Study on the evaluation and countermeasures of ecosystem status of Guangzhou

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Abstract. It is the first time that we constructs the evaluation index system of Guangzhou's ecosystem status from three aspects of ecological resources, ecological structure and ecological quality, analyzes the historical change characteristics of Guangzhou's ecosystem status in the past 11 years and the ecosystem status of 11 districts. Due to the decrease of ecological land area and the continuous increase of construction land area, the evaluation scores of ecosystem status in Guangzhou have declined in recent years, and the differences of ecosystem status in 11 districts are also obvious. Guangzhou will promote the regional ecological environment and further carry forward the construction of ecological civilization through various methods, such as strengthening the protection of natural ecological environment, stepping up the supervision of ecological environment, etc.

1. Introduction
In recent years, the quality of China's ecological environment has continued to improve, showing a steady and positive trend, but the effect is not stable. The construction of ecological civilization is in a critical period of pressure superposition and heavy load. Guangzhou has entered the crucial period of providing more high-quality ecological products to meet the people's growing demand for beautiful ecological environment. The constraints of resources and environmental factors in Guangzhou are tightening. There is still a certain gap between the environmental quality and the requirements of the central government, the overall development of the society and the expectations of the masses.

Many scholars have carried out a lot of research work on ecological environment quality [1-9], ecological carrying capacity [10-16], ecological security [17-20] and other aspects from different perspectives, and made some progress. It is the first time that we constructs the evaluation index system of Guangzhou's ecosystem status from three aspects of ecological resources, ecological structure and ecological quality, analyzes the historical change characteristics of Guangzhou's ecosystem status and the ecosystem status of 11 districts. Through the above analysis, this paper analyzes the problems of Guangzhou's ecosystem status and puts forward targeted measures and suggestions.

2. Overview of the study area
The research area is Guangzhou, the capital of Guangdong Province, located in the south of China, the lower reaches of the Pearl River and the South China Sea. The research scope includes the whole Guangzhou and its subordinate 11 districts, including Liwan District, Yuexiu District, Haizhu District,
Tianhe District, Baiyun District, Huangpu District, Zengcheng District, Huadu District, Conghua District, Panyu District and Nansha District.

3. Data resources and research method

3.1. Selection principles of evaluation indexes
In this paper, we select relevant evaluation indexes and construct the index system by collecting relevant policies, planning and research results at home and abroad, and combining with the characteristics of natural resources and economic development of Guangzhou. The selected indexes are operable, representative, integrated, scientific and hierarchical.

3.2. Construction of evaluation index
According to the relevant national standards and relevant research at home and abroad, and the relevance of each index, we evaluated nine indexes from three aspects of ecological resources, ecological structure and ecological quality. Table 1 is the evaluation index system of ecosystem status.

| Factor level       | Index level                                                                 |
|--------------------|-----------------------------------------------------------------------------|
| Ecological resources| Proportion of Fengshui forest area (only the evaluation index of district) |
|                    | Proportion of ecological protection area                                    |
|                    | Landscape fragmentation index (dimensionless)                               |
| Ecological structure| Ecological structure index (dimensionless)                                   |
|                    | Ecological stress index (dimensionless)                                     |
|                    | Humidity index (dimensionless)                                              |
|                    | Vegetation index (dimensionless)                                            |
| Ecological quality  | Surface temperature index (dimensionless)                                   |
|                    | Impervious area index (dimensionless)                                       |

3.3. Determination method of evaluation index weight
At present, there are many methods to determine the weight at home and abroad, such as analytic hierarchy process, fuzzy comprehensive evaluation method, factor analysis method, entropy weight method, etc. In view of the reliability and scientificity of the index weight and the importance of the impact on the comprehensive evaluation results, the entropy weight method is adopted in this report to determine the weight of each index.

3.4. Calculation method of evaluation index

3.4.1. Proportion of Fengshui forest area. Fengshui forest of the village has a high ecological value. It has a lot of zonal biodiversity resources. It is an important gene pool of biological resources and has an important ecological function. Data of Fengshui forest in each district comes from Guangzhou Fengshui forest.

3.4.2. Proportion of ecological protection area. The legal ecological protection area such as natural reserves, forest parks, wetland parks, scenic spots should be protected stronger than other areas, with better ecological function or potential ecological value. Therefore, the proportion of the total areas of ecological protection area to the land area should be taken as the index of ecological resource evaluation.

3.4.3. Landscape fragmentation index. Landscape fragmentation index is used to describe the fragmentation degree of the whole landscape or a certain landscape type at a given time.

\[ FN_i = \frac{N_i}{A_i} \]  \hspace{1cm} (1)
In equation (1): $FN_i$ is landscape fragmentation index; $N_i$ is the number of class i patches; $A_i$ is the total areas of class i patches.

3.4.4. Ecological structure index. The ecological structure index is determined to the Technical Criterion for Ecosystem Status Evaluation.

\[
\text{ecological structure index} = 0.375 \times \text{proportion of forest land area} + 0.25 \times \text{proportion of grassland area} + 0.375 \times \text{proportion of water wetland area}
\]

(2)

3.4.5. Ecological stress index. The ecological stress index is determined to the Technical Criterion for Ecosystem Status Evaluation.

\[
\text{ecological stress index} = 0.57 \times (\text{proportion of cultivated land and construction land}) + 0.43 \times \text{proportion of moderate and above soil erosion area}
\]

(3)

3.4.6. Humidity index. The humidity component is closely related to the humidity of vegetation and soil, so the humidity index in this paper is represented by the humidity component wet.

\[
Wet = 0.2626\rho_1 + 0.2141\rho_2 + 0.0926\rho_3 + 0.0656\rho_4 - 0.7629\rho_5 - 0.5388\rho_7
\]

(4)

In equation (4): $\rho(i = 1,\ldots,7)$ are the reflectivity of each corresponding band of ETM+ image.

3.4.7. Vegetation index. Normalized difference vegetation index (NDVI) is undoubtedly the most widely used vegetation index, which is closely related to plant biomass, leaf area index and vegetation coverage. Therefore, NDVI is selected to represent vegetation index.

\[
\text{NDVI} = \frac{(\rho_4 - \rho_3)}{(\rho_4 + \rho_3)}
\]

(5)

3.4.8. Surface temperature index. The surface temperature representing the surface temperature index can be calculated by using the model of Landsat user's manual and the latest revised calibration parameters.

\[
L_6 = \text{gain} \times DN + \text{bias}
\]

\[
T = \frac{K_2}{\ln(K_1/L_6+1)}
\]

(6)

(7)

In equation (6): $L_6$ is the radiation value of ETM+ thermal infrared 6-band pixel at the sensor [W/(m$^2$·sr·μm)]; DN is the pixel gray value, gain and bias are 6-band gain and bias respectively.

In equation (7): T is the temperature value at the sensor (k); $K_1$ and $K_2$ are calibration parameters respectively, $K_1=606.09$ W/(m$^2$·sr·μm), $K_2=1282.71$ K.

The calculated temperature T must be corrected for specific emissivity to become LST.

\[
\text{LST} = \frac{T}{1+(\lambda T/\rho)\ln\varepsilon}
\]

(8)

In equation (8): LST is the surface temperature (k); $\lambda$ is the center wavelength of ETM+6 band ($\lambda = 11.45$ μm); $\rho = 1.438 \times 10^{-2}$ m·K; $\varepsilon$ is 0.97 of the surface emissivity.

3.4.9. Impervious area index. The impervious area index (NDBSI) can be synthesized by both the building index (IBI) and the soil index (SI).

\[
\text{NDBSI} = \frac{(\text{IBI} + \text{SI})}{2}
\]

(9)

\[
\text{IBI} = \frac{2\rho_5/(\rho_5 + \rho_4) - [\rho_4/(\rho_4 + \rho_3) + \rho_3/(\rho_3 + \rho_2)]}{2\rho_5/(\rho_5 + \rho_4) + [\rho_4/(\rho_4 + \rho_3) + \rho_3/(\rho_3 + \rho_2)]}
\]

(10)

\[
\text{SI} = \frac{[(\rho_5 + \rho_3) - (\rho_4 + \rho_1)]}{[(\rho_5 + \rho_3) + (\rho_4 + \rho_1)]}
\]

(11)

4. Evaluation results and analysis

4.1. Evaluation results of Guangzhou's ecosystem status
Table 2 is the calculation results of ecosystem status indicators of Guangzhou. Table 3 is the evaluation results of Guangzhou's ecosystem status after considering the weight of the evaluation indicators. Figure 1 shows the changes of Guangzhou's ecosystem status in the past 11 years.

From 2005 to 2016, the score of ecosystem status evaluation of Guangzhou has changed a little. In 2005, it was basically the same as that of 2010. The score of ecosystem status was 0.482 and 0.483, respectively. In 2016, it decreased to 0.468, mainly due to the decrease of the score of ecological structure and ecological quality, especially the three indicators of ecological structure.

**Table 2. Calculation results of ecosystem status indicators of Guangzhou.**

| Factor level       | Index name                        | 2005   | 2010   | 2016   |
|--------------------|-----------------------------------|--------|--------|--------|
| Ecological resources | Proportion of ecological protection area | 0.295  | 0.302  | 0.308  |
|                    | Landscape fragmentation index     | 0.403  | 0.362  | 0.323  |
| Ecological structure | Ecological structure index        | 0.170  | 0.159  | 0.130  |
|                    | Ecological stress index           | 0.719  | 0.755  | 0.713  |
|                    | Humidity index                    | 0.806  | 0.785  | 0.790  |
| Ecological quality | Vegetation index                  | 0.662  | 0.730  | 0.761  |
|                    | Surface temperature index         | 0.332  | 0.349  | 0.342  |
|                    | Impervious area index             | 0.529  | 0.465  | 0.397  |

**Table 3. Evaluation results of Guangzhou's ecosystem status.**

| Year | Ecological resources | Ecological structure | Ecological quality | Total score |
|------|----------------------|----------------------|--------------------|-------------|
| 2005 | 0.054                | 0.147                | 0.282              | 0.482       |
| 2010 | 0.055                | 0.145                | 0.284              | 0.483       |
| 2016 | 0.056                | 0.132                | 0.280              | 0.468       |

**Figure 1. Changes of Guangzhou's ecosystem status in the past 11 years.**

4.2. Evaluation results of the ecosystem status of all districts in Guangzhou

According to the same way above, the ecosystem status of all districts of Guangzhou in 2016 is evaluated, and the calculation results are shown in Table 4 and Figure 2.

In 2016, Conghua District got the highest score of 0.651, and Liwan District got the lowest score of 0.308. The ranking from low to high of 11 districts was Liwan, Nansha, Yuexiu, Haizhu, Panyu, Tianhe, Baiyun, Huadu, Huangpu, Zengcheng and Conghua.

In terms of the score composition of ecosystem status, the score of ecological quality in each district is basically the same, ranging from 0.142 to 0.176; the score range of ecological structure in each district
is from 0.127 to 0.202; the score gap of ecological resources in each district is large, ranging from 0.007 in Liwan District to 0.282 in Conghua District. It can be seen that the low score of ecosystem status in Liwan district is related to the lowest score of ecological resources and ecological structure, while the score of ecological resources and ecological structure in Conghua district is the highest in each district.

Table 4. Evaluation results of the ecosystem status of all districts in Guangzhou.

| District   | Ecological resources | Ecological structure | Ecological quality | Total score |
|------------|----------------------|----------------------|--------------------|-------------|
| Liwan      | 0.007                | 0.127                | 0.174              | 0.308       |
| Nansha     | 0.013                | 0.164                | 0.142              | 0.319       |
| Yuexiu     | 0.000                | 0.157                | 0.166              | 0.323       |
| Haizhu     | 0.028                | 0.149                | 0.165              | 0.342       |
| Panyu      | 0.026                | 0.169                | 0.163              | 0.358       |
| Tianhe     | 0.064                | 0.155                | 0.164              | 0.383       |
| Baiyun     | 0.071                | 0.153                | 0.171              | 0.395       |
| Huadu      | 0.088                | 0.146                | 0.176              | 0.410       |
| Huangpu    | 0.089                | 0.171                | 0.167              | 0.427       |
| Zengcheng  | 0.185                | 0.183                | 0.173              | 0.541       |
| Conghua    | 0.282                | 0.202                | 0.167              | 0.651       |

Figure 2. Evaluation results of the ecosystem status of all districts in Guangzhou.

5. Ecological problems

5.1. The area of ecological land decreases gradually
Based on the ecosystem status evaluation of Guangzhou from 2005 to 2016, the evaluation score of ecosystem status has declined in recent years, mainly due to the decline of the score of the ecological structure. In recent years, the area of forest land, grassland, water wetland and other ecological land in Guangzhou has been reduced, and the forest land area has been transformed into garden land, construction land and so on. The decrease of forest land area leads to the decrease of vegetation coverage in important ecological functional area, the damage of plant biomass and productivity, and the impact on ecosystem function.

5.2. The difference of ecosystem status in each district is obvious
In 2016, the ranking of the evaluation scores of ecosystem status of each district from low to high is Liwan, Nansha, Yuexiu, Haizhu, Panyu, Tianhe, Baiyun, Huadu, Huangpu, Zengcheng and Conghua. The difference of ecosystem status in each district is obvious.

6. Suggestions on ecological environment protection

6.1. Strengthen the protection of natural ecological environment
Improve the ecological quality, strengthen the protection of ecological land and reduce the area of construction land.

6.2. Strengthen the supervision of ecological environment
Strengthen the coordination and co-governance of all departments. Build a regional collaborative pollution control mechanism. Build an environmental governance system with the government as the main guide, enterprises as the main body, social organizations and the public participation. Improve industrial and environmental policies and improve the green level of industrial development.

6.3. Implement environmental protection reform
Establish the ecological compensation policy based on regional compensation. Strengthen the pollution control policy and improve the permit system of pollutant discharged.

6.4. Promote the formation of green production and life style
Promote the implementation of strategic environmental assessment and planning environmental assessment. Improve environmental economic policies, deepen green tax, green trade and green financial policies, and guide enterprises to implement green production.

6.5. Continuously improve the basic capacity of ecological environment protection
Focus on the construction of four environmental protection systems under the new situation, namely, environmental protection management system, environmental protection infrastructure supervision system, environmental protection pollution prevention system, and environmental protection law enforcement and supervision system. Strengthen the protection of ecological spatial pattern, implement ecological red line, and optimize road planning and urban planning space.

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