Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 10 (2011) 2067 – 2074

Procedia Environmental Sciences

2011 3rd International Conference on Environmental Science and Information Application Technology (ESIAT 2011)

Comparison Study on Ways of Ecological Vulnerability Assessment

----- A Case Study in the Hengyang Basin

Yin Li1,a, Ya-ping Tian*2,b and Chao-kui Li[1,c]

1Institute of Geospatial Information Science, Hunan University of Science and Technology, Xiangtan 411201, China
2Department of Resources Environment and Tourism Management, Hengyang Normal University, Hengyang 421008, China
w.s_lin@yahoo.com.cn

Abstract

In the paper, Authors separately used analytical hierarchy process, expert scoring method, principal component and BP network to establish the weights of ecological vulnerability evaluation Index system in the Hengyang Basin as a case, and used hierarchical-comprehensive index -clustering model, principal component-comprehensive index-clustering analysis model, expert scoring-composite index-clustering analysis model, BP artificial neural network model to evaluate separately the reality vulnerability in 2000. The results shows that study area are moderate weak, and the results broadly similar. Authors think that Principal component and artificial neural network model can avoid subjective factors, and taking the way of the expert group judgment is to reduce the error of ecological vulnerability assessment.

With the impact of global change and the strengthening of fragile ecosystems, China has carried out many researches and practices on vulnerability assessments[1,14].Although Vulnerability assessment in many ways, not yet formed a unified evaluation method, this paper draw on previous evaluation methods based on [1,11], using AHP, principal component analysis, BP neural network and expert scoring method on quantitative assessment and analysis, then clustering the results by comparison to determine which method to evaluate the most accurate.Authors analysis the Hengyang Basin reality vulnerability in 2000,attempting to explore a more suitable and easy erosion in hilly areas degraded fragile vulnerability assessment method.

Keywords: Ecological vulnerability; Index system; Hierarchical analysis; Principal component analysis; Clustering analysis; BP artificial neural network model

Research Methods

The distribution of the weight factor directly affects results of the evaluation of Vulnerability. So it is important to confirm the most suitable method to determine the weight. In this study, the writer use AHP

doi:10.1016/j.proenv.2011.09.323

method, principal component analysis method, expert scoring method, artificial neural network method to determine the weights in order to find the most suitable and reasonable ways.

Analytical Hierarchy Process(AHP)

The analytical hierarchy process, was put forward in the middle of 1970's by professor Thomas L.Saaty[9].You need to establish evaluation system according to the specific situation of the level of structure to facilitate the evaluation of object-level analysis, to establish a clear hierarchical index system. Adopt expert giving assessment scores and mathematical synthesis method, to constructing a judgement matrixe. Let a layer has n elements (X1,X2,..., Xn) on the impact on the target layer, then each take two factors Xi, Xj are compared, A=Aij(m×n) said all the results, A judge of a matrix. To determine the value of Aij, Saaty proposed as a reference to the numbers 1-9 and the reciprocal scale, that is to say it is to be expressed by I,2,3,4,5,6,7,8,9,and their reciprocal value, its meaning is to take I,3,5,7,9 to express: the same important, a little more important, important, important much, absolute important; to take 2,4,6,8 to express the value taken being between the neighboring two items. the reciprocal value of each scale has opposite meanings.

Principal Component Analysis

Principal Component Analysis(PCA**)** can reduce the dimensions of multiple variables, so more of the original indicators were consolidated into fewer number of integrated indicators that is the common factor or principal components, when their cumulative contribution rate arrived 80% to 90% or more, they represent a strong common factor, the principle is:

$$\left.\begin{aligned} zx_1 &= u_{11}x_1+u_{21}x_2+\ldots+u_{p1}x_p \\ zx_2 &= u_{12}x_1+u_{22}x_2+\ldots+u_{p2}x_p \\ zx_p &= u_{1p}x_1+u_{2p}x_2+\ldots+u_{pp}x_p \end{aligned}\right\} \quad (1)$$

$u^2_{i1}+u^2_{i2}+\ldots+u^2_{ip}=1(i=1,2,\ldots,p)$,covariance matrix of $X=(x_1,x_2,\ldots,x_p)^T$ is $\Sigma>0(\lambda_1\geq\lambda_2\geq\ldots\geq\lambda_p\geq0,\lambda_i$ is non-zero characteristic root of Σ,u_i is λ_i feature vector).Calculating accumulation contribution of the principal component $zx_1,zx_2,\ldots,zx_p$, when accumulated variance are more than 85%,they represent a primitive variable. According to factor matrix of the evaluation factors, Calculated the common factor variance, and normalize it, so that the weight of each index can be obtained[11].

Expert Scoring

Expert scoring method is through anonymous consult the relevant experts, Based on the statistic al, analysis and induction, after many rounds of consultation, feedback and adjustment to analysis.

Back-Propagation(BP)Neural Network

Artificial Neural Network, is a nonlinear contains many simple computational units and BP network is one of the most widely used. Commonly, BP neural network comprises input, output and hidden layers. Neurons between adjacent layers are interconnected by weighting factors. BP network can learn to modify the connections between neurons weights, so the final error could to be minimum.
Input layer weights Hidden layer weights Output layer

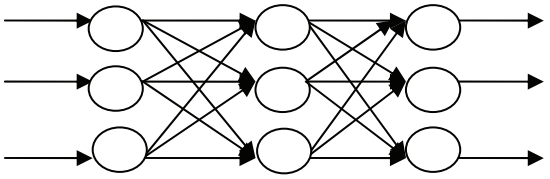

Fig. 1 BP network structure

Study Region

Hengyang City,is located in the south of Hunan Province, longitude 110°32'16"~113°16'32", Latitude 26°07'24"~27°28'24".Including the provincial cities of Hengyang City and Hengyang, Hengdong, Hengnan, Qidong, Changning and Leiyang other seven counties, the total land area 15310.2km^2,it has a certain basis of the vulnerability of the ecological environment.

Vulnerability Analysis

Those fragile environment has its own structural instability, and poor self-restoring the ecological environment. According to the study area south, the main choice could easily lead to erosion degradation factors and key indicators as evaluation indicators. Divide the ecological vulnerability into the reality vulnerability and potential vulnerability, the potential vulnerability includes climate, topography, material and soil and other natural elements determined by the combined effects of external interference may cause the sensitivity of ecosystem degradation ;the reality of vulnerability refers to the actual reality of the ecological environment caused by human activities have degraded the sensitivity of the ecosystem, human activities in considering the effect of interference generated by the potential vulnerability on the basis of an amendment. In this paper, the the reality vulnerability of 2000 Hengyang Basin were analyzed.

Constructing Assessment Index System

In the evaluation of scientific and operational principle of combining the indicator system. Select the main choice of altitude, slope, soil erodibility K values, rainfall, rainstorm, rainy and dry weight of the rainfall index for the potential vulnerability of drought index, select the forest cover and sloping vulnerability index as a realistic assessment of potential indicators of vulnerability based on indicators of human factor correction (Table1).As forest cover and sloping land area is the regional man-land relationship, socio-economic level of development and management of the combined effects of the results, it is no longer stack other indirect factors related indicators[7].

Table 1Grade and point value of evaluation indicators of Ecological vulnerability in Hengyang Basin

Ecological vulnerability	Factor	Grade and value	1	2	3	4	5
		Indicators	0～20	20～40	40～60	60～80	80～100
		Altitude[m](P_1)	>800	<100	500~800	300~500	100~300
		Slope[。]((P_2)	<5	5~10	10~15	15~25	>25
		Soil erodibility K values (P_3)	<0.15	0.15~0.20	0.20~0.25	0.25~0.35	>0.35
The	Natural factors	Rainfall [mm](P_4)	<800	800~1000	1000~1200	1200~1500	>1500
Reality		rainstorm [>100mm](P_5)	<1	1~4	5~8	9~14	>15
Environ							

-mental vulnera -bility		The proportion of rainfalland rainy(P_6)	<0.35	0.35~0.40	0.40~0.45	0.45~0.50	>0.50
		Dry index (P_7)	<1	1~1.25	1.25~1.67	1.67~2.5	>2.5
	Humanistic factors	Vegetation Coverage(P_8)	>70	50~70	30~50	10~30	<10
		Slopeindex (P_9)	5~10	10~15	15~20	20~25	>25

Calculation of Vulnerability Assessment Model

Each factor based on the evaluation index system of standardized values(f_i) and weight(w_i),using the following weighted sum of a common assessment model index calculated value of ecoenvironment vulnerability (p).The greater its value, the higher vulnerability.

$$p = \sum_{i=1}^{n=9} f_i \times w_i$$

An Empirical Comparison of Vulnerability Assessment

This paper takes the county collected for the evaluation of the indicator data. Using Index score standardize the original, the standard in Table 1,climate and vegetation cover index values are deri veed from statistical data, according to climatic characteristics of Hengyang City, the proportion of rainfall and rainy with 4 to 6 months of rain calculation, dry drought index of 7 to 9 months with rainfall and evapotranspiration calculation. Altitude, slope and slope farmland to the county level indicators of the size and the index score calculated weighted sum of standardized index; the value of soil erodibility index K of the soil types taken in the area of the county and the corresponding k value of the score calculation of the weighted sum of standardized index, the determination of weights is a key point of ecological fragility, use four methods to determine the weight on evaluation of ecological vulnerability assessment.

Evaluation Based on AHP

Using AHP to determine weights, the matrix shown in Table 2,and solve method matrix, then che ck consistency calculate the weights in Table 3,vegetation coverage and slope farmland weight is relatively large, namely 0.32 and 0.2,followed by the soil erodibility K values of 0.16,then slope is 0.1,the smallest is the drought index, as 0.02.Composite index calculated by the vulnerability is in Table 4.The most vulnerable is Hengnan, vulnerable value is 52.82,followed by Qidong, vulnerable value is 53.56,then the Hengshan and Hengdong vulnerable values respectively are 43.26, 40.09,Leiyang and Changning rather minimal, vulnerable values respectively are 40.11,40.6.

Table 2 Judgment matrix

B	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
P1	1	1/5	1/5	2	1/2	1/3	3	1/7	1/7
P2	5	1	1/2	4	3	2	5	1/5	1/3
P3	5	2	1	5	4	5	7	1/3	1/2
P4	1/2	1/4	1/5	1	1/3	1/5	3	1/8	1/7
P5	2	1/3	1/4	3	1	1/3	5	1/6	1/5
P6	3	1/2	1/5	5	3	1	6	1/5	1/4
P7	1/3	1/5	1/7	1/3	1/5	1/6	1	1/9	1/8
P8	7	5	3	8	6	5	9	1	3
P9	7	3	2	7	5	4	8	1/3	1

Table 3 Weights

Factor	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Weights	0.04	0.10	0.16	0.03	0.05	0.08	0.02	0.32	0.20

Table 4 Scores of Eco-logical vulnerability

County	Hengnan	Hengyang	Heng shan	Heng dong	Lei yang	Chang ning	Qi dong
Ecological vulnerability	52.82	45.61	43.26	40.09	40.11	40.60	49.36

Evaluation Based on Principal Component Analysis(PCA)

Using SPSS17.0 software to analysis all factors by principal component analysis, according to principal component loading matrix, calculate the factor of common factor variance, and be normalized to calculate the weight of each factor in Table 5,the maximum weight is the slope of 0.127, followed by vegetation cover and land slope, weights are 0.121, the value of the soil K, annual rainfall and annual torrential rain days, respectively 0.115,0.114 and 0.111,the smallest drought index, was 0.092. Composite index calculated by the vulnerability in Table 6.The most vulnerable is Hengnan, vulnerability value is 57.77, followed by Hengyang and Qidong, vulnerability values are 54.96,53.56,and then the Hengshan, vulnerability values are 51.69, 49.49 Hengdong, Leiyang and Changning are minimal, Vulnerability values are 48.11,46.18.

Table 5 Weights

County	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Weights	0.11	0.13	0.12	0.11	0.11	0.09	0.09	0.12	0.12

Table.6 Scores of Eco-logical vulnerability

County	Hengnan	Hengyang	Heng shan	Heng dong	Lei yang	Chang ning	Qi dong
Ecological vulnerability	57.77	54.96	51.69	49.49	48.11	46.18	53.56

Evaluation Based on Expert Scoring Method

Expert scoring method is through anonymous consult the relevant experts, opinions of experts in statistics, processing, analysis and induction, after many rounds of consultation, feedback and adjustment, determining the weights. weight in Table 7,the largest are land vegetation cover and slope, respectively 0.181,0.170, followed by soil K value, 0.116,drought index of the smallest, 0.062.Composite index calculated by the vulnerability in Table 8,we can find value for the Hengnan the most vulnerable, vulnerability value is 54.75,followed by the Hengyang and Qidong, vulnerability values are 50.46,51.30, and then the Hengshan, is 47.59,45.13 Hengdong, and Changning and Leiyang are minimal, vulnerability values are 44.10,43.27.

Table 7 Weights

Factor	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Weights	0.09	0.11	0.12	0.08	0.09	0.10	0.06	0.18	0.17

Table 8 Scores of Eco-logical vulnerability

County	Hengnan	Hengyang	Heng shan	Heng dong	Lei yang	Chang ning	Qi dong
Ecological vulnerability	54.75	50.46	47.59	45.13	44.10	43.27	51.30

Evaluation Based on BP Neural Network

To improve the generalization ability of neural networks(the correct response of data learning ability),normalized the input data between [0,1],the normalized function is p (:, i) = (p (:, i)-min (p (:, i)))/(max (p (:, i)) -min (p (:, i)));In this case the input layer has 9 neurons, the number of hidden layer according to n1 = 2n +1[14],identified the 23 neurons, output layer has 5 neurons in different levels, use of Matlab's neural network toolbox processing, in which selected newff, init, train, sim, respectively on behalf of the establishment of the network, initialization, training and simulation, created by the function as follows: net=newff(threshold,[23,5] ,{ 'tansig', 'log sig'},'traingdx').

Comparative analysis of evaluation results

Based on the four methods and cluster the evaluation results in Table 9.Obtained by county on the 2000 reality ecological vulnerability of Hengyang Basin, contrast the classification of ecological indicators of vulnerability[15],all show moderately weak, and the four methods results of cluster analysis are generally similar, so the four methods are feasible, PCA and expert scoring method was consistent, indicating that experts scoring and PCA can achieve consistent results. Four methods Calculated Hengnan, Hengyang relatively large degree on vulnerability, and Qidong second, Chan gning rather smaller. PCA, neural network are based on the training samples, could avoid the impact of human factors, the expert scoring method and principal component analysis can achieve consistent results based on many experts.

Table.9 Analysis results

Case Number	County	Cluster Membership（2000） Evaluation Based on AHP	Evaluation Based on Principal Component Analysis	Evaluation Based on Expert Scoring Method	Evaluation Based on BP Neural Network
1	Hengnan	1	1	1	1
2	Hengyang	2	2	2	2
3	Hengshan	3	3	3	3
4	Hengdong	4	4	4	3
5	Leiyang	4	4	5	4
6	Chang ning	4	5	5	5
7	Qidong	2	2	2	3

Conclusion

According to the vulnerability assessment methods, results of four methods are similar, so four methods are feasible, principal component analysis and expert scoring was consistent.

(1) AHP allows analysts and decision makers to communicate with each other. However, the compa rison, the judgments, and the results of calculations are rough, does not apply to high precision. pairwise comparison matrix established which subjective factors put a large impact on it, makes the results

difficult to make all the decision makers accept. Of course, group experts determine ways to reduce ecological vulnerability assessment error.
(2) Expert scoring method also has subjective factors. The results of it and PCA are very close, indicating that a number of expert scoring and the use of PCA can achieve consistent results.
(3) PCA method could objective and reasonable to determine weights and overcome artificial defects. Using SPSS17.0 calculating becomes relatively simple, objective and reliable.
(4) BP neural network model has its outstanding advantages, mainly reflected in the findings of the evaluation model of objectivity and universal applicability. BP artificial neural network model for model building, stability, convergence is also a need to ensure that the process over and over again, which is BP artificial neural network deficiencies. The neural network can be improved to enhance the scope of the network capacity.

Acknowledgement

The paper is supported by National Natural Science Foundation of China (40971067). Corresp onding author is Ya-ping Tian(1958-),Female, Lulong, Hebei Province, Ph.D, Professor. Engaged in physical geography teaching and research, her email is typnj@163.com. The Graduate Innovation Foundation,Hunan University of Science and Technology,China,under grant S100130.

References

[1] Wei-ci Su and Jing-lan Mo: A Preliminary study on the regionalization of Eco-environmental fragility in karst region. Guizhou Science. Vol.11(1993), p.24~30.

[2] Shu-fang Huang: Application of Principle Component Analysis and Mapinfo in the Assessment of Fragile Degress of Eco-environment. Fujian Geography. Vol.17(2002),p.47～49.

[3] Ke Zhao Yi Rao, Li-li Wang, et al: Evaluation of f Eco-environmental fragility in southwest of China. Journal of Geological Hazards and Environment Preservation. Vol.15(2004),p.38~42.

[4] Jian Yao Study on Eeo-environmental Fragility and Assessment in Upper Researches of Minjinag River.Sichuan: Sichuan University(2004).

[5] Yunhua Gu:Study on Assessment of Eco-environment Fragility in Karst Areas Based on RS&GIS. Guizhou: Guizhou normal University (2004).

[6] Jian Yao DING Jing and AI Nan-shan: Assessment of Ecological Vulnerability in Upper Reaches of Mingjiang River. Resources and Environment in the Yangtze Basin.Vol.13 (2004),p.380~383.

[7] Ya-ping Tian, Peilin Liu, Wen-wu Zheng: Vulnerability assessment and analysis of hilly area in Southern China: a case study in the Hengyang Basin. Geographical Research,Vol.24 (2005), p. 843-852.

[8] Hong-mei Zhang: The Application Study of Monitoring and Appraisal about the Regional Ecological Environment Fragility Based on Remote Sensing and GIS. Fuzhou: Fujian normal University(2005).

[9] Huan-zhen Chen: Eco-environmental Vulnerability Evaluation on Dawenhe River Drainage Area of Shandong Province Based on GIS and Countermeasures. Sci/Tech Information Development &Economy, Vol.15(2005),p.208~209.

[10] Zhi-feng Zhao: Evaluation of Eco-environment Fragility in Dengkou County, Inner Mongolia, China. Lanzhou: Xibei normal University(2007).

[11] Wei-you Huang: Study on the Ecological fragility in Minjiang Watershed Based on GIS Technology. Fujian: Fujian. Fujian Agriculture and Forestry University(2007).

[12]Li Li: Assessment index system and evaluation methods of research on Small towns ecological environmental quality. Wuhan: Wuhan Agriculture and Forestry University(2008).

[13] Peng Wang, Ying Zhao, Ya-ping Tian: Study on the Vulnerability of Ecological Environment in Hengyang City Based on GIS. Research of Soil and Water Conservation, Vol.16(2009),p.24~29.

[14] Guo-jun Sun: Evaluation of Eco-environment Fragility with BP artificial neural networks in Wu late Country, Inner Mongo lia, China. Lanzhou: Xibei normal University(2009).

[15] Deming Shi, Yin Liang: Evaluation and Conservation of Fragile Ecological Environment in China. Journal of Soil and Water Conservation,Vol.1(2002),p.6～10.