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A Review of Research Methods of Land Resources Carrying Capacity

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Abstract

The carrying capacity of land resources is the basis of urban development strategy decision-making, which is of great significance for guiding urban sustainable development and serving the national strategic needs. This paper combs the historical development process of the theory of land resources carrying capacity from the initial stage to the regional carrying capacity stage, and the relevant research hotspots at home and abroad in recent years. The research on the carrying capacity of land resources gradually began to cross with the directions of ecological environment, socio-economic development, climate change and other disciplines, and the research direction continued to expand. However, at present, there are still some shortcomings in the research on the carrying capacity of land resources, some quantitative research and dynamic monitoring mechanisms are not yet mature, and the evaluation index system of land resources carrying capacity needs to be further improved. At present, the more mature analysis and evaluation methods include TOPSIS method with entropy weight, global Moran's I index method, geographical probe analysis method and so on. In the future, in order to further guide and serve the ecological sustainable development of cities, the research on land resources carrying capacity still needs to be expanded to multi-scale and multi-factor aspects, and more statistical models and machine learning should be introduced to meet the multi-faceted needs of the new era.

Keywords

Carrying Capacity of Land Resources; Suitability Evaluation; Sustainable Development; Spatial Planning.

1. Introduction

Land resources refer to the land and its natural and cultural resources within a certain geographical scope, including soil, water, climate, vegetation, animals, minerals and cultural heritage. The carrying capacity of land resources refers to the capacity of population and economic development that land resources can carry in a certain period of time. The carrying capacity of land resources is an important index to evaluate the sustainable utilization of land resources, and it is also one of the basic conditions to protect the ecological environment and realize sustainable development.

In the study of land resources carrying capacity, different regions and scholars have different understanding and application of its definition and evaluation method. Therefore, there are many studies aimed at formulating more scientific evaluation methods of land resources carrying capacity, such as the evaluation methods of ecological carrying capacity based on material, energy and information flow, and the evaluation methods of land carrying capacity based on land quality and land use types.

The carrying capacity of land resources is affected by many factors, including land quality, land use pattern, population density, climate change and so on. Through model simulation, statistical

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analysis and other methods, the researchers discussed the influence mechanism of different factors on the carrying capacity of land resources, and provided scientific basis for formulating the sustainable utilization strategy of land resources.[1,2].

In view of the problems existing in different regions and different types of land resources carrying capacity, the researchers put forward a variety of sustainable land management strategies, such as optimizing land use structure, implementing land ecological restoration and protection, and improving agricultural production methods. The researcher also evaluates the impact of different strategies on the carrying capacity of land resources through field investigation and case study, and puts forward implementation suggestions.[3].

The carrying capacity of land resources is an important basic condition to realize sustainable development. Therefore, researchers have conducted in-depth research on the relationship between the carrying capacity of land resources and sustainable development, and put forward a variety of theoretical frameworks and practical methods, which provide important reference and guidance for realizing sustainable land use and sustainable social development.

At present, the scientific research on land resources carrying capacity in the world mainly focuses on evaluation methods, influencing factors, sustainable land management strategies and the relationship between land resources carrying capacity and sustainable development. [4].

2. The Development of the Theory of Land Resources Carrying Capacity.

The development of land resources carrying capacity theory has gone through different stages, such as initial stage, quantitative evaluation stage, ecological carrying capacity stage and regional carrying capacity stage. The theoretical framework and evaluation method have been continuously improved and innovated, which provides theoretical basis and method support for the sustainable utilization of land resources, and also provides important reference for protecting the ecological environment and realizing sustainable development. The development course of the theory of land resources carrying capacity can be summarized as the following stages:

1. Initial stage: The initial stage of the theory of land resources carrying capacity appeared in the 1970s, mainly focusing on the study of land use intensity. The representative research results at this stage include "land carrying capacity model" proposed by Blomquist, a Dutch scholar, and "land resources carrying capacity model" proposed by Pimentel, an American scholar.

2. Quantitative evaluation stage: In 1980s, the theory of land resources carrying capacity gradually developed towards quantitative evaluation. The representative research results at this stage are the "economic and ecological model" put forward by American scholar Daly, and the quantitative evaluation methods such as "maximum sustainable output" and "ecological and economic indicators" are put forward.

3. Ecological carrying capacity stage: In 1990s, with the improvement of environmental protection awareness, the theory of land resources carrying capacity further developed towards ecological carrying capacity. The representative research results at this stage include the concept of ecological carrying capacity put forward by China scholar Li Xueyong and the model of ecological productivity put forward by Dutch scholar Reijnder.

4. Regional carrying capacity stage: Since the 21st century, with the intensification of economic globalization and regional development differences, the theory of land resources carrying capacity has further developed in the direction of regional carrying capacity. The representative research results at this stage include "Evaluation Model of Regional Land Carrying Capacity" proposed by China scholar Wang Shaoqiang and "Regional Sustainability Index" proposed by American scholar Cohen.

ISSN: 2710-0723

3. Research Hotspots of Land Resources Carrying Capacity

With the continuous growth of global population, the acceleration of urbanization and the influence of climate change, the problem of land resources carrying capacity has been paid more and more attention. Scientific research around the world mainly focuses on the following aspects:

1. Evaluation of regional land resources carrying capacity;

Through the construction of evaluation index system and evaluation model, the carrying capacity of land resources in different regions is comprehensively evaluated, which provides scientific basis for policy formulation and decision-making.

2. Study on the relationship between land resources carrying capacity and ecological environment;

This paper discusses the relationship between the carrying capacity of land resources and the ecological environment, analyzes the influence of land resources development and utilization on the ecological environment, and puts forward reasonable land use methods to ensure ecological security.

3. Study on the relationship between land resources carrying capacity and social and economic development;

This paper discusses the relationship between the carrying capacity of land resources and population and economic development, analyzes the impact of land resources development and utilization on social economy, and puts forward reasonable land use planning and management measures to promote sustainable development.

4. Study on the relationship between land resources carrying capacity and climate change;

This paper discusses the influence of climate change on the carrying capacity of land resources, analyzes the suitable utilization mode and development mode of land resources under different climate conditions, and puts forward adaptive land use strategies to meet the challenges of climate change.[5].

4. Insufficient Research on Land Carrying Capacity.

The research on land resources carrying capacity is still insufficient in quantitative research, spatial analysis, dynamic monitoring and social participation, so it is necessary to further strengthen the research and improve the scientific and credible evaluation. Mainly in the following aspects:

1) Insufficient quantitative research:

At present, most of the research on land resources carrying capacity adopts qualitative methods, but there is still a lack of quantitative evaluation methods and index system. Therefore, in the actual evaluation process, there are often subjective and difficult to compare problems, and can not provide scientific basis.

2) Spatial analysis ability is not strong:

The existing research on the carrying capacity of land resources is mainly concentrated in local areas, lacking overall research and in-depth research on spatial analysis. Therefore, it is difficult to provide comprehensive evaluation results of land resources carrying capacity and scientific spatial planning suggestions.

3) Lack of dynamic monitoring mechanism:

The carrying capacity of land resources is a dynamic concept, which needs to be monitored and evaluated over time. However, at present, there is no effective dynamic monitoring mechanism, which makes it difficult to update and adjust the evaluation results of land resources carrying capacity in time and adapt to the development needs of different stages.[6].

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4) Social participation is not high:

The research of land resources carrying capacity needs extensive social participation, but at present, the research often lacks extensive public participation, which leads to the lack of credibility and acceptability of the evaluation results and affects the practical application effect of land resources carrying capacity.

5. Evaluation Index System of Land Resources Carrying Capacity

The evaluation index system of land resources carrying capacity is an important tool to measure the sustainable utilization ability of land resources, which usually includes four indicators: natural, economic, social and ecological.[7]. The following is the specific evaluation index system:

1) Natural indicators:

Including land quality, land type, topography, water resources, climate conditions and other natural environmental factors. These indicators mainly reflect land productivity, hydrogeological conditions, natural environment protection and so on.

2) Economic indicators:

Including land use efficiency, industrial structure, labor resources, capital resources and other economic factors. These indicators mainly reflect the economic sustainability and availability of land.

3) Social indicators:

Including social and environmental factors such as population density, education level, medical and health care. These indicators mainly reflect the social sustainability and adaptability of land.

4) Ecological indicators:

Including biodiversity, soil erosion, land degradation, ecological environment protection and other ecological factors. These indicators mainly reflect the ecological sustainability and environmental sustainability of land.

These indicators interact and influence each other, and jointly determine the carrying capacity of land resources. In the actual evaluation process, it is necessary to determine reasonable evaluation indexes and weights according to the characteristics and purposes of different regions, and make evaluation and analysis in combination with specific conditions.[4,8].

6. Evaluation Method of Land Resources Carrying Capacity

The evaluation of land resources' carrying capacity refers to the ability of land resources to bear the maximum utilization intensity and load under the premise of meeting the needs of human social and economic development in a certain period of time. At present, the commonly used evaluation methods of land resources carrying capacity mainly include the following:

1. State space method: Based on the principles of physics and ecology, this method regards the carrying capacity of land resources as a state space and evaluates the carrying capacity of land resources by measuring the influence of various factors on land resources.

2. AHP: AHP is a multi-criteria decision-making method, which can quantify the influence of various factors and evaluate the carrying capacity of land resources by calculating the weight.

3. Comprehensive index method: this method is to normalize the values of each index, and then add the weights of each index to get the comprehensive index, thus evaluating the carrying capacity of land resources.

4. GIS-based model: By establishing a GIS model, this method comprehensively analyzes and evaluates the spatial distribution, attributes and changes of land resources, and can realize accurate evaluation and spatial analysis of land resources carrying capacity.

ISSN: 2710-0723

5. BP neural network method: This method uses the nonlinear mapping ability of BP neural network to simulate and predict the influence of various factors on the carrying capacity of land resources, so as to evaluate the carrying capacity of land resources.

At present, several mature methods are commonly used, such as entropy weight TOPSIS method, global Moran's I index method, geographical detector analysis method and so on.[9].

6.1. Entropy Weight TOPSIS Method

6.1.1. Specific Steps of Entropy Weight TOPSIS Method

The specific steps of evaluating the carrying capacity of land resources by using entropy weight TOPSIS method are as follows:

1. Determine the evaluation index:

According to the purpose and demand of land resources carrying capacity evaluation, the corresponding evaluation indexes are selected. Evaluation indicators include land quality, water resources, climate conditions, land use types and so on.

2. Data processing:

Collect the data needed for evaluation index and preprocess the data. Including data cleaning, normalization and so on, to ensure comparability between indicators.

3. Calculate index weight:

The entropy weight method is used to calculate the weight of each index to determine the importance of each index in comprehensive evaluation. The specific steps have been mentioned in the previous answer.

4. Determine the positive and negative ideal solutions:

According to the specific meaning of evaluation index and the characteristics of evaluation object, positive and negative ideal solutions are determined. The positive ideal solution represents the value of each index in the optimal state, and the negative ideal solution represents the value of each index in the worst state.

5. Calculated distance:

Calculate the distance between each evaluation object and the positive and negative ideal solutions. Euclidean distance, Manhattan distance and other methods are used to calculate the distance, and the specific method depends on the actual situation.

6. Calculate the comprehensive evaluation index:

According to the distance, the comprehensive evaluation index is calculated. The larger the comprehensive evaluation index, the better the evaluation object. Finally, the evaluation object with the largest comprehensive evaluation index is selected as the optimal scheme.[10,11].

6.1.2. Entropy Weight TOPSIS Method to Evaluate the Effect.

Using entropy weight TOPSIS method to evaluate the carrying capacity of land resources can achieve the following effects:

1.Comprehensive consideration of multiple evaluation indicators:

The evaluation of land resources carrying capacity involves many aspects, such as land quality, water resources, climate conditions and land use types. The entropy weight TOPSIS method can comprehensively consider the weight and relationship between multiple evaluation indexes, reduce the one-sidedness and subjectivity of single index evaluation, and evaluate the carrying capacity of land resources more comprehensively and objectively.

2.Improve the accuracy and accuracy of evaluation;

Using entropy weight method to calculate the index weight can fully consider the information content and contribution degree of each index, avoid the interference of human subjective factors, and improve the evaluation accuracy and accuracy.

ISSN: 2710-0723

3.Convenient and practical:

Entropy weight TOPSIS method is simple, transparent and convenient for practical application. At the same time, the data and information needed by this method are conventional and easy to obtain and process.

4.Strong adaptability:

The entropy weight TOPSIS method is suitable for the evaluation of land resources carrying capacity of different scales and levels, and can be applied in different time and space ranges with strong adaptability.

Using entropy weight TOPSIS method to evaluate the carrying capacity of land resources can improve the comprehensiveness, objectivity and accuracy of evaluation, which is convenient for practical application and is an effective evaluation method.[12].

6.2. Global Moran's I Exponential Method

The global Moran's I index can be used to analyze the spatial distribution characteristics of land resources carrying capacity, so as to determine the spatial aggregation phenomenon and regional differences of land resources carrying capacity.

6.2.1. Specific Steps of Global Moran's I Index Method

The specific steps of the global Moran's I index method are as follows:

1.Constructing spatial weight matrix

Spatial weight matrix is the basis of global Moran's I index calculation, which can be used to describe the spatial correlation of land resources carrying capacity. Commonly used spatial weight matrices include adjacency matrix, distance weight matrix, K-adjacency matrix and so on. When constructing the spatial weight matrix, it is necessary to consider the spatial distance between the carrying capacity of land resources and the spatial proximity.

2.Calculate the global Moran's I index

According to the formula of global Moran's I index, the value of global Moran's I index can be obtained by calculating the spatial correlation between all land resources carrying capacity indexes. In the calculation process, parameters such as weight matrix, mean value and standard deviation of land resources carrying capacity index need to be used.

3.Analyze the results and draw a spatial map.

The global Moran's I index ranges from -1 to 1, and the closer it is to 1, it means that there is a significant spatial positive correlation, that is, aggregation phenomenon; When its value is closer to -1, it means that there is a significant spatial negative correlation, that is, dispersion phenomenon; When the value is closer to 0, it means that there is no significant spatial correlation in the carrying capacity of land resources. By analyzing the results of global Moran's I index, the spatial distribution characteristics of land resources carrying capacity can be determined, and the areas with aggregation and dispersion can be identified, which provides scientific basis for land resources planning and management.

In addition, the spatial distribution of land resources carrying capacity can be displayed intuitively by drawing the spatial map of the global Moran's I index, which plays an important role in deeply understanding the spatial characteristics of land resources carrying capacity, identifying spatial agglomeration phenomena, and making spatial analysis and planning decisions.[13].

6.2.2. Evaluation Effect of Global Moran's I Index Method

Using the global Moran's I index to analyze the carrying capacity of land resources can achieve the following effects:

1.Identify spatial aggregation phenomenon

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The global Moran's I index can be used to determine the spatial aggregation phenomenon of land resources carrying capacity, that is, there is spatial correlation between areas with high land resources carrying capacity and areas with low land resources carrying capacity. This is of great significance to the planning and management of land resources.

2.Identify problem areas

Through the global Moran's I index analysis, the spatial distribution characteristics of land resources carrying capacity can be determined, and the areas with aggregation and dispersion can be identified. Especially for the areas with agglomeration, it is necessary to further analyze the reasons and take corresponding measures to avoid over-exploitation and utilization of land resources, so as to achieve sustainable development.

3.Provide scientific basis for land resources planning and management.

Global Moran's I index analysis can provide scientific basis for land resources planning and management. By analyzing the spatial distribution characteristics of land resources carrying capacity, we can determine the reasonable land use mode and development direction, and formulate scientific land use policies, so as to realize the efficient utilization and sustainable development of land resources.[14].

Global Moran's I index analysis can help us deeply understand the spatial characteristics of land resources carrying capacity, identify the phenomenon of spatial agglomeration, provide scientific basis for land resources planning and management, and help to realize the efficient utilization and sustainable development of land resources.[15].

6.3. Analysis Method of Geographical Detector

6.3.1. Specific Steps of Geographical Detector Analysis Method

The following steps are needed to analyze the carrying capacity of land resources by using geographical detectors:

1.Determine the study area and related data:

According to the research purpose and demand, determine the research area, and collect relevant data on land resources, environment, social economy, including topography, soil types, climate, population density, etc.

2.Determine the index system of land resources carrying capacity;

According to the required research indicators, determine a reasonable index system of land resources carrying capacity, including land use, cultivated land quality, water resources, ecological environment and other aspects.

3.Making spatial data:

The collected data are sorted and processed by GIS software, including map making, data processing and data processing, so as to obtain the required spatial data.

4.Conduct geo-detector analysis:

The collected data are analyzed and modeled by using the geographic detector model to explore the relationship between the carrying capacity of land resources and various factors, and to evaluate the influence degree and spatial difference of each factor on the carrying capacity of land resources.

5.Interpretation and analysis results:

According to the analysis results of geographical detectors, the spatial distribution and influencing factors of land resources carrying capacity are explained and analyzed, and then measures and suggestions to improve land resources carrying capacity are put forward.[16].

The analysis of geographical detectors can help us to deeply understand the present situation and changing trend of land resources carrying capacity, so as to better plan and manage land resources and protect and utilize land resources.

ISSN: 2710-0723

6.3.2. Evaluation Effect of Geographical Detector Analysis Method

Using geographical detectors to analyze the carrying capacity of land resources can achieve the following effects:

1.Assessing the carrying capacity of land resources more accurately;

By establishing a mathematical model, the geographical probe analysis can accurately evaluate the influence of various factors on the carrying capacity of land resources, including spatial differences, thus improving the accuracy of the evaluation results.[17].

2.More comprehensive analysis of the carrying capacity of land resources;

Geodetector analysis can comprehensively analyze multiple influencing factors and evaluate their influence on the carrying capacity of land resources, so as to obtain more comprehensive and accurate evaluation results.[18].

3.Better discover the spatial variability of land resources carrying capacity;

Geographical detector analysis can analyze the spatial distribution of land resources carrying capacity, find the spatial variability between different regions, and provide more targeted suggestions and measures for land resources planning and management.[19].

4.Better guide the planning and management of land resources;

Through the analysis of geographical detectors, we can find out the main factors and key areas that affect the carrying capacity of land resources, and put forward corresponding land resources planning and management measures, so as to better utilize and protect land resources.[20].

5.More efficient decision support:

Geographic detector analysis can help decision makers better understand the carrying capacity of land resources and its influencing factors, provide scientific basis and reference for decision-making, and improve the efficiency and accuracy of decision-making.

Using geographical detectors to analyze the carrying capacity of land resources can improve the accuracy, comprehensiveness and pertinence of land resources evaluation and provide better support and guidance for land resources planning and management.[21].

7. Development of Evaluation Methods for Future Land Resources Carrying Capacity

The future development direction of land resources carrying capacity evaluation methods may include the following aspects:

1.Multi-scale evaluation:

In view of the differences in space and time scales in the evaluation of land resources carrying capacity, it is necessary to adopt multi-scale evaluation methods to accurately evaluate the land resources carrying capacity at different scales.

2.Statistical model and machine learning;

With the advent of the era of big data, statistical models and machine learning technologies will be gradually applied to the evaluation of land resources carrying capacity to improve the accuracy and efficiency of the evaluation of land resources carrying capacity.

3.Evaluation based on ecosystem services;

Ecosystem services refer to all kinds of material and intangible wealth provided by natural systems for human beings. The evaluation of land resources carrying capacity will pay more and more attention to the quality and quantity of ecosystem services in order to maintain the sustainable development of the ecological environment.

4.Comprehensive consideration of socio-economic factors:

ISSN: 2710-0723

In addition to ecological factors, the evaluation of land resources carrying capacity also needs to consider the comprehensive influence of social and economic factors in order to realize the scientific and rational utilization and management of land resources.

5.Evaluation based on earth observation technology;

Using earth observation technology such as remote sensing and geographic information technology, a large number of land resources data can be obtained quickly, which provides more accurate data support for the evaluation of land resources carrying capacity.

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