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Research and Application of Carbon Storage Prediction and Management Evaluation Model

Hanlin Cui[#], Junye Jiang[#], Xue Ren[#]

School of Electrical and Informtion Engineering, Wuhan Institute of Technology, Wuhan, China
[#]These authors contributed equally.

Abstract: *Firstly, based on CASA model and LULC data, this paper establishes a carbon sequestration and oxygen release service model. By estimating the carbon storage in different regions, the effect of influencing factors on carbon sequestration is obtained. Establish a differential equation to fit the amount of carbon dioxide storage, and compare the impact of different management methods on carbon storage. The results showed that under the constraints of UN indicators, the weight of the impact of reasonable forest breeding on carbon sequestration was 0.401, higher than other indicators. Secondly, a tree cutting decision-making model is established in combination with tree growth characteristics and ecological and economic benefits to obtain the expression of ecological and economic benefits and the carbon sequestration stock of trees under the optimal cutting cycle. By analyzing the operation of the management mode, it is found that the management mode is the acquisition of ecological forest system, and the combination of forest compensation and gradual cutting has the maximum benefit. Fitting can get that there is no case that no cutting is allowed. Finally, based on the existing data, the time series analysis is established to obtain the change curve of carbon sequestration and the change of forest area*

Keywords: *Carbon sequestration and oxygen release service model; Tree cutting decision-making model; Time series analysis*

1. Introduction

Since the 21st century, due to the overexploitation and utilization of natural resources by human beings, the atmospheric CO2 concentration has risen from 338 ppm in 1980 to 399 ppm in 2014, exceeding the pre-industrial revolution 40%, and the CO2 emission rate in 2013 has reached 10.7 Pg C· a. The greenhouse effect caused by the increase in CO2 content in the atmosphere will lead to a series of serious consequences such as sea level rise, the emergence of extreme weather, and land desertification. Reducing the amount of CO2 in the atmosphere requires humans to reduce carbon emissions while increasing the amount of CO2 stored in the atmosphere, that is, carbon sequestration, which is isolated from the atmosphere by biosphere or mechanical means. After investigation, the forest has accumulated nearly half of the CO2, so we need to give full play to the role of the forest in the solidification of CO2, but also can not ignore the other values brought by the forest, such as economic value, cultural and recreational value, etc., rational management of forests has a positive effect on its better realization of value. Therefore, we need to build a forest carbon sequestration model to calculate the storage of carbon by forests, and at the same time develop a set of rational forest management measures to better realize the value of forests [1-3].

Before establishing a carbon sequestration model, we must first understand the significance of carbon sequestration, that is, carbon sequestration. Refers to a method of capturing carbon and sequestering it safely [4,5]. After understanding the concept, we searched through the literature to find relevant indicator data. For example, the carbon sequestration per unit of forest area, the impact of climatic, geographical, anthropogenic and other factors on the carbon sequestration, and the impact of different forest management methods on the carbon sequestration capacity, local economic benefits, culture and recreation of forests [6-9].

After establishing the data, for predicting the carbon sequestration of forests under different management methods, we use two types of models, gray forecasting and time series, when there is a data between a larger value and a smaller value in the different management methods, it is called a transition point. Secondly, we used two models to assess the weights of the impact of different impact factors on forest carbon sequestration, and used analytic hierarchy to evaluate the advantages and disadvantages between different management methods. Finally, it is possible to judge whether there is a way to avoid

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deforestation.

2. Model of Carbon sequestration

2.1. The establishment of net primary productivity(NPP)

The carbon sequestration of trees in forests is related to the growth characteristics of trees and the planting conditions, that is, their distribution density. [5] We can set NPP as the amount of carbon sequestration in the forest, NPP refers to the total amount of organic matter synthesized by green plants after photosynthesis minus the organic matter consumed by their own respiration, and the remaining energy values that can be used for plant growth, development and reproduction are used to express the amount of carbon sequestration of green plants [8,10-13]. The use of NPP to invert the carbon sequestration of surface vegetation can not only reflect the growth status of plants, complete the monitoring of vegetation quantity, but also play an important auxiliary role in the study of carbon cycle and the transformation of the entire global climate. Natural ecosystems absorb CO2 from the atmosphere during photosynthesis to synthesize organic matter, fix carbon in plants or soils, and release oxygen. This function is conducive to reducing the concentration of CO2 in the atmosphere and slowing down the greenhouse effect.

Calculate the total amount of carbon sequestration of the forest in years. After that, the differences between the sequestration of carbon by different tree species were considered.

First of all, we calculate the amount of CO2 that a tree has accumulated in a year, it is known that plants release carbon sequestration through photosynthesis, and we introduce the calculation method of carbon sequestration according to the relevant literature: first determine the total weight of the green part of the tree, followed by the dry weight of the tree, that is, the part of the water, and then determine the weight of the carbon in the tree, and then find out the weight of the CO2 fixed by the tree, and finally calculate the weight of the CO2 fixed by the tree every year, which can obtain the amount of carbon sealed by a tree every year (Figure 1).

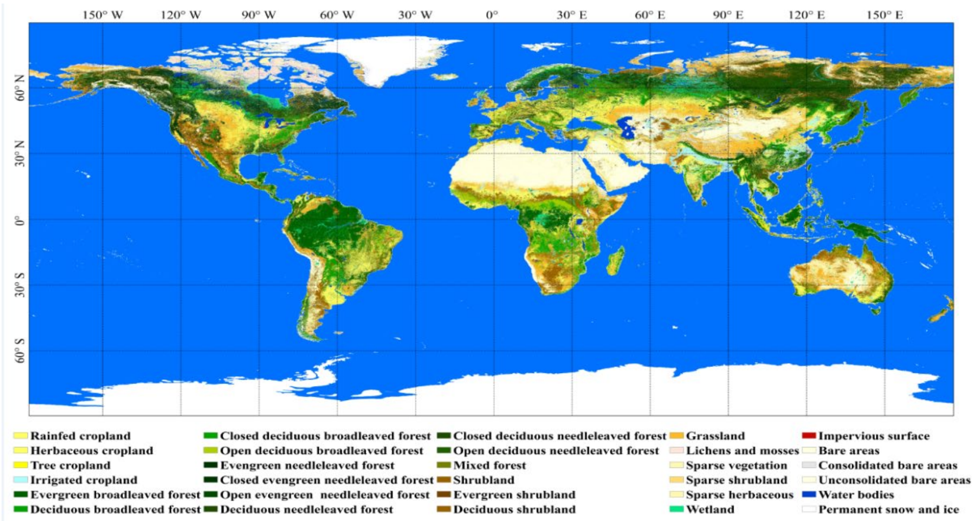

Figure 1: Global land cover

2.2. Calculate the amount of CO2 absorbed by trees every year

The formula for calculating the weight of the tree is:

For trees with D < 11: W = 0.25D2 H

For trees with D >= 11: W = 0.15D2 H

The weight of a tree's root system is about 20% of the weight of the part of the tree located above ground. Therefore, to determine the total weight of the green of the tree, we multiplied the weight of the above-ground part of the tree by 120%, the dry matter weight of the tree accounted for 72.5% of the total weight of the tree, and the moisture accounted for 27.5% of the total weight of the tree. The average carbon content is about 50% of the total weight of the trees [1].

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$$CS = CA \times CD \times CSA \tag{1}$$

Where, *CS* is the carbon sequestration of forests, CD is the cover area of forests, CSA is the carbon sequestration of a tree.

Specific values of forest cover can be obtained by remote sensing techniques, which will not be repeated here. We can also predict the annual carbon sequestration changes in different areas of the forest according to the carbon sequestration capacity of the forest per unit area, so that the difference in the carbon sequestration caused by different forests can be obtained and calculated separately. After consulting the relevant information, we found the carbon sequestration per unit area of a variety of vegetation, removed the extreme values in the data and calculated to obtain the average carbon sequestration of the forest per unit area, and at the same time, we can get the annual forest area changes in different countries and regions, from which we can know the changes in the annual forest carbon sequestration in the region [7].

2.3. Establish grey prediction model

Since the carbon sequestration of forests in an area will change with the accumulation of time and the change of influencing factors such as climate and soil conditions, we need to calculate according to its general situation, search for relevant multiple sets of data, and then use gray prediction to generate raw data to find the law of system change, and generate a data sequence with strong regularity, and then establish a corresponding differential equation model to predict the future development trend of things.

We build GM (1,1) using raw discrete non-negative data columns, generate new discrete data columns that weaken randomness by accumulating them at one time, and then model them by building differential equations. Approximate estimates of the original data generated by the cumulative subtraction of the solution at the discrete point are obtained to predict the subsequent carbon sequestration over time.

$$u = (a, b)^T, Y = \begin{bmatrix} x_{(2)}^{(0)} \\ x_{(3)}^{(0)} \\ \vdots \\ x_{(n)}^{(0)} \end{bmatrix}, B = \begin{bmatrix} -m_{(2)}^{(1)} & 1 \\ -m_{(3)}^{(1)} & 1 \\ \vdots & \vdots \\ -m_{(n)}^{(1)} & 1 \end{bmatrix} \tag{2}$$

According to the least square's method, the parameters a and b are estimated as:

$$\hat{\boldsymbol{u}} = \begin{pmatrix} \hat{a} \\ \hat{b} \end{pmatrix} = (\boldsymbol{B}^T\boldsymbol{B})^{-1}\boldsymbol{B}^T\boldsymbol{Y} \tag{3}$$

Available according to the definition of definite integrals:

$$\begin{gathered} x^{(0)}(k) = -\hat{a}z^{(1)}(k) + \hat{b} \Rightarrow x^{(1)}(k) - x^{(1)}(k-1) = -\hat{a}z^{(1)}(k) + \hat{b} \\ x^{(1)}(k) - x^{(1)}(k-1) = \int_{k-1}^{k} \frac{dx^{(1)}(t)}{dt} dt \\ z^{(1)}(k) = \frac{x^{(1)}(k) + x^{(1)}(k-1)}{2} \approx \int_{k-1}^{k} x^{(1)}(t)\, dt \end{gathered} \tag{4}$$

$$\begin{aligned} \int_{k-1}^{k} \frac{dx^{(1)}(t)}{dt} dt &\approx -\hat{a}\int_{k-1}^{k} x^{(1)}(t)\, dt + \int_{k-1}^{k} \hat{b}\, dt \\ &= \int_{k-1}^{k} [-\hat{a}x^{(1)}(t) + \hat{b}]\, dt \end{aligned} \tag{5}$$

2.4. Establish grey prediction and evaluation model

In order to maximize the value of forests without causing further damage to the environment, the ecological value of forests should be realized as much as possible, especially in the increasingly warming of the world, and forests should be reasonably sequestration of CO2 as much as possible to the maximum amount. In addition, the physical value of forest land is also very important, many of our daily necessities come from forest trees, which bring land economic benefits can not be underestimated, in addition, forest products also have the role of carbon sequestration, long life of forest products can store more CO2. After that, the forest ecosystem is rich in species and has good research significance to explore and create more potential value. Based on this, we will appropriately analyze and simplify the value mode of forests to better analyze the main value modes of forests and their proportion, so as to further realize the higher value of forests, and then introduce the proportion of specific forest management measures from the value of forests [14].

From the above method, we obtain the following modeling process, from top to bottom, first analyze the relationship between forest value and various evaluation indicators, and then analyze the direct relationship between forest management measures and various evaluation indicators, and finally obtain a forest management decision-making model.

Aggregate the value of forests together to generate a set of evaluation indicators. Due to the wide variety of influencing factors of forest values, we have obtained a collection of the following five main evaluation indicators X by looking at the literature and simplifying them appropriately.

$$X = \{x_1, x_2, \dots, x_m\} \tag{6}$$

Among them, x_1 is carbon sequestration, x_2 is for biodiversity maintenance, x_3 is economic benefit, x_4 is entertainment value, and x_5 is cultural value.

Each measure affects the value mode of the forest, so we summarize and combine the forest management measures to establish a set of influencing factors *Y*.

$$Y = \{y_1, y_2, \dots, y_m\} \tag{7}$$

Among them, y_1 is rational logging, y_2 is afforestation, and y_3 is geographical transplantation.

Affected by the characteristics of these evaluation indicators themselves, it is impossible to directly quantify them. So, we need to calculate their respective weights.

Establish a weight set of each evaluation index and influencing factors.

$$A = (a_1, a_2, \dots, a_m) \tag{8}$$

In the formula, a_1 represents the weight value corresponding to each specific evaluation index, and there are currently two ways to determine the value of a. One is subjective evaluation, the other is model calculation evaluation: different weight assignments will also make differences in subsequent evaluation results. Here we calculate the corresponding index weights according to the literature and analysis.

Establish a judgment matrix and calculate the weights of evaluation indicators, so as to form an evaluation system.

First, we design the importance scale, as shown in the table below, and then we check it for consistency (Table 1).

Table 1: Importance Scales

Importance scale	Meaning (ratio of two elements)
1	The importance is the same
3	The former is slightly more important
5	The former is clearly important
7	The former is strongly important
9	The former is extremely important
2, 4, 6, 8	Represents the median value of the two adjacent judgments mentioned above
Reciprocal	If the ratio of the importance of element *i* to element *j* is a_{ij}, the ratio of the importance of element *j* to element *i* is $a_{ji}=1/a_{ij}$

2.5. Model of forest management

According to the Forest Ecosystem Sustainable Assessment, the diversity, complexity, health, stability, adaptability and other characteristics of the ecosystem are the basis for achieving ecosystem sustainability. On this basis, the sustainability of forest ecosystems is considered. To ensure that the amount of timber that can be harvested each year is not reduced and that the amount of wood that can sustain the forest is not reduced, so that the various efficiencies of the forest are not reduced, and future generations have no less wealth than the previous generations. The dynamic efficiency principle requires foresters to arrange production according to the optimal harvesting cycle in order to maximize the return on unit area of forest land. However, if the number of trees of different ages on a forest land varies greatly, it will affect the

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satisfaction of the principle of intergenerational equity, because it will cause fluctuations in the supply of wood and the volume of living standing wood. Therefore, if the requirements of the principle of intergenerational equity are to be met, it is best for foresters to grasp the speed of afforestation and steadily expand their area.

The best time for a tree to be cut down is T years. The annual forest area of a forest is "y hm"^2, so that by the end of the T year, there are basically equal numbers of trees with an age of 1 to T years, and the total amount of living standing wood accumulation is H(t). The amount of logging that began at this time and only the earliest planted trees, which have reached the age of T years, will be cut down in this year:$n \cdot y \cdot V(t)$

n is the density variable, the number of trees per hectare of land; y is the planting area in hectares;$V(t)$For the amount of wood for each tree. The amount of new net increase in wood for all tree in the next year is:

$$n \cdot x \cdot \{V(1) + [V(2) - V(1)] + [V(3) - V(2)] + \cdots + [V(t) - V(T-1)]\} = n \cdot x \cdot V(t) \tag{9}$$

Forest reserves do not change after one year, the formula is expressed as:

$$H(T+1) = H(t) - n \cdot x \cdot V(t) + n \cdot x \cdot V(t) = H(t) \tag{10}$$

Considering only the sale of wood, the benefits under the social optimal harvesting model are:

$$(p-c)V(t_{\mathrm{ED}})\mathrm{e}^{-n_{\mathrm{ED}}} \cdot \frac{1}{1-\mathrm{e}^{-n_{\mathrm{ED}}}} = \frac{(p-c)V(t_{\mathrm{ED}})}{\mathrm{e}^{nt_{\mathrm{ED}}}-1} \tag{11}$$

The environmental benefits are:

$$W(t_{\mathrm{ED}}) \lim_{T\to\infty} \frac{T}{t^{\circ}_{\mathrm{ED}}} \tag{12}$$

The model satisfies both the dynamic efficiency principle and the intergenerational equity principle of resource utilization, and the amount of new wood added each year, that is, the wood yield, remains unchanged, and the total amount of living standing wood accumulated H(t) remains unchanged. Economic benefits are guaranteed; trees per unit area remain unchanged, while also ensuring that carbon sequestration remains constant; after adding economic benefit measures, it is possible to log trees without compromising economic benefits and having minimal impact on ecosystems.

3. Analysis

3.1. Analysis of grey predictive models

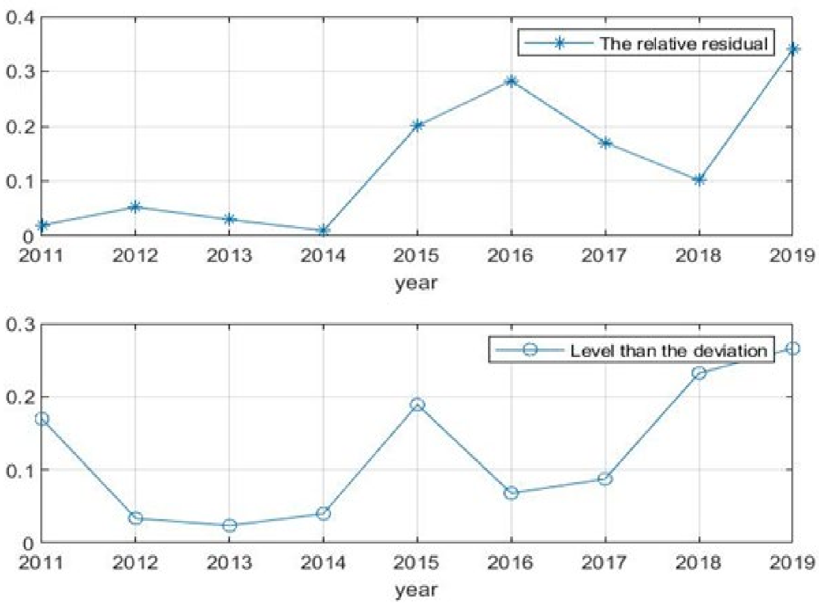

Figure 2: Residual curve

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Since the number of data years is greater than 4, the data can be divided into training groups and experimental groups, and the experimental group data can be predicted by three gray prediction methods, and then compared with the original data and the sum of squares of errors is calculated, so that the prediction method with less error in the prediction result is selected as the actual prediction method. The run output is as follows:

The sum of squares of error predicted by conventional GM (1,1) for experimental group is 219. 65968.The sum of squares of error of GM (1,1) for experimental group prediction is 220. 67911.The sum of squares of error predicted by metabolic GM (1,1) for experimental group is 279. 87496.Therefore, the traditional forecasting method is selected for prediction. Residual tests and fractional deviation tests based on the predicted results (Figure 2,3):

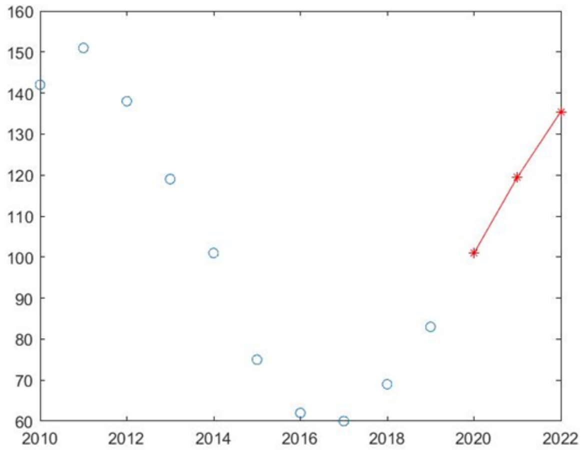

Figure 3: Prediction results

3.2. Analysis of time series models

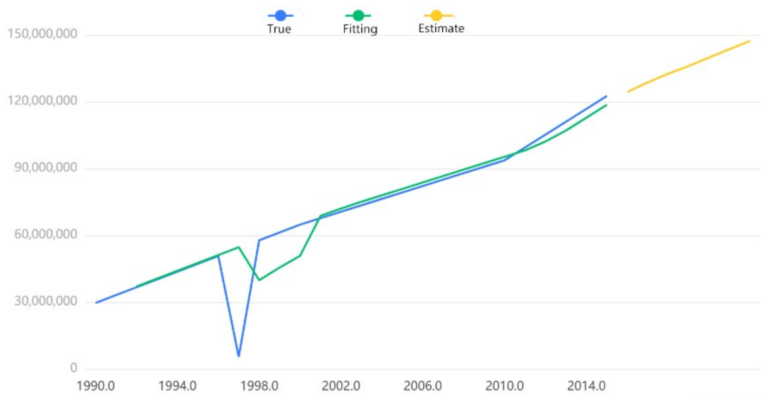

Figure 4: Accuracy analysis

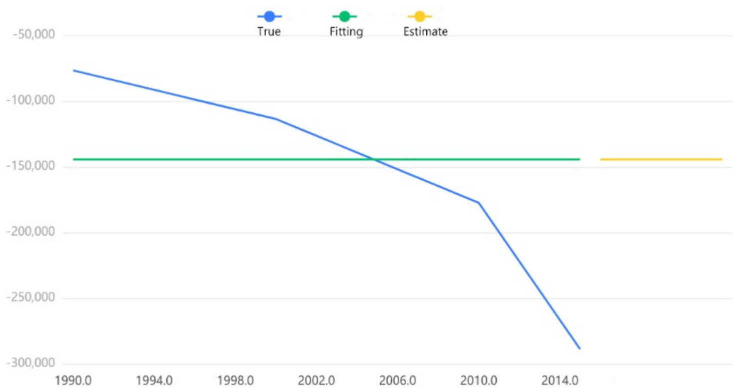

Figure 5: Transition point curve

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The forecast increases in carbon sequestration in 2015 is 124313838.655g, while the actual increase in carbon sequestration in 2015 is 122556697.6g, with an error of 1.434%.

The model predictions are normal. Moreover, in the prediction of multiple sets of data, there is a situation in which the predicted value is unchanged, which is regarded as a transition point for different forest management methods.

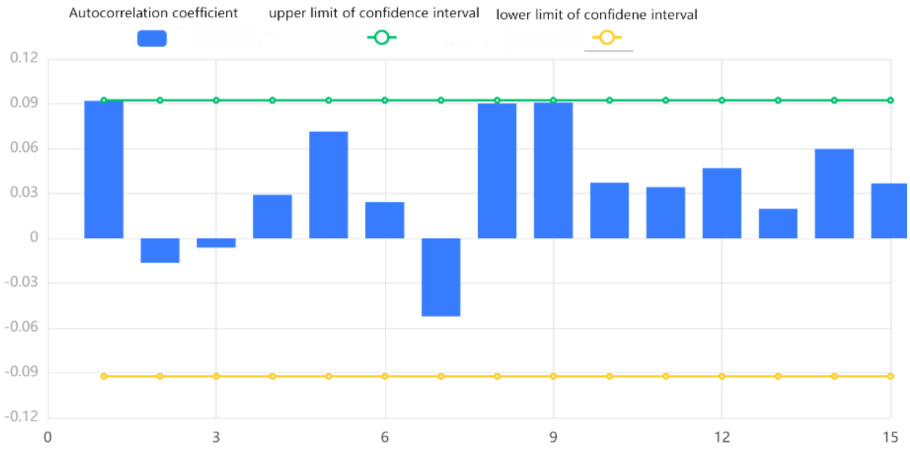

Figure 6: Auto-correlation plot of final differential data

Chart description: From the autocorrelation plot, we can see that the first-order autocorrelation coefficient is obviously greater than 2 times the standard deviation range, and since the first-order autocorrelation coefficient, the rest of the autocorrelation coefficients are within the range of 2 standard deviations, and we can judge that the autocorrelation plot is truncated (Figure 4, 5, 6).

4. Conclusion

First, we obtained the prediction data with high accuracy and small error through the gray prediction model, which is in line with the predicted value of predicting forest carbon sequestration under different management methods. At the same time, we used the NPP model framed by the CASA model to obtain an influencing factor associated with forest carbon sequestration, which has been used in many forms in many differential equations courses in the Department of Mathematical Sciences for several Through this model, we can see that the methods we can manage forests are: tree planting and breeding, geographical transplantation, periodic logging, and we use analytic hierarchy to evaluate the advantages and disadvantages of management methods. The results show that, in order to consider all aspects of the indicators, there is no management method that can abandon rational logging.

Second, by merging the aforementioned predictive model with the decision model, we get values that can touch the range of larger variations, which allows us to predict the amount of carbon sequestration change over a long period of time. At the same time, through the decision model, we find out the management method of carbon sequestration changing with constant constant, and initially solve the problem.

However, our solution has the disadvantages of insufficient data granularity and mutual constraints on the impact factors.

In short, we have reached several valuable conclusions about the nature of Different management methods for carbon sequestration and other indicators , and some of the possible policy solutions that can be implemented to make it more effective ,Most importantly, we believe in the absolute necessity of (Second, we have drawn several valuable conclusions about the nature of different management approaches to carbon sequestration and other indicators, as well as some possible policy solutions that can be implemented to make it more effective and, most importantly, we believe in the absolute necessity of implementation.

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