

A RESEARCH ON THE ASSESSMENT OF REGIONAL ECOLOGICAL SECURITY BASED ON GIS&RS

Zou xiuping^a, Chen Shaofeng^{a*}, Qi Qingwen^b

^aInstitute of Policy and Management, CAS, Haidian Zhongguancun donglu 55#, Beijing 100190, China. -
zouxp@casipm.ac.cn, sfchen@casipm.ac.cn.

^bInstitute of Geographical sciences and Natural Resources Research, CAS, Anwai Datun Road A11#, Beijing
100101, China. - qiqw@igsrr.ac.cn

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ABSTRACT:

Ecological security is an important basis of the entire human security system, the cornerstone for human survival. The assessment of ecological security is crucial for making decisions to avoid ecological disaster. This paper investigates the methods on ecological security assessment in existing research, and develops an assessment method for assessing the spatial-temporal change of regional eco-security based on RS and GIS. The method includes the several steps: (1)establishing evaluation standards and indicator system, (2)environment information extracting from remote sensing images, (3)specialization of census data, (4)establishing the weight overlay model based on multi-source data in GIS environment. The paper describes an application of this method as a case study. Taking Xishuangbanna as an example, we select the remote sensing images and the census data in 2000, and establish an assessment method including the indicator system and assessment model, and construct an integrated assessment framework based on data integrity, security assessment with the support of the ARCGIS9.2 environment. The proposed assessment method enables decision makers to better know the spatial-temporal status of ecological security in making policies for achieving sustainable development.

1. INTRODUCTION

The development of human society have exploited natural ecosystem such as land, forest, and water, and caused changes in component, structure and function of natural ecosystem. As the serious results, landscape is fragmented, natural species are reduced, some of them are extinct, some exotic organisms and even useless materials (waste) are introduced, air and water is polluted, and soil is eroded. These changes have brought out many serious eco-environment problems: soil erosion and degradation; forest decrease; air pollution; water pollution; poverty; disaster; greenhouse gases increase; ozone layer depletion; energy shortage; ocean pollution; and, species extinction. Furthermore, these serious eco-environment problems have caused many even more serious ecological security problems: environment health problems, ecological refuges, and resource war, species extinction. These severe eco-security problems have menaced the vital interests of a nation or people seriously, and blocked the development of human society further. It is urgent to find effective ways to resolve the problems (Xiaoqing Shi, 2005).

Environmental security as a formal science term is appeared in the famous report named "Our common Future". Environmental degradation is fundamentally implicated in economic and political insecurities in 1987 (Mayers, 1993). Ecological security, a concept first proposed by the government of the United States, has drawn considerable attention from the international research community (Ezeonu, 2000). Because of the short history of study of this concept, there is no universally accepted definition of ecological security. At present, there exist broad-sense and narrow-sense concepts of ecological security. The broad-sense ecological security is the status

reflecting the threat to human living, health, basic right, living guarantee, necessary resources, social orders and the abilities to adapt to environment change, which includes natural, economic, and social ecological security (Costanza et al., 1992; Dobson et al., 1997; Norton et al., 1992). The narrow-sense ecological security is the security of nature and semi-nature ecosystem, which is the reflection of the ecosystem integrity and health (Xiao et al., 2002). Ecological security Focus on interactions between economic development and the ecological environment, on the presence of a sound ecosystem, on sustainable exploitation of natural resources, and on harmony between humans and nature.

Assessment of ecological security evolved from the fields of ecological risk analysis and ecological health studies based on hierarchical patch dynamics. Since the assessment of ecological security require a lot of data such as social economic data, environment data, natural resource data and so on, it is essential to establish an assessing model which can integrate the multi-sources data, and provide a quantitative and more effective assessment.

Currently, the methods of comprehensive evaluation, ecological modeling, and landscape ecology are the main approaches being adopted for the assessment of ecological security. Comprehensive evaluation simplifies the evaluation process and provides comparatively objective results by simplifying the indices without losing key index information. It has been widely used in evaluating geographically typical regions or ecosystems. The ecological modeling method, which is based on the development of a mathematical model, has gradually become a valid tool in the assessment and management of ecological security. This method is further applied at the levels

of individuals, communities, and even whole ecosystems. The landscape ecology method is relatively new, and has gradually become an important tool for studying ecological security. It has shown considerable promise, at both whole nation and even global scales. All these methods were able to achieve a quantitative analysis of the ecological security status by using the statistical data, but lacked the information of pattern graphical. Thus it is essential to establish a regional system for assessment ecological security that can provide a quantitative and more effective assessment.

2. METHODS

As ecological security assessment needs a large and real-time data support and it also needs to feed back its result to the policy maker on time, so it requires the support from the system that could provide information instantly and truly. RS&GIS technology meets this requirement. Geographic information system (GIS), as a useful tool to analyze and manage spatial information, has a superior advantage in ecological security assessment. The RS data, such as satellite images and aerial photo of different periods, can be utilized to realize dynamic

Remote sensing inspection of land cover changes and acquires dynamic or mutative information to update and perfect the data correlative with environment management. And the huge amount of multi-temporal and multi-sensor data of earth's surface can be acquired and used to analyze in order to achieve reliable, precise and satisfying results.

2.1 Indicators system

This paper took the 'pressure-state-response' model (PSR) that has been proposed by OECD and the United Nations UNEP (Qian et al., 2001) as the foundation of an indicator system for assessing ecological security (Figure 1). The PSR approach is a causal one that covers causes and effects influencing a measurable state. In this sense, three categories of indicators are distinguished (OECD, 1993):

- Indicators of environmental Pressure describe pressures on the environment originating from human activities, including quality and quantity of natural resources (e.g., emissions, mining of raw materials, fertilizer input).
- Indicators of environmental conditions (State) are designed to describe the status quo of the environment and the quality and quantity of resources and their changes over time (e.g., forest area, protected areas).
- Indicators of societal Response show to which degree society is responding to environmental changes and concerns. This could be the number and kind of measures taken, the efforts of implementing or the effectiveness of those measures. Responses may range from public (e.g., legislation, taxation, promotion) to private sector activities (e.g., reduced consumption, recycling) (Linsler, 2001).

The PSR model has proven to be a logical, comprehensive tool to picture environmental issues from an anthropocentric perspective. Instead of observing a single phenomenon or problem a causal model of causes, impacts and effects on the environment is generated. This approach is rather powerful in communicative and opinion-building processes (Wolfslehner, 2007).

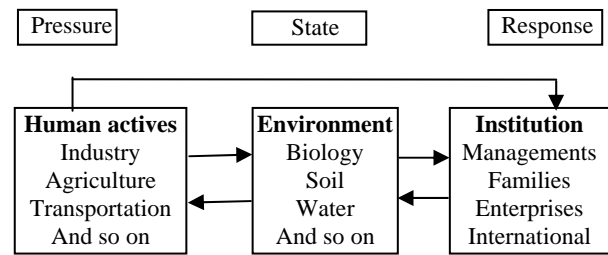


Figure 1. PSR concept model of OECD

2.2 Establishment of the assessing model based GIS

Based on the indicators combined with the weight calculated using the AHP model, we developed the following formula for the ecological security index (ESI):

$$ESI = \sum W_i * S_i$$

Where S_i represents the results for indicator i , and W_i represents the weight of indicator i .

2.3 Remote sense information extraction

Environment monitoring is an important aspect of remote sensing application. The use of remote sensing as a data source for environmental management is increasing. In middle-scale area, the rapid and macro monitoring of vegetation cover in mountainous area of Xishuangbanna is based on remote sensing responsive spectral characteristic analysis. This paper extract Normalization Difference Vegetation Index selected (NDVI) to identify the vegetation cover states. NDVI is the most extensive application of a vegetation index. NDVI is linear related with distribution of vegetation density and the state of vegetation growth and spatial distribution of vegetation in the best direction factor. NDVI calculate formula:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where, NIR is Near-Infrared spectral band and R is red spectral band.

3. APPLICATION

3.1 Case study area

Xishuangbanna is located in southern Yunnan Province, in southwest China (24° 10' to 22° 40' N, 99° 55' to 101° 50' E) bordered by Laos in the south and southeast and Burma in the southwest. It is a famous region in China for its diverse flora, fauna and beautiful landscape. It is estimated that about 5000 species of higher plants (16% of those in China) exist in this area of 19,200 km² (0.2% of that in China), of which nearly 1000 species of wild plants can be directly utilized by the people. This area has one of the greatest diversities of species in China and is of great importance in the maintenance of regional biodiversity (Cao and Zhang 1997; Shanmughavel et al. 2001). In the early 1950s, about 60% of the total area of Xishuangbanna was covered by forest (Xu 1985). Recent investigation has revealed that this has declined greatly due to the rapid expansion of the local population and irrational

exploitation of local forest cover has declined to 27% at the beginning of 1990s (Shanmughavel et al. 2001). Like other tropical areas of the world, Xishuangbanna is inhabited by many indigenous minority groups who have only recently started to develop economically. Managing conflicting interests between tropical rain forest conservation and economic development has attracted attention in recent years (Liu 2006).

3.2 Indicator system and model for assessment

3.2.1 Indicators selection

We selected three categories of indicators that would be useful in assessing ecological security (natural, social, and economic factors) and that would comprehensively reflect the characteristics (show in table1)

| | | |
|---------|----------------------------|--|
| ESI (A) | Pressure (B ₁) | Population density (C ₁) |
| | | Population nature growth rate (C ₂) |
| | | Food per capita (C ₃) |
| | | Agricultural output value per capita (C ₄) |
| | | Human Activities disturbance index (C ₅) |
| | | Resident distribution (C ₆) |
| | | Road (C ₇) |
| | State (B ₂) | Vegetable Index (C ₈) |
| | | Landscape diversity index (C ₉) |
| | | Slope (C ₁₀) |
| | | Ecosystem Service Function (C ₁₁) |
| | | Soil erosion intensity (C ₁₂) |
| | Response (B ₃) | Area of nature protection (C ₁₃) |
| | | >25°Returning slope Farmland area (C ₁₄) |
| | | Land use adjusts index (C ₁₅) |

Table.1 the indicators based on PSR

3.2.2 Determination of the weights of the indicators

We chose the method of Analytic Hierarchy Process (Wang and Zhang, 1993) for determining the allocation of weights. The weights of each of the 15 indicators used in the present paper

can be determined by using the methods. The analysis result as table2:

| A | B ₁ | B ₂ | B ₃ | |
|-----------------|----------------|----------------|----------------|--------|
| | 0.6479 | 0.2299 | 0.1222 | |
| C ₁ | 0.0494 | 0 | 0 | 0.0320 |
| C ₂ | 0.0977 | 0 | 0 | 0.0633 |
| C ₃ | 0.0269 | 0 | 0 | 0.0174 |
| C ₄ | 0.0541 | 0 | 0 | 0.0350 |
| C ₅ | 0.4005 | 0 | 0 | 0.2595 |
| C ₆ | 0.1397 | 0 | 0 | 0.0905 |
| C ₇ | 0.2317 | 0 | 0 | 0.1501 |
| C ₈ | 0 | 0.1433 | 0 | 0.0330 |
| C ₉ | 0 | 0.2400 | 0 | 0.0552 |
| C ₁₀ | 0 | 0.0438 | 0 | 0.0101 |
| C ₁₁ | 0 | 0.5102 | 0 | 0.1173 |
| C ₁₂ | 0 | 0.0627 | 0 | 0.0144 |
| C ₁₃ | 0 | 0 | 0.7235 | 0.0884 |
| C ₁₄ | 0 | 0 | 0.1932 | 0.0236 |
| C ₁₅ | 0 | 0 | 0.0833 | 0.0102 |

Table.2 weights of the indicators

3.2.3 The framework of assessing model

In this paper, spatial weight overlay model was taken to achieve the ecological security index quantitative calculation. Firstly, we took the standardization and quantification of data and then established the ecological security assessment model of Xishuangbanna in the ARCGIS9.0. The Figure 2 is show the data flow of the assessment model.

3.3 The sources of data

There were three types data included remote sense images, vector theme map and statistic data. The raw remote sense images data in this study were TM images in September 2000. Based on the topographic map in scale of 1:10,000, the geometry of the images was first corrected by the RS image processing system, ERDAS 8.7. After verification and matching, the RS images in different periods were classified by visual-interpretation based on the method of direct spectrum classifications. Ultimately the map of land use was charted. The vector theme map included road, resident, land use/cover, soil and so on. The statistic data included population, agriculture, and food.

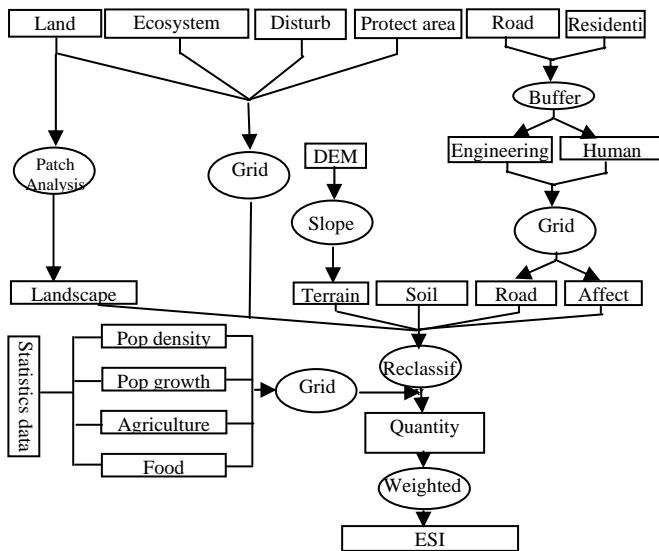


Figure 2. The data flow ecological security assessment based on GIS

3.4 The Ecological security of Xishuangbanna in 2000

The result showed that the ESI average values for Xishuangbanna in 2000 were 58.7, the maximum is 98.8 and the minimum is 18.7 (show Figure 3.). From the view of spatial distribution, the state of ecological security in high elevation region is much better than low elevation region. And eastern region is better than western region.

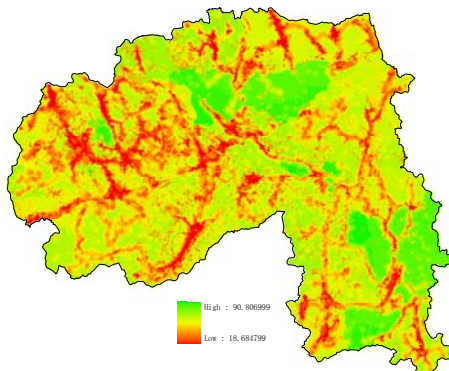


Figure 3. Ecological security synthetic index map in Xishuangbanna in 2000

4. CONCLUSIONS

Eco-security is becoming more and more important with the rapid development of our modern society and information technology. Knowing the status of eco-security is crucial for making sustainable development policy. Ecological security evaluation is an important element in the ecological security study. The assessment based on the GIS&RS provides scientific basis with the correct analysis of the development and decision-making of ecological environment.

REFERENCES

Cao M. and Zhang J.H. 1997. Tree species diversity of tropical forest vegetation in Xishuangbanna, SW China. *Biodiversity and Conservation* 6: 995 - 1006.

Costanza, R., Norton, B., Haskell, B.J. (Eds.), 1992. *Ecosystem Health: New Goals for Environmental Management*. Island Press, Washington, DC.

Dobson, A.P., Bradshaw, A.D., Baker, A.J.M., 1997. Hopes for the future: Restoration ecology and conservation biology. *Science* 277, 515-524.

e-science environment. *The Journal of Systems and Software* 79 (2006) 246 - 252

Ezeonu, I.C., Ezeonu, F.C., 2000. The environment and global security. *The Environmentalist* 20, 41-48.

HONGMAO LIU et al. The impact of *Amomum villosum* cultivation on seasonal rainforest in Xishuangbanna, Southwest China. *Biodiversity and Conservation* (2006) 15:2971 - 2985

Linser, S., 2001. *Critical Analysis of the Basics for the Assessment of Sustainable Development by Indicators*. Schriftenreihe Freiburger Forstliche Forschung Bd. 17, Freiburg.

Myers, N., 1993. *Ultimate Security: The Environmental Basis of Political Stability*. W.W. Norton & Co., New York.

Norton, S.B., Rodier, D.J., Gentile, J.H., et al., 1992. A framework for ecological risk assessment at the EPA. *Environmental Toxicology and Chemistry* 11, 1663-1672.

OECD, 1993. *Core Set of Indicators for Environmental Performance Reviews: A Synthesis Report by the Group on the State of the Environment*. Environment Monographs, Vol. 83. Organisation for Economic Co-operation and Development, Paris.

Pressure-State-Response framework, *Journal of Environmental Management* (2007), doi:10.1016/j.jenvman.2007.01.027

Shanmughavel P., Sha L.Q., Zheng Z. and Cao M. 2001. Nutrient cycling in a tropical seasonal rain forest of Xishuangbanna, Southwest China. Part 1: trees species: nutrient distribution and uptake. *Bioresource Technology* 80: 163 - 170.

Wang, F., Zhang, Y.-L., 1993. Investigation about the 'weight' and the method of its distribution. *Systems Engineering* 11 (5), 11-15 (in Chinese, with English summary).

Wolfslehner, B., Vacik, H., Evaluating sustainable forest management strategies with the Analytic Network Process in X. Shi et al. *Assessment of eco-security in the Knowledge Grid*

Xiao, D.-N., Chen, W.-B., Guo, F.-L., 2002. On the basic concepts and contents of ecological security. *Chinese Journal of Applied Ecology* 13, 354-358 (in Chinese, with English summary).

Xu Y.C. (Ed.) 1985. *The Synthetic Investigation Report of Xishuangbanna Nature Reserve Area*. Yunnan Science and Technology Press, Kunming.

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