Fitting Analysis and Prediction of Carbon Sequestration in China Based on Clustering and Mode Decomposition

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Abstract. The Topsis algorithm is used to evaluate the environmental status of the existing countries and give suggestions for the overall environmental development. In this paper, a method of statistical clustering and pattern decomposition is proposed. Among them, pattern decomposition is an idea to evaluate the work of evaluating carbon sequestration from different angles, and then comprehensively consider the evaluation. Statistical clustering is to describe the similarity between different regions more clearly. This study finally predicts the potential carbon sequestration in China, which is a new attempt for carbon sequestration research. This paper aims to achieve the following objectives : 1. Analyze the common characteristics between different regions in China, and make a reasonable explanation, systematically evaluate the current carbon sequestration level and potential capacity in China.2. 2. Long-term and short-term prediction of China 's future carbon sequestration level. Discuss and clarify the experimental conclusions in detail, and give systematic and reasonable suggestions. It is concluded that the carbon sequestration level of the two regions in the next 40 years will increase by 6 ~ 700,000 tons of carbon sequestration on the basis of the original.

Keywords: Carbon sequestration, Topsis, statistical clustering, pattern decomposition, LSTM.

1. Introduction

Global environmental issues have received widespread attention, among which global warming is particularly critical. Countries are actively introducing corresponding policies to reduce greenhouse gas emissions such as carbon dioxide. The World Meteorological Organization (WMO) ' 2021 Global Climate Status ' report shows that the global average temperature in 2021 is about (1.11 ± 0.13) ° C higher than that before industrialization. This means that the intensity of 2030 emission reduction commitments should be increased by at least seven times to meet the goals of the Paris Agreement. The proposal of the ' double carbon ' goal, on the one hand, shows China 's courage to assume the international responsibility of a great power; on the other hand, it also emphasizes the important determination of our country to strive to achieve high-quality low-carbon transformation and development [1-3]. In the new era of planning reform, in the face of the requirements of the " double carbon " goal, how to integrate the requirements of carbon peaking and carbon neutrality into all aspects of work is the focus of current research by workers in various industries.

2. Materials and methods

2.1. Data set characteristics

We collected data on agricultural resources and ecological resources in each region of China from 1999 to 2022, and all the data came from the China Statistical Yearbook. Since the data in the China Statistical Yearbook are displayed in the form of pictures, and the corresponding document data, such as csv, xlsx, etc., are not published, we use the crawler to download the corresponding pictures, and develop a picture recognition text system to recognize them, and then proofread the format of the recognized information through python script, and then write them into the xlsx file, and then proofread the data manually, which basically realizes the completeness and correctness of the data collection process. Basically, realize the completeness and correctness of the dataset collection process. In the end, we organized three documents, which are major provinces data, major cities data

and China ecological data. The first two documents are 21 copies of 21 years of data from 2000 to 2021, each containing more than ten forms, each containing the corresponding provinces and cities in the country as well as the corresponding attributes. China's ecological data contains more than twenty forms, the statistics are the overall data of the country each year, mainly containing ecological, related data of different industry sectors. Some of the data are shown in the appendix. The following is a brief introduction to the main utilized data attributes:

In terms of energy: due to the diversity of energy types, representative indicators of total energy consumption in China were selected to simplify the analysis of this issue, we selected and aggregated 16 attributes from 605 different indicators in the data we looked for to portray energy consumption, production and import and export in different dimensions. The indicators are total energy consumption in commerce, industry, housing, transportation, production and consumption per capita of crude oil, production and consumption per capita of natural gas, production and consumption per capita of coal, imports and exports of the above-mentioned energy sources, GDP as a proxy for the economic development of the current society, and carbon emissions due to industrial production and consumption.

In the case of forests and rivers, the total amount of carbon sequestered was taken as the main variable in the study, referring to the findings of Xu Xinliang et al. (2007) on the carbon stock of vegetation in forest ecosystems in China [4]. composition, river basin area, and wetland area. The main purpose of the above factors is to better characterize the specific relationship between natural resources and carbon sequestration in different dimensions [5-8].

In agriculture, we selected the following indicators including, major crop cropping structure, yield per unit area, livestock rearing, irrigated area of arable land, fertilizer application, and sown area of crops [9-12]. The main purpose is to portray the production status of agriculture, the breeding situation, and to analyze the relationship between carbon emissions and carbon fixation of the local animal husbandry industry and the above production activities based on data mining tools [13].

2.2. Research Methods

The basic idea of evaluating the level of carbon sequestration in China in general and in each region is as follows: 1) Collect data related to agricultural resources, ecological resources, and carbon emissions in each region of China from 1999 to 2022.2) Artificially select important indicators related to the amount of carbon sequestered in the environment, such as the amount of precipitation, the area of soil, the area of forests, and other indicators.3) Conduct a correlation analysis of the data using Pearson, grey correlation analysis and evaluation of the comprehensive indicators using indicator evaluation.4) Cluster analysis of the factors of carbon sequestration in different regions (the pseudo-code of the statistical clustering algorithm is shown in Fig. 1), combined with the results of the indicator ratings in the previous step, to analyze which factors are more effective in influencing the amount of carbon sequestration.5) Plotting and characterizing the overall amount of carbon sequestration in China, and comparing the level of carbon sequestration in different provinces and cities using Gaussian process analysis, which can also be used as a result of short-term forecasting.6) The series of data obtained from the processing were processed using pattern decomposition, and the results of each segment of the processing were put into a forecasting model to predict the level of carbon sequestration development in China in 2050. Most of the data attributes of the study, on the basis of complete data processing, further fitting analysis to predict the total amount of carbon sequestration in the future 2035 and 2050 sequestration model, drawing the corresponding charts and quantitative calculations.

Algorithm 1 The Clustering Algorithm Based on Variance Deviation

set ={} ;
$1 \leq m \leq 14$;
$\alpha = 0.9$(Setting);
P=$(P_{ij})(1 \leq i \leq 14, 1 \leq j \leq 14)$;
$Target \leftarrow$ Threshold Master Subtype;
$one - hot = [o]^x$;
Require: $weight$ // Weight of the $j_{th} data of ith\ sample of each attribute index$; **return**$\text{Set}_m$; // Different Attribute Columns of the Sample;
for $X_i in X$ **do**
  for $i = 1 \rightarrow 14$ **do**
    if $X_{i-mainlabel}$ ="High Quantity Carbon Sequestration" **then**
      $\varepsilon_1 \leftarrow \varepsilon \sim N(0, 5)$
      $S_{X_j} \leftarrow \frac{\sum_{i=1}^{n}(\frac{X_{ij}}{P_{ij}} - \bar{X}_j)^2}{n-1}$
      $Target \leftarrow \alpha \cdot S_{X_j} + \varepsilon_1$
      if $|X_{ij} - X_j| \leq Target$ **then**
        $one - hot_j = 1$
      else
        $one - hot_j = 0$
        $X_{i-mainlabel}$ ="Low Quantity Carbon Sequestration"
        $\varepsilon_2 \leftarrow \varepsilon \sim N(0, 10)$
        $S_{X_j} \leftarrow \frac{\sum_{i=1}^{n}(\frac{X_{ij}}{P_{ij}} - \bar{X}_j)^2}{n-1}$
        $Target \leftarrow \alpha \cdot S_{X_j} + \varepsilon_2$
        if $|X_{ij} - X_j| \leq Target$ **then**
          $one - hot_j = 1$
        else
          $one - hot_j = 0$
        end if
      end if
    end if
  end for
  $Set_i.add(arg_{X_i} max(one - hot \otimes weight))$ //
end for

Fig. 1 Statistical Clustering Algorithm Pseudo-Code

3. Algorithmic Implementation

3.1. Data Analysis

In order to further identify the factors affecting the environment and the economy more quickly, we use the gray correlation analysis model to analyze the three aspects of carbon sequestration in forests and carbon emissions and economic effects from energy use. The model provides a quantitative measure of the development and change of the system, which is suitable for the dynamically changing system of energy, environment and economy, and does not require the distribution function of the data or the amount of data due to the relationship between the numerical values dealt with in the analyzing process, and the computational volume is small, which does not produce difficult-to-interpret results. Finally, the complex system of multiple indicators is transformed into a simple system of a few integrated indicators [14].

Next, we calculate the forest data from 2000 to 2019, and the results of the correlation coefficient calculation are shown in Table I.

Tab. 1 Calculation of forest-related coefficients

indicator	Disease area	Fire area	Afforestation area	Forest area	Annual rainfall	Percentage of middle-aged	Area of felling
correlation coefficient	0.563	0.541	0.723	0.334	0.433	0.882	0.234

Finally, the above results were ranked from largest to smallest, and we selected the four indicators with the highest correlation with carbon sequestration: proportion of middle-aged forests, afforestation area, disease area, and fire area. Surprisingly, only by the correlation coefficient analysis in China, carbon sequestration seems to be not obviously related to annual rainfall but referring to the conclusion of the study on rainfall in China by Chewu et al. we found that the rainfall in both the southern and northern cities of China has a clear seasonal pattern. The rainfall characteristics of

southern and northern cities are highly differentiated. The unevenness of rainfall in southern and northern cities can be quantitatively described by the unevenness coefficient. The rainfall inhomogeneity coefficient of northern cities is twice as much as that of southern cities [15].

The same method is used to examine the data of energy system for similar analysis, to study the factors affecting carbon emissions and GDP, respectively, assuming carbon emissions and GDP as a known reference series, bringing the data related to the energy part of China in the past years (the unit of energy of 10,000 tons are referred to the calories of 10,000 tons of standard coal as a standard of measurement) into the formula to calculate, and finally making $\rho = 0.5$, to calculate the correlation coefficients between each factor and carbon emissions. The results of the correlation coefficient between each factor and carbon emission are shown in Table II, and the results of the correlation coefficient with GDP are shown in Table III.

Tab. 2 Top four correlation coefficients of carbon emissions at $\rho = 0.5$

indicator	Coal consumption	Industrial consumption	Crude oil consumption	Coal imports
correlation coefficient	0.923	0.897	0.872	0.843

Tab. 3 Top four correlation coefficients of GDP at $\rho = 0.5$

indicator	Industrial consumption	Crude oil consumption	Natural gas consumption	Natural gas imports
correlation coefficient	0.943	0.912	0.875	0.862

Through the calculation results, we found that the four indicators with the greatest correlation with GDP: industrial consumption, crude oil consumption, natural gas consumption, natural gas imports. From the point of view of China's various energy production, we can find that the development of industry has the greatest effect on the promotion of the economy, and from the point of view of the use of energy in various industries, industry is the main body of development, but it also has a considerable impact on the environment. Natural gas, as one of the energy sources that is gradually beginning to be used in our country, has a very high economic efficiency and environmental value.

From the above results, we can find some unexpected results: coal is the biggest contributor to carbon emissions, but not so much to the economic value, and this conclusion may provide some theoretical basis for a new agreement on abandoning coal at the COP26 conference in November 2021, which will be held in a number of countries that are highly dependent on coal [16].

We also note that the area of diseases and the area of fires have similar impacts on carbon sequestration, but they both contribute to deforestation, and that in other countries deforestation is one of the main ecological damaging factors, while in China deforestation is not a major factor in environmental problems, suggesting that China's protection of its existing forests has been effective. Therefore, the regulation of forest fires and pests should be maintained as one of the most important ways to maintain the quality of forests [17].

From the point of view of China's various energy production, and we can find that the development of industry has the greatest effect on the promotion of the economy, from the point of view of the use of energy in various industries, industry is the main body of development, but at the same time, it also has a considerable impact on the environment. Natural gas as one of the energy sources gradually used in our country has a very high economic efficiency and environmental value. We can see that the production of natural gas has been on the rise in recent years, so we should shift the center of gravity of energy use appropriately, and then need to further research on the energy structure.

3.2. Indicator weighting and clustering

We can find that the development of industry has the greatest effect on the promotion of the economy, from the point of view of the energy use of various industries, industry is the main body of development, but at the same time, it also has a considerable impact on the environment, so in the consumption of industrial consumption and crude oil consumption we have a special treatment, we are especially on the consumption of industrial consumption and crude oil consumption of the indicators are greatly maximized, minimized processing. The final weights of the indicators are shown in Table IV and Table V:

Tab. 4 Weights of indicators (weights of maximized indicators)

indicator	Industrial consumption (large)	Crude oil consumption (large)	Natural gas consumption	Natural gas imports	afforestation area	Percentage of medium-aged forests
w_j	0.091	0.097	0.085	0.070	0.086	0.049

Tab. 5 Weights of indicators (weights of minimization indicators)

indicator	Industrial consumption (small)	Crude oil consumption (small)	Coal imports	Coal consumption	Disease area	Fire area
w_j	0.108	0.048	0.137	0.129	0.040	0.036

According to the calculation of the normalization matrix weights, organized and calculated to get get the normalization matrix, part of the normalization matrix results are shown in Table VI:

Tab. 6 Partially normalized matrix results

indicator	Industrial consumption (large)	Industrial consumption (small)	Crude oil consumption (large)	Crude oil consumption (small)
2015	0	0	1	1
2016	0.20	0.19	0.80	0.81
2017	0.56	0.37	0.44	0.63
2018	0.75	0.66	0.25	0.34
2019	1	1	0	0

Finally, the fit score metrics for the last five years were calculated, and the results are shown in Table VII below.

Tab. 7 Composite scores from 2015 to 2019

Year	2015	2016	2017	2018	2019
Fit Score (T)	0.571	0.621	0.693	0.781	0.758

Three aspects of carbon sequestration in forests and carbon emissions and economic effects from energy use are analyzed. Then the cluster analysis is carried out, firstly, the element replacement probability transfer matrix P is introduced, which is the mutual replacement probability between different elements in the soil, which may involve the transformation of carbon sequestration. Among them, we consider each row of its own elements, and the rest of the probabilities are assumed to obey a uniform distribution, to obtain the coefficient matrix, where each of them retains two decimal places. Using the coefficient matrix, combined with the clustering algorithm we adjusted the parameters separately, and the results are shown in Fig. 2.

We use the model to carry out several experiments, according to the characteristics of each figure, it is not difficult to find that, for a specific area, the results obtained from several experiments in

different years are roughly the same pattern, which is reflected in the area of crop cultivation, the age composition of the forest, the area of afforestation and the original area of the forest, and the impact of irrigated area of arable land is relatively high. Natural gas, as one of the sources of energy that is gradually being used in China, has a high economic and environmental value. From which we can see that the production of natural gas has been on the rise in recent years, so we should be to shift the center of gravity of the use of energy appropriately, and then all kinds of results in the front-end web page to show the effect as shown in Figure Part of the distribution of clustering categories shown in Fig. 3. Based on the image features, we can get based on the Daqing and Wuhan two regions based on specific categories for comparison.

Based on the image features, we can easily find that the results obtained for many experiments are roughly the same, which are reflected in the relatively high impacts of crop cultivation area, age composition of forests, afforestation area and the original area of forests, and irrigated area of arable land. Therefore, carbon sequestration and carbon development in similar areas can be further explored.

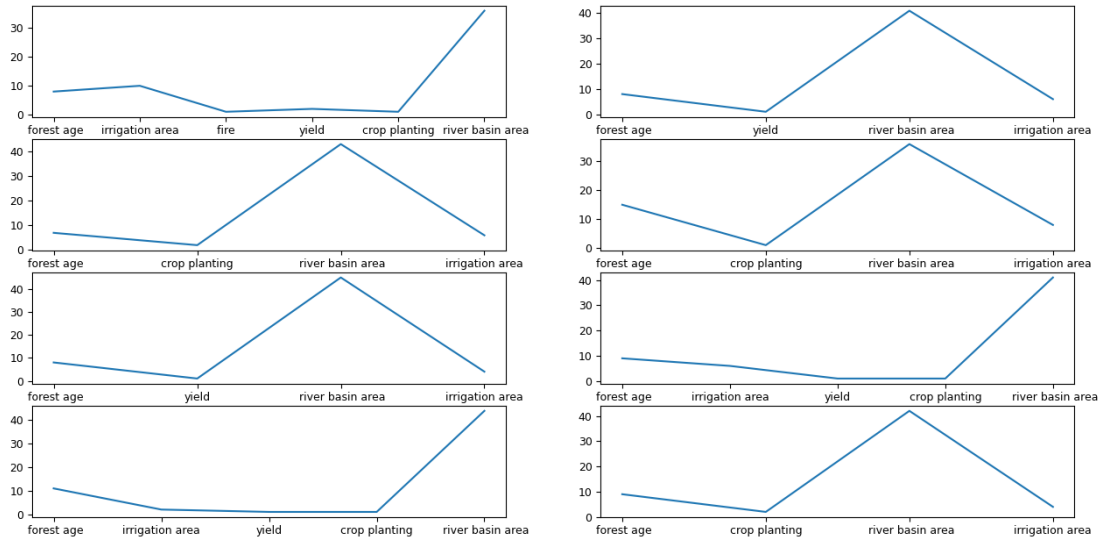


Fig. 2 Adjustment of parameters, clustering results for different regions

3.3. Data fitting and prediction

We used Gaussian regression process model to predict and process the carbon sequestration in Wuhan and Daqing. In the past, we evenly distributed the data and calculated the data of Wuhan and Daqing in the past ten years, and the fitted image is shown in Fig. 3.

We explore the sensitivity to parameters in the model. For the forecasting part, we find that for the short-term model, the parameters are insensitive and do not have a significant impact on the forecasts. For the long-term prediction, it is more sensitive to the parameters, but ultimately it can be seen to converge around 50 tons. When the parameter is greater than 0.3 or less than 0.1, the model tends to be stabilized and the fit is better, and the parameter between 0.3 and 0.1 has a great influence on the model. The results show that the fitting effect is good, and the model parameters have little effect on the model, and the test results are shown in Fig. 4.

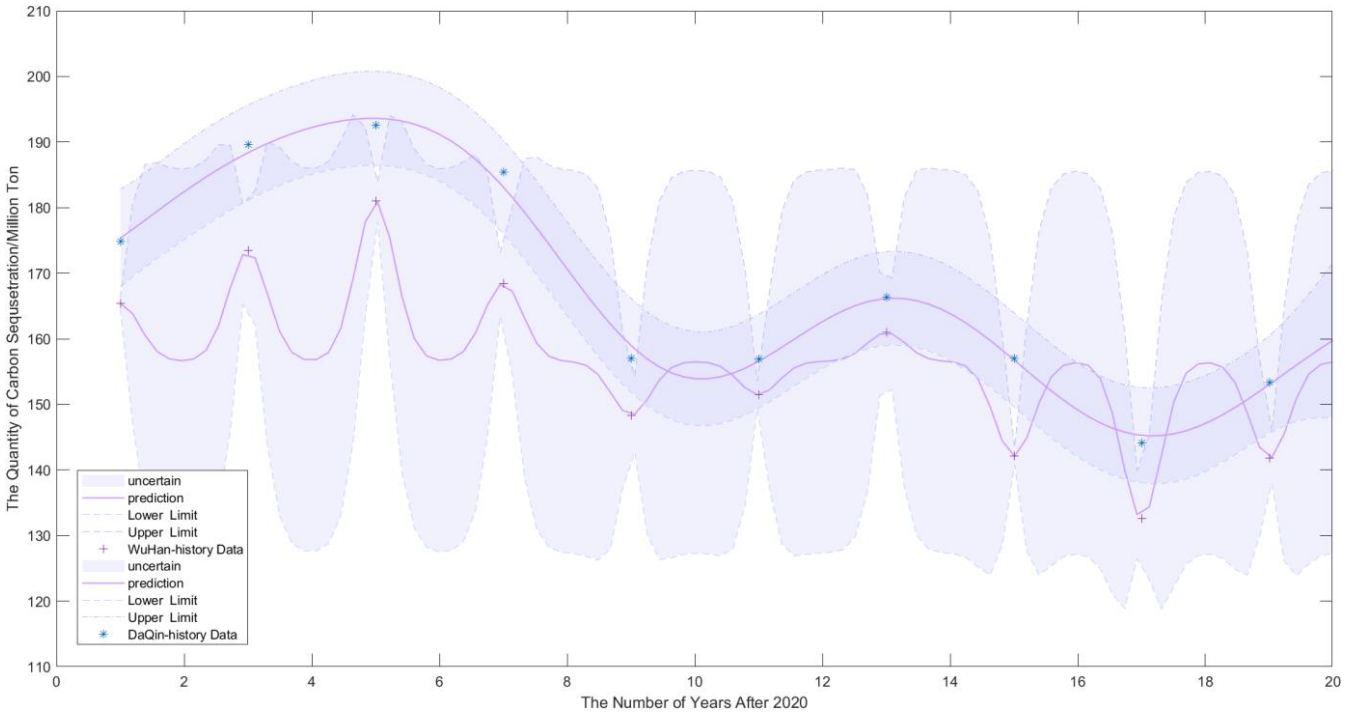


Fig. 3 Fitted images of carbon sequestration in Wuhan and Daqing

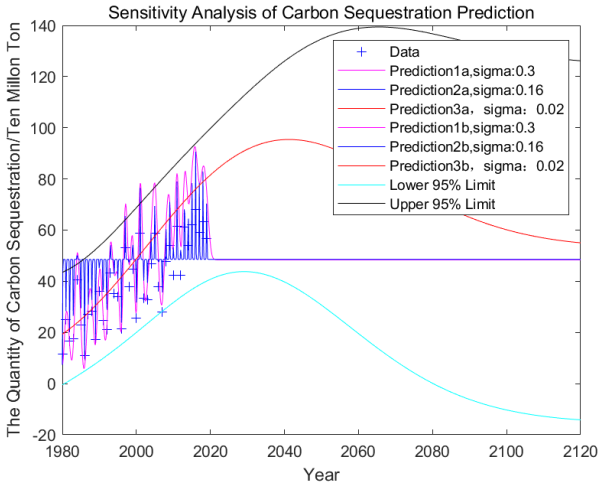


Fig. 4 Sensitivity analysis of fitted prediction models.

We then proceeded to test the optimized model, where α and β are extended adjustable positive parameters in the range (0, 1). The calculation results of different parameters are shown in Tables VIII and IX. where α corresponds to the parameter of the positive distance of the model, i.e., the influence factor of maximization, and β corresponds to the parameter of the negative distance of the model, i.e., the influence factor of minimization. It can be seen that the factors that play a positive role in the level of forest carbon sequestration account for a large proportion of the impact on the composite score.

Tab. 8 With different values of α, the calculation of L

α	0.1	0.3	0.4	0.5	1
L	7.3	8.2	8.6	8.9	9.4

Tab. 9 With different values of $\boldsymbol{\beta}$, the calculation of L

β	0.01	0.013	0.015	0.02	0.035
L	8.3	7.8	7.8	8.4	8.9

Finally, we used different models to predict the development of carbon sequestration using the indicator assessment results synthesized with the clustering analysis results as input values and carbon sequestration as output values.

The effect of using LSTM model prediction is shown in Fig. 5, and the model obtained by clustering batch training is compared with the model obtained without clustering batch training, and it is found that the clustering training has a larger loss on the training set, but the accuracy in prediction is ten percentage points higher on average. This also reflects that clustering has a positive effect on the effectiveness of training.

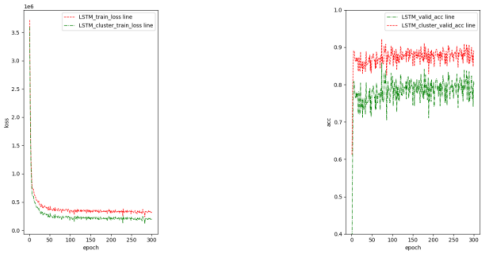


Fig. 5 Comparison effect of LSTM model prediction

We then used a series of machine learning models to learn predictions of carbon sequestration in different regions after clustering. The decision tree algorithm, also known as a classification tree, as the name suggests, is an algorithm that uses a tree structure to categorize and describe data. The algorithm consists of nodes (internal nodes representing attributes and leaf nodes representing classes) and directed edges. Decision trees are excellent at handling irregular data and are more logical and intuitive.

Support Vector Machine (SVM) model is a classifier for binary classification of data. Here we process continuous values into discrete values and then into continuous values, processing support vector machine uses the idea of hyperplane separation of samples algorithm similar to the perceptual machine model, to classify and separate the data to be processed, and combined with the idea of optimization problems to solve. The support vector machine algorithm can usually be used to solve problems under small sample conditions. The training effect is shown in Fig. 6. The machine learning model is prone to overfitting and other situations may have a certain impact on the prediction results, and the model parameters of machine learning is less, therefore, we have conducted many experiments in the process, and the use of k-fold cross-validation method to make full use of the data information with mining, so that it has fewer parameters, the algorithm is simpler and so on, the machine learning prediction model in the recent prediction of the performance of the model is more good. However, we can see from the above figure that the model is greatly affected by the parameters, so we need to find out the appropriate parameters for learning.

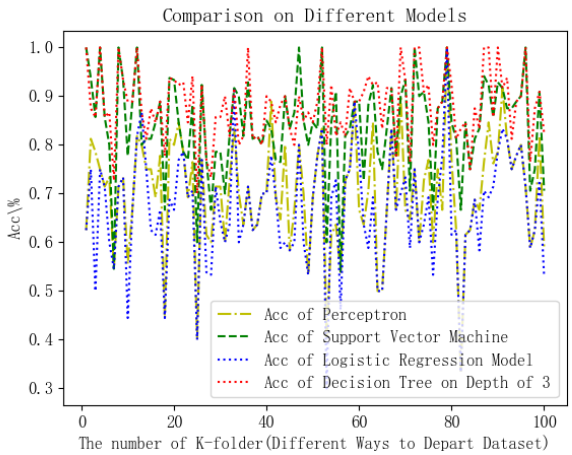


Fig. 6 The effect of training different models for machine learning

4. Analysis of results

We can find from the carbon sequestration evaluation results that the overall scoring trend is basically rising year by year, in which it can be seen that the overall comprehensive assessment indicators are optimal in 2018, and through analysis, we find that the comprehensive evaluation indicators tend to favor the energy consumption of crude oil and industry, the consumption of natural gas, the afforestation area and the amount of natural gas imported. At the same time, the score of 2019 compared with that of 2018 has slightly decreased, and it can be roughly inferred through data comparison that the large-scale development and use of the three types of energy in 2019 has caused a certain negative effect, and the increase in afforestation area has helped to improve carbon sequestration.

4.1. Calculation of coupling-related metrics

Then the calculation obtained China's degree of coordination, comprehensive development index and coupling degree calculation results in these three aspects in the past five years as shown in Table X.

Tab. 10 Assessment of coupling-related indicators from 2015 to 2019

Year	2015	2016	2017	2018	2019
coherence	0.551	0.531	0.523	0.575	0.598
Composite development index	0.794	0.821	0.843	0.892	0.875
coupling (physics)	0.661	0.660	0.663	0.716	0.723
Economic development indicators	0.811	0.860	0.893	0.916	0.943
Environmental development indicators	0.761	0.736	0.743	0.776	0.763
Energy development indicators	0.838	0.894	0.914	1.008	0.944

4.2. Evaluation of coupling levels and analysis

Referring to the relevant documents issued by the National Bureau of Statistics and the research results of Cai Yurong et al [7], the coupling coordination level is a significant indicator for assessing the current environmental situation and the development of a series of human activities, including ecological resources, air conditions, biodiversity, etc., and human activities, including socio-economic conditions, the use of energy resources, the use of agricultural land, and so on. From the results of a series of studies, we derive a coupling harmonization classification as shown in Table XI.

Tab. 11 Classification of coupling

coupling (physics)	coupling class
[0.9,1.00]	high degree of coordination
[0.8,0.9)	good coordination
[0.7,0.8)	Moderate coordination
[0.6,0.7)	Primary coordination
[0.5,0.6)	Mild disorder development
[0.4,0.5)	Moderately dysfunctional recession
[0.0,0.4)	serious dislocation and recession

As a result, we can see that the country is currently moving from primary to moderate coordination, and there is now a gradual trend towards developing good coordination, with the degree of coordination having improved in the last two years and the three coupling being highest in 2019. Currently there is a gradual trend of development to good coordination, coordination has increased in the last two years, and the three coupling is highest in 2019.

It can be seen that the management of disease and fire needs to be maintained, and the area of disease and the area of fire affect carbon sequestration to a similar extent, but both cause deforestation phenomenon, and in other countries deforestation caused by carbon emissions is one of the main

factors destroying the ecology, while in China deforestation phenomenon causes environmental problems is not the main factor, indicating that China's protection of existing forests has an effect. Therefore, the regulation of forest fires and pests should be maintained as one of the most important ways to maintain the quality of forests. In agricultural production, the main sources of carbon emissions are soil reclamation, irrational application of fertilizers, CH4 emissions from livestock, and crop respiration. Carbon sequestration mainly comes from the net productivity of photosynthesis in crops and the level of carbon sequestration in the soil (including the level of microbial activity and diversity in the soil surface and inner layers).

Rainfall has a large impact on the amount of carbon sequestered in forests, and because of the obvious seasonality of rainfall in both northern and southern cities in China, there is a great deal of variability in the characteristics of rainfall in both northern and southern cities, resulting in an inconspicuous relationship between the overall amount of carbon sequestered in forests and the amount of annual rainfall. Therefore, we suggest that we should fully respond to seasonal climatic changes by planting different types of trees for different regional climates. Specifically, areas north of the Qinling-Huaihe River should be planted with evergreen trees that are adapted to the arid climate and have higher carbon sequestration, such as cedar; areas south of the Qinling-Huaihe River should be planted with evergreen trees that are adapted to the humid climate and have higher carbon sequestration, such as camphor. At the same time, the age composition of trees is the core factor of carbon sequestration in forests, so while expanding the forest area, it is mainly necessary to increase the proportion of middle-aged forests.

High-quality energy sources, such as natural gas and crude oil, have been one of the stimuli for China's economic development and have contributed to environmental protection. However, coal is still the main source of energy used in China, and we should support the development of the quality energy industry by subsidizing the establishment of new companies and setting up the right benchmarks in the market in order to promote healthy competition in the market. We should make innovations in the high-quality energy industry to contribute to China's environmental and economic development.

In order to further analyze the coupling degree of the system, we compare the values of the indicators of economy, energy and environment, we can see that the development level of the economy has been increasing year by year, and the development of energy has declined in 2019, and although the amount of carbon sequestered by the forests of our country is continuing to improve, the level of development of the environment has not been significantly improved, and at the same time, we have found that the development of the energy sources affects the development of the environment, and coal has always been used as the main source of energy in our country Coal has always been the main source of energy in China, and in recent years there has been a downward trend, while crude oil and natural gas are both growing, and there is a large increase in the value, but it is not yet able to become the main source of energy. Therefore, we should reduce the use of coal energy, and vigorously develop the use of natural gas and other clean energy to promote the coupling of environment and energy, but also shows that the current measures to protect the environment are still far from enough, we need to continue to increase the environmental protection of forests and other environmental protection measures, and to continue to control forest pests, fires, and other deforestation events. We should reduce the use of coal energy and vigorously develop the use of natural gas and other clean energy sources to promote the coupling of environment and energy, and at the same time, it also shows that the current measures to protect the environment are not enough, and we need to continue to increase the environmental protection measures such as forests and continue to control forest pests, fires and other deforestation incidents.

5. Conclusions

We analyze the energy production and utilization, forest protection, economy, and environmental impacts in a comprehensive consideration at the national level as a whole, and we compare the values

of the indicators of economy, energy, and environment, and we can see that the level of development of the economy has been increasing year by year, and the development of energy has declined in 2019, and although the amount of carbon sequestered by the forests of our country is continuing to increase, the level of development of the environment has not been significantly improved, and at the same time, we find that the development of energy affects the development of the environment. The development of energy affects the development of the environment, so we should reduce the use of coal energy and vigorously develop the use of natural gas and other clean energy sources to promote the coupling of environment and energy, but also shows that the current measures to protect the environment are far from enough, and we need to continue to increase the environmental protection measures of forests and other environmental protection measures, and to continue to control forest pests, fires, and other deforestation events.

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