Prediction of Carbon Peak Time in Jiangxi Province Based on Random Forest Model

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Abstract. The trend of global warming is irresistible, and achieving carbon peaking and carbon neutrality as soon as possible is widely believed to be one of the main ways to solve climate warming. In the 14th Five-Year Plan announced by China, it is again emphasized that China will achieve carbon peak before 2030 and achieve carbon neutrality around 2060. This paper adopts the prediction method of random forest and sets three different scenarios, including the baseline scenario, the energy optimization scenario and the low-carbon scenario. Predict whether Jiangxi Province can reach its carbon peak by 2030 under different scenarios. The forecast results show that under the baseline scenario, Jiangxi Province will achieve carbon peaking in 2029, under the energy optimization scenario, Jiangxi Province will achieve carbon peaking in 2028, and under the low-carbon scenario, Jiangxi Province will achieve carbon peaking in 2026. By continuously optimizing the influencing factors of carbon emissions, Jiangxi Province will gradually advance the carbon peak time.

Keywords: Carbon Emission · Scenario Analysis · Random Forest Model · Jiangxi Province

1 Introduction

Addressing climate change is the most important area of global sustainable development. In 2015, the 21st United Nations Climate Change Conference is held in Paris. A new agreement on global climate change, the Paris Agreement, proposed to control the global average temperature increase within 2 °C compared with the pre-industrial period by 2100, and to make efforts to target the temperature rise to within 1.5 °C [1]. On September 22, 2020, president Xi Jinping announced in his speech at the general debate of the 75th United Nations General Assembly: "China will increase its nationally determined contribution, adopt more powerful policies and measures, and strive to achieve carbon emissions peak by 2030 and strive to be carbon neutral by 2060." In the face of huge pressure to reduce emissions, the importance of green and low-carbon development to address climate change is becoming more and more important. Jiangxi's non-ferrous metal smelting, machinery manufacturing, porcelain making and other industries are its pillar industries, and its development scale ranks among the top in China. As an underdeveloped province, Jiangxi Province's economy is in a period of transformation

D. Qiu et al. (Eds.): ICBBEM 2022, AHIS 5, pp. 1529–1535, 2023.
https://doi.org/10.2991/978-94-6463-030-5_153

development, with strong energy demand and a high proportion of coal consumption, resulting in a rapid increase in carbon emissions. Under the background of national carbon emission reduction, it is of great significance to predict the carbon emissions of Jiangxi province.

2 Litrrature Review

The research on carbon emissions in domestic and foreign academic circles mainly focuses on three aspects: carbon emissions measurement, carbon emissions influencing factors, and carbon emissions forecast research. In the research of carbon emission measurement, most scholars use the method provided by IPCC to measure the carbon emission of a certain region or country. Guo Xiaoyi (2021) [2] selects 26 energy sources through the energy balance table to accurately measure the carbon emissions of energy consumption in Shaanxi Province from 2000 to 2019. The existing research on the factors affecting carbon emissions is carried out around the decomposition of the IPAT identity, and the research results focus on three aspects: population, economy and technology. When Zhu (2009) [5] studies carbon emissions from energy consumption in my country from 1980 to 2007, he finds that population size can promote carbon emissions. Scholars such as Zhu have expanded the traditional STIRPAT model to incorporate urbanization into the model [6]. The study finds that urbanization has a promoting effect on carbon emissions. The main method used in carbon emission forecasting research is scenario analysis. Scholar Qu predicted that China's carbon emission peak will appear in 2020–2045 through scenario setting [4] Huang Rui et al. studies the influencing factors of carbon emissions in Jiangsu province, and used scenario analysis to predict future carbon emissions in Jiangsu province [3].

3 Matrrials and Methods

This paper calculates the carbon emissions of energy consumption in Jiangxi Province from 1995 to 2019 based on the carbon emissions calculation method provided by IPCC. According to this method, a calculation model of energy consumption carbon emissions in Jiangxi Province was established.

$$\mathbf{C} = \sum_{\mathbf{i}=1}^{7} \mathbf{E_i} * \boldsymbol{\sigma}_\mathbf{i} \tag{1}$$

In the formula, the characters of $\mathbf{E_i}$ and $\boldsymbol{\sigma}_\mathbf{i}$ respectively represent the final consumption of seven types of energy and the carbon dioxide emission coefficient. Energy Balance Sheet (physical quantity) from 1995 to 2018 in the "China Energy Statistical Yearbook 1996–2019", and the physical quantity i derived from the Jiangxi Province sources come from the energy balance table. The carbon emissions converts into standard coal through a conversion factor. The kinds of energy, the total energy consumption data are all coefficients and the converted standard coal coefficients of the kinds of energy sources are shown in Table 1.

Table 1. Carbon emission calculation factor

energy type	Average low calorific value (KJ/kg)	Carbon emission factor (kgC/GJ)	Carbon oxidation coefficient
coal	20908	25.80	1
crude	41816	20.00	1
gasoline	43070	20.20	1
kerosene	43070	19.50	1
diesel fuel	42652	20.20	1
fuel oil	41816	21.10	1
natural gas	38931	15.30	1

3.1 Model Setting

Random Forest is a classic bagging model whose weak learner is a decision tree model. The random forest model will randomly sample from the original data set to form multiple different sample data sets, then build multiple different decision tree models based on these data sets, and finally obtain the final result according to the average of these decision tree models. This paper predict carbon emissions in Jiangxi Province relying on the random forest model.

This article uses pycharm software to call the scikit-learn machine learning algorithm library, and uses the regression function to build a random forest algorithm model. Taking six indicators such as GDP as independent variables, and carbon emissions as dependent variables, construct input sample data that combine them to form the model. In the model training process, all samples are randomly generated in two copies, 80% of the sample size is used as the training sample, and 20% of the sample size is used as the prediction sample, so as to conduct model training and prediction. After the training samples are trained, the relevant parameters of the model are obtained, and the prediction samples are used to test the accuracy of the model parameters after bringing them into the parameters.

3.2 Parameter Tuning

In machine learning, because the training set and test set are divided randomly, we sometimes reuse the data to better evaluate the effectiveness of the model and select the best model. This practice is called crossover verify. Specifically, the original sample data is divided, and then combined into multiple sets of different training sets and test sets, the training set is used to train the model, and the test set is used to evaluate the model. A certain training set may be the next test set, so it is called cross-validation.

There are three methods of cross-validation, including simple cross-validation, K-fold cross-validation and leave-one-out cross-validation. Among them, K-fold cross-validation is widely used. K-fold cross-validation refers to randomly dividing the data set into K parts, selecting K-1 parts as the training set to train the model each time, and then using the remaining 1 part as the test set to obtain After K models, the average test effect of these K models is used as the final model effect.

Grid search is an exhaustive search parameter adjustment method: it traverses all candidate parameters, builds a model in a loop and evaluates the validity and accuracy of the model, and selects the best performing parameter as the final result. Taking the maximum depth max_depth of the decision tree model as an example, we can traverse the different values of [1, 3, 5, 7, 9], and use the accuracy or the AUC value of the ROC curve as the criterion to search for the most suitable max_depth value. The process of traversing is like searching in the grid (Grid), so this method is also called GridSearch grid search. Through data analysis, this paper finally chooses 5-fold cross-validation to iterate the optimal parameters and train the model.

4 Results and Discussion

4.1 Carbon Emission Analysis

According to the carbon emission calculation formula published by IPCC, the carbon emission in Jiangxi Province has been increasing year by year, from 713,100 tons in 1995 to 2,164,900 tons in 2018, with an average annual growth rate of 8.83%. The main reason is that the high energy-consuming industries represented by metal smelting in Jiangxi Province account for a large proportion. Therefore, the carbon emissions in Jiangxi Province have been increasing year after year. Even after the 18th National Congress of the Communist Party of China, the central government attached great importance to environmental issues. Carbon emission is still no sign of slowing down (Fig. 1).

4.2 Scenario Analysis

The target setting of the baseline scenario mainly refers to the development status of Jiangxi Province and the 14th Five-Year National Economic Development Plan issued by Jiangxi Province. This scenario is to explore when Jiangxi will be able to achieve the carbon peaking target according to the current development model. The energy

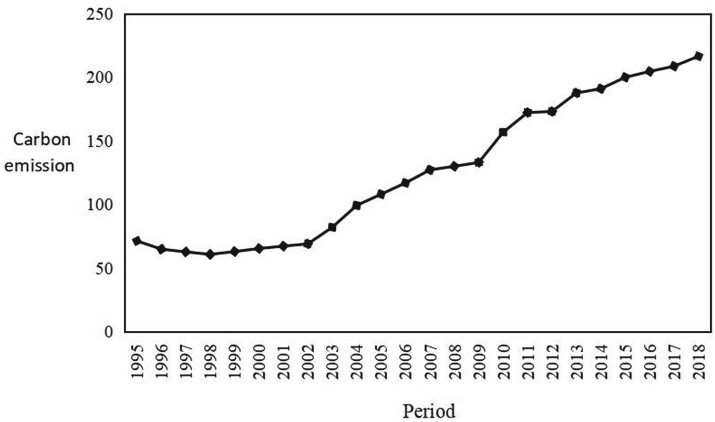

Fig. 1. Carbon emission

Table 2. Scenario settings

	Population	GDP	Industrial structure	Energy structure	Energy intensity	Urbanization rate
Baseline Scenario	1.005	1.07	0.992	0.982	0.982	1.02
	1.003	1.065	0.993	0.985	0.984	1.017
Energy Optimization Scenario	1.005	1.07	0.992	0.98	0.978	1.02
	1.003	1.065	0.993	0.983	0.98	1.017
low carbon scenario	1.003	1.065	0.99	0.98	0.978	1.02
	1.001	1.06	0.992	0.983	0.98	1.014

optimization scenario is to change the rate of change of the two indicators of energy intensity and energy structure on the basis of the basic scenario. On the basis of existing policies, the energy structure and energy intensity are further reduced, aiming to explore whether energy optimization can advance the carbon peaking time of Jiangxi Province. The low-carbon scenario is based on the energy optimization scenario, and all indicators are optimized. This scenario is forcing Jiangxi Province to achieve the carbon peaking goal by 2030. The purpose is to explore the bottom line of each influencing factor in Jiangxi Province that should be improved in order to achieve the carbon peaking goal. The change rate of each influencing factor in Jiangxi Province under the three scenarios is shown in the Table 2.

5 Carbon Emissions Forecast

This paper forecasts the carbon emissions of Jiangxi Province from three scenarios: the baseline scenario, the energy optimization scenario and the low-carbon scenario. It can be seen from Table 3 that under the baseline scenario, Jiangxi Province will reach its carbon peak in 2029, and its carbon emissions will reach 2.5887 million tons. In the low-carbon scenario, Jiangxi Province can achieve a carbon peak in 2026, with a total carbon emission of 2.5442 million tons.

Table 3. Carbon emissions forecast.

Year	Baseline Scenario	Energy Optimization Scenario	low carbon scenario
2019	225.373876	225.373876	225.373876
2020	225.885673	225.885673	225.885673
2021	231.804215	231.632259	230.914968
2022	237.507699	237.158919	235.782757
2023	242.865348	242.336471	240.390426
2024	247.723454	247.013179	244.622691
2025	251.904834	251.014275	248.347049
2026	255.212034	254.146267	254.417687
2027	257.60489	256.370209	253.809549
2028	257.892251	257.498207	252.380045
2029	258.875694	256.335548	251.97883
2030	257.357546	255.688673	250.452032

6 Conclusions

The article uses the carbon emission calculation formula published by IPCC to calculate the carbon emissions of Jiangxi Province from 1995 to 2019. Based on this, GDP, population, industrial structure, energy structure, energy intensity, and urbanization rate are selected as independent variables. Taking emissions as the dependent variable, scenario analysis and random forest model were used to predict the time and amount of carbon peaking in Jiangxi Province.

The empirical results show that since 1995, the carbon emissions in Jiangxi Province have gradually increased, with an average annual growth rate of 8.83%. Under the baseline scenario forecast, Jiangxi Province's carbon peak time will be in 2029, while under the low-carbon scenario forecast, Jiangxi Province's carbon peak time will be in 2026. Therefore, in the future development process of Jiangxi Province, it is necessary to strengthen the adjustment of the industrial structure, strengthen the structural reform of the supply side, and strive to achieve the carbon peak of Jiangxi Province before 2030, and contribute strength and wisdom to the realization of the national carbon peak.

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