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Extension and application of Saihanba ecological model based on fuzzy comprehensive evaluation method

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Abstract: In order to extend the ecological protection model of Saihanba to the whole country, considering the regional heterogeneity, we improve the evaluation index system of problem one, constructing a three-level fuzzy comprehensive evaluation model, scoring the ecological environment status of each region, and then selecting Tianjin, Shanxi, Shandong, Ningxia and Hebei, which have lower scores, as the ecological region construction place. Finally,according to the national average level and the selected regions' own situation, suggestions on the number and scale of construction are given,and through the carbon absorption and forest area fitting curve, the contribution of ecological area construction to China's carbon neutral target is judged.

1. Introduction

Upholding the concept of living in harmony with nature, China insists on implementing a sustainable development strategy.With the help of the Chinese government, China's Saihanba Forest Farm has recovered from the desert and has now become an eco-friendly green farm with a stable sand prevention function. On the one hand, there is the historical mission that "civilization will develop followed with zoology thriving". On the other hand, there are new issues encountered on the road of green development. Therefore, since the 18th National Congress of the Communist Party of China, Saihanba people have successively launched three major projects, namely, afforestation, natural improvement of artificial forests, and near-naturalization cultivation of natural forests, trying to make artificial forests closer to natural ones.

In this paper, we first analyse the environmental impact of Saihanba's ecological model, then we plan to extend the ecological protection model of Saihanba to the whole country, build a mathematical model and collect relevant data, to determine which geographical locations in China need to build ecological areas, and fix the number or scale of ecological areas to be built; moreover, to evaluate its impact on achieving China’s carbon neutral target.

2. Model Establishment and solution

2.1 Analysis on the impact on the ecological environment of Saihanba

To begin with, we select appropriate evaluation indicators.Then, referring to the construction components of the ecological environment assessment index (EI) and relevant literature experience, the index is to be constructed in a comprehensive level according to the nature.

Comprehensively reading the relevant literature, and combining the available data, we select the forest coverage, coverage, forest storage, water retention, carbon dioxide absorption, oxygen release as the second-level indicators, and climate impact and biological abundance as the first-level indicators to build the Saihanba environmental quality evaluation index system.

Next, as for the secondary indicators,we use the entropy method to calculate the weight, and as for the first level ones,based on the research results of Jin (2014) using the analytic hierarchy process, we give the weight of climate measurement and biological abundance by analogy.In this way, we can get a weighted environmental evaluation indicator system. Then, data from 1962-2010 is to be selected, combining with the weights, a multi-level fuzzy comprehensive evaluation model can be constructed to obtain the relative scores of Saihanba's environmental conditions in each year.

Finally, we find that the score increased by approximately 80% over the 49 years, which is a really great giant.That shows that the construction of Saihanba really contributes to the improvement of the regional environment.

2.2 Comprehensive Evaluation System of Ecological Environment

In order to promote Saihanba's ecological protection model to the whole country, we select Chinese provinces as the evaluation objects to determine the construction locations of the ecological area.

Based on accessible data from China Statistical Yearbook, we make some improvements of the evaluation system, enriching the indicators to meet the regional heterogeneity.The new system is shown in Table 1.

Table 1: Comprehensive Evaluation System of Ecological Environment

<table>
<tr><td rowspan="3">Biological abundance 0.75</td><td colspan="2">Forest coverage (0.2084)</td></tr>
<tr><td colspan="2">Forest area (0.445)</td></tr>
<tr><td colspan="2">Total live wood savings (0.3471)</td></tr>
<tr><td rowspan="4">Environmental quality 0.25</td><td rowspan="2">Acoustic Environment 0.2</td><td>Road traffic noise equivalent sound level (0.4229)</td></tr>
<tr><td>Regional environmental noise equivalent sound level (0.5771)</td></tr>
<tr><td rowspan="2">Air Environment 0.8</td><td>Annual average concentration of PM2.5 (0.8196)</td></tr>
<tr><td>The number of days when the air quality reaches or is better than Grade II (0.1804)</td></tr>
</table>

2.3 Ecological District Construction Selecting Model

First we use the entropy method to determine the weight of each indicator, and then construct a multi-level fuzzy comprehensive evaluation model to filter out the areas with lower scores.

Referring to conclusions of Jin (2014), who use AHP to establish the weight, we still give Environmental quality and Biological abundance weights of 0.25 and 0.75 respectively, and 0.8 and

0.2 for Air environment and Acoustic Environment respectively.

The weight system is shown in Table 1

Then determine the membership function:

$$\theta_1=\begin{cases}0, 0\leqslant x\leqslant 5\\ \dfrac{x}{2700}, 5<x<2700\\ 1, x\geqslant 2700\end{cases}\quad \theta_2=\begin{cases}0, 0\leqslant x\leqslant 2\\ \dfrac{x}{100}, 2<x<70\\ 1, x\geqslant 70\end{cases}\quad \theta_3=\begin{cases}0, 0\leqslant x\leqslant 70\\ \dfrac{x}{7000}, 70<x<7000\\ 1, x\geqslant 7000\end{cases}\quad \theta_4=\begin{cases}0, 0\leqslant x\leqslant 60\\ -\dfrac{x}{100}+1, 60<x<71\\ 1, x\geqslant 71\end{cases}$$

$$\theta_5=\begin{cases}1, 0\leqslant x\leqslant 50\\ -\dfrac{x}{100}+1, 50<x<60\\ 0, x\geqslant 60\end{cases}\quad \theta_6=\begin{cases}1, 0\leqslant x\leqslant 35\\ \dfrac{75-x}{40}, 35<x<70\\ 0, x\geqslant 75\end{cases}\quad \theta_7=\begin{cases}0, 0\leqslant x\leqslant 200\\ \dfrac{x}{366}, 200<x\leqslant 366\end{cases}$$

Next, determine the single factor evaluation matrix according to the membership function, and finally get the ecological environment evaluation scores of the provinces in China.The scores of some provinces are listed in the table below:

Table 2: Ecological environment evaluation scores of the provinces

Region	Score	Number of national ecological areas	Region	Score	Number of national ecological areas
Tianjin	0.1963	3	Hubei	0.4376	22
Shanxi	0.2356	8	Chongqing	0.4392	6
Shandong	0.2357	7	Guizhou	0.4765	10
Ningxia	0.2443	9	Hunan	0.4782	23
Hebei	0.2456	13	Xizang	0.4921	11
Shanghai	0.2776	2	Zhejiang	0.4983	11
Xinjiang	0.2804	15	Hainan	0.5111	10
Qinghai	0.2813	7	Guangdong	0.5197	15
Henan	0.2873	13	Jiangxi	0.5673	16
Jiangsu	0.2922	3	Inner Mongolia	0.6024	29
Gansu	0.3184	21	Guangxi	0.6071	23
Beijing	0.3425	2	Sichuan	0.6255	32
Anhui	0.3724	8	Heilongjiang	0.6408	49
Liaoning	0.3933	19	Fujian	0.6679	17
Shanxi	0.4113	26	Yunnan	0.7732	20

The results are visualized in the map of China. The lighter the color, the lower the score.

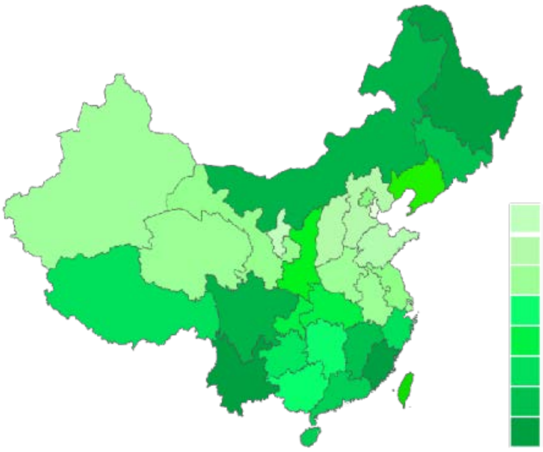

Figure 1: Ecological environment evaluation scores of Chinese provinces

We establish a threshold of 0.25, and build ecological areas for areas with a score below 0.25, including Tianjin, Shanxi, Shandong, Ningxia and Hebei.

Table 3: Description of the status of ecological areas in low-scoring areas

Region	total national nature reserve area/ten thousand hectares	number of national ecological areas	average area/ten thousand hectares
Tianjin	3.8	3	1.27
Shanxi	14.1	8	1.76
Shandong	22	7	3.14
Ningxia	46	9	5.11
Hebei	26.1	13	2.01

According to the data on the number of national ecological areas in each region in the 2020 China Statistical Yearbook, the average number of protected areas in each province is calculated to be 15.Therefore, we define the number of ecological areas to build as:

$$N_i=15-NUMBER_i$$

N_i is number of ecological areas to build of each of the low-score areas selected, $NUMBER_i$ is the number of existing ecological areas in these areas.

Define the construction scale of the ecological areas as:

$$SCALE_i=N_i*AVERAGE_i$$

$SCALE_i$ is the ith province's construction scale of the ecological areas, $AVERAGE_i$ is the average area of the selected provinces's exiting national ecological areas.

Then we can calculate the number of ecological areas to build in the provinces selected.

Table 4: Number of ecological areas to build

area	Tianjin	Shanxi	Shandong	Ningxia	Hebei
Number of ecological areas to build	12	7	8	6	2
construction scale of the ecological areas/ten thousand hectares	15.20	12.34	25.14	30.67	4.02
Total increase in area/ten thousand hectares	87.36				
Total ecological areas' area after construction	19.00	26.44	47.14	76.67	30.12

Taking 70% of the forest coverage in the nature reserve, the total increase in forest area is calculated to be approximately 611,500 hectares.So the average increase is about 17,500 hectares.

3. Forecast of impact on carbon neutral target

First we make a scatter plot of the amount of carbon dioxide absorption versus the forest coverage area to observe the impact of the ecological area on carbon absorption:

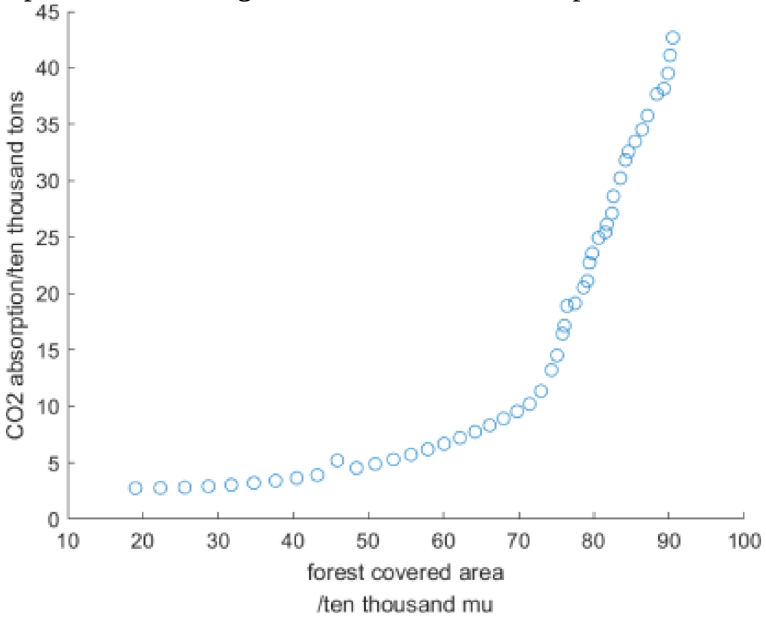

Figure 2: Forest Covered Area-CO2 Absorption Scatter Diagram

From the figure, we can find that the amount of carbon dioxide absorption and the forest cover show an exponential growth relationship, so we use an exponential function to fit the relationship between the two:

$$y = 5.831e^{-0.03646x} + 0.1278e^{0.0644x} \quad (SSE = 98.34 \;\; R^2 = 0.9875)$$

So when the forest area increases by 611,500 hectares, the carbon dioxide absorption will increase by approximately 20.036 million tons per year that obviously contributes a lot to the goal of carbon neutrality.

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