The Study on the Potential Eco-Environment Evaluation Based on GIS in Longzhong Loess Plateau

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Abstract

This paper evaluates the potential eco-environment of Longzhong Loess Plateau by using the principal component analysis with GIS software Arc/info. Firstly, found the Digital Environmental Model (DEM) which consists of seven influential factors to the potential eco-environment of the study area; secondly, perform principal component analysis to the second class indexes to obtain the first class indexes—terrain indexes, soil indexes, and eco-climate indexes; get the potential eco-environment index in the same way. There are many methods that could be used to evaluate eco-environment, such as AHP (The Analytic Hierarchy Process), but most of them are subjective. The principle component analysis not only extracts a fewer factors from many influential factors, but also provides the weights of the principal components to avoid the subjectivity of the experts.

I. INTRODUCTION

The degeneracy of eco-environment is one of the most essential problems that people are facing at present throughout the world. It not only makes the natural resources dried up increasingly, the diversification of organism reduced constantly, but also hinders the sustainable development of social economy seriously. It is now threatening the existence of mankind (Ye et al., 1992; Yan et al., 1999; Fu et al., 1996). The degeneracy of eco-environment has caused people's great concern and the study on recovering and reconstructing the ecological environment has become one of the hottest spot subjects at present (Jordan, 1987; Hobbs, 1996). Therefore, It urgently needs to analyze and appraise the potential ecological environment to provide foundations for recovering and reconstructing ecology.

There are lots of methods for studying eco-environment, such as Qualitative analysis, fuzzy clustering (Yang et al., 2000), and overlaying the eco-environment factors (Gao et al., 1999; Hu et al., 2000; Li et al., 2000; Meng 2000; Xiao et al., 1999; Ye and Liu, 2000; Zhao and Zhang, 1999). The last method is most be used and where the shoe pinches by using the method is that how to confirm the weights of the eco-environmental factors. There are two methods most be used that can do this work. One is AHP (Meng et al., 2000; Gao et al., 1999) which assesses the weights of the eco-environmental factors by expert, the other method is by using regressing the index of eco-environment and the eco-environmental factors. The former method is subjective for the acquisition of the weights by experts' assessing and the latter is very difficult to acquire the index of eco-environment which often we want to get at last.

This paper chooses the PCA (principal component analysis) method, which can integrate the information containing many indexes to a fewer index to reduce the redundancy of data which is very important to retrench the resource of computers. And then, use the sum of the product of the principal component and its corresponding weight which is the quotient of its corresponding eigenvalue to the sum of all the eigenvalues of their correspond principal components to substitute the sum of the primal data and their correspond weights, which is objective.

II. THE STUDY AREA

Longzhong Loess Plateau is a part of Gansu Loess Plateau. The northern boundary is the front of the east part of Qilian Mountains, the eastern boundary is the Liupan Mountains, the southern boundary is the northern foot of Taizi Mountain-western Qinling Mountains, and the western boundary is the borderline between Gansu Province and Qinghai Province. The elevation is mostly 1200-2000m, and the northern part is higher than southern part. The physiognomy is mainly made up of Loess girder, ridge, and river valley, etc, which cause gully dense, the slope steep, the ditch close and the topography broken. The study area belongs to half-arid region, temperate zone. It shows the characteristic of heat, which places upside down in north and south in some scope. From the south to the north the annual precipitation decreases from 600mm to 150mm and the annual precipitation variability is up to 40%. These natural conditions outstandingly reflects vegetation distribution, which displays typical grasslands in southern part and hungriness in northern part.

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III. MATERIAL AND METHODS

The Index system and the source of data

The eco-environment is a life system, which consists of different layers of organism in ecosystem except the human population (Jin, 1992). The potential eco-environment means the developing base of this life system and it includes three systems: terrain, climate and soil. According to the regional characteristics of Loess Plateau, this paper chooses seven indexes which are in three subsystems to build a comprehensive index system which can reflect the potential eco-environmental condition of this area(Table 1).

The terrain data come from the 1:250,000 digital topographic maps provided by Survey and Map Bureau of Gansu Province; the ecological climate data come from the practical measuring documents of 46 stations, which is provided by Gansu Weather Bureau and the soil data come from the 1:500000 soil type map.

Construct the DEM

The DEM (Digital Environment model) has been developed on the basis of DTM (digital Terrain model), which emphatically reflects the digital terrain characteristic of eco-environment. The DEM is chiefly used to assess and analyze environment. Usually the GRID structure is easier to apply than vector structure because the operation of union and the logical algebra can be easily carried out, which just meet the needs of environment analysis and evaluation (ESRI, Inc.,1992). Through the unified ALBERS' projecting shift, all eco-environment factors in the model are changed into GRID data with unified size of 50*50m, and then various operations of algebra and logic on the basis of GRID structure can be achieved.

The projection parameters used in this paper: the central meridian is 104.649°E, the two-secant latitudes respectively are 34.674°N and 37.045°N and the initial calculating latitude is 34.080°N. The method of converting to the unified GRID data format is different, because the acquisitive ways of environment factors are different (vector data, GRID data and ASCII data format).

Process terrain data

Terrain data are vector form and contain three coverages: the one containing contour lines, other containing the spots of elevation, another containing lakes which will be used to replace poly coverage in TIN. Firstly, the original Gauss-Kruger projection of these coverage is converted to ALBERS projection which is needed by assessment; Secondly, the point coverage and line coverage are converted to GRID form by using the ARCTIN and TINLATTICE command of ARC/INFO. Then using the gradient and slope direction function provided by GRID module produces the GRID form of gradient and slope direction.

Process ecological climate data

Ecological climate index is dot and location data. Firstly, the latitude and longitude coordinates of 46 observational stations inside and nearby the area are changed into ALBERS projection system according to projection parameters. Then, the precipitation index is linked with space locations, using the Build command of ARC/INFO to create space topology and using the ARCTIN and TINLATTICE command to change dot-location data into GRID data through interpolation.
ABT changes greatly with the elevation increasing, however, the interpolation method provided by ARC/INFO does not consider the changes of topography on the whole at present. Therefore it is necessary to adjust the ABT of interpolation. Under the statistics software SPSS' support, according to the formula provided by Hold ridge's life belt classification system, the monthly average temperature data should be pretreated (Fang et al., 2000), then regression analyzing can be started to get the regression coefficient, which is -0.00368. And then adjust the ABT of station providing these data to the datum when the elevation is the lowest. At last ABT is changed into GRID form using the conversion mode of rainfall and is adjusted according to regression coefficient. Finally the data model of ABT is formed.

Under GRID module and according to evapotranspiration formula provided by Hold ridge (Fang et al., 2000), the calculation of potential evapotranspiration rate forms the digital model using algebraic operation.

Table 1. The system of potential eco-environment assessment index

First class index	Second class index	Data's realization
	Elevation height	DEM
Topographic index	Gradient	SLOPE command form
	Slope direction	ASPECT command form
	ABT	$1/12\sum t_i$ (t_i is the monthly average temperation, $0 \leq ti \geq 30$℃)
Ecology climate index	PER	58.93ABT/P (ABT is the biotemperature, P is the annual average precipitation)
	P	the annual average precipitation
Soil index	Soil assess	

Process soil data

The soil evaluation index comes from soil type map and the attribute of soil type can be defined according to each type of soil resources assessment result provided by The soil in GANSU. Using POLYGRID command provided by ARC/INFO, the soil evaluation map of vector can be converted to GRID structure.

Quantize processing of index

The quantification of index is one of the vital technologies whether the eco-environment can be evaluated correctly and quantitatively (Zheng and Wang, 2000). The assessment index and eco-environment have two kinds of relations, positive and negative. No matter seen from the classified results of index or from the measure unit, neither of them has comparability. Therefore it is necessary to carry out the quantification processing for index. This paper adopts classified standardization processing method and the basic principals are as follows:

1). The definition of environment factor classifying bases on the correlative study of eco-environment quality.

2). The factors that have positive correlative effect on eco-environment should use the following formula to carry out the quantification processing: 100 (Xi – Xmin) / (Xmax – Xmin); the factors that have negative correlative effect should use following formula to carry out the quantification processing: 100 (Xmax – Xi) / (Xmax – Xmin). In these formulas, Xi is the actual datum of this factor; Xmin is the minimal domain datum in the study area; Xmax is the biggest domain datum of this factor in the study area. Those indexes, which need the basis of class, first be classified, and then use the formulas mentioned above to process quantification.

Principal component analysis and calculation of synthetic assessment index

The condition of eco-environment is affected by multifactor synthetic environment, and it is always very worthy of discussing this problem of synthesizing many indexes to one synthetic evaluation index at the time of synthetic evaluation (Hu and Ren, 1998; Hu, 1998; Huang et al., 2000). In the course of actual application, the basic condition of defining the number of principal component is to meet the balance between contribution rate and accumulative contribution rate of principal component. Usually it is very desirable when accumulative contribution rate is over 80% (Xu, 1994).

On the basis of accomplishing principal component, construct the assessment's model and calculate the potential eco-environment synthetic index. The synthetic index is defined as the weighted sum of m kinds of principal component and the weight is given by corresponding contribution rate of each principal component. Therefore the evaluation model can be defined as: Y = a1*Y1 + a2*Y2 + … + am* Ym. According to the dimensions of Y, each evaluation unit can be sequenced. Under the supporting of ARC/INFO GRID module, with PRINCOMP function people can adopt the principal component analysis each first index.

1). Select elevation height, gradient and slope direction to do principal component analysis and calculate the topography synthetic index:
OUTDEM = 0.583 * DPC1 + 0.4165 * DPC2
In this formula, OUTDEM is terrain synthetic index; DPC1 is the first principal component extracted from gradient, slope direction and elevation height's principal component analyzing and DPC2 is the second principal component. The accumulative contribution rate of two principal components is 99.95%. It means that the information loss is only 0.05% and the credibility is high.

2). Select ABT, precipitation and potential evapotranspiration rate to do principal component analysis and calculate the synthetic index of ecology climate.
OUTM = 0.7276 * MPC1 + 0.2461 * MPC2
In this formula, OUTM is the synthetic index of ecology climate; MPC1 is the first principal component extracted from ABT, precipitation and probably evapotranspiration rate's principal component analyzing and MPC2 is the second principal component. The accumulative contribution rate of two principal components is 97.37%. It means that the information loss is only 2.63% and the credibility is high.

3). Selecting terrain, ecological climate and soil evaluation synthetic index to do principal component analysis and calculate the potential eco-environment index:
EE = 0.4472* EEPC1 + 0.3404 * EEPC2 + 0.2124 * EEPC3
In this formula, EE is the potential eco-environment index; EEPC1 is the first principal component extracted from terrain; soil and climate factor's principal component analyzing, EEPC2 is the second principal component and EEPC3 is the third principal component. The accumulative contribution rate of three factors is up to 100% with almost no information losses.

IV. RRESULTS

According to the above analysis, the potential eco-environment quality condition in Longzhong Loess Plateau has been shown by Figure 1 which is obtained by classifying the grid of the EE to 10 classes. In this area, the broken terrain results in the great difference between climate and soil condition, therefore the potential ecology condition does not show the clear horizontal regionalism, but it shows very strong vertical regionalism. Those areas with better environment distribute the river-valley region, in contrast, those area with worse quality distribute in the higher elevation region. Table 2 shows the concrete content of potential eco-environment in this area. Using the Arc/INFO command of CORRELATION to calculate the cross correlation between the grid EE and OUTDEM, and the correlation coefficient is 95.2%.

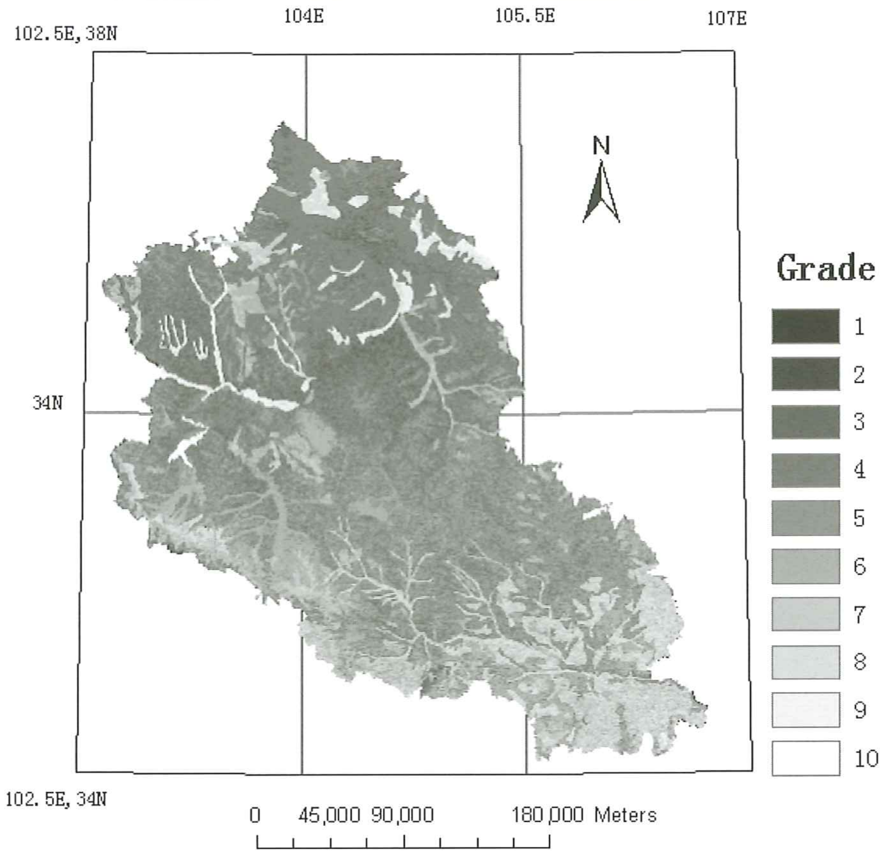

Figure 1. Synthetic assessment index grade of eco-environment in Longzhong Loess Plateau

Table 2 shows the concrete content of the potential eco-environment in this area. The best condition (The grade$\geq$ 8) which is no restriction for the growth of vegetables is 7.65%, the secondary (8 > the grade$\geq$ 6) Which has some restriction to the growth is 21.58%, the bad condition (The grade < 6) is 70.76%. That is to say, Most of the study area is under the bad condition which is not suited to plant. If these areas has been developed to plant, they are should be changed to grow grass or some kinds trees which are agreeable to the condition of the area.

Table 2. Synthetic assessment index grade of eco-environment in Longzhong Loess Plateau

Grade	Synthetic Index	Percent
1	0~10	0.000121365
2	10~20	0.003575189
3	20~30	0.056210922
4	30~40	0.333366552
5	40~50	0.314340727
6	50~60	0.120944121
7	60~70	0.094926865
8	70~80	0.057780478
9	80~90	0.017188088
10	90~100	0.001545693
Mean Grade	5.1036	

From the point of regionalism, the potential eco-environment shows greatly zoned. Figure 2 is calculated though the following the formula.

$$SCIn = A1\times N1 + A2\times N2 + \ldots\ldots. + Am\times Nm$$

where n is the country, SCI is the synthetic Index of the country's potential eco-environment, m is the number of the kinds of the value which the country has, A is the potential eco-environment value which is a floating point number and ranges from 0 to 10, and N is the number of the grid whose value equals to A.

Table3 is the detailed information of all the countries in this area. There is not big difference among these countries, but it shows strongly zoned. Generally, the south is better than the north in this area and it is easily to see that there are three zones which strongly relate to the economical and social development. It is significant to calculate the synthetic index of the country for it can make the natural factors which have the fine scales such as DEM match the social or economical factors which have coarse scale (In china, it often makes country as the units).

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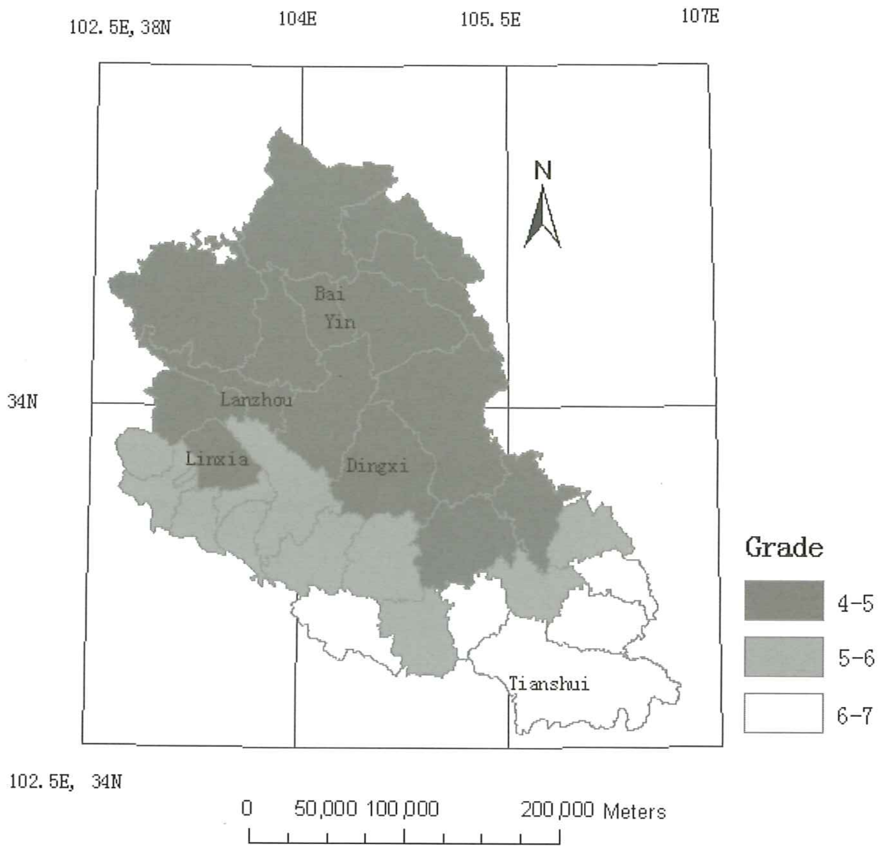

Figure 2. Potential Eco-environment assessment of countries in Longzhong Plateau

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Table 3. The synthetic potential Eco-environment assessment of countries in Longzhong Plateau

The country name	SCI	The county name	SCI
Baiyinshi	4.35	Dingxi	4.70
Jingtai	4.52	Jingyuan	4.68
Yongdeng	4.70	Gaolan	4.52
Lanzhou	4.94	Yuzhong	4.50
Huining	4.60	Yongdeng	4.50
Lintao	5.08	Dongxiang	4.70
Jishishan	5.09	Linxiaxian	5.52
Jingning	4.95	Linxiashi	5.86
Tongchuan	5.02	Hezheng	5.87
Tongwei	4.98	Kangle	5.65
Longxi	5.20	Zhangjiachuan	6.43
Qin'an	5.84	Gangu	6.01
Qingshui	6.39	Zhangxian	6.02
Wushan	5.49	Tianshuishi	6.50
Weiyuan	5.80	Zhuanglang	5.08
		Mean	5.10

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