Original Research Article

# Analyzing the ecological carrying capacity of the Qinghai lake surrounding area based on the ecosystem services value

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***Abstract:*** Investigating the changes in ecological carrying capacity around Qinghai Lake is of great significance for balancing human activities and natural resource pressures. It promotes the harmonious coexistence of economic growth and ecological conservation, ultimately leading to sustainable development. Using the equivalence factor method and the ecological footprint equation, we measured the ecological carrying capacity. The results show that: The ecological surplus around Qinghai Lake was $3.08\times10^4$ $hm^2$ in 2000, $19.93\times10^4$ $hm^2$ in 2010, and $11.93\times10^4$ $hm^2$ in 2020. The overall trends of both ecological carrying capacity and ecological footprint are relatively stable throughout the study period. Notably, the ecological footprint consistently being less than the ecological carrying capacity, showing an overall ecological surplus. By analyzing the ecological carrying capacity and ecological footprint around Qinghai Lake, this study provides valuable insights for regional ecological construction.

***Keywords:*** Ecological carrying capacity; Equivalence factor; Surrounding area of Qinghai lake

## 1. Introduction

Ecological Carrying Capacity (ECC) is a measure of an ecosystem's ability to withstand external disturbances, particularly the impacts of human activities, while maintaining the integrity of its functions and structure[1]. As a key indicator for assessing regional ecological changes and the potential for sustainable development, numerous scholars have conducted research on ECC from various perspectives, including the Ecological Footprint method[2], Resource and Demand Rating method[3], Comprehensive Evaluation method. Among these, the Ecological Footprint (EF) refers to the amount of biologically productive land area required by a specific population to provide for their consumption of goods and services over a certain period. with the deepening understanding of the value of ecosystem services, scholars have begun to integrate these concepts and functions into the EF. corrections based on the value equivalents of ecosystem services provide new perspectives for exploring regional development. Therefore, the EF model, which integrates multiple functional characteristics of various ecosystems such as forests, grasslands, arable land, and water bodies, can assess the ecosystem's capacity in terms of productive products and effectively measure human utilization of non-biological products, providing a more realistic reflection of the ECC status in small regions.

This study selected three counties around Qinghai Lake (Gangcha, Haiyan, and Gonghe) and used EF methods to explore the evolution of biological resource carrying capacity in the area, aiming to provide a scientific basis for ecological assessment, sustainable development, and environmental protection there.

## 2. Materials and methods

### 2.1. Study area overview

The study area is located in the northeastern part of the Qinghai-Tibet Plateau (99°20′44″-101°20′E, 35.5°-38°04′04″N). It includes Gonghe County in the Hainan Tibetan Autonomous Prefecture and Haiyan and Gangcha Counties of the Haibei Tibetan Autonomous Prefecture. The altitude varies from 2460 to 5290 meters, encompassing a total area of approximately $307.35\times10^4$ hectares. The mean annual temperature is low, with annual precipitation ranging from 250 to 450 mm. The evaporation is high and unevenly distributed throughout the year, with an annual volume ranging from 1500.6 to 1847.8 mm, and there is no absolute frost-free period.

## 2.2. Data sources

Land use data were obtained from the Geospatial Data Cloud Platform (www. gscloud. cn). After image interpretation, the data met the research requirements and were reclassified into six categories: forest land, grassland, water bodies, arable land, construction land, and unused land. The socioeconomic data were obtained from the National Bureau of Statistics website (https://data. stats. gov. cn/) and through an application to the Qinghai Survey Team of the National Bureau of Statistics.

## 2.3. Research methods

### 2.3.1. Land use transition matrix

The land use transition matrix can express the changes in land use structure over the study period. Its expression is as follows:

$$A_{ij} = \begin{Bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{Bmatrix} \tag{1}$$

In Equation 1: Aij represents the area unit of land use type i that transitions to land use type j during the study period; n is the number of land use categories.

### 2.3.2. Equivalence factor table adjustment

This study refers to the table of ecological service values per unit area of terrestrial ecosystems in China. For construction land, the coefficients from the Qilian Mountain region are referenced to derive the equivalence factor table for the study area. This table, combined with the revision method based on agricultural land as a benchmark, reflects the differences in ecosystem service values between the study area and the national average state. Subsequently, the Consumer Price Index (CPI) is utilized to adjust for inflation.

### 2.3.3. ECC assessment

The EF measures the area of land required to support human activities within a region, whereas the ECC indicates the area of land that can provide ecosystem services for social development. The calculation formula is as follows:

$$\mathrm{ECC} = \mathrm{N} \times e_c = N \times \sum_{j=1}^{n} a_j \times r_j \times y_j \tag{2}$$

$$\mathrm{EF} = \mathrm{N} \times e_f = \mathrm{N} \times \sum_{j=1}^{n} a_j \times r_j \tag{3}$$

$$\mathrm{ED} = \mathrm{ECC} - \mathrm{EF} \tag{4}$$

$$r_j = \frac{P_j}{P_{NP}} = \frac{D_t \times F_j}{\sum_0^n D_t \times F_j \times S_j / \sum_0^n S_j} \tag{5}$$

$$y_j = \frac{P_j}{E_j} = \frac{D_t \times F_j}{D_{qt} \times F_{qj}} \tag{6}$$

In Equations 2-6, ECC represents the Ecological Carrying Capacity of the study area, measured in hectares. EF refers to the EF of the region, also measured in hectares. ED represents the Ecological Surplus measured in hectares. N indicates the number of people residing in the study area. The term ec is used to express the per capita ECC, in units of hectares per person, while ef signifies the per capita EF, with the same unit. The variable yj stands for the yield factor, aj for the per capita area of biological production, and rj for the equivalence factor. Fj is the sum of the ecosystem service value equivalent factors for ecosystem type j, Sj is the area of ecosystem type j in hectares ($hm^2$), Dqt is the ecosystem service value of one standard equivalent factor for China's terrestrial ecosystems in year t (in yuan/$hm^2$), and Fqj is the sum of the ecosystem service value equivalent factors for ecosystem service type j in China's terrestrial ecosystems. The yield factor for construction land is replaced by the value of arable land.

# 3. Results and analysis

## 3.1. Land use changes around Qinghai lake

Most construction lands are situated in proximity to roads and arable fields. Over the study period, the transition out areas for forest land, grassland, arable land, water bodies, construction land, and unutilized land were $3.99\times10^4$ $hm^2$, $18.70\times10^4$ $hm^2$, $1.56\times10^4$ $hm^2$, $3.37\times10^4$ $hm^2$, $0.06\times10^4$ $hm^2$, and $24.41\times10^4$ $hm^2$, respectively. The net area changes for each land use type were an increase of $0.64\times10^4$ $hm^2$ for forest land, 7.55×104 $hm^2$ for grassland, $1.29\times10^4$ $hm^2$ for arable land, $5.18\times10^4$ $hm^2$ for water bodies, $2.02\times10^4$ $hm^2$ for construction land, and a net decrease of $16.68\times10^4$ $hm^2$ for unutilized land.

## 3.2. EF model parameter analysis of the Qinghai lake area

The mean values of the equilibrium factors across the different ecosystem types are ordered as follows: water bodies (3.463) > forest land (0.640) > grassland (0.470) > cropland (0.156) > construction land (0.052) > unutilized land (0.027). When considering the order of magnitude, the equilibrium factor for water bodies is substantially higher than that of the other ecosystems. At each temporal milestone, the mean yield factors for the different ecosystems are ordered as follows: grassland (1.098) > water bodies (1.038) > forest land (0.778) > unutilized land (0.574) > cropland (0.557) = construction land (0.557).

## 3.3. Analysis and evaluation of ECC in the Qinghai lake area

### 3.3.1. ECC and EF under different land use types

The variation in ECC and EF across various ecosystem service types in the Qinghai Lake area is relatively minor (**Table 1**). Over different time periods, the water bodies consistently exhibit the highest values, while the construction land has the lowest. An analysis of the contribution rates of ECC and EF for each land use type reveals the following insights: In terms of ECC, water bodies contribute the most significantly, accounting for 67.41%, followed by grasslands at 29.55%, forest lands at 2.50%, and unutilized lands at 0.32%. The contributions from croplands and construction lands are relatively negligible, at 0.22% and 0.01%, respectively.

**Table 1.** ECC and EF of various land use types in the Qinghai lake surrounding area ($10^4$ $hm^2$) .

| Land Types | ECC | | | EF | | |
|---|---|---|---|---|---|---|
| | 2000 | 2010 | 2020 | 2000 | 2010 | 2020 |
| Forest | 7.29 | 7.54 | 7.20 | 9.64 | 9.43 | 9.25 |
| Grassland | 85.50 | 90.20 | 84.69 | 80.21 | 79.92 | 77.06 |
| Cropland | 0.59 | 0.66 | 0.66 | 1.08 | 1.15 | 1.19 |
| Water Body | 191.99 | 202.35 | 199.60 | 190.51 | 189.65 | 192.12 |
| Construction Land | 0.01 | 0.01 | 0.06 | 0.01 | 0.02 | 0.11 |
| Unutilized Land | 1.06 | 0.97 | 0.76 | 1.89 | 1.65 | 1.32 |
| Total | 286.43 | 301.74 | 292.98 | 283.35 | 281.82 | 281.05 |

### 3.3.2. Ecological surplus and deficit analysis

The ecological balance around Qinghai Lake shows deficits in forest, farmland, construction, and unused land. In terms of the magnitude of change, the ECC of water bodies and grasslands shows the greatest variation, while cropland and construction land remain relatively stable. The contributions of different land use types to the ecological surplus and deficit of the study area can be analyzed as follows: grasslands and water bodies make positive contributions, with cropland contributing 66.44% and water bodies contributing 62.01%. In contrast, forest land, cropland, construction land, and unutilized land exhibit negative contributions of -18.01%, -4.34%, -0.18%, and -5.93%, respectively.

### 3.3.3. ECC assessment

The overall changes in the total ECC and EF in the Qinghai Lake area have been relatively stable (**Figure 1**). The ECC has consistently exceeded the EF, indicating an ecological surplus in the Qinghai Lake area. In terms of development trends, the ecological surplus initially increased before decreased, with the highest surplus recorded in 2010 at 19.93×104 hectares (hm2), and the lowest surplus in 2000 at 3.08×104 hm2. There was a decline in the ecological surplus by 2020.

The per capita ECC, per capita EF, and per capita ecological surplus in the Qinghai Lake area for the years 2000, 2010, and 2020 have also remained relatively stable (Figure1). However, compared to the year 2000, there was a decrease of 3.23% and 6.45% in per capita ECC and EF, respectively, while the ecological surplus increased by 72.77%.

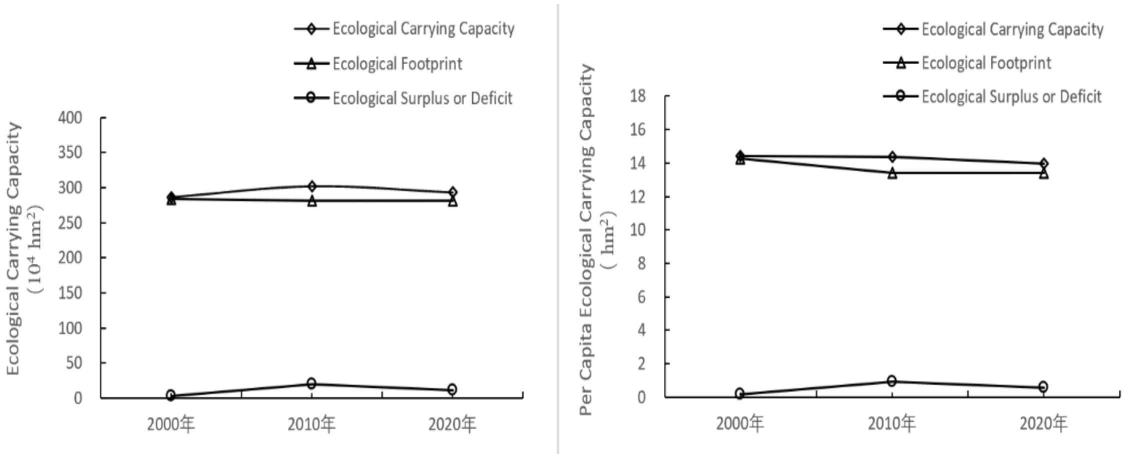


**Figure 1.** The changes in ECC around Qinghai lake from 2000 to 2020.

## 4. Discussion

The characteristics of natural resources determine the features of ECC and EF in the Qinghai Lake area. The vast grasslands, centered around Qinghai Lake, play a leading role in the ECC of the surrounding area and are an important ecosystem type for balancing the ecological service surplus and deficit within the region. During the study period, the Qinghai Lake area has generally shown an ecological surplus, with the ECC maintaining an overall good condition, capable of meeting the daily living and production needs of the local population. However, it is still significantly affected during major natural disasters. In 2003, the Qinghai Provincial People's Congress passed the "Regulations on the Protection of the Ecological Environment of the Qinghai Lake Basin," providing a legal basis for the protection of Qinghai Lake. Subsequently, in 2008, the Qinghai Lake Basin Ecological Environment Protection and Comprehensive Management Project, with an investment of 1.567 billion yuan, was officially launched in Gangca, Haiyan, Tianjun, and Gonghe counties, leading to a significant improvement in the overall ecological environment during this period. Policy orientation has played an important role in enhancing the ECC of the Qinghai Lake area.

the ECC in the study area is higher than the EF, mainly due to the high value of ecosystem services in the grasslands and water bodies within the region. Forest land, cropland, construction land, and unutilized land show an ecological deficit, partly because the study area mainly relies on animal husbandry, with underdevelopment crop production, resulting to limited agricultural product production capacity. Additionally, the ecological environment of the region is relatively fragile, confronting environmental issues such as land desertification which is exacerbated by overgrazing. The expansion of human activity and the acceleration of urbanization have led to the degradation of the original ecological environment, further weakening the ECC.

## 5. Conclusions

Over the period from 2000 to 2020, the ECC and EF in the Qinghai Lake area have been relatively stable. Water bodies have made the most substantial contributions to both the ECC and the EF. Grasslands and water bodies have contributed to an ecological surplus, whereas forest land, cropland, construction land, and unutilized land have all exhibited an ecological deficit. The ECC has overall surpassed the EF, signifying that the ecological balance in the Qinghai Lake area is in a state of surplus.

## References

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