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# *Water Resources Ecological Footprint Based on ARIMA Model*

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***Abstract:*** Water resources are an important part of maintaining the normal operation of ecosystems and the normal development of human society. With the continuous development of social economy, water shortage and water pollution have increasingly attracted the attention of the international community. The purpose of this work is to study the prediction of the ecological footprint of water resources based on the ARIMA model. Based on the ecological footprint theory, a water resources ecological footprint prediction model is established to provide specific reference for the planning goals of sustainable water resource utilization in the future. By studying the time series analysis method, that is, using the eviews software to establish a time series analysis model ARIMA (p, d, q) model, a short-term forecast of M province from 2018 to 2021 is made. According to the time series analysis The prediction results of the model ARIMA (4, 1, 2) show that: from 2018 to 2021, the ecological footprint in M province is on the rise, and the water crisis situation will become increasingly severe. The ARIMA model has a good prediction effect.

## 1. Introduction

Water is the source of life. In today's human understanding, water is an important condition for the formation of life [1-2]. A measure of whether an ecosystem can be sustainable over time. The Ecological Footprint model considers all ecological resources in the entire area and whether human use of these resources can be removed from the area [3]. Therefore, the ecological footprint of water resources is one of the ecological footprint models, and the water ecosystem footprint modeling is also an important tool for ecosystem footprint modeling [4-5].

The ecological footprint theory is an important scientific basis of ecological economics [6]. Some scholars have used a political ecology approach to analyze the controversy over the eucalyptus plantations in Mount Taita, Kenya. The approach recognizes the social construction of environmental resources and the pluralism of the sense of power. They found that locals not only viewed eucalyptus plantations as a threat to local water resources, but also highlighted historical injustices and loss of control over the land and cultural relationships [7]. The ARIMA model enables efficient forecasting, and Sharma S is based on the Box-Jenkins method for the appropriate model type to forecast defense spending in India. A one-step look-ahead forecasting method was used for annual data from 1961 to 2020. The results show that the static forecast ARIMA(1, 1, 1) model is best suited for forecasting India's defense spending [8]. Therefore, it is of great practical significance to correctly evaluate the sustainability of water resources, discuss the problems existing in the development and propose corresponding countermeasures [9].

This paper takes the water footprint of M province as the basis of the water ecological footprint, and incorporates the prediction of the ARIMA model into the calculation of the ecological footprint of the M province's water volume. It can better reflect the regional water resources utilization status. At the same time, the research results complement and expand the water ecological footprint accounting projects and research contents.

## 2. Research on Prediction of Water Resources Ecological Footprint Based on ARIMA Model

### 2.1. Ecological Footprint

Ecological footprint can understand the sustainable development of an ecosystem and is widely used in many fields. The Ecological Footprint Framework divides human impacts on ecosystems into six types of production land: grasslands, mining areas, construction land, cultivated land, forest land, and watersheds. The Ecological Footprint addresses this issue by measuring the ecological issues of different crops at variable scales. When measuring the ecological footprint of many countries, the ecological footprint method is adopted, which is an intuitive and effective method [10-11].

Water is the source of life. People are not isolated from water in their daily life, but participate in the entire production process. Only the sustainable use of water resources can ensure the sustainable development of society and economy [12]. The Ecological Footprint compares the impact of human activity on an ecosystem to the large footprint on Earth, which is the area ofnatural production that an ecosystem needs to absorb human waste. The water ecological footprint is one of the six ecological footprints. The understanding of water here includes the natural production capacity of water resources to regenerate aquatic products, as well as the power of water resources in agriculture, industry and life.

### 2.2. Measures for Sustainable Utilization of Water Resources

(1) Protection of water resources

First, conscientiously implement the strictest water resource management system proposed by the government, and strengthen the security measures for drinking water sources [13]. Secondly, starting from all aspects of water supply, water use and sewage treatment, in addition to expanding water supply sources, it is also necessary to strengthen the restrictions of laws, regulations and market policies in the process of water use, strengthen residents' awareness of water conservation and publicity for protecting water resources, and minimize pollution and waste. Improve the level of sewage treatment and strengthen the construction of sewage treatment facilities [14-15]. Finally, protect the quality of groundwater and surface water. Strengthen research on agricultural fertilizers to reduce the pollution of groundwater by pesticides and chemical fertilizers; conscientiously implement the river chief system and strengthen the protection of rivers and lakes; control a series of problems caused by the excessive exploitation of polluted river courses and groundwater to improve the water environment; strengthen water Monitoring and early warning of drought disasters, and establishing a disaster prevention and mitigation system for the whole society [16].

(2) Rational use of surface water and groundwater resources

The carrying capacity of groundwater resources are different in different years. First, the use of surface water resources should be prioritized, the exploitation of groundwater resources should be reduced, and excess floods during flood season should be used to recharge groundwater overexploitation areas. Second, alleviate the situation of surface water shortage. Finally, in areas with a high degree of groundwater development, it is important to store surface water [17].

### 2.3. ARIMA Model

The ARIMA model is an extension of the ARMA model and is suitable for non-stationary time series data for short-term time series forecasting [18].

The general process used by the ARIMA model is as follows:

(1) Obtain the observation time series, and identify its stationarity according to the time series diagram, autocorrelation diagram, partial autocorrelation diagram and unit root test of the observation value. If the time series is stationary, go to the third step; if the time series is not, go to the second step.

(2) Perform differential operation on the non-stationary time series data, and then identify its stationarity again according to the method of the first step, until the time series after the difference operation becomes stable, and then enter the third step.

(3) Select the corresponding time series model according to the properties of the stationary series identified in steps 1 and 2. After the time series is stabilized, if the partial autocorrelation function (PACF) is tailed and the autocorrelation function (ACF) is truncated, the MA model is established.

(4) According to the properties of time series autocorrelation and partial correlation, estimate the autocorrelation order p and the moving average order q, plus the number of differences d, and perform ARIMA (p, d, q) model fitting.

(5) The significance test of the model is the white noise test of the residual sequence. If the residual is a non-white noise mode, there is still relevant information in the residual that has not been extracted, indicating that the model is inconsistent and needs to be re-fitted.

(6) Model optimization, establish multiple fitting models, select the optimal model among multiple fitting models, and usually use the AIC criterion to judge the quality of the model. In addition, in the forecasting process, the data is updated every time the forecast is made, and the latest data is used for forecasting, so that a better forecasting effect can be obtained when forecasting in the next period.

(7) Use the optimized model for time series prediction.

## 3. Investigation and Research on Prediction of Water Resources Ecological Footprint Based on ARIMA Model

### 3.1. Overview of the Study Area

Province M is an inland province located in the middle latitudes. The province's total area is 160,000 square kilometers, accounting for 1.5% of the national area. Affected by geographical location and natural conditions, M province belongs to a temperate continental monsoon climate. It is characterized by four distinct seasons, synchronous rain and heat, and sufficient light. The annual average temperature in all parts of M province is between 5-12 ℃, and the overall distribution trend is to increase from north to south and decrease from the basin to the mountainous area; all parts of the province is between 400 ℃ and 600 mm, and there is a serious seasonal distribution. The problem of unevenness is that the precipitation in summer is relatively concentrated from June to August.

### 3.2. M Provincial Water Resources Ecological Footprint

During the period from 2018 to 2021 in Province M, the water resources of Province M have been in a state of slight deficit during the period from 2018 to 2021. This shows that water consumption has greatly exceeded its carrying capacity, and the problem of water crisis has become increasingly prominent. However, this tense situation has finally been greatly reversed in 2020, and there has even been an ecological surplus of water resources for the first time in three years. In 2021, the total amount of water resources in M province will reach 56.1 billion m3. Under the circumstance that the per capita water footprint does not change much or even declines, the water resources carrying capacity is greatly improved, indicating that province M has achieved remarkable results in improving water use efficiency and open source measures.

### 3.3. ARMA Model Equation

The autoregressive AR(p) model equation is shown in Equation 1:

$$Xt = c + \sum_{i=1}^{p} \phi_i X_{t-i} + \varepsilon_t \tag{1}$$

The regression moving average model ARMA(p, q) model equation is shown in Equation 2:

$$Y_t = \mu_t + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_i \varepsilon_{t-j} \tag{2}$$

To construct a suitable ARMA(p,q), the following issues must be considered. One is the selection of the sequence, including the selection of p (autoregressive sequence) and q (moving average sequence); the second is parameter estimation, including the estimation of the values of p and q, and finally, the best fitting model is selected as the prediction model.

## 4. Analysis and Research on Prediction of Water Resources Ecological Footprint Based on ARIMA Model

### 4.1. Model Checking

Strictly speaking, it is not rigorous enough to judge whether the residual of the ARIMA (4, 1, 2) model is a white noise process only by observing the graph. The model test results are shown in

Table 1:

*Table 1. Unit root test results for model residual series*

| Variable | ADF test statistic | Significance level (%) | Critical value |
|---|---|---|---|
| Residual | -8.148 | 1.5 | -6.821 |
| | | 3 | -4.154 |
| | | 8 | -3.982 |


*Figure 1. Model checking results*

The results of the ADF test of the residual sequence of the ARIMA (4, 1, 2) model show that the residual sequence is a white noise process at the three significant levels of 1.5%, 3%, and 8%, as shown in Figure 1.. Based on the above analysis, it can be determined that the ARIMA(4,1,2) model is the best model.

## 4.2. Model Prediction

Table 2 shows the goodness of fit between the actual value and the predicted value of the per capita water resources ecological footprint in province M from 2018 to 2021, and the fitting graph is shown in Figure 2.

*Table 2. Actual vs Forecast*

| Years | Actual value ($hm^2$/cap) | Predictive value ($hm^2$/cap) |
|---|---|---|
| 2018 | 0.416 | 0.413 |
| 2019 | 0.445 | 0.442 |
| 2020 | 0.625 | 0.620 |
| 2021 | 0.663 | 0.660 |

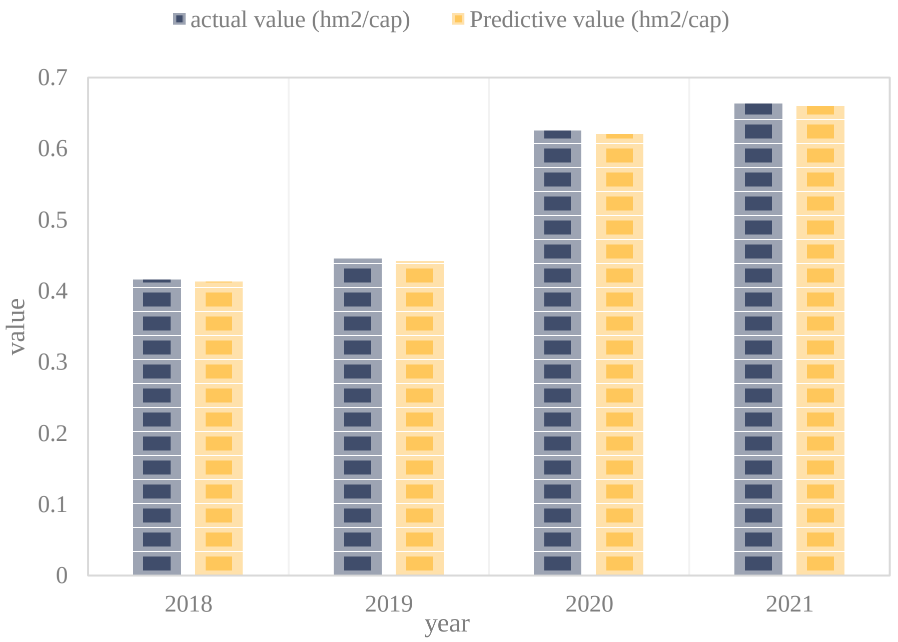


*Figure 2. Scatter fitting diagram of actual and predicted values of per capita water resources ecological footprint in M province from 2018 to 2021*

The relative error between the actual value and the predicted value of M province from 2018 to 2021 is shown in Table 3:

*Table 3. Relative errors in forecasting per capita water resources ecological footprint in M province from 2018 to 2021*

| Years | Relative error |
|---|---|
| 2018 | 0.006 |
| 2019 | 0.005 |
| 2020 | 0.013 |
| 2021 | 0.009 |

By using the ARIMA (4, 1, 2) model to carry out the extrapolation forecast for the M province from 2018 to 2021, the overall forecast trend is a downward trend, and it will drop to the lowest value of 0.41 in 2018. Using the ARIMA (4, 1, 2) model When extrapolating the forecast for M province in the future from 2018 to 2021, we will see that the forecast trend gradually rises from the lowest value of 0.41 in 2018 to 0.66 in 2021. Figure 2 shows the ecological footprint of per capita water resources in province M from 2018 to 2021. The goodness of fit between the actual value and the predicted value scatter point. It can be seen from the figure that the actual value of the per capita water resources ecological footprint in province M from 2018 to 2021 has a good fitting effect with the predicted value, the change trend is very consistent, and the error The value is very small, indicating that the ARIMA (4, 1, 2) model initially established in this paper can be well applied to the prediction of per capita water resources ecological footprint in M province from 2018 to 2021.

## 5.Conclusion

Sufficient water storage data brings not only new opportunities but also challenges. How to quickly and efficiently collect open data, manage data effectively, and mine comprehensive data is the basis for enhancing the value of data. The importance of predicting the ecological footprint of water resources lies in providing business decision-making services for the construction and management of water resources. This paper combines the concept of water footprint with the ecological footprint of water volume and the impact of pollution on the ecological footprint of water quality. Additional results are more in line with actual water consumption. On this basis, the relationship between the change trend and the population and economic factors was analyzed, and the change trend of the ecological footprint of water resources in the M area was predicted by using the ARIMA time series prediction model.

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## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

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