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Saihanba's Impact on Beijing's Environment and Its Reference to China

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Abstract. With the development over time, people and the government gradually realize the importance of the environment. From 1962 to 2021, the forest coverage of Saihanba increased from 13% to 80%. This article used the AR model to establish time series from three aspects: oxygen release, carbon dioxide acceptance and water source storage to analyze the ecological environment before and after Saihanba ecological protection action. In addition, a time series of air quality in Beijing was established to show that the environmental improvement of Saihanba has helped reduce the dust weather in Beijing. After that, AHP analytic hierarchy process model was used to evaluate the significance of altitude, temperature, wind force, humidity and precipitation for the establishment of ecological areas. China is divided into four regions according to the differences in geographical environment. The demand degree of ecological areas was evaluated for these four regions, and the areas that need established ecological areas were selected. Then the scale of the ecological area of the site was determined through the best benefit and cost evaluation. In conclusion, based on the ecological environment construction mode of Saihanba, this report established a model that can be used to evaluate the ecological environment benefits and the best implementation site.

Keywords. Environment, autoregressive model, analytic hierarchy process model

1. Introduction

Beginning in 1962, 369 young Chinese came to the wasteland of Saihanba to start planting trees. After half a century of hard work by foresters, Saihanba has now become the largest man-made forest in the world. Saihanba currently plays an important role in the protection of Beijing and Tianjin. Under the leadership of the government, foresters are working hard to transform Saihanba from a man-made forest into a natural forest. After decades of efforts, Saihanba now has a forest area of 76,700 hm^2 and a forest coverage rate of 82%. It has become the largest human-made forest in the world and built a Great Wall that saved water supply and blocked sandstorms for Beijing [1]. This case of transforming deserts into forests has given many countries a reference value. Not only Saihanba, but the entire China may be able to successfully replicate the successful model of Saihanba, bringing more hope and effort to the dream of turning the desert into an oasis. According to the forest ecological environment monitoring index system issued by the government, the impact of Saihanba on Beijing's environment can be evaluated from three aspects: oxygen release, carbon

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dioxide absorption and water conservation [2]. According to the Woodland Trust policy paper, the sustainable management of man-made forests should follow the following principles: maintaining and improving forest resources and ensuring the contribution of forests to the carbon cycle. Maintaining the health of forest systems. Maintain and safeguard the soil and water conservation function of forests [3].

According to the information we gathered from sources, we assumed that Saihanba could provide a positive effect on the environment of Beijing and even the whole China region. To verify our hypothesis, we need to select serval models to clean the data we got from the government website and manage to summarize the patterns of the data and make reasonable guesses. In the forest ecological environment monitoring index system, we select oxygen release, carbon dioxide absorption and water conservation as target patterns. In this case, we choose Autoregressive Model to find the regular pattern among these data. The autoregressive model is developed from the normal linear regression model. There are two parameters contained in this model, the first one is the patterns we selected from references, and the second one we chose is the year. Based on these two parameters, the Autoregressive Model could summarize the relationship between environment patterns and year. In addition, this model proved the assumption that Saihanba brought positive inspection to the environment of Beijing is true. After realising the positive effect Saihanba brought to the environment, we assumed its reference is useful to the China region. The Analytic Hierarchy Process Model is a method of determining a question and separating the related elements into several hierarchies. In this paper, the China region has been divided into four blocks. The Analytic Hierarchy Process Model would use five aspects to calculate a summary score for each block. After getting the final marks of each block, it will be easy to confirm which region is the perfect place to learn the successful afforested experience in Saihanba.

In conclusion, this paper will divide into two parts to elaborate on the benefits that Saihanba brought to the environment. The first model will show the improvement of environmental quality by using the Autoregressive Model. The second model will recommend a suitable place in the China region to promote the Saihanba afforested model by calculating the score with Analytic Hierarchy Process Model.

2. Autoregressive Model

2.1. Model Introduction

The Autoregressive Model is developed from the Linear Regression Model. The linear regression model contains two parameters x and y and uses x to predict y by finding the relationship between x and y.

In 1855, Galton published a paper demonstrating the regression of genetic height to the mean [4]. Using the average height of each couple in 1,078 couples as the independent variable and the height of their children as the dependent variable, he analyzed the relationship between the height of the children and the height of their parents and found that the height of the parents can predict the height of the children, and they are almost in a straight line. This is the so-called regression effect.

The linear autoregressive model usually deals with time series, using the same variable, such as x, the value of the previous period to predict the value of this period, such as x1 to xt-1 to predict the performance of xt, and assume that they are linear. It is precise because of this univariate prediction that it is called an autoregressive model [5].

2.2. Methodology

The data on carbon dioxide absorption, oxygen release, and oxygen water content in recent years is selected. Then, AR model was used to analyze, fit and predict these data.

2.2.1. Data Cleaning with lag_plot

Data Cleaning: The lag_plot in the pandas library is used to determine whether the data grows linearly year by year, whether there are abnormal points, whether there is autocorrelation, and whether there is a seasonal or periodic law.

2.2.2. Data Pre-processing

Since the model needs to ensure the stability of the data, that is, the variance and the mean do not change significantly, the difference is used to make the data more stable (Figure 1).

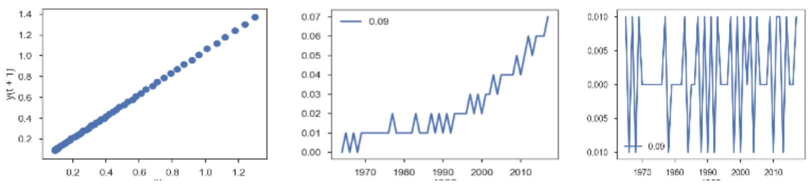

Figure 1. The first, second and third differences of data.

2.2.3. ACF and PACF

The autoregressive model needs to determine an order p, which means that the historical values of the previous periods are used to predict the current value. The formula of the p-order autoregressive model is defined as follows, where y_t is the current value, μ is the constant term, μ is the order γ_i is the autocorrelation coefficient, e_t is the error

$$y_t = \mu + \sum_{i=1}^{p} Y_i y_{t-1} + e_t \tag{1}$$

Here, ACF and PACF are used for model identification and order determination. By observing the tailing and truncation of the ACF and PACF models, the value of p or q can be judged (Figure 2).

The definition of ACF autocorrelation function is as follows,

$$ACF(k) = \rho_k = \frac{Cov(y_t, y_{t-k})}{Var(y_t)} \tag{2}$$

According to different censored and trailing situations, different models can be selected respectively (Table 1).

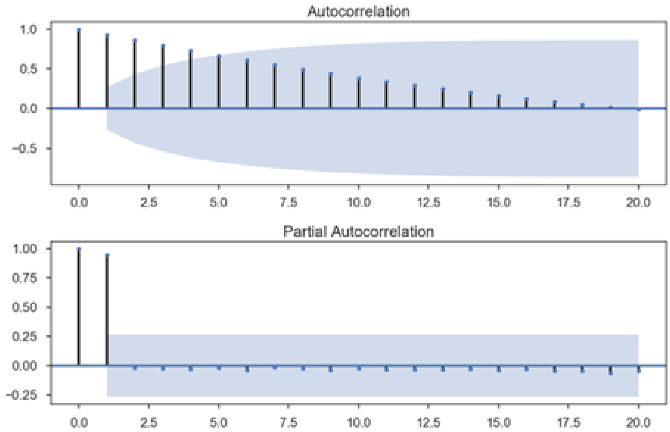

Figure 2. ACF and PACF analysis.

Table 1. Parameter *p* and *q* in ACF and PACF.

Model	ACF	PACF
AR(p)	Trailing to 0	Censored after p
MA(q)	Censored after q	Trailing to 0
ARMA (p, q)	Trailing to 0 after q	Trailing to 0 after q

2.2.4. Using AIC and BIC to Find the Best p, q Values

The AIC criterion is called the AKAIKE information criterion, the calculation equation is:

$$\begin{aligned} AIC &= 2*(numbers\ of\ model\ parameters) \\ &\quad \text{-}2ln(maximum\ likelihood\ function\ value\ of\ model) \end{aligned} \tag{3}$$

The AIC standard has certain shortcomings. When the sample size is large, the information provided by the fitting error in the AIC criterion will be amplified by the sample size, and the penalty factor for the number of parameters has nothing to do with the sample size (always 2), so when the sample size is large, the model selected using the AIC criterion does not converge with the real model, and it usually contains more unknown parameters than the real model. BIC (Bayesian information criterion) Bayesian information criterion makes up for the shortcomings of AIC. The calculation formula is as follows:

$$\begin{aligned} BIC &= ln(n)*(numbers\ of\ model\ parameters) \\ &\quad \text{-}2ln(maximum\ likelihood\ function\ value\ of\ model) \end{aligned} \tag{4}$$

2.2.5. Application of the Model

We use the AR model to model time series data, find out the correlation between time-series data, and predict the future. Among them, prediction mainly has two functions, one is the predict function and the other is the forecast function. The period for forecasting in the prediction must be in the data we train the ARIMA model, that is to say, the prediction belongs to the test set part, and the forecast is right in estimating the value of the next period at the end of the training data set (Figure 3).

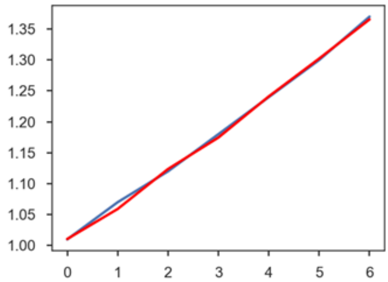

Figure 3. Prediction of quantity in next 6 years.

3. The Analytic Hierarchy Process Model

3.1. Model Introduction

The AHP used in this paper is normal in evaluating the weight. Nevertheless, the criteria and assigned weights cannot be completely defined objectively. With your goals in mind, you can refer to some complete resources, including ranking indicators for mainstream leaderboards. The AHP method, in the opinion of many experts, allows for more convincing and practical optimization.

The analytic hierarchy process (AHP) is a method of determining a question and separating the related elements into several hierarchies.

3.2. Methodology

Two factors have an equivalent influence on cautious selection. The first one is altitude. Trees cannot grow above the forest line because they are restricted by altitude [6]. At this altitude, air pressure is low and carbon dioxide is greatly reduced, but carbon is essential for all plant life. On the other hand, wind power should also be taken into account [7]. In general, with the increase in wind speed, it can cause the plant to reduce leaf area, internode shortening, stem total reduction, and result in plant dwarfing.

3.2.1. Divide the Hierarchical Model

The ecological reservation has five attributes of environment and four attributes of regions (Figure 4).

3.2.2. Quantitative Index

Comparison of quantitative values between indicators provides a comparison matrix (Tables 2-3).

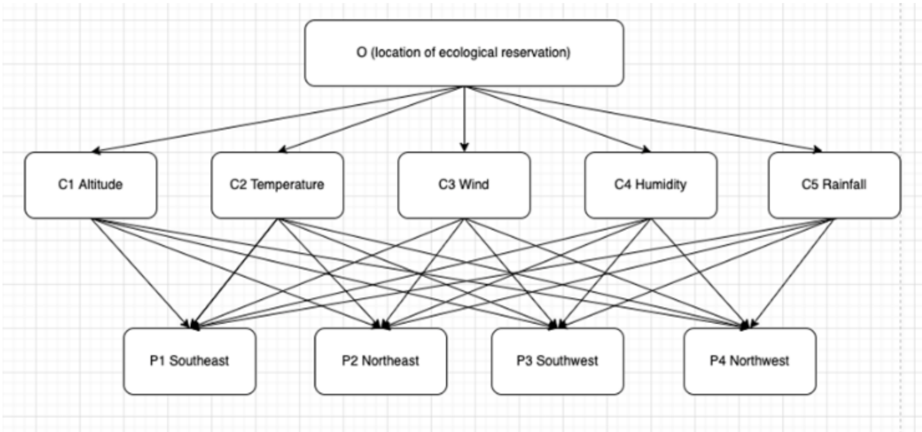

Figure 4. Hierarchical model structure.

Table 2. Judgment matrix.

Intensity	Definition
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important
Reciprocals	aij=1/aji

Table 3. Judgment at target level and index level.

Z	C1	C2	C3	C4	C5
C1	1	1/7	1	1/5	1/9
C2	7	1	5	1/3	1/8
C3	1	1/5	1	1/6	1/9
C4	5	3	6	1	1/5
C5	9	8	9	5	1

3.2.3. Calculation of the Index Weight and Rationality

We use geometric average, calculate Aw, and check rationality (Tables 4-5).

$$\lambda_{max} = \sum_{i=1}^{n} \frac{[A\omega]_i}{n\omega_i} \tag{5}$$

$$\lambda_{max} = 5.5063414 \tag{6}$$

$$CI = \frac{\lambda - n}{n-1} = 0.0126 \tag{7}$$

Table 4. Geometric average method.

Z	C1	C2	C3	C4	C5	Row product	Fifth power	Weights
C1	1	1/7	1	1/5	1/9	0.00317	0.316382062	0.03705
C2	7	1	5	1/3	1/8	1.45833	1.078378354	0.12627
C3	1	1/5	1	1/6	1/9	0.0037	0.326317485	0.03821
C4	5	3	6	1	1/5	18	1.782602458	0.20873
C5	9	8	9	5	1	3240	5.036269965	0.58972

Table 5. Aw and rationality check.

Z	C1	C2	C3	C4	C5	ω	Aω
C1	1	1/7	1	1/5	1/9	0.0404	0.2053
C2	7	1	5	1/3	1/8	0.1486	0.7708
C3	1	1/5	1	1/6	1/9	0.0402	0.2071
C4	5	3	6	1	1/5	0.2022	1.2048
C5	9	8	9	5	1	0.568	3.4932

The corresponding average random consistency index (RI) can be checked by table RI. The RI of level 5 is 1.12 (Table 6).

Table 6. RI table.

n	1	2	3	4	5	6
RI	0	0	0.52	0.89	1.12	1.26

$$RI = 0.112 \tag{8}$$

$$CR = CI / RI = 0.01125 \tag{9}$$

3.2.4. Elements of Judgement Matrices

We begin to determine which tree should be in, divide the country into four areas: northeast, northwest, southwest, and southeast, and evaluate the degree of suitable tree planting [8].

Five 4x4 matrices are used to evaluate: altitude, temperature, wind, humidity, and precipitation. From the perspective of northeast, northwest, southwest, and southeast tree planting needs.

The importance of each area in the same factor is analyzed. There are a total of five factors. The larger the number, the more trees need to be planted in the area.

3.2.5. Determine the Location of Protection Areas

Combining the weight table of regions and factors, the total weight of each region is calculated and shown in Tables 7-8.

Table 7. The weight table of regions and factors.

		SE	NE	SW	NW
Altitude	0.0370573	0.060112	0.126944	0.556565	0.256378
Temperature	0.12627	0.065017	0.5081437	0.28876	0.138078
Wind	0.0382176	0.058319	0.233503	0.47467	0.23350
Humidity	0.208733	0.06318	0.213560	0.132472	0.59077
Rainfall	0.589719	0.061541	0.207140	0.140360	0.590958

Table 8. The weight table of regions.

SE	NE	SW	NW
0.0621479	0.2445244	0.1856528	0.5076747

To make the weights more intuitive in the scoring process, we have drawn the following Figure 5, which shows intuitively and clearly the differences between each index.

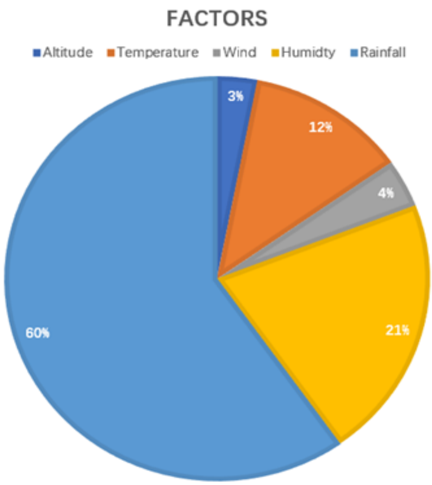

Figure 5. Visualization of weights.

It was found that the NW northwest has the greatest weight, and an ecological protection zone should be established in the northwest.

3.2.6. Calculate the Protection Areas to Be Established

Based on the absorption rate of carbon dioxide by the artificial forest and the planting cost (Figure 6), it is concluded that 560002800.0 to 653336600.0 square meters of the ecological forest should be planted in the northwest region [9].

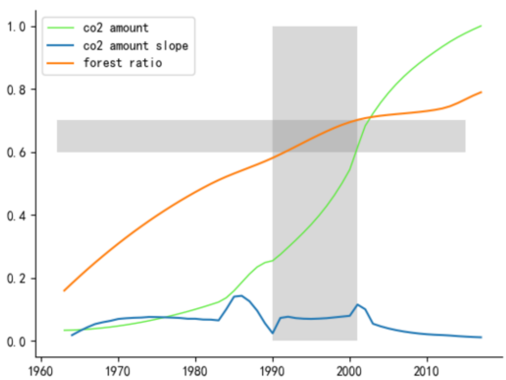

Figure 6. Visualization of CO_2 and forest ration.

4. Conclusion

To sum up, this paper uses the AR model to establish a time series analysis from three aspects: oxygen release, carbon dioxide acceptance and water source storage. It is concluded that the ecological environment before and after Saihanba's ecological protection action is gradually getting better. In addition, through the time series analysis of air quality in Beijing, it is known that the improvement of the Saihanba environment has helped to reduce the dust weather in Beijing. After that, AHP analytic hierarchy process model is used to evaluate the significance of altitude, temperature, wind force, humidity and precipitation for the establishment of an ecological area. After the comprehensive weight, precipitation has the greatest significance for the ecological environment. After evaluating the demand degree of ecological areas in northwest, northeast, southwest and southeast China, it is found that the comprehensive ecological area in Northwest China has the highest priority. Then, through the best benefit and cost evaluation, it is determined that the scale of the ecological area of the site should be 60000 square meters.

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