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Construction of ecological security evaluation index system supported by PSR model

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Abstract. Ecological security assessment, as an important content of ecological security research, is of indicating significance in maintaining national, regional ecological security and sustainable development. Based on pressure, state and response (PSR) framework model, this paper took Dehong Prefecture, Yunnan Province as an example to construct the ecological security assessment index system. The weight of index was determined based on entropy method. The results showed that the ecological security integrated index of Dehong Prefecture increased from 2001 to 2010, and the ecological security undergoes unsafe, critical safe and relative safe status. Ecological system response is the most influential factor (weight 0.42157), which has played an important role in the ecological security of Dehong Prefecture, but due to the system pressure still larger (weight 0.41516), and the growing trend, the ecological security status in Dehong Prefecture is still facing a severe challenge.

Key words. Ecological security, PSR model, Dehong prefecture.

1. Introduction

Ecological security is a new theme for the sustainable development of human society in the 21^{st} century. With the continuous improvement of global change, global change has brought great pressure and threat to human survival and development. Ecological security research has become hot spot in domestic and foreign research [2]. As the fundamental problem of human survival and development, ecological security has become the frontier field and hotspot in multidisciplinary research fields, such as

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geographical science, environmental science, ecology, disaster science, safety science and sustainable development. It has become the main components for construction of ecological civilization in China [3].

Since the western economic development plan has been launched, the economy in Yunnan Province is rapidly developed. Meanwhile, ecological environment deterioration, land degradation and other resources and environmental problems continue to emerge. Because Yunnan is in a special geographical position, namely it connected with Myanmar, Laos and Vietnam and located in the upper reaches of a number of international rivers, the ecological environment in Yunnan border area is not only related to the socio-economic sustainable development in China and a number of neighboring countries, but also related to cross-border ecological security [4]. Dehong Autonomous Prefecture (short for Dehong) is located in the southwest border of China, and it is one of the eight ethnic autonomous prefectures in Yunnan Province; ethnic minority population accounts for 48% of the total population. It connects with the Burmese Federation in the south, west and northwest border. Except Lianghe County, the boundary line passes through the whole Dehong. The boundary line is up to 503.8 km in length. At present, the important bridgehead for opening up to the southwest and the vanguard of the national ecological civilization construction are under construction in Yunnan Province. Dehong is the most convenient channel to Southeast Asia and South Asia. It is the best frontier for opening to the southwest of China. Dehong serves as the research object in the Thesis. Based on the pressure, state and response (PSR) framework model extensively used in the research on ecological security evaluation [5], 32 indicators were used to establish the evaluation index system on ecological security, and the entropy method was used to determine the weight of each index [6, 7]; the method of comprehensive evaluation index was used to evaluate the ecological security status of Dehong in 2001-2010.

2. Research method

2.1. Source of research data

The original data in the research are derived from the statistical data of *Statistical Yearbook of Yunnan Province* (2002-2011), *the Statistical Yearbook of Dehong* (2002-2011) and the relevant functional departments. The missing data in individual year are obtained by the sliding average or trend extrapolation.

2.2. Construction of ecological security evaluation index and weight calculation

The evaluation index system of ecological security in the research is constructed on the basis of the PSR framework model, that is, the Pressure—State—Response framework model. Combined with the actual situation of Dehong, the 32 indicators closely related to ecological security status of Dehong are selected to constitute the evaluation index system (Table 1).

The data of Dehong ecological security evaluation index are standardized by the

method of maximum difference normalization. The original data is transformed into the dimensionless comparable value of 0-1 interval based on the principle that the smaller the value is, weaker the disturbance of human activity is. The Formula is:

$$\text{Positive index: } Y = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}. \tag{1}$$

$$\text{Negative index: } Y = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}. \tag{2}$$

Where Y refers to standardized value of the original value; X_i refers to the original value of i^{th} index; $X_{\max}$ refers to the maximum value in the indexes; $X_{\min}$ refers to the minimum value in the indexes.

The weight of each index standardized is determined by entropy method, except human subjectivity. The formula is:

$$W_i = \frac{1 - E_i}{n - \sum E_i}. \tag{3}$$

Where $W_i (i = 1, 2, 3.....n)$ refers to the weight value of the i^{th} index after standardized treatment; n refers to the total number of index, of which $0 \leq W_i \leq 1$, $\sum W_i = 1$.

Table 1. Index system of ecological security in dehong based on PSR model

Target layer	Criterion layer	Index layer	Nature of index	Total weight	Weight
Index System of Ecological Security in Dehong	Pressure	Agricultural acreage per capita (hectare)	+	0.41516	0.02943
		Public green land area per capita (m^2)	+		0.03453
		Living space of rural residents per capita (m^2)	+		0.03240
		Road density (km/km^2)	+		0.06989
		Application amount of fertilizer in cultivated land (ten thousand tons)	-		0.02003
		Application amount of pesticides in cultivated land (ton)	-		0.02016
		Discharge amount of wastewater for ten thousand Yuan GDP (ton)	-		0.01591
		Emissions of exhaust gas for ten thousand Yuan GDP (m^3)	-		0.01410
		Discharge amount of solid waste for ten thousand Yuan GDP (ton)	-		0.01385
		Population density (person/ km^2)	-		0.03706
		Natural population growth rate (‰)	-		0.03301
		Urbanization level (%)	+		0.02766
		GDP per capita (yuan)	+		0.05234

Target layer	Criterion layer	Index layer	Nature of index	Total weight	Weight
Index System of Ecological Security in Dehong	Pressure	Agricultural acreage per capita (hectare)	+		0.02943
		Engel coefficient of urban residents (%)	-		0.01479
		Green coverage ratio of built-up area	+		0.16318
		Air pollution index	-		0.02226
		Registered unemployment rate in urban area (%)	-		0.02353
		Ratio of service output value (%)	+		0.02675
		Food production per capita (ton)	+		0.03316
		Disposable income of urban residents per capita (yuan)	+	0.41516	0.02461
	Response	Treatment rate of domestic sewage (%)	+		0.01467
		Rate of multipurpose utilization of industrial solid waste (%)	+		0.01791
		Forest coverage rate (%)	+		0.07004
		Discharge standard-meeting rate of industrial wastewaters (%)	+	0.42157	0.04332
		Number of ten thousands of students in college (person)	+		0.03974
		Proportion of service output value on GDP (%)	+		0.02675
		Number of hospital bed for thousand people (number)	+		0.04076
		Health workers for thousand people (number)	+		0.02865
		Investment in urban fixed assets (ten thousand yuan)	+		0.05319
		Proportion of funds invested in environmental protection and pollution control on GDP (%)	+		0.02309
		Proportion of education spending on GDP (%)	+		0.01133
		Proportion of investment in public service facility on GDP (%)	+		0.05212

+ refers to positive index; the larger the index value is, the better the ecological security state is; - refers to negative index, the state is on the contrary.

2.3. Calculation of comprehensive index of ecological security

The comprehensive index method is widely used in the evaluation of ecological security. On the basis of establishing the index system, the index is linearly weighted, and finally the evaluation index is obtained. The formula is:

$$ES_i = \sum_{i=1}^{n} W_i y_{ij} \,. \tag{4}$$

Where ES_i refers to the comprehensive index of ecological security; W_i refers to the entropy weight of the i^{th} index, and y_{ij} refers to the normalized value of the ith index in j^{th} year. The larger the ES_i value is, the higher the ecological security grade is; the smaller the ES_i value is, the lower the ecological security grade is, and

the higher the ecological risk is. With reference to the results of relevant researches [8], the comprehensive index of ecological system security is divided into five grades (Table 2).

Table 2. Criteria for classification of grade of dehong ecological security evaluation

Grade	Threshold value of comprehensive index	Evaluation
I	[0.8,1.0]	Very security
II	[0.6,0.8)	Safer
III	[0.4,0.6)	Criticality security
IV	[0.2,0.4)	Insecurity
V	[0,0.2)	Terribly insecurity

3. Results and analysis

After each index is normalized, the weights of the indexes are obtained through Formula (3) (Table 1); the weights of the pressure system, state system and response system are 0.41516, 0.6318 and 0.42157, respectively, which reflects that the the pressure and response subsystem have a serious effect on the ecological security evaluation in Dehong, and the state subsystem has a lower effect on the ecological security evaluation. The comprehensive evaluation index of ecological security in Dehong in 2001-2008 is calculated by using the Formula (4), and the change trend is shown in Fig. 1.

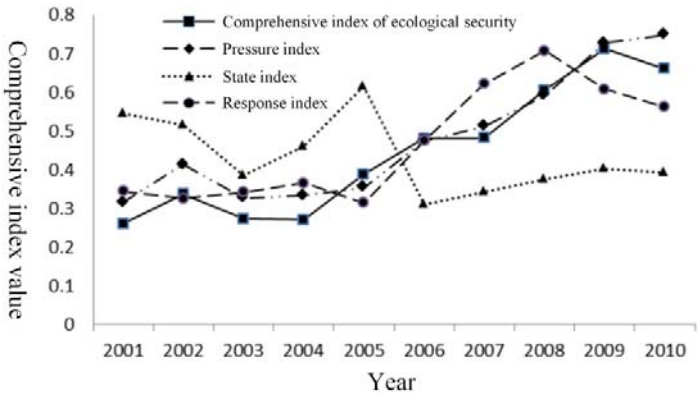

Fig. 1. Ecological security status of dehong in 2001-2010

3.1. Pressure index

Pressure index score of Dehong in 2001-2010 showed the overall upward trend and rose from 0.32 in 2001 to 0.75 in 2010; the rate of rise is 137.75%. The reason is that the housing area, population density, road density, public green area, GDP

and urbanization rate per capita in rural areas of Dehong in 2001-2010 increased in a certain degree, of which urbanization rate increased by 3.7%; housing area per capita in rural areas increased by 36.76%; population density increased by 18.05%; road density area increased by l42.46%; GDP per capita increased by 214.43%; public green area per capita increased by 139.36%. The change in the value reflects that economic society of Dehong in 2001-2010 is in the rapid development stage of urbanization. At the same time, the emissions of exhaust gas, waste water and solid waste for ten thousand yuan GDP in pressure indexes were effectively controlled and significantly reduced, of which the emission of exhaust gas was reduced by 43.03% from 27609m^3 in 2001 to 15728m^3 in 2010; the emission of wastewater was reduced by 71.31% from 122 tons in 2001 to 35 tons in 2010; the emission of solid waste was reduced by 8.24% from 0.85 tons in 2001 to 0.78 tons in 2010.

3.2. State index

The score of state index of Dehong in 2001-2010 was reduced from 0.54 in 2001 to 0.39 in 2010. Among them, it shows downward trend from 2001 to 2003, upward trend in 2004-2005, downward trend in 2006 and upward trend in 2007-2009; the score was gradually increased to 0.39 in 2010; the overall trend is downward. Through the analysis, the main factors that affect the change of state indexes are the air pollution index, green coverage ratio of built-up area, grain output per capita and disposable income of urban residents per capita. These indexes increased by 51.3%, fell by 19.11%, increased by 38.89 % and 1110.54% respectively in 2001-2010. The air pollution index reflects the quality of the air environment in Dehong, which is itself a negative index. The smaller the pollution index is, the better the air quality is. However, the air pollution index is increased to make the score of ecological security status reduced.

3.3. Response index

The score of response index of Dehong in 2001-2010 rose from 0.34 in 2001 to 0.71 in 2008, and then fell to 0.56 in 2010 year by year. The results show that although the overall score of the response system is on the rise, it recently showed a downward trend. The main factors that affect the score of response indexes through further analysis were forest coverage rate, discharge standard-meeting rate of industrial wastewaters, proportion of education expending on GDP, proportion of investment in public service facility on GDP, number of ten thousands of students in college, number of hospital bed for thousand people, treatment rate of domestic sewage, rate of multipurpose utilization of industrial solid waste and investment in urban fixed assets, of which the forest coverage rate increased from 61.19% in 2001 to 67.07% in 2010, and the discharge standard-meeting rate of industrial wastewaters increased from 61.39% in 2001 to 73.9% in 2010. The discharge standard-meeting rate of industrial wastewaters exceeded 87% in 2006-2008, which is the main reason that the response index reached the maximum in 2008. The proportion of education expending in GDP rose from 4.74% in 2001 to 6.46% in 2009; proportion of investment

in public service facility in GDP rose from 1.74% in 2001 to 5.71% 2009, and fell to 1.29% in 2010. The number of ten thousand students in college increased by 1754.96% from 2.62 in 2001 to 48.6 in 2010; the treatment rate of domestic sewage increased from 39.5% in 2001 to 63%; the rate of multipurpose utilization of industrial solid waste increased from 65.51% in 2001 to 76% in 2010; investment in urban fixed asset increased by 1359.11% from 900 million yuan in 2001 to 13.132 billion yuan in 2010.

3.4. Comprehensive index of ecological security

According to the calculation results of the comprehensive index of ecological security evaluation of Dehong (Fig. 1), and combined with the classification of ecological security grade of the comprehensive index method (Table 2), the ecological security grade of Dehong in 2001-2008 was obtained (See Table 3).

Table 3. Results of ecological security rating of dehong in 2001 - 2010

Year	Comprehensive index	Security grade
2001	0.26	Insecurity
2002	0.34	Insecurity
2003	0.27	Insecurity
2004	0.27	Insecurity
2005	0.39	Insecurity
2006	0.48	Criticality security
2007	0.48	Criticality security
2008	0.61	Safer
2009	0.71	Safer
2010	0.66	Safer

As shown in Fig. 1, the comprehensive index of ecological security of Dehong in 2001-2008 was on the rise, and the grade of ecological security had experienced insecurity, critically security and safer. Specifically, the comprehensive index of ecological security in 2001-2005 was distributed between 0.2-0.4 and in insecurity state, of which the comprehensive index of ecological security in 2002 was significantly higher than that in 2001, but then it decreased sharply in 2003 and 2004. According to the analysis of existing data, it could reflect that the force for integration of resources for economic development in Dehong in the period was small and large capacity of exhaust gas for then thousand yuan GDP and waste water were discharged. The way of economy development was in extensive form and economic development was in low level. Especially degree of education was low, which reflected that lack of sustainable concept for overall development of environmental and resources in local economic development caused ecological security in the process at an insecurity level. Although the comprehensive index of ecological security in 2005 has been greatly improved on a previous basis, it is still at an insecurity level.From 2006 to 2007, the comprehensive index of ecological security in Dehong was between 0.4 and 0.6, and

the ecological security was at the critically security level. The phase was important for coordinated development of economy and environment in Dehong. On the basis of growing of economic strength, lessons should be taken from the environmental problems exposed in the process of economic development on the previous phase to lay the foundation for the future construction of ecological security in Dehong, which mainly showed that GDP per capita increased significantly to 60-70 million yuan; number of ten thousand of students in college was increased continuously, and the growth rate was more than 70%, the level of education was gradually improved; proportion of investment in environmental pollution control on GDP increased, especially the total quantity of GDP was rapidly increased, which reflected that the local government began to attach importance to environmental governance and put sustainable development concept into action in the process of economic development.

The comprehensive index of ecological security in 2008-2010 was between 0.6 and 0.8, and the ecological security of Dehong was at a security level. Among them, the comprehensive index of ecological security in 2008 and 2009 was further enhanced and the level of economic development has been effectively improved, especially the national policy provided support for border economic development. Dehong has a number of open ports for foreign economic development; the regional advantage for economic development is prominent, and economic development is rapidly. The total investment in urban fixed assets was increased more than 10 times in 2001. The disposable income of urban residents is 10 times higher than that in 2001. The proportion of investment in public service facility on GDP was increased greatly, and the growth rate was 400%, which is the highest level in history. In the area of environmental protection, the forest coverage rate increased to 67.07%, and the discharge quantity of three industrial wastes decreased continuously. In 2010, except for the little change on solid waste, the total amount of waste gas and waste water was 50% and 20%, which reflected that the economy in Dehong has entered a benign cycle development period. The comprehensive index of ecological security in 2010 fell, but ecological security remained at a relatively security level. The main reason was that the proportion of investment in environmental pollution control and education expending on GDP declined. Therefore, under the circumstance that the natural environment, social and economic development conditions remain unchanged, the level of ecological security has an important relationship with the implementation of environmental policy of government.

4. Conclusion

Based on the PSR framework model, the ecological security status of Dehong in the last ten years from 2001 to 2010 is analyzed by using entropy weight method and comprehensive index method in the Thesis. The results show that the comprehensive index of ecological security in Dehong in 2001-2010 was on the rise, and the ecological security level went through the grade of insecurity, critically security and safer. The weight of response system is 0.42157, which is the largest in the ecological security evaluation and plays an important role in enhancing the ecological security of Dehong. However, the system pressure intensity is 0.41516, which is still large,

and the trend is increasing. Therefore, Dehong still faces more severe challenges in maintaining and improving the level of ecological security in the region. The results of the research provide scientific reference to further understand the temporal evolution rule of ecological security in the border areas of Yunnan Province and explore the law of the impact of land use change on ecological security in border areas, so as to put forward corresponding measures for control of ecological security and optimal allocation scheme of land resources.

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