Research on Eco-geological Environment Carrying Capacity Based on GIS Technology

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Abstract. The environmental carrying capacity is also called environmental bearing capacity. The eco-geological environment carrying capacity is the limit of the environmental capacity to support human society and economic activities under a certain environmental condition in a certain period of time, combined with the factors of the ecological environment, the geological environment, and the socio-economic environment, it is an important basis for developing resources. Resources and the environment are the basis for human survival and development, with the development of society and the development of resources, the carrying capacity of resources and the environment in many areas has exceeded the limit, which has caused many environmental problems. Therefore, this paper studies the ecological environment carrying capacity based on GIS, hopes to provide some guidance for environmental protection.

Keywords: carrying capacity, GIS technology.

1. Introduction
With the increase of human activities, the impact of humans on the natural environment is also increasing. Due to the excessive development of human environment and resources, a large number of environmental problems emerge, such as soil erosion, land desertification, environmental pollution, and species reduction, etc., the ecological environment is deteriorating day by day, and one of the reasons is that humans have caused a lot of direct and indirect pollution to the land when developing the land. When people use lands develop projects, many times they do not consider the pollution to the ecosystem and the cost of subsequent damage to the environment. Based on this, this paper calculates the ecosystem services for the cost of land use and establishes the corresponding indicator system, the index was determined by using principal component analysis, and the eco-geological environment carrying capacity is calculated according to different project scales.
2. Research Status at home and Abroad

2.1. Research status of environmental carrying capacity

At present, many researchers at home and abroad have done studies related to environmental carrying capacity, they have done a lot of studies on related theories, scientific significance, quantitative models, measurement methods, and evaluation index systems of environmental carrying capacity, and have obtained a certain amount of research results, believe that in-depth research on issues related to environmental carrying capacity will help regulate social and economic activities. In recent years, environmental carrying capacity has been widely used in the research fields of various environments and resources, such as land, water environment, atmospheric environment, biology, transportation environment, mineral resources, and tourism environment. The research on the related issues of environmental carrying capacity continues to develop, and there are more and more theories and research results on environmental carrying capacity, this paper uses table to list the viewpoints of various scholars.

Table 1. Research on quantitative models of foreign environmental carrying capacity

| time         | scholar             | main viewpoint                                                                 |
|--------------|---------------------|-------------------------------------------------------------------------------|
| 1960s and 1970s | American D. Meadows et al. | use the system dynamics model evaluate the interrelationship between the resource environment and human society worldwide |
|              | British scholar     | use the Ecco model calculate the carrying capacity of resources and the environment, this model comprehensively considers the population and resources and environment elements, and simulates the elastic relationship between the population and the carrying capacity of the resources and the environment under different development models |
|              | Slesse              | use multi-objective decision analysis method calculate the carrying capacity of land resources, analyze the calculation results, and put forward corresponding improvement measures |
| 2001         | Italy Sergio Ulgiati | on the basis of the energy analysis of regional environmental resources, introduce a quantitative method for evaluating the carrying capacity of economic development, which includes two parts: long-term carrying capacity and short-term carrying capacity |

2.2. Research methods and technological routes

This paper draws on the experience of the research methods adopted by the predecessors, studies the eco-geological environment carrying capacity, determines the index, thus establishing the evaluation index system, constructs the evaluation model, and then combines the GIS technology to carry out the evaluation, put forwards opinions and suggestions on resource development, functional zoning and land use, as shown in Fig.1.
Fig. 1 Technological route of ecological environment carrying capacity research

2.3. Research status of geological environment evaluation
Environmental assessment is a branch of environmental science. In the 1960s, countries around the world began to pay attention to environmental quality research (see Table 2).

| time  | scholar                                      | main viewpoint                                                                 |
|-------|----------------------------------------------|--------------------------------------------------------------------------------|
| 1969  | American scholars                            | formulated the National Environmental Policy Law and established the environmental impact assessment system for the first time |
| 1971  | Scholars from the United States, Canada, Russia and other countries | proposed various environmental indexes to measure the level and changes of environmental quality |
| 1974  | International Union of Science              | held environmental quality conference and published after the conference proceedings |
| 1999  | Chinese scholars                             | gave the guiding exposition on the methods and processes of applying GIS technology to realize regional geological environment evaluation |
3. Index Establishment
In order to determine the true economic cost of land use projects when considering ecosystem services, we first establish a formula to calculate the true economic cost:

\[ W = T + C + E + O \]

In the formula, \( W \) is the real economic cost, \( T \) is the land cost, \( C \) is the construction cost, \( E \) is the environmental cost, and \( O \) is other costs. For this model, the environmental cost is mainly analyzed; the environmental cost includes the pollution control cost caused by the production of raw materials, the pollution control cost during the construction period, the pollution control cost during operation, and the benefits generated by environmental governance. Among them, there are many influencing factors on the pollution control cost during the operation of the project, so the influencing factors in this area are firstly screened, furthermore, with the minimum cost; the main indexes are selected to simplify the formula for calculating the pollution control cost during operation.

This paper uses the Pressure-State-Response model to construct the scientific and reasonable land development environmental performance evaluation index system, and analyzes it from a new perspective, and evaluates pollution costs. The new evaluation indexes are shown in Table 3.

| first-level index                          | second-level index                                      |
|-------------------------------------------|--------------------------------------------------------|
| basic indexes of air quality              | total suspended particulate(TSP), sulfur dioxide (SO\(_2\)), nitrogen oxides (NO\(_x\)) |
| basic indexes of water environment quality| chemical oxygen demand (COD), ammonia nitrogen, total nitrogen |
| basic indexes of soil environment quality  | Chromium (Cr), Arsenic (As), Lead (Pb), Copper (Cu), Zinc (Zn), Nickel (Ni) |

Since some pollution factors produced by land use projects are difficult to control and are costly, and the amount of pollution factors is small, and the pollution to the environment is small, priority is given to factors that cause greater environmental pollution. 14 pollution factors that have a relatively large impact on the environment are selected, and the pollution conditions and indexes of large, medium, and small land use projects are collected through remote sensing images and various data, and the images are processed and extracted by ArcGIS software data. Later, the principal component analysis is conducted, and the factors after the principal component analysis are scored, the two secondary indexes of air, water environment, and soil with higher scores are selected as the main indexes for the final calculation, namely screening out the 6 main real economic cost indexes of the project, and use principal component analysis to classify and verify the project. It is believed that the three categories of small engineering projects, medium-sized engineering projects, and large-scale engineering projects can be separately estimated for cost, and then pave the way for calculating environmental costs and benefits.

4. Build the Model
Standardize the raw data. There are \( m \) index variables for principal component analysis, namely \( x_1, x_2, x_3,..., x_m \), there are a total of \( n \) evaluation objects, and the value of the \( j \)-th index of the \( i \)-th evaluation object is \( a_{ij} \). Convert each index value \( a_{ij} \) into standardized index value, there are:

\[ a_{ij} = \frac{a_{ij} - \bar{u}_j}{s_j} \]

\( i = 1, 2, ..., n; j = 1, 2, ..., m \)

In the formula, \( \bar{u}_j = \frac{1}{n} \sum_{i=1}^{n} a_{ij} \), \( s_j = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (a_{ij} - \bar{u}_j)^2} \)

\( j = 1, 2, ..., m, u_j, s_j \) is the sample mean and sample standard deviation of the \( j \)-th command. Corresponding, \( x_j = \frac{x_j - \bar{u}_j}{s_j} \), \( j = 1, 2, ..., m \) are standardized index variables.

Calculate the correlation coefficient matrix \( R \). Correlation coefficient matrix \( R = (r_{ij})_{m \times m} \),
\[ r_{ij} = \frac{\sum_{k=1}^{n} a_{ki}}{n - 1} \]

\(i,j=1,2,\ldots,m.\)

In the formula, \(r_{ii}=1, r_{ij}=r_{ji}\), \(r_{ij}\) is the correlation coefficient between the \(i\)-th index and the \(j\)-th index.

Calculate eigenvalues and eigenvectors. Select \(p(p<m)\) principal components and calculate the comprehensive evaluation value. Calculate the information contribution rate and cumulative contribution rate of eigenvalue \(\lambda_j\) (\(j=1,2,\ldots,m\)).

\[ b_j = \frac{\lambda_j}{\sum_{k=1}^{m} \lambda_k} \]

\(j=1,2,\ldots,m\) is the information contribution rate of the main component \(y_j\), moreover,

\[ a_p = \frac{\sum_{k=1}^{p} \lambda_k}{\sum_{k=1}^{m} \lambda_k} \]

is the cumulative contribution rate of the principal components \(y_1, y_2, \ldots, y_p\). When \(a_p\) is close to 1 (usually \(\alpha_p=0.85, 0.90, 0.95\)), the first \(p\) index variables \(y_1, y_2, \ldots, y_p\) are selected as \(p\) principal components, replace the original \(m\) index variables, thereby comprehensive analysis is conducted for \(p\) principal components.

Calculate the comprehensive score \(z = \sum_{j=1}^{p} b_j\); \(b_j\) is the information contribution rate of the \(j\)-th principal component, which can be evaluated based on the comprehensive score.

5. Conclusion

It can be seen that there is strong correlation between certain indexes, if these indexes are directly used for comprehensive evaluation, it will inevitably cause overlap of information and affect the objectivity of the evaluation results. By evaluating secondary indexes, we can more accurately estimate the eco-geological environment carrying capacity of a certain place.

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