

# An ecological reserve evaluation and site selection model based on AHP method and cluster analysis

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**Abstract.** On September 22, 2020, the Chinese government proposed in the 75th United Nations General Assembly that "China will strive to reach peak carbon by 2030 and achieve carbon neutrality by 2060." Adhering to the concept that green water and green mountains are priceless treasures, environmental protection and natural restoration are put in the first place. It is of practical significance to study ecological protection construction and its environmental impact assessment. In this paper, we focus on the impact evaluation of the ecological protection construction of the Seyhanba Forest, based on the mining and analysis of the collected official data and with the help of spss and other software, we give the evaluation model of the impact of Seyhanba on the environment before and after restoration, the mathematical model of the impact evaluation of Seyhanba on the ability of Beijing to resist sandstorms, and the mathematical model of other areas in China that need to build ecological reserves, and extend to the Asia-Pacific region. Mathematical models were provided for the construction of ecological reserves in other countries.

**Keywords:** spss; information retrieval; AHP; entropy weight method; nonlinear multiple regression fitting; systematic cluster analysis.

## 1. Introduction

### 1.1 Problem Background

On September 22, 2020, the Chinese government proposed in the 75th session of the United Nations General Assembly that "China will strive to reach peak carbon by 2030 and achieve carbon neutrality by 2060." A good ecological environment is an inherent requirement for national development, and it is important to respect nature, protect nature and implement sustainable development strategies. At present, the construction of ecological civilization and ecological protection of the environment still faces many difficulties and challenges, and there are many shortcomings [1].

Among the ecological protection actions currently being carried out, the restoration of the Seyhanba Forest Farm with the help of the Chinese government is a very good and positive example. Located in China's Hebei Province, the Sekhamba Forest was originally a place of rich grass and water, but after 1863, the vegetation was destroyed, and within the next 100 years, it deteriorated further and became a desert. In 1962, 369 young people came to this desert, dedicating their lives to planting seeds to fight the wind and sand by planting trees. After more than half a century of struggle, the largest artificial forest in the world was built on the land of Seyhanba, and the ecological environment of Seyhanba was restored [2].

### 1.2 Restatement of the Problem

Nowadays, it is crucial to explore a correct and effective ecological conservation model. It is not as easy as people think to turn a desert into an oasis, and the difference between a man-made forest and a naturally occurring forest makes the mechanical repetition of planting trees less effective, so it is important to adopt a reasonable method to make the planted forest close to the natural forest, and at the same time, the wrong approach in all aspects will make the ecology better. Therefore, it becomes important to establish a mathematical evaluation model of ecological conservation model.

## 2. Evaluation model of the ecological impact of the restoration of the Seyhanba

### 2.1 Data Description

The study required us to build an evaluation model for the ecological impact of Seyhanba woodland restoration [3]. In order to construct this model, through information retrieval, combined with the retrieval and analysis of relevant literature, we selected five indicators that we believe play a key role in the ecological impact assessment model of Saihanba restoration: forest coverage, forest reserves, water content, Biodiversity and carbon dioxide uptake. We collected official data for these five indicators, and performed data preprocessing and data visualization analysis [4].

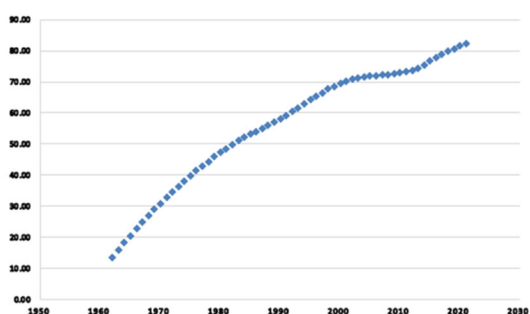


Figure 1. Forest cover as a function of year

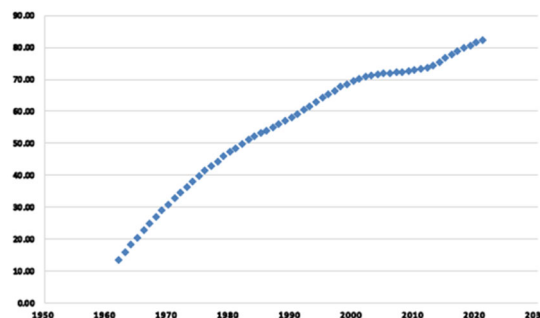


Figure 2. Forest stock versus year

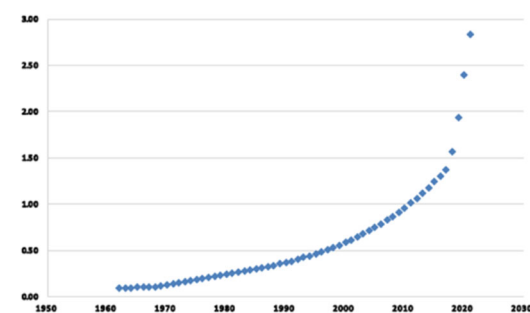


Figure 3. Volume of cultured water versus year

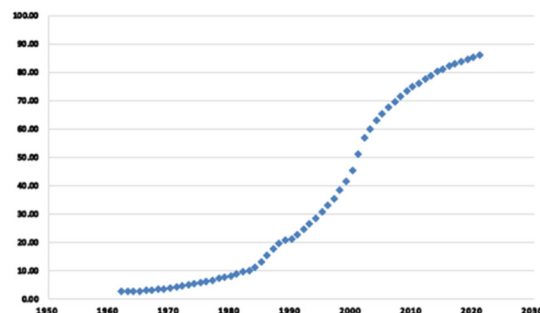


Figure 4. CO<sub>2</sub> uptake versus year

### 2.2 Modeling of subjective evaluation

In the model of subjective evaluation, we used the collected data to first divide them into indicators, and obtained five more critical indicators as the criteria for evaluation through visualization [5]. Since the human judgment is not accurate, we introduced the 1-9 scale method. A large number of simulation experiments proved that the 1-9 scale is feasible and more effective in quantifying the thinking judgment compared with other scaling methods. By using 1-9 scale, we got the weights of different influencing factors and finally got the scores of ecological environment before and after restoration of Seyhan Dam. By comparing the magnitude of the scores, we quantitatively worked out the evaluation model of the impact of ecological environment before and after restoration of Seyhan Dam [6].

The AHP method was used to assign weights and establish the evaluation model. Scales 1-9 were introduced.

Table 1. 1-9 scale table

Scale	Meaning
1	indicates that two factors are equally important compared to each other
3	Indicates that one is slightly more important than the other when compared to two factors
5	Indicates that one is significantly more important than the other when compared to two factors
7	Indicates that one is strongly more important than the other when compared to two factors
9	Indicates the extreme importance of one over the other when compared to two factors
2,4,6,8	Median of two adjacent judgments
1/3	If the scale of A compared to B is 3, B compared to A is 1/3

Then we obtain an importance matrix based on the correlation coefficients as well as the experts' assessments [7].

The consistency index CI is introduced. The maximum eigenvalue A of the importance matrix is introduced.

$$CI = \frac{A - n}{n - 1} \tag{1}$$

**Table 2.** Introduction of the average random consistency index RI.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Perform consistency tests (see Appendix I for codes).

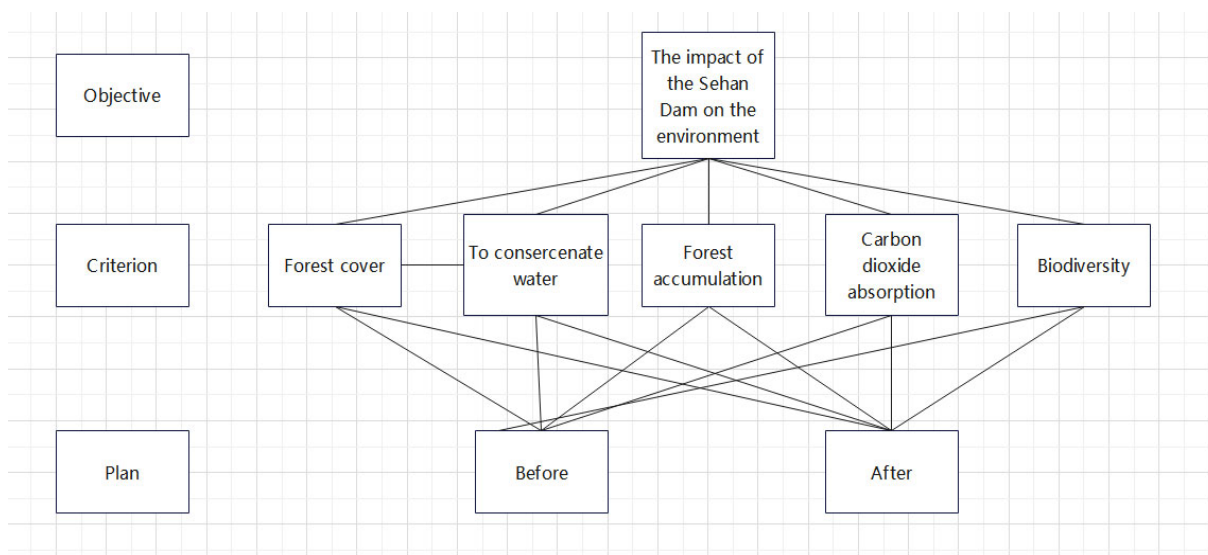
Introduce consistency ratio CR:

$$CR = \frac{CI}{RI} \tag{2}$$

If  $CR < 0.10$ , the consistency test of the importance matrix was considered to be passed and the obtained data were valid [8]. By using three methods: arithmetic mean method, geometric mean method and eigenvalue method, the corresponding weights were derived. The scores were then calculated, and finally the scores of the ecological impacts before and after the restoration of the Sekhangba environment were obtained quantitatively.

### 2.3 Solving for subjective evaluation methods

In the subjective evaluation, the first thing we had to do was the selection of indicators. Based on the official data collected and after data visualization, we selected five indicators with greater influence: forest cover, forest stock, water storage, biodiversity, and CO<sub>2</sub> absorption. We first mapped the stratification structure based on [9].



**Figure 5.** Layered structure diagram

Based on the 1-9 rule and a review of relevant professional literature, we obtained the following importance matrix.

**Table 3.** Importance Matrix

	Forest coverage	Forest stock	Amount of water contained	Biodiversity	Carbon dioxide absorption
Forest coverage	1	7	7	2	3
Forest stock	1/7	1	1	1/5	1/6
Amount of water contained	1/7	1	1	1/5	1/6
Biodiversity	1/2	5	5	1	1/5
Carbon dioxide absorption	1/3	6	6	5	1

Calculated,  $CI=0.1106$ ,  $RI=1.12$ ,  $CR=0.0987 < 0.10$

So the consistency of the importance matrix is acceptable [10].

Applying the eigenvalue method to the importance matrix to find the weights.

**Table 4.** Eigenvalue method to obtain weight table

	Weights
Forest coverage	0.4278
Forest stock	0.0429
Amount of water contained	0.0429
Biodiversity	0.1593
Carbon dioxide absorption	0.3272

The obtained weight is multiplied by the ecological environment indicators before and after the restoration of Saihanba, and the score of the ecological environment before and after the restoration of Saihanba is obtained [11].

**Table 5.** Scoring table of ecological environment

	Before	After	Weights	Points before	Points after
Forest coverage	0.111	0.889	0.4278	0.047486	0.380314
Forest stock	0.099	0.901	0.0429	0.004247	0.038653
Amount of water contained	0.099	0.901	0.0429	0.004247	0.038653
Biodiversity	0.167	0.833	0.1593	0.026603	0.132697
Carbon dioxide absorption	0.099	0.901	0.3272	0.032393	0.294807

Total evaluation score before restoration of the Seyhanba forestry site: 0.114976.

The total evaluation score for the post-restoration of the Seyhanba forestry site: 0.885124.

In the subjective evaluation, it can be clearly concluded that the restoration of the Seyhanba played an important role in preventing wind and sand, protecting the environment and maintaining ecological balance and stability.

### 3. Evaluation method and results

In order to select regions for the establishment of nature reserves, we decided to analyze and evaluate the need for the establishment of nature reserves in each region of China using systematic cluster analysis [12]. Because of the variability in area and population, we used forest resources per capita, wastewater emissions per capita, nitrogen oxides emissions per capita, afforestation area per capita, land area, and dust emissions per capita as variables to establish a cluster analysis model using SPSS for the 31 regions of the country. In order to visualize the differences we divided the 31 regions into 2 to 5 clusters, and then used the five clusters resulting from the classification to classify the need for establishing nature reserves in each region into five classes [13].

	The cluster			
	cluster5	cluster4	cluster3	cluster2
1:Beijing	1	1	1	1
2:Tianjin	1	1	1	1
3:Hebei Province	1	1	1	1
4:Shanxi Province	1	1	1	1
5:Inner Mongolia Autonomou	1	1	1	1
6:Liaoning Province	1	1	1	1
7:Jilin Province	1	1	1	1
8:Heilongjiang Province	1	1	1	1
9:Shanghai	1	1	1	1
10:Jiangsu Province	1	1	1	1
11:Zhejiang Province	1	1	1	1
12:Anhui Province	1	1	1	1
13:Fujian Province	1	1	1	1
14:Jiangxi Province	1	1	1	1
15:Shandong Province	1	1	1	1
16:Henan Province	2	2	1	1
17:Hubei Province	3	1	1	1
18:Hunan Province	3	1	1	1
19:Guangdong Province	3	1	1	1
20:Guangxi Zhuang Autonomou	3	1	1	1
21:Hainan	3	1	1	1
22:Chongqing	3	1	1	1
23:Sichuan Province	3	1	1	1
24:Guizhou Province	3	1	1	1
25:Yunnan Province	3	1	1	1
26:Tibet Autonomous Region	3	1	1	1
27:Shaanxi Province	3	1	1	1
28:Gansu Province	3	1	1	1
29:Qinghai Province	3	1	1	1
30:Ningxia Hui Autonomous Region	4	3	2	2
31:Xinjiang Uygur Autonomou	5	4	3	1

Figure 6. Clustering results for different regions

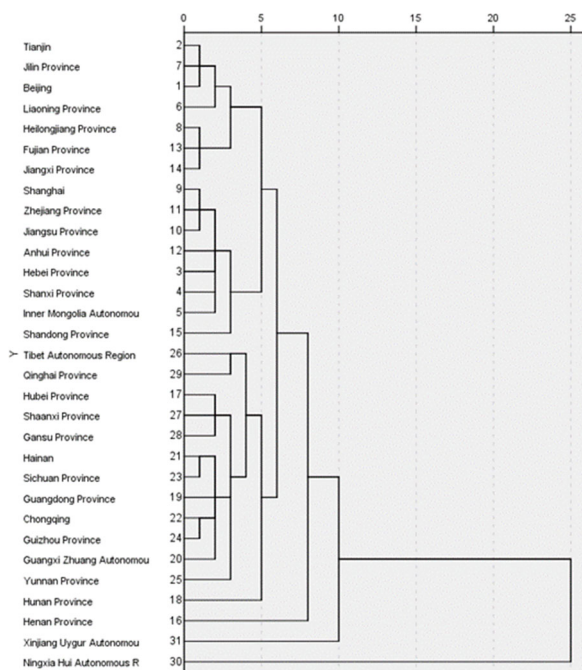
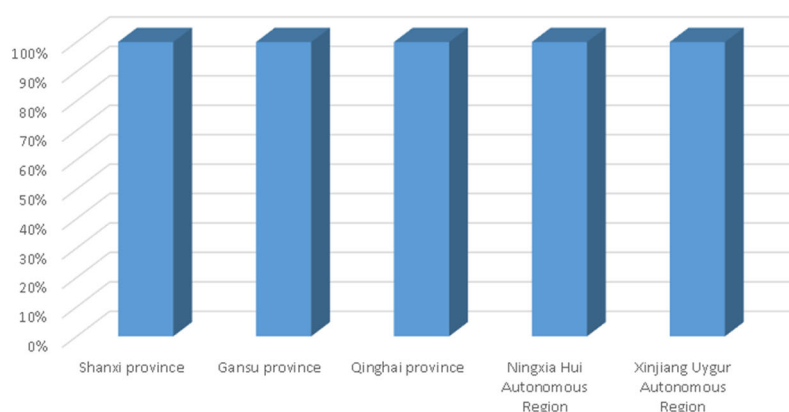


Figure 7. Dendrogram results for the use of average linkage for different regions

Based on the results obtained from the cluster analysis, we clearly found regions with a high demand for the establishment of ecological reserves: Shaanxi Province, Gansu Province, Xinjiang Uyghur Autonomous Region, Ningxia Hui Autonomous Region, and Qinghai Province. These provinces are generally characterized by a lack of economic development and are in a lower rank in terms of afforestation area and water resources per capita [14].

China's Ministry of Ecology and Environment issued instructions on September 29, 2019, that the total area of nature reserves in China should account for 15% of the terrestrial land area; the United Nations' Convention on Biological Diversity proposes that the protected area should reach a target of 17% by 2020; the ecological protection red line in Hubei Province stipulates that ecological reserves

should account for 22.3% of the province's land area; according to the different regulations, we can find that 17%-20% of the province's land area for ecological protection zones are among the levels above the qualified line. Combining the available data, we find that the percentages of ecological protection zones in Qinghai Province and Gansu Province in the province's land area have been basically satisfied, but Shaanxi Province, Xinjiang Uyghur Autonomous Region and Ningxia Hui Autonomous Region still have a greater demand for the establishment of ecological protection zones [15].



**Figure 8.** Percentage of ecological reserves in some provinces to the province's land area

Based on the above, we concluded the following: Shaanxi Province, Ningxia Hui Autonomous Region, and Xinjiang Uyghur Autonomous Region need to establish ecological reserves. According to the United Nations Convention on Biological Diversity, we define the percentage of ecological reserves in the province as a qualified level at 17% of the province's land area. Among them, the specific required ecological reserve construction area is shown in the following table.

**Table 6.** Construction Area of Ecological Reserves

	Construction area of ecological protection area required
Shanxi Province	23644 square kilometers
Ningxia Hui Autonomous Region	5976 square kilometers
Xinjiang Uyghur Autonomous Region	86574.8 square kilometers

#### 4. Conclusion and Prospective

This model comprehensively considers the status of existing ecological forests in China and other Asia-Pacific regions, the requirements of different trees for the growth environment, how to balance ecological forest land, and the layout of economic development and industrial land, and whether there is enough land in the target geographic area to develop ecological protection. Areas and other issues, and can provide feasible suggestions for the site selection and construction of ecological protection areas.

After determining the large scope of the establishment of ecological protection areas, we can apply our systematic aggregation method based on factors such as annual water coverage, forest coverage, average air quality index, residents' water demand satisfaction, and greenhouse gas emissions as evaluation indicators. The class model performs cluster analysis on different areas, and by dividing different areas into multiple categories, it is more effective to find the areas that most need to establish ecological reserves. By referring to the specific measures in the restoration process of Saihanba, we can understand and comprehend some measures that have a positive effect on ecological protection: afforestation, natural improvement of artificial forests and near-natural cultivation of natural forests; these measures make artificial forests closer Natural forests have made a lot of contributions to the restoration of the ecological environment.

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