A Study on Sustainable Development of Island Economy Based on Ecological Footprint Approach - A Case Study of Changhai County, Liaoning Province

Yan Jiao* and Miaomiao Li
School of Landscape Architecture, Beijing University of Agriculture, Beijing, China

*Email: jiaoyan@bua.edu.cn

Abstract. The ecological footprint method, as one of the methods to evaluate sustainable development, has been widely used at home and abroad. This paper adopts the ecological footprint analysis method, introduces the ecological footprint model and ecological carrying capacity model, accounts for the data based on 2015-2019 statistics, quantitatively calculates the data of the economic development of the island, and explores the economic, social and ecological sustainable development of Changhai County, so as to provide reference for other island economic development models.

1. Foreword
With the development of economy and the improvement of people's living standard, the problems of population, environment and resources are becoming more and more prominent, and the research on ecological carrying capacity of sustainable development level has become a research hotspot.

The ecological footprint can reflect both the intensity of resource consumption of individuals or regions and the regional resource supply capacity and total resource consumption, and also reveals the ecological threshold of sustainable human survival. Ecological footprint accounting provides an effective tool for people to judge whether human consumption of ecosystems is sustainable, and can support the sustainable use of natural resources, sustainable management of ecosystems and the construction of ecological civilization in China[1].

2. Study regional context and data sources
2.1 Natural environment
Changhai County, Dalian City, Liaoning Province has a total area of about 10,466.84 square kilometers, with a land area of 142.84 square kilometers and a sea area of 10,324 square kilometers, and its geographical coordinates are 38°55′48″ to 39°34′37″ north latitude and 122°17′38″ to 123°13′16″ east longitude. Changhai County is located in the northern sea area of the Yellow Sea on the east side of Liaodong Peninsula, Liaoning Province, and is subordinate to Dalian City, Liaoning Province, which is the only island county in Northeast China and the only island border county in China[2], and its geographical location is shown in Figure 1, and the current traffic situation is shown in Figure 2.
2.2 Economic markets
Changhai County occupies an excellent geographical location and has rich natural resources, coupled with a long cultural history, which gives it an obvious resource advantage in development. The main industries of Changhai County unfold by the sea, mainly include seawater aquaculture and marine fishing, etc. It is the largest seafood aquaculture base in China and has three geographical indication certification trademarks. From 2010 to 2019, the GDP of Changhai County has always maintained a rapid growth trend, as shown in Figure 3.

Under the influence of natural and social factors, combined with its geographical location and the composition of its resources, Changhai County's gross product has grown steadily and its industrial structure has been optimized, with the structure of the three industries being 61.6:12.0:26.4 in 2010 and 57.1:5.0:38.0 in 2019, with the proportion of the tertiary industry increasing, as shown in Figure 4.
3. On ecological footprint analysis methods

3.1 Concept and model of ecological footprint

The basic model of ecological footprint consists of three aspects: firstly, the calculation of ecological footprint; secondly, the calculation of ecological carrying capacity; and finally, the comparison of ecological footprint and ecological carrying capacity\(^\text{(3)}\).

In general, biologically productive land area is divided into six categories: cropland, grassland, forest land, water area, building land, and fossil fuel land. In the paper, the ecological footprint calculation is divided into two types: biological resources ecological footprint and energy ecological footprint. The ecological footprint calculation model is as follows:

\[
\text{EF} = N \cdot e_f = N \cdot \sum (a_{ai}) = \Sigma r_j A_i = \Sigma (c_i/p_i)
\]

(1) In equation, \(\text{EF}\) is the total ecological footprint, \(N\) is the total population of the study area, \(e_f\) is the ecological footprint per capita, \(i\) is the type of consumption commodity and input, \(a_{ai}\) is the converted biologically productive area per capita for \(i\) traded commodities, \(c_i\) is the per capita consumption of \(i\) commodities in the study area, \(p_i\) is the average productive capacity of \(i\) consumption commodities, and \(r_j\) is the equilibrium factor.

Ecological carrying capacity is the maximum limit of the number of individuals of a certain kind that exist under certain conditions\(^\text{(4)}\). It is calculated by the formula:

\[
\text{EC} = N \cdot e_c = N \cdot (\Sigma a_i \cdot r_j \cdot y_j)
\]

(2) In the equation, \(\text{EC}\) is the total ecological carrying capacity, \(N\) is the total population of the study area, \(e_c\) is the ecological carrying capacity per capita of the study area, \(a_i\) is the area occupied per capita of biologically productive land of class \(j\), \(r_j\) is the equilibrium factor of biologically productive land of class \(j\), and \(y_j\) is the yield factor.

The equilibrium factor is the ratio of the average productivity of a type of productive land at the global scale to the average productivity of all productive land at the global scale, with 2.8 for cropland and building land, 1.1 for forest and fossil fuel land, 0.5 for grassland and 0.2 for water.

The yield factors were obtained mainly by comparing the local average yield of similar biologically productive land with the global average yield of 1.66 for cropland, 1.0 for watershed, 0.91 for woodland and 0.19 for grassland, and deducting 12% for biodiversity conservation land.

By comparing the ecological footprint with the ecological carrying capacity, we can determine...
whether the ecological needs of the area are within its ecological carrying capacity. If the ecological footprint is greater than the ecological carrying capacity, it is an ecological deficit; conversely, if the ecological footprint is less than the ecological carrying capacity, it is an ecological surplus\cite{5}.

3.2 Ecological footprint accounting
In this section, the ecological footprint and ecological carrying capacity of Changhai County during 2015-2019 are calculated to analyze the impact on the ecosystem during the economic development of Changhai County, and to determine whether the economic development of Changhai County is in a sustainable state in terms of area.

In this paper, data such as total population and gross product are mainly obtained from Dalian City and Changhai County statistical yearbooks, and bottom-up component analysis is used to account for the ecological footprint of Changhai County.

3.2.1 Accounting for biological resources accounts. In terms of the consumption structure of the residents of Changhai County, the consumption of biological resources mainly includes food crops, other crops, animal products, aquatic products, and forest products.

In this paper, the world average production of biological resources accounted by the Food and Agriculture Organization of the United Nations (FAO) in 1993 is taken as the average productivity, and the various biological resources are converted into the corresponding biologically productive areas and then multiplied by the corresponding equilibrium factors respectively to obtain the adjusted ecological footprint, as shown in Table 1.

| Project/Year     | 2015   | 2016   | 2017   | 2018   | 2019   |
|------------------|--------|--------|--------|--------|--------|
| Cropland (hm²/cap) Before | 0.0449 | 0.0432 | 0.0478 | 0.0587 | 0.0647 |
|                  After  | 0.1256 | 0.1214 | 0.1286 | 0.1513 | 0.1845 |
| Grassland (hm²/cap) Before | 0.4837 | 0.5128 | 0.4783 | 0.5174 | 0.6835 |
|                  After  | 0.2419 | 0.2648 | 0.2671 | 0.2565 | 0.3389 |
| Forest land (hm²/cap) Before | 0.1349 | 0.0435 | 0.1902 | 0.1822 | 0.0864 |
|                  After  | 0.1524 | 0.0498 | 0.2039 | 0.2071 | 0.0912 |
| Water area (hm²/cap) Before | 0.6329 | 0.7415 | 1.0227 | 1.2291 | 0.8293 |
|                  After  | 0.1534 | 0.1496 | 0.2135 | 0.2393 | 0.1659 |

3.2.2 Accounting for energy accounts. The energy consumed in Changhai County mainly includes electricity, coal and diesel fuel. The county's electricity consumption is converted into land for construction, and the rest of energy sources are converted into fossil fuel land. Taking the world average heat generation per unit of fossil fuel productive land area as the standard, different types of energy are converted into heat consumption, and then the heat is converted into energy ecological footprint by using the global average energy footprint coefficient, and finally the adjusted value is obtained by yield factor as shown in Table 2.

| Project/Year     | 2015   | 2016   | 2017   | 2018   | 2019   |
|------------------|--------|--------|--------|--------|--------|
| Building land (hm²/cap) Before | 0.0045 | 0.0047 | 0.0046 | 0.0044 | 0.0046 |
|                  After  | 0.0126 | 0.0132 | 0.0131 | 0.0128 | 0.0129 |
| Fuel land (hm²/cap) Before | 1.0861 | 0.8649 | 0.9038 | 0.8081 | 0.7958 |
|                  After  | 1.1628 | 0.9405 | 1.0312 | 0.9234 | 0.8427 |

3.2.3 Accounting for ecological carrying capacity. Changhai County has a small land area and relatively homogeneous land types, with biologically productive land mainly consisting of water, forest land, construction land and cultivated land types. The area of grassland in the county is small
and is neglected in the calculation of land area per capita. According to the ecological carrying capacity formula, the ecological carrying capacity was calculated for the period of 2015-2019, as shown in Table 3.

Table 3 Ecological Carrying Capacity Accounting

| Project/Year | 2015       | 2016       | 2017       | 2018       | 2019       |
|--------------|------------|------------|------------|------------|------------|
| Area per capita (hm²/cap) |            |            |            |            |            |
| Cropland     | 0.0118     | 0.0128     | 0.0135     | 0.0107     | 0.0162     |
| Forest land  | 0.0967     | 0.1004     | 0.0981     | 0.0865     | 0.0993     |
| Water area   | 10.1765    | 10.2065    | 10.1537    | 10.2158    | 10.3145    |
| Building land| 0.0309     | 0.0305     | 0.0314     | 0.0328     | 0.0337     |
| Ecological carrying capacity per capita (hm²/cap) |            |            |            |            |            |
| Cropland     | 0.0489     | 0.0562     | 0.0637     | 0.0539     | 0.0851     |
| Forest land  | 0.2135     | 0.1962     | 0.2008     | 0.2124     | 0.2257     |
| Water area   | 1.7865     | 1.8162     | 1.8182     | 1.7954     | 1.8217     |
| Building land| 0.1352     | 0.1339     | 0.1392     | 0.1424     | 0.1439     |

3.2.4 Ecological footprint evaluation. Based on the above accounting results of biological resources account and energy account, the ecological footprint per capita for each year from 2015-2019 can be obtained and compared with the ecological carrying capacity to understand the ecological surplus and deficit in that year, as shown in Table 4.

Table 4 Ecological Footprint and Ecological Carrying Capacity

| Project/Year | 2015       | 2016       | 2017       | 2018       | 2019       |
|--------------|------------|------------|------------|------------|------------|
| Ecological footprint (hm²/cap) | 1.8487     | 1.5393     | 1.8574     | 1.7904     | 1.6361     |
| Ecological carrying capacity (hm²/cap) | 2.1841     | 2.2025     | 2.2219     | 2.2041     | 2.2764     |
| Ecological Profit and Loss (hm²/cap) | 0.3354     | 0.6632     | 0.3645     | 0.4137     | 0.6403     |

From the calculation results, it can be seen that the per capita ecological carrying capacity of Changhai County basically remains stable, the per capita ecological footprint shows a decreasing trend year by year, and the economic development is basically in a sustainable state, but the ecological demand is basically close to the ecological carrying capacity, which shows that Changhai County needs to strictly control the economic development under the ecosystem carrying capacity of the island, so as to maintain the sustainable development of the whole ecosystem.

From the perspective of ecological supply, the supply of various types of biologically productive land area in Changhai County is unbalanced, and the ecological carrying capacity per capita in the waters is the largest. The area of the county's sea area remains unchanged, and the ecological carrying capacity provided by the sea area shows an increasing trend because the total population continues to decrease. The contribution of forest land to the ecological carrying capacity is also relatively large, and the forestry ecology of the island uses afforestation to increase the forest cover of the island as well as to improve the regional microclimate.

From a vertical perspective, the overall per capita ecological footprint shows a decreasing trend, mainly reflected in the decreasing level of energy consumption in Changhai County. The consumption of energy in the production of aquatic products processing industry increases, the pressure of fish farming gradually rises, and the arable land and forest can meet the ecological needs of local residents.

4. Evaluation and reflection on the state of economic development in Long Beach County

4.1 Economic development characteristics
During 2010-2019 Changhai County has always maintained a rapid growth trend (Figure 3), the three industrial structure ratio varies widely, typical resource-dependent economy, the leading industry
unfolded by the sea, the ratio of three industries in 2019 was 57.1:5:38, the proportion of the primary industry with fisheries as the mainstay was relatively high, the secondary industry with aquatic product processing industry as the leading industry and the tertiary industry with tourism as the focus. The ratio is relatively low.

The tourism industry needs to be upgraded, strategic analysis of tourism for each island, construction of supporting service facilities, while strengthening overall planning, transformation of marine fishery development from near shallow sea to deep and distant sea.

4.2 Characteristics of changes in the ecological footprint
Changhai County mainly provides four types of biologically productive land, including watershed, forest land, cropland, and building land, to support its economic production. The total ecological carrying capacity provided by various types of biologically productive land has basically remained at a relatively stable level since the period from 2015 to 2019, and the supply of various types of biologically productive land areas is very uneven due to a small increase in per capita ecological carrying capacity as the population of Changhai County has been declining year by year.

4.3 Proposals for achieving sustainable development in Changhai County
In order to reduce the ecological footprint of Changhai County so that the economic development of Changhai County is sustainable, the following measures can be taken specifically.

4.3.1 Accelerated industrial restructuring. By increasing the technological content of industries, building industrial symbiotic chains, enhancing industrial relevance and promoting the proximity of highly related industries, shortening the distance between upstream and downstream enterprises.

4.3.2 Strengthening clean energy development. Give full play to the unique location and resource advantages, unswervingly take the ecological priority, green low-carbon high-quality development path, so that clean energy gradually replace traditional fossil energy.

4.3.3 Vigorous efforts to bring in talent. To adhere to the technology as a guide, use advanced science and technology to solve the problems in the development of the island, and seek ways to achieve sustainable socio-economic development.

5. Concluding remarks
Assessing the economic indicators and ecological footprint indicators of Changhai County, it can be found that the economy and ecological environment of Changhai County can be developed in a relatively harmonious way, but at the same time, it also brings certain pressure to the ecological environment. In view of the problems in the development, corresponding measures should be taken to reduce the ecological footprint while ensuring the economic development, reduce the material consumption and improve the material utilization rate to further realize the sustainable development of Changhai County.

It follows the principle of giving priority to ecological protection, protects coastal mudflats, builds a charming shoreline with clean water and clean shore, ecological harmony and land-sea linkage, increases forest accumulation, enhances the microclimate regulation capacity of urban ecosystem, promotes the coordinated development of green economy, blue economy and marine ecological environment, develops marine economy with high quality, and shares blue home with high quality.

Acknowledgement
This paper was supported by Beijing Social Science Foundation (15GB055) and related horizontal projects, and completed under the guidance of Professor Yonggang An.

References
[1] Huang, Baorong, Cui, Shuhong, Li, Yingming. Characteristics of ecological footprint changes and influencing factors from 2000 to 2010 in China[J]. Environmental
[2] Ke Lina, Wang Quanming, Li Yonghua, Cao YQ. An evaluation model for sustainable development of sea islands based on variable fuzzy set theory: an example from Changhai County, Liaoning Province[J]. Journal of Natural Resources, 2013, 28(05): 832-843. [In Chinese]

[3] Zhou T, Wang YP, Gong JZ, Wang F, Feng YF. Model revision and method improvement of ecological footprint[J]. Journal of Ecology, 2015, 35(14): 4592-4603. [In Chinese]

[4] HANDI P, BARG S, HODGER T. Measuring sustainable development: review of current practice[J]. Occasional Paper, 1997(17): 49-51

[5] Tian Lingling, Luo Jing, Dong Ying, Liu He Tao, Zeng Ju Xin. Study on the spatial and temporal dynamics of ecological footprint and ecological carrying capacity in Hubei Province[J]. Yangtze River Basin Resources and Environment, 2016, 25(02): 316-325. [In Chinese]