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Method evaluation of ecological safety based on GIS and regional space ecological footprint

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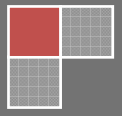
ABSTRACT

In the face of the increasingly prominent overloaded operation of the life support system on earth currently, the ecological environmental problems on a global scale become more and more serious, and the ecological safety of the geographic space attracts extensive attentions increasingly. Based on GIS and space ecological footprint, this paper builds the ecological safety evaluation index system, sets up the evaluation criterion, further designs the space ecological safety evaluation model, and analyzes the evaluation results of the provincial regions of China from 1998 to 2012, so as to have the definite reference significance for promoting the space ecological safety of China.

KEYWORDS

GIS; Space ecological footprint; Ecological safety; Evaluation index system.



INTRODUCTION

With the rapid development of the world economy, the increasing world population, the aggravated gap between the rich and the poor, the degenerated land resources, the shrinking forestry area, and the sharp decline in biodiversity, the life support system on earth carries out the overloaded operation and is increasingly prominent, and the ecological environmental problems on a global scale become more and more serious, and the ecological safety is threatened increasingly. Thus, research on the space ecological safety has important significance.

BUILD REGIONAL SPACE ECOLOGICAL SAFETY EVALUATION INDEX SYSTEM AND SET UP EVALUATION CRITERION

Establishment of space ecological safety evaluation index system

Abide by the representative principle, comprehensive systematic principle, dominance principle, operability principle, comparability principle, and regionalism principle, utilize the regional remote sensing monitoring data and socioeconomic statistical data, and refer to the relevant regional space ecological safety evaluation quantitative index system, to build the regional ecological safety evaluation index system (TABLE 1). The index system is composed of the target layer, criterion layer, and index layer.

(1) Target layer. It regards the space ecological safety comprehensive index (A) as the target layer, to comprehensively represent the state and dynamic changes of the regional ecological environment quality.

(2) Criterion layer. The main factors of restricting the regional space ecological environment quality represent the internal difference in the ecological environment quality. It adopts the ecological environment bearing capacity (B), ecological environment development capacity (B2) and ecological environment stress (B3) as the criterion layer.

(3) Index layer. The index layer is composed of the measurable indexes. It is the most basic layer in the comprehensive evaluation index system of the regional environment quality, as well as the unit and element of conducting the quantification, dynamic evaluation and real-time regulation. This paper selects 22 indexes, and builds the ecological safety evaluation index from four aspects.

Space ecological safety evaluation unit

While making the comprehensive evaluation analysis of the ecological environment quality by the remote sensing and geographic information system, it is necessary to firstly determine the evaluation unit, which reflects the definite space and entity. Due the relatively large study regional area, the data volume is very huge. In order to reduce the data volume, this paper adopts 10000m grids as the basic unit of the ecological safety evaluation. The selected index sources are different, so they can not use the same standardized method, but they need making the standardization processing for these two evaluation indexes respectively.

(1) Forward index standardization

The forward index means some factor value being the same as the evaluation result. The higher the vegetation coverage is, the better the ecological environment quality is, and the higher the ecological safety degree is. For such index, we adopt Formula 1 for the standardization processing.

$$N_{ij}^{'} = \frac{N_{ij} - N_{j\min}}{N_{j\max} - N_{j\min}} * 100 \quad \textbf{(1)}$$

(2) Backward index standardization

The backward index means some factor value contrary to the evaluation result. The higher the population density is, the larger the regional bearing pressure is, and the lower the regional ecological safety degree is. For such index, we adopt Formula 2 for the standardization processing.

$$N_{ij}^{'} = \frac{N_{j\max} - N_{j}}{N_{j\max} - N_{j\min}} * 100 \quad \textbf{(2)}$$

In Formula 1 and Formula 2, N'_{ij} is the nondimensionalization value after conversion of j index in i region. N_{ij} is the original value before standardization of j index in i region. N_{jmax} is the maximum original value of j index in various regions. N_{jmin} is the minimum original value of j index in various regions.

Standard setting and main factor classification

For the sake of the study, this paper mainly adopts the standard specified by the country, industry and local, background and background standard, and existing standard or analogical standard. The terrain is the indirect factor of influencing the ecological safety as well as one of the important factors of determining the water and soil erosion, also restricts the land utilization type and the degree of water and soil erosion, and has important significance for the regional space ecological safety. Therefore, this study deems the Digital Elevation Model (DEM) based on 1:1,500,000 topographic map and grid of 10000m as the data base, carries out the gradient and slope aspect extraction, and analyzes the relief amplitude, so as to

reflect the terrain state of the provincial regions. Table for weight of the ecological safety evaluation index factors is shown in TABLE 2.

TABLE 1 : Space Ecological Safety Index System

Target layer	Criterion layer	Index layer	Data sources
State index of space ecological system	Climate index	Annual precipitation D1	Statistical data
		Runoff volume D2	Statistical data
		>0 ℃ accumulated temperature D3	Statistical data
		>l0 ℃ accumulated temperature D4	Statistical data
		Solar radiation intensity D5	Statistical data
	Terrain index	Gradient D6	DEM
		Slope aspect D7	DEM
		Relief amplitude D8	DEM
	Soil type	Soil fertility D9	Survey data
	Landscape structure index	Diversity index D10	Remote sensing data
	Ecological elasticity	Degree of fragmentation D11	Remote sensing data
		Ecological elastic force D12	Remote sensing data
	Vegetation coverage	Forest coverage rate D13	Remote sensing data
Space humanity and society pressure index	Industrial density	Industrial density D14	Statistical data
	Per capita cultivated land	Per capita cultivated land D15	Remote sensing data
	Reclamation rate	Reclamation rate D16	Remote sensing data
	Regional development index	Regional development index D17	Remote sensing data
	Population density	Population density D18	Statistical data
Environmenta l stress index	Desertification degree	Desertification degree D19	Remote sensing data
	Water and soil erosion rate	Water and soil erosion rate D20	Remote sensing data
Humanity and society response index	Resident cognition	Resident cognition D21	Survey data
	Resident response	Resident response D22	Survey data
	Net income of farmer	Net income D23	Statistical data

DESIGN OF REGIONAL SPACE ECOLOGICAL SAFETY EVALUATION MODEL AND ANALYSIS OF EVALUATION RESULT

Evaluation model

In view of the above analysis on the regional space ecological safety factors, we will make the quantification evaluation for the regional space ecological safety in the method of multi-stage weighted summation model for the evaluation factor attribute. The calculation model is shown in Formula 3.

$$V_{es} = \sum_{i=1}^{n} U_i W_i \quad \textbf{(3)}$$

In Formula 3, V_{es} means the ecological safety evaluation index, and U_i means the index magnitude. W_i means the index weight coefficient. n means the index number of some level in the evaluation index system.

We can comprehensively utilize the above model, calculate the weighted summation layer upon layer, and finally get the comprehensive index of the ecological environment evaluation.

Classification of space ecological safety evaluation

The regional space ecological safety degree is divided into 5 grades (TABLE 3), i.e. ideal safe conditions, good safer conditions, common early warning state, worse moderate warning state, worst serious warning state. The index values are between 1 and 0. The corresponding ecological system structure from perfection to loss of function, and the ecological system service function is decreased progressively till losing.

TABLE 2 : Table for Numerical Standardization of Regional Ecological Safety Evaluation Index Factors and Weight

Index layer	Level	Data standardized method	Symbol	Weight	Index layer	Level	Data standardized method	Symbol	Weight
D1	5	Range standardization	+	0.04702	D13	5	Range standardization	+	0.04035
D2	5	Range standardized method	+	0.03315	D14	5	Range standardized method	+	0.06982
D3	5	Range standardized method	+	0.03315	D15	5	Range standardized method	-	0.06982
D4	5	Range standardized method	+	0.03315	D16	5	Range standardized method	-	0.04896
D5	4	Range standardized method	-	0.03315	D17	5	Range standardized method	-	0.04896
D6	5	Expert classification method	+	0.06053	D18	5	Range standardized method	-	0.04896
D7	9	Expert classification method	+	0.04912	D19	5	Range standardized method	-	0.04035
D8	6	Expert classification method	-	0.04912	D20	5	Range standardized method	+	0.04035
D9	5	Range standardized method	+	0.03441	D21	5	Expert classification method	-	0.06982
D10	5	Range standardized method	+	0.04035	D22	5	Expert classification method	-	0.06982
D11	5	Range standardized method	+	0.04035	D23	4	Range standardized method	+	0.04513
D12	5	Range standardized method	+	0.04035	D24	4	Range standardized method	+	0.04513

Evaluation result

The factors of influencing the space ecological safety of the provincial regions in China include the natural factors as well as the social economic factors. Based on the model of "state – pressure – response", this paper builds the ecological safety evaluation index system of the provincial regions in China. By calculation, the ecological safety index of the provincial regions in China is 0.502, and the minimum regional ecological safety index is 0.288 and the maximum index is 0.669 in 1998. The ecological safety index of the provincial regions in China is 0.497, and the minimum regional ecological safety index is 0.298 and the maximum index is 0.611 in 2005. The ecological safety index of the provincial regions in China is 0.513, and the minimum regional ecological safety index is 0.265 and the maximum index is 0.596 in 2012. For the cross-section analysis, the whole ecological environment of the provincial regions in China is relatively poor, and the ecological environment is integrally in the common state (moderate warning). For the time series analysis, the regional space ecological safety degree of Yulin has the definite fluctuation, but it develops towards the favorable direction as a whole.

COUNTERMEASURES OF REGIONAL SPACE ECOLOGICAL SAFETY CONSTRUCTION

In order to slow down the ecological footprint, increase the ecological carrying capacity, and reinforce the ecological safety, firstly, it is necessary to strengthen the investment and management force of the ecological environment construction, and implement the natural forest protection project, grain for green project, and comprehensive treatment of water and soil erosion in drainage basin etc. Secondly, it is necessary to research and develop the appropriate technology, and promote the ecological benefits constantly. Thirdly, it is necessary to regard the technological reformation as the core, and the

industrial spatial structure adjustment as the main line, transform to the technology intensive from the labor intensive, and optimize the allocation of resources.

TABLE 3 : Classification of Regional Space Ecological Safety Evaluation

Grade	Safe conditions	Evaluation standard value	Index characteristics
I	Safe (ideal)	>0.9	The ecological system service function is basically complete, and the ecological system structure is complete. The ecological system is equipped with larger elasticity, and the ecological disaster is small.
II	Safer (good)	0.8-0.9	The overall ecological system service function is comparatively complete, and the ecological system structure is comparatively complete. The ecological system is equipped with the definite elasticity, and the ecological problem is smaller.
III	Early warning (common)	0.6-0.8	The ecological system service function is degenerated, and the ecological system structure has changes. The ecological system is equipped with the definite elasticity, and has larger changes even if it is subject to the smaller interference.
IV	Moderate warning	0.4-0.6	The ecological system service function is seriously degenerated, and the ecological system structure is incomplete. The ecological system hardly has the elasticity, and the ecological problem is serious even if it is subject to the smaller interference.
VI	Serious warning	≤0.4	The ecological system service function is basically lost, and the ecological environment has heavy damages. The ecological system structure is incomplete. The ecological problem is evolved into the ecological disaster.

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