Modification and Improvement of Ecological Footprint Model in Land Use

Rui Wu¹, Chengying Li² and Zhiqi Gong¹*

¹Engineering Management, Qinghai University, Xining, Qinghai, 810000, China
²Engineering Management, Qinghai University, Xining, Qinghai, 810000, China
*Corresponding author’s e-mail: wurui3144@163.com

Abstract. The ecological footprint analysis method realizes the unified description of various natural resources by presenting the concept of ecological productive land and has strong reproducibility and easy to understand. In the past 20 years, the ecological footprint has become one of the indicators for quantitative evaluation of sustainable development, and it has been applied to various fields of land use research. Because the ecological footprint model itself has ecological bias, conservative results, inaccurate and static defects, and implemented at land use, the spatial expression ability is insufficient, and the land diversity is neglected. Scholars have revised the ecological footprint model. This paper sets out the revision and improvement of the ecological footprint model in land use. Finally, it puts forward the insufficiency and prospect in land use.

1. Introduction

In the 1980s, the human economy grew rapidly, the population surged, and the excessive use of resources caused a series of environmental problems. Over the past 20 years, scholars from various countries have begun to work on sustainable development research and have put forward some constructive evaluation methods such as Environmental Carrying Capacity Theory (EBC), Life Cycle Assessment (LCA), Energy Theory and so on. The ecological footprint analysis method represents one of the methods for quantifying the degree of sustainable development and accounting for natural resources. Canadian economist William Rees proposed the concept of ecological footprint in 1992. His student Wackernagel completed the calculation model in 1996. The ecological footprint is simply defined as: providing the area of biological production and water resources needed for human life, and the need for waste, calculating the ecological carrying capacity, and determining whether it is in a state of sustainable development. It is a measurement tool that measures the exact area of human life. It can also be understood as an environmental system analysis. It is because mankind consumes natural resources and produces waste, it will definitely affect the ecological environment of the earth. The carrying capacity of the Earth's environment is restricted, and human survival depends on the Earth's environment. Therefore, it is very meaningful to calculate the ecological footprint of humans and the carrying capacity of the environment. In the ecological footprint model, the required biological production area can be calculated based on the amount of human natural resources consumed.

The concept of sustainable land use was formally proposed in 1990 at the first international seminar on sustainable land use systems jointly organized by the Indian Agricultural Research Association, the United States Department of Agriculture, and the United States Rodale Institute in New Delhi. The ecological footprint has been widely used in different spatial domains in various fields, but there are few
studies on the evaluation of sustainable land use. Therefore, the “ecological footprint method” is constructed to evaluate the sustainability of the land, the ecological footprint and land data are used to analyze the problems existing in the land, and then the ecological carrying capacity is used to analyze the evolution process of sustainable land use, which is comprehensively evaluated and given. Reasonable and feasible policies are the hotspots of future research.

2. State of the Art
There are relatively few researches on the analysis of land use and assessment using the ecological footprint analysis method. The main research areas include: ① City needs land calculation. ② Calculation of regional land carrying capacity. ③ The degree of natural capital utilization in cities. ④ Planning of transportation land use. ⑤ Optimized allocation of crops and woodland planting areas. As an instrument for quantitative analysis of environmental carrying capacity and measurement of land and environmental sustainability, the ecological footprint model helps to identify the principal contradiction of sustainable development. On the micro-scale to the macro-scale, it provides a certain basis for the decision-making of global sustainable development. On the whole, the ecological footprint method still has many shortcomings in studying land use. As a systematic environmental assessment system, ecological footprint does not maximize the social and economic benefits of land. In the calculation of urban demand land, the research methods of ecological footprint mainly focus on the accuracy of calculation, but the equilibrium factor and production factor rarely take into consideration regional differences. The discussion on the calculation results of small-area ecological footprint is not deep enough. The calculation method, calculation process and calculation result must be consistent. For the uncertainty in the calculation, it is preferable to perform a sensitivity analysis. When studying land carrying capacity, the ecological footprint is seen as a closed system with no exchange of exterior materials. Therefore, the ecological footprint of the areas dominated by imported materials is relatively small, while the ecological footprint of the areas dominated by exports is relatively high. In the subsequent calculations, the study of ecological footprint standardization should be strengthened. The ecological footprint model also has its flaws. Ecological footprint does not take into account the impact of human beings on social and economic sustainability and is ecologically biased. And it is static, can only represent the ecological footprint of a period of time, does not possess the dynamics of the process of land use evolution, but does not have the function of forecasting and warning. It is unfavorable for scholars to propose land use policies. Furthermore, the ecological footprint model did not take into account the impact of environmental pollution on the environment, making the results slightly conservative. Improving the above ecological footprint model is insufficient in land use, which is our current research trend.

3. Modification and Improvement In Land Use
The defects and improvement methods of ecological footprint in land use are shown in Table 1 below.

| Defects                        | Improvement Methods                                                                 |
|-------------------------------|--------------------------------------------------------------------------------------|
| 1. Ecological bias            | Combined with net green domestic production, sustained economic welfare index, social welfare index, etc. |
| The calculated result is less than the actual value | ① combined with input-output method analysis |
| Two-dimensional ecological footprint | ② combined energy theory |
|                               | Introduce the depth and breadth of the ecological footprint using a three-dimensional ecological footprint model |
2. Equilibrium factor
Yield factor

① “provincial hectares” and “national hectares” instead of “global hectares”
② Set equalization factor and yield factor based on net primary productivity

3. Temporality of time
Add time series

4. Ignore land function diversity
The “yield factor” is replaced by a “productivity factor” that reflects the value of the average ecosystem service system.

5. Spatial expression is not strong
Combine GIS spatial analysis function

3.1. Improvement of own defects in the model
The ecological footprint model is ecologically biased. Its calculation results reflect the relationship between people and the environment, seldom involve social, economic and other aspects. Hanley used the ecological footprint model in combination with Green Net Domestic Production, Continued Economic Welfare Index, and Net Primary Productivity to measure the sustainability of Scottish development; Liu Yijun used the regional per capita ecological coordination coefficient to analyze the development model in Hubei Province and conducted horizontal comparisons between regions. Chen Chengzhong used the ecological footprint efficiency model to perform a 58-year time series dynamic assessment of the ecological sustainability of China from 1949 to 2006. When using the ecological footprint model to evaluate the sustainability of land, it is necessary to choose a suitable evaluation system. In order to improve the scientifcicty and operability of data and reduce the unity of data, it is no longer just to evaluate the results based on the ecological footprint model. Social, economic, and other factors must be evaluated.

Wassily W. Leontief is the founder of the input-output account. Input-output analysis is an approach used to study the balance between various sectors of the national economy. Starting from the assumption of general equilibrium, the dependence of the product quantity of each department is given in a system of equations. In 1998, Bicknell et al. used this method to calculate the ecological footprint of New Zealand and enhanced the structural and comparability of the ecological footprint model. The advantages of the Ecological Footprint and Input-Output Method (EF-IO) are particularly noticeable. The structure of the Ecological Footprint Model has been enhanced. These data are not only full, effective, and comprehensive. In the calculation of the ecological footprint, taking into account human pollution to the environment, the value of the ecological footprint is more accurate, and the flow of the pollution footprint can be clearly defined, providing a reliable basis for national policies. However, this method also has many deficiencies. For example, it is easy to duplicate the computing waste, the data is difficult to collect, and it is difficult to apply it on the micro level. Therefore, the combination of ecological footprint and input-output method is still far from being enough, and another method needs to be combined with EF-IO. Energy theory can analyze the impact of ecological economic benefits on the environment in land use. Energy theory is a comprehensive analysis of the conversion mechanism of various energy flows in ecological economic systems, and an important theory to quantitatively study the relationship between ecological benefits and economic benefits. The combination of ecosystem and energy theory was proposed by Odum, and it is mainly used to evaluate natural assets and ecosystem functions. Lu proposed using the energy value theory model to measure the connotation of the ecological footprint in international trade, and actually measured the trade ecological footprint of China from 1991 to 2010. Compared with the traditional ecological footprint, it has the advantage of energy conversion. It can convert matter, energy, etc. into uniform and comparable solar energy for analysis. The coefficients of energy conversion factor and energy conversion rate are relatively stable. Compared with the equilibrium factor and production factor in the ecological footprint model, the energy density parameter is stable.
In the field of research on urban resource utilization, Niccolucci et al. proposed improving the traditional two-dimensional ecological footprint model and using the three-dimensional ecological footprint model. Xiang uses the improved 3D ecological footprint model to dynamically study the ecological footprint of Shanghai from 2000 to 2014. The results show that the per capita ecological footprint, bearing capacity, and deficits in Shanghai are on the decline, while the total ecological footprint, bearing capacity, and deficits are on the rise. The traditional two-dimensional ecological footprint model represents land area and does not reflect the relationship between natural capital and stock. The 3D model represents a spatio-temporal model. The depth and breadth of the ecological footprint is introduced to dynamically study the state of capital utilization and to measure whether the use of natural resources is excessive.

3.2. Modification of equalization factor and yield factor
In the calculation of urban land demand research, the equilibrium factor, also called the equivalence factor, makes the ratio of the biological productivity per unit area of a type of biological productive land to the per unit area of biological productive land with the world average productivity. This factor can make the calculation results of different types of bio-productive land uniform and comparable. The index does not highlight the ecological importance of woodland, grassland, etc. Therefore, the NPP-based equilibrium factor proposed by Venetoulis et al., which can reflect the biomass under the disturbance of human system. In the calculation of ecological carrying capacity, the production factor is the ratio of the average productivity of certain types of bio-productive land in a certain region or country to the average productivity of the same type of land in the world. This factor can make the calculation results of different regions comparable. However, it does not take into account the impact of the environment on farming methods, and the production factors of various types of land are also quite different. Liu et al. calculated the production factors of various kinds of land in China based on the NPP method. The revised production factors make the calculation results of ecological carrying capacity reflect the consumption of ecological systems by human consumption.

In addition, the equilibrium factors and production factors under the “global hectare” do not reflect the ecological footprint and bearing capacity of various countries, provinces, cities, or smaller regions. Therefore, Gu Xiaowei proposed the ecological footprint model to replace “global hectares” with a “countries of hectares” as a unit of measure and has deducted 12% of the biodiversity conservation area in both measurement units. On this basis, Lin Cuizhen also put forward a more accurate ecological footprint model with a unit of hectares of hectares. This can better reflect the ecological differences between regions and clearly recognize the real needs and supply of land and ecological pressure among people in all regions.

3.3. Modification of the instantaneousness in the model
Another drawback of the ecological footprint is that it is transient, and the calculation results can only represent the ecological footprint of a certain period of time (one year). In view of the non-dynamic defects of the ecological footprint model, Nick Hanley used 7 different indicators to analyze the sustainability of the Scottish region from 1980 to 1990; Liu Yuhui calculated the ecological footprint of China from 1961 to 2005 and analyzed the evolution of the coordination of human and land. Increasing the time series of ecological footprints and converting them to a dynamic analysis can calculate the sensitivity of ecological footprint to changes in the social environment.

3.4. Consideration of the diversity of land functions
Furthermore, the ecological footprint model does not take into consideration the versatility of the land. The ecological footprint theory is based on the "spatial mutual exclusion" of land ecological functions, because only the basic functions of the land's material production are considered in the calculation, and other land service functions are not taken into account, for example, prevention of flood disasters, absorption of carbon dioxide, protection of biodiversity, etc. So we are only calculating the footprint of human consumption, not the ecological footprint of the land in the ecosystem. Wang Jinliang improved
the production factor in the model and improved it to the productivity factor. Productivity factor is defined as the value of unit area ecosystem services for a certain type of land use divided by the average ecosystem service value for that type of land in the country. The improved ecological footprint of the model not only reflects the human resource occupation of the six kinds of bio-productive land, but also the ability to produce resources and energy and supply capacity of ecological services in various land types.

3.5. **Strengthen spatial expression**

It is because the ecological footprint model lacks spatial expression ability, when it is used to optimize the field of crop and woodland planting area allocation, it is not conducive to land use structure and layout under different targets. Land use analysis can be performed with the ability of GIS's powerful spatial data management and analysis system. Xia Minfeng established a spatial attribute database through GIS software, obtained the intensive utilization degree of the development zone in Jiangxi Province, and evaluated its land use. Zheng Huawei used Sichuan Province as an example to analyze the spatial difference of cultivated land use in Sichuan Province using GIS. The ecological footprint model is combined with GIS to establish a visual model. When crop allocation, evaluation and prediction for land use, the current situation, utilization status and applicability of each type of land can be matched and analyzed, and the sustainable use of land can be constructed and adjusted. Critical role. In addition, spatial attributes can be optimized and variable combinations, which is beneficial to urban land planning.

4. **Conclusion**

The focus of the ecological footprint is to measure the impact of humans on the environment in a certain area, without considering the level of development of the area, people's consumption and lifestyle. Therefore, it is easy to draw the more developed areas, the greater the ecological footprint; the more backward the region, the smaller the ecological deficit. This shows that the ecological footprint model only pays attention to the land ecological benefits of the land, and does not pay attention to the social and economic benefits of the land, or does not reflect it. Therefore, it is necessary to combine the population elasticity coefficient, the ecological diversity index, the development ability and other indicators to draw a comprehensive conclusion. In addition, the ecological footprint model in land use research lacks predictive function and cannot predict the impact of population growth, economic development, and technological upgrading on land use in a specified region. With the help of the spatial analysis of geographic information, a land database can be established and the ecological footprint prediction system can be developed. According to the overall layout, the economic and ecological environment in the region will be analyzed, evaluated and forecasted. The lack of carbon footprint calculation and forecasting is also one of the key points that the model needs to improve in the future. Because carbon emissions can better explain human activities, human consumption and contributions, and whether it will put more pressure on land and will be used for land use. This data will provide more viable basis for land policy.

Although many scholars have proposed many improvements to the ecological footprint, the ecological footprint model still needs improvement.

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