosystems have been well studied, and the quantitative assessment of large-scale ecological vulnerability caused by natural and human factors is now one of the most active topics in the field. Taking the Guangxi Xijiang River Economic Belt in southwest China (GXEB) as a case study, we assess ecological vulnerability based on the Vulnerability Scoping Diagram (VSD) model. The indices system is decomposed into three sub objects, ten elements and 25 indicators layer by layer, which included factors from both natural and human fields. Results indicate that zones with lower, middle-lower, middle, middle-higher and higher vulnerability account for 11.31%, 22.63%, 27.60%, 24.39%, and 14.07%, respectively. The western and eastern parts of GXEB are more vulnerable than the central part and the mountain and urban areas are of higher vulnerability than the basins and river valleys. Compared with a vulnerability assessment based on natural factors only, it is concluded that human activities indeed cause the transition from naturally stable zones to vulnerable zones. The nature-dominated vulnerable zones are different with human-dominated ones in size and distribution, the latter being smaller, more scattered and distributed in urban areas and their surroundings. About 53% of total construction land is distributed in zones with middle and middle-higher ecological vulnerability; less vulnerable zones should attract construction in the future. Relevant suggestions are proposed on how to reduce vulnerability according to inducing factors. The VSD model has a significant advantage in the quantitative evaluation of ecological vulnerability, but is insufficient to distinguish nature- or human-dominated vulnerability quantitatively.

Key words: ecological vulnerability; interaction of natural and human factors; VSD model; Guangxi Xijiang River Economic Belt in China

1 Introduction

The effect of humans on the earth is sustained and increasing (Vitousek et al. 1997). A worldwide problem, the increasing serious relationships among people, resources, environment and development first appeared in the 1950s and led to the transition of geographical research from nature-dominated to human-dominated environmental change. Consequently, the interactions among natural, biological and human activities have received increasing attention (Vitousek et al. 1997; Lu 2011).

Research on ecological vulnerability has a similar tendency (Berry et al. 2006). The concept of vulnerability has its roots in the study of natural hazards, and natural hazard researchers started focusing on the impacts of human activities on environmental change, especially climate change, after the 1960s (Niu 1989; Blaike et al. 1994; Füssel 2007; Xiao et al. 2010). Although vulnerability is one of the inherent features of ecosystems, it only emerges under natural and/or human disturbances (Zhao et al. 1998; Ran et al. 2002; Yu et al. 2012). Some researchers distinguish two kinds of ecological vulnerability based on the dominant inducing factor, i.e. the natural vulnerability caused by internal successions of the ecosystem and external vulnerability caused by outside disturbance, especially human activities (Polsky et al. 2007; Moreno and Becken 2009). Therefore, from the aspect of
human–land relationships, vulnerability has become a Collection of Concepts, which has diverse relationships with other concepts, such as Risk, Marginalization, Natural Hazard, Disasters, Stress & Impact, Sensitivity, Adaptation & Response, Adoptive Potential, and Flexibility (Newell et al. 2005; Liu et al. 2009). Based on the summarization of the extension process of spheres of vulnerability, Birkmann (2007) concluded that its connotation had expanded from vulnerability as an internal risk factor (intrinsic vulnerability), to multi-dimensional vulnerability encompassing physical, social, economic, environmental and institutional features. Xu et al. (2009) concluded that research on ecological vulnerability had turned from focusing on single natural factors to the integrated effect of regional man-land systems. Various researchers agree that vulnerability should include not only natural vulnerability caused by natural factors or the successions of natural ecosystems, but also the external vulnerability caused by human activities (Newell et al. 2005; Li et al. 2008; Liu et al. 2009).

As an expansion of the connotation of vulnerability, research methods are constantly changing. Early researchers carried out single-dimension analysis aimed at solving vulnerability from a particular risk factor such as fire, drought, alien biological invasions, biodiversity loss, and slope land cultivation. With the expansion of its connotation, assessments on vulnerability are not only related to multivariate analysis, but also the high uncertainty that exists in the natural, human subsystem and their interactions (Cutter 2003). Therefore, comprehensive evaluation methods have been developed such as Synthetic Index Analysis, Fuzzy Matter-Element Evaluation and Risk Analysis (Li et al. 2008; Liu et al. 2009). Although the models are jumbled and varied, their proposers generally agree that vulnerability has fixed components, i.e. exposure, sensibility and adaptive capacity (Roberts and Yang 2003; Adger 2006; Chen and Chen 2010). Polsky and colleagues developed a model of the vulnerability scoping diagram from the American Project for Public Spaces (VSD model hereafter) (Polsky et al. 2007). The VSD model resolves vulnerability into three dimensions (exposure, sensibility and adaptive capacity) and organizes and evaluates data though “Dimensions of Vulnerability”, via “Components of Dimensions”, to “Indicators of Components” layer by layer. The model provides a normative organization and clear process and is adopted widely (Monero and Becken 2009; Liu et al. 2009; Pearsall 2009; Carter and Mäkinen 2011).

As an undeveloped region within China, the Guangxi Xijiang River Economic Belt (GXEB) in the Guangxi Zhuang Autonomous Region has an opportunity to speed up urbanization and industrialization. As a representative ecologically fragile area dominated by Karst landforms, the influences of, and interactions between, natural and human factors means that ecological vulnerability is unprecedentedly complex in this area. Taking GXEB as a case study here, we conduct a regional ecological vulnerability assessment by adopting the VSD model of Polsky et al. (2007). We aimed to not only provide a significant case for the application of the VSD model, but also indicate the vulnerability caused by natural and human factors so as to promote regional sustainable development.

2 Study area and methods
2.1 Study area
GXEB includes seven prefecture-level cities (Nanning, Liuzhou, Wuzhou, Guigang, Laibin, Baise, and Chongzuo) and is located between 104°26′–111°35′E and 22°04′–26°05′N. The largest stridden distance is 714 km from east to west, and 447 km south to north (Fig. 1). The total area is $13\times10^4$ km$^2$, representing 55.26% of Guangxi and 1.36% of China. It is a multiracial and poverty-stricken region, and the GDP per capita was 20 000 CNY in 2010, accounting for only two-thirds of the national average.

GXEB is located at a low-latitude region and the tropic of cancer crosses the center. It is the transition zone from the Yun’nan-Guizhou plateau to the southeast coast of China, and is of typical basin-shape landscape with more mountains than flat regions. GXEB is the upstream region of the Pearl River watershed and urban agglomeration of the Pearl River Delta, with various levels of rivers and rich water resources. The flora is very complex and the vegetation is replaced by species that are relatively more tolerant to drought gradually from the east to the west. Given its rich wildlife species, GXEB and its surrounding areas are a key region with international significance in terms of terrestrial biodiversity protection (Chen 1993). However, this area is a typical karst landscape and soils developed from thick limestone materials are widely distributed. Natural hazards are also very common, including meteorological disasters, such as winter injury, tropical cyclones, strong convective whether, and geological disasters such as landslides, collapses, debris flow, ground subsidence caused by karst or goaf (Fan 2011).

The mountain valleys and basins of different sizes
are the major population and industry gathering regions, including the Yongjiang River Basin of Nanning, Liujiang River Basin of Liuzhou and Laibin, Yujiang River Basin of Guigang, and Youjiang River Basin of Baise. According to the investigation data on land use of China for 2008, the proportion of construction land was about 3.86% of the whole belt, which is a little higher than the average for China. The major land use types of hillies, and middle and lower mountains are forests and grasslands, while the basins along the river valleys, river deltas and lower platforms are the major regions where most construction and cultivated lands are distributed (Fig. 1). As the interface of China with Southeast Asia, which includes 11 countries (Vietnam, Laos, Cambodia, Thailand, Berma, Malaysia, Singapore, Indonesia, Brunei, the Philippines and East Timor), GXEB faces great development opportunities. How to coordinate the relationship between development and protection in such a vulnerable region and realize regional sustainable development remains a major challenge.

2.2 Methods

The VSD model proposed by Polsky et al. (2007) was adopted to evaluate ecological vulnerability for GXEB. Vulnerability in the VSD model is divided into three sub-objects: exposure, sensitivity and adaptive capacity (McCarthy et al. 2001; Liu et al. 2009). Exposure indicates the degree of environmental and social pressure or disturbance on ecosystems, and is related with the strength, frequency, duration and propinquity to the surrounding system indicated by land use and the distribution of population and industry (Tian et al. 2005; Liu et al. 2009). Sensibility means the degree of the positive or negative impact of stress on exposing landscape, and is the multidimensional relationship between stress and consequences reflected by topography, climate and vegetation (Zhao et al. 1998; Guan et al. 2006). Adaptive capacity means the ability of the system to deal with or adapt to stresses and recover from the consequence of stress, and could be expressed by threshold and scoping extent, such as economic development level and investment on ecological protection (Liu et al. 2009; Chen and Chen 2010). According to the data availability and the containment of exposure, sensitivity and adaptive capacity, the following index system is constructed (Table 1) (Wang...
et al. 2005; Liu et al. 2009; Chen and Chen 2010). The general target is ecological vulnerability, and the sub-objects include exposure, sensibility and adaptive capacity. Each sub-object has three or four elements divided into several indicators layer by layer.

Most of the indicators are divided into five levels after data normalization and standardization based on their effects on vulnerability. Levels 1 to 5 represent lower, middle-lower, middle, middle-higher, and higher vulnerability, respectively. This evaluation is on the basis of former research achievements in the fields of ecology, environment, economy and society. The orientations of different indicators are designed based on existing research and expert suggestions. Among which, indicators labeled “+” mean a positive relationship with ecological vulnerability, and “−” measures the negative relationship. For the indicator of “Orientation of local policy”, we divide seven cities into two groups: in favor of ecological construction (Baise, Guigang, Chongzuo and Laibin) and in more favor of ecological construction (Nanning, Liuzhou and Wuzhou), according to informal discussions with local governors and experts during field investigation for the General Planning of Guangxi Xijiang River Economic Belt Development.

On the basis of single indicator evaluation, the analytic hierarchy process (AHP) was adopted to identify the weight of each element and indicator. AHP was raised in the 1970s by Saaty, an American Operations researcher. Through hierarchical and structured analysis on the multi-indicators’ system of target program, AHP identifies the weight of each indicator using fuzzy quantitative methods on qualitative indexes. AHP divides decision problems into different hierarchical structures from general target, via sub target, to element and specific indicator. Hereafter, on the basis of solving the characteristic vector of the judgment matrix, the weight of each element or indicator is identified (Table 2). The weighted method was used to calculate the final weights of each indicator to the general target layer by layer (Table 1). Based on the results of single indicator evaluation and weight, the sub targets (exposure, sensibility, and adaptive capacity) and general target (vulnerability) were calculated using the weighted method (see the following formula). For the implementation of AHP, YAAHP was used. YAAHP v0.5.2 was developed by Zhang Jianhua and is widely adopted for carrying out AHP (Xu and Zhang 2013). The spatial overlay analysis between ecological vulnerability oriented zoning and the distribution of current construction land was also carried out to identify their relationship and reveal the effect of construction on ecological vulnerability.

\[
R = \sum_{i=1}^{n} C_i W_i
\]

where, \( R \) represents ecological vulnerability or its components, i.e. exposure, sensibility, and adaptive capacity; \( i \) means the number of elements or indicators; \( C_i \) is the evaluation results of each element or indicator; and \( W_i \) is the weight of each element or indicator.

Spatial analyzing processes were carried using ArcGIS v9.3 and its grid computing modules.

3 Results

3.1 Exposure, sensibility and adaptive capacity

The left, middle and right parts of Fig. 2 are the results of exposure, sensibility and adaptive capacity, respectively. As the main gathering area of population and industry in GXEB, the central region is more developed than other regions and so has higher exposure. Dominated by steep and high mountains, the western and eastern regions are mostly forest and grassland with fewer people and...
lower development intensity. As for different indicators and connotation, sensibility follows the opposite spatial distribution pattern to exposure, and the central part of the region is less sensitive on the whole. However, the mountains in the central area are also of high sensibility for their geomorphologic features. From the aspect of adaptive capacity, the more developed central region has a higher willingness and ability to protect ecosystems and the environment, and its adaptive capacity is therefore higher.

3.2 Ecological vulnerability

Based on integrated analysis of exposure, sensibility and adaptive capacity, classification methods using “by natural breaks” in ArcGIS were used to identify zones with five-level ecological vulnerability. This comprehensive vulnerability indicated zones with lower, middle-lower, middle, middle-higher and higher vulnerability accounted for 11.31%, 22.63%, 27.60%, 24.39%, and 14.07% of GXEB, respectively (Fig. 3; Table 3). The economic belt is dominated by zones with middle-lower, middle and middle-higher vulnerability.

4 Discussion

4.1 Distribution of five vulnerable zones and their regulation

Zones with higher vulnerability. Results from Fig. 3 and Table 3 indicate that zones with higher vulnerability are mainly distributed in the western and eastern regions of GXEB. Among the seven cities of GXEB, Baise is of highest vulnerability and zones with higher vulnerability account for 47% of the total. Guigang and Chongzuo are also vulnerable, where zones with higher vulnerability account for 19% and 17% of the total, respectively. Zones with middle-higher vulnerability are mainly steep and high mountains with widely distributed karst landforms. Given the importance of water conservation, bio-diversity protection and water and soil conservation, these zones are not suitable for construction and should be well protected.

Zones with middle-higher vulnerability. The spatial distribution is more dispersed than zones with higher vulnerability. Most of these zones are distributed in Baise, where zones with middle-higher vulnerability account for 40% of the total. Liuzhou and Nanning only account for 4% and 6%, respectively. Similar to zones with higher vulnerability, zones with middle-higher vulnerability are found mostly in mountain areas. However, the surrounding areas of Nanning and Liuzhou are also of middle-higher vulnerability for their high exposure and sensibility caused by increasing development. Considering dominant inducing

<table>
<thead>
<tr>
<th>Zones of different vulnerability</th>
<th>Lower</th>
<th>Middle-lower</th>
<th>Middle</th>
<th>Middle-higher</th>
<th>Higher</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baise</td>
<td>0.04</td>
<td>0.43</td>
<td>1.01</td>
<td>1.26</td>
<td>0.87</td>
<td>3.61</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>2.70</td>
<td>14.53</td>
<td>27.98</td>
<td>39.50</td>
<td>47.28</td>
<td>27.60</td>
</tr>
<tr>
<td>Chongzuo</td>
<td>0.23</td>
<td>0.42</td>
<td>0.37</td>
<td>0.39</td>
<td>0.31</td>
<td>1.72</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>15.54</td>
<td>14.19</td>
<td>10.25</td>
<td>12.23</td>
<td>16.85</td>
<td>13.15</td>
</tr>
<tr>
<td>Guigang</td>
<td>0.01</td>
<td>0.10</td>
<td>0.24</td>
<td>0.37</td>
<td>0.35</td>
<td>1.07</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>0.68</td>
<td>3.38</td>
<td>6.65</td>
<td>11.60</td>
<td>19.02</td>
<td>8.18</td>
</tr>
<tr>
<td>Laibin</td>
<td>0.04</td>
<td>0.28</td>
<td>0.44</td>
<td>0.44</td>
<td>0.15</td>
<td>1.35</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>2.70</td>
<td>9.46</td>
<td>12.19</td>
<td>13.79</td>
<td>8.15</td>
<td>10.32</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>0.36</td>
<td>0.86</td>
<td>0.50</td>
<td>0.14</td>
<td>0.00</td>
<td>1.86</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>24.32</td>
<td>29.05</td>
<td>13.85</td>
<td>4.39</td>
<td>0.00</td>
<td>14.22</td>
</tr>
<tr>
<td>Nanning</td>
<td>0.77</td>
<td>0.67</td>
<td>0.52</td>
<td>0.20</td>
<td>0.05</td>
<td>2.22</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>52.03</td>
<td>22.64</td>
<td>14.40</td>
<td>6.27</td>
<td>2.72</td>
<td>16.97</td>
</tr>
<tr>
<td>Wuzhou</td>
<td>0.03</td>
<td>0.20</td>
<td>0.52</td>
<td>0.38</td>
<td>0.11</td>
<td>1.25</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>2.03</td>
<td>6.76</td>
<td>14.40</td>
<td>11.91</td>
<td>5.98</td>
<td>9.56</td>
</tr>
<tr>
<td>Total</td>
<td>1.48</td>
<td>2.96</td>
<td>3.61</td>
<td>3.19</td>
<td>1.84</td>
<td>13.08</td>
</tr>
<tr>
<td>Proportion (%)</td>
<td>11.31</td>
<td>22.63</td>
<td>27.60</td>
<td>24.39</td>
<td>14.07</td>
<td>100.00</td>
</tr>
</tbody>
</table>
factors, protecting eco-environments and limiting large-scale development and construction is the main task for nature-dominated vulnerable zones. For human-dominated vulnerable zones, it is effective to prevent increasing vulnerability though environmental management and ecological restoration.

Zones with middle vulnerability. They are more equally-distributed than the above two kinds of vulnerable zones. Baise is with most zones with middle vulnerability, but its proportion is 28%. Nature-dominated vulnerable zones are mostly distributed in the western and eastern mountainous areas, and human-dominated vulnerable zones are mainly in the surrounding areas of cities and towns in the central region. Urban expansion and industrial development could occupy these zones moderately, but disturbances on important ecological processes and their sources should be prohibited.

Zones with middle-lower vulnerability. These zones are mainly distributed in central regions, and Liuzhou and Nanning account for 29% and 23% of the total, respectively. The main landforms are basins, river valleys and low and hilly type mountains which are quite suitable for construction. Therefore, the development of cities and towns in these zones should be promoted to gather population and industry gradually.

Zones with lower vulnerability. These zones are mainly distributed in the central region, especially in Nanning, which accounts for 52% of the total. Liuzhou and Chongzuo are also of high proportions. The other four cities (Baise, Guigang, Laibin and Wuzhou) contain just a few zones with lower vulnerability. These zones are of flat landform and rich land and water resources, and are quite suitable for economic development and urban construction. The aim should be to attract floating populations from zones with higher and middle-higher vulnerability; rapid industrialization and urbanization should also be carried out here to gather industry and population. As cultivated lands are widely distributed in these zones, future development should avoid occupying cultivated lands of high quality.

4.2 Spatial overlay relationship between ecological vulnerability-oriented zoning and construction land

On the whole, the distribution of construction land is highly corrected with more vulnerable zones. More than one-half of construction land is distributed in zones with middle-higher and middle vulnerability, while zones with lower vulnerability account for only 9% of the total construction area (Table 4). From the aspect of construction land type, urban construction land is mainly distributed in zones with middle-higher, higher and middle vulnerability, accounting for 88% of total urban construction land. Only 1% of urban construction land is distributed in zones with lower vulnerability. However, the spatial distribution of rural construction land is relatively equally-distributed, and the maximum is 492 km$^2$ in zones with middle vulnerability and the minimum is 209 km$^2$ in zones with lower vulnerability. Other construction land is mainly distributed in zones with middle vulnerability and zones with middle-higher, middle-lower and lower vulnerability (Table 4; Fig. 4).

There are many construction lands in vulnerable zones, which could be classified into two different types. The former are mainly caused by increasing human activity and a shift from stable to vulnerable ecosystems; most of them are located in urban areas or their surroundings. Two large cities in GXEB, Nanning and Liuzhou and their surrounding areas, are all of higher or middle-higher vulnerability. However, the natural conditions of these areas are relatively invulnerable with flat landforms and rich water and land resources, meaning that vulnerability is mainly induced

![Fig. 4 Spatial overlay relationship between ecological vulnerability-oriented zoning and construction land.](image-url)
by human activity. Previous research reached a similar conclusion regarding city ecosystems as vulnerable and unstable systems because of high energy and resource consumption, intense environmental polluting pressure, and infrequent natural resource storage (Xie and Li 2004). With rapid urbanization and industrialization, a lot of original ecological land is occupied by construction, and the integrated material cycle and energy flow are broken. With increasing human disturbance, it exceeds the ecological adaptive capacity and vulnerability increases gradually (Xie and Li 2004; Tao et al. 2006). However, in some middle sized and small towns with only several hundreds of thousands of people, disturbances from human activities are not strong enough to destroy the ecological adaptive capacity of the ecosystem. What could be expected is the possible occurrence of vulnerable zones following large-scale construction projects. The reason why the cultivated land concentrated zones are also of higher or middle-higher vulnerability is related not only to disturbance from high-intensity agricultural production activities, but also with the Karst landform (Xie and Yang 1998). Therefore, such vulnerable zones are mainly distributed in the Youjiang River corridor and Laibin Plain, which are the main agricultural areas in GXEB and Guangxi. Strict population and industry policy should be formulated and implemented to prevent increasing vulnerability. The latter type is mainly mining land distributed in originally vulnerable zones in Baise and Chongzuo. Future exploitation of mineral resources should pay more attention to environmental impact assessment and eco-environment restoration (Zhou 1997).

5 Conclusions

The VSD model is a newly developed method for ecological vulnerability assessment and was used here to carry out quantitative evaluation on ecological vulnerability induced by both natural and humanistic factors. Our results indicate the existence of different kinds of vulnerable zones, and also their distribution, scale and inducing factors. On the whole, nature-dominated vulnerable zones are mainly distributed in areas with steep slopes, high elevation and destroyed vegetation. However, human-dominated vulnerable zones are mainly caused by high-intensity and extensive human activity, and dispersed in urban areas and their surrounding regions. From the aspect of the distribution of natural- and human factor-dominated vulnerable zones, the former patches are larger and more spatially concentrated.

It is of great significance to realize regional sustainable development by comprehensive regulation of vulnerable zones. Therefore, it is necessary to carry out targeted regulation based on dominant inducing factors. For nature-dominated vulnerable zones, the primary importance is large-scale afforestation to optimize the structure of ecosystems and increase the ability for soil and water conservation. In some mountain areas where human activities intensify nature-dominated vulnerability though slope land reclamation, measures including ecological migration and the conversion of croplands to forests and grasslands should be adopted. The exploitation of mineral resources is also occurring in some mountain areas with nature-induced vulnerability and it is important to conduct environmental impact assessments before exploitation and ecological restoration after exploitation to minimize the negative impact on original ecosystems (Liu and Liu 2010; Li et al. 2011). For human-dominated vulnerable zones, several measures could be adopted to decrease the intensity of vulnerability. First, sufficient research should be carried out including setting the urban growth boundary and building urban greenbelts. Second, green land networks should be built to increase the connectivity of urban green lands with surrounding open spaces. Third, middle and small scale cities and towns should be constructed so as to disperse the population and industry of big cities. Ecological agricultural should be well developed to decrease the use of chemical fertilizers and pesticides (Li et al. 2011).

As natural and human factors are mixed in the VSD model, it is quite difficult to distinguish natural and human-dominated vulnerability quantitatively. The unclear boundary causes a spatial overlay relationship amongst different kinds of vulnerable zones and makes it less distinguishable. A major subject in future research will be how to break down the indices according to natural and human aspects and distinguish the vulnerability caused by different factors.

References

基于VSD模型的区域生态系统脆弱性评价
——以广西西江经济带为例

李平星1，樊杰2

1 中国科学院南京地理与湖泊研究所，南京 210008；
2 中国科学院地理科学与资源研究所，北京 100101

摘 要：生态系统脆弱性受到自然与人文因素双重影响，以广西西江经济带为例，采用VSD模型，通过暴露度、敏感性和适应能力分解脆弱性，构建包含自然和人为因素的25指标的评价体系，开展脆弱性评价与分区。结果表明，不脆弱区、一般区、脆弱区、很脆弱区和极脆弱区分别占11.31%、22.63%、27.60%、24.39%和14.07%，不脆弱区、一般区脆弱性较低，自然因素导致的脆弱区主要分布于东西部山区，人为因素主导的脆弱区分布于中部盆地的城镇及其周边；经济带约53%的建设用地分布于很脆弱区和脆弱区，未来新增建设用地需要重点向不脆弱区和一般区转移。根据分区结果和诱因差异，提出了不同类型区开发与保护的相关建议。

关键词：生态脆弱性；自然与人为因素的交互作用；VSD模型；广西西江经济带