Carbon Sequestration Model Based on Decision Tree Regression and Logic Tree Model

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Abstract: *We established a carbon sequestration model including a decision tree regression model and a logic tree model. First, we used data from various regions of the world, selected ten indicators using climatic factors, geographical factors, and forest attribute factors, established a forest net productivity pre- diction model using the decision tree regression method, and then proposed the "logic tree". Then we proposed the concept of "logical tree", in which the whole forest is considered as one big tree, and the use time of forest products is calculated as the whole cycle of forest management by weighting method, and finally, we concluded that we select suitable tree species according to climate type, control the indicators of climate, geography, and forest attributes, and then adjust the types of forest products and processing methods appropriately to achieve the net productivity of forest and carbon storage of forest products. To maximize the benefits of forest net productivity and forest product carbon sequestration.*

Keywords: *Decision Tree Regression; Logic Tree; Carbon Sequestration*

1. Introduction

In today's rapidly advancing technology, the earth's climate is beginning to send change with the massive emissions of greenhouse gases. A management program for greenhouse gas emissions is necessary to relieve the pressure on the earth and for a better tomorrow for us humans, but simply reducing greenhouse gas emissions is not enough. We need to make more efforts to increase the reserves of carbon dioxide that we isolate from the atmosphere through biosphere or mechanical means. Therefore, a carbon sequestration program that is adaptable and effective, and a forest management program that integrates carbon sequestration, economic values, and ecological values are essential.

2. Carbon Sequestration Model

The carbon sequestration of a forest as a whole is reflected in the net ecosystem productivity NEP of the forest ecosystem and the carbon sequestration of the existing forest products. To explore the influence of climate, geography, forest attributes, and forest products on the carbon sequestration of the forest, we established the carbon sequestration model, and the whole model is divided into two parts [2].

The first part is a decision tree regression model that can predict NEP by taking each indicator of climate, geography, and forest attributes as independent variables and the net ecosystem productivity of forest ecosystem NEP as a dependent variable and using the data training found in earth data and other websites.

The second part is the average carbon sequestration of forest products calculated with the loss rate, carbon content, and use time of forest products as independent variables [3].

2.1. Decision tree regression model

To prepare predictions of the net ecosystem productivity NEP of forests using climatic factors, geographic factors, and forest attribute factors, we designed a decision tree regression model using each of the above factors, with ten variables: temperature, humidity, precipitation, altitude, sand content of the soil, mud content of the soil, stand density, tree diameter at breast height, tree height, and tree age as input variables and the net ecosystem productivity NEP of forest ecosystems as output variables [4].

i. First, a training data set is created using the processed data.

$$D = \{(x_1, y_1), (x_2, y_2), ..., (x_N, y_N)\} \quad (1)$$

Where $x_i = \left(x_i^{(1)}, x_i^{(2)}, \dots, x_i^{(n)}\right)$, y_i is the corresponding *NEP* value.

ii. Take the *j*th feature variable *x*(*j*) in the training set and its taken value *s*, as the cut-off variable and the cut-off point, and define two regions: $R_1(j,s) = \{x \mid x^{(j)} \le s\}$ and $R_2(j,s) = \{x \mid x^{(j)} > s\}$. Solve the optimal cut-off variable *j* and cut-off point *s*.

$$\min_{j,s}\left[\sum_{x_i\in R_1(j,s)} (y_i - \widehat{c_1})^2 + \sum_{x_i\in R_2(j,s)} (y_i - \widehat{c_2})^2\right] \quad (2)$$

Where $\widehat{c_1} = \sum_{x_i\in R_1(j,s)} y_i / N_1$, $\widehat{c_2} = \sum_{x_i\in R_2(j,s)} y_i / N_2$. Iterate over the variable *j*, scan the cut point s for a fixed cut variable j, and choose the pair (*j*,*s*) that minimizes the above equation [5].

iii. Divide the region with the selected pair (*j*,*s*) and decide the corresponding output value.

iv. Continue to call steps 1, 2 for both sub-regions until the stopping conditions are met.

v. Divide the input space into M regions $R_1, R_2, R_3, R_4, \dots, R_M$, generating a decision tree.

$$f(x) = \sum_{m=1}^{M} \widehat{c_m}\, I(x \in R_m) \quad (3)$$

Where *I* is the indicator function that

$$I = \begin{cases} 1, x \in R_m \\ 0, x \notin R_m \end{cases} \quad (4)$$

We then obtained the decision tree regression model for calculating the net ecosystem productivity NEP of the forest ecosystem, and the importance of the ten features is shown in Figure 1.

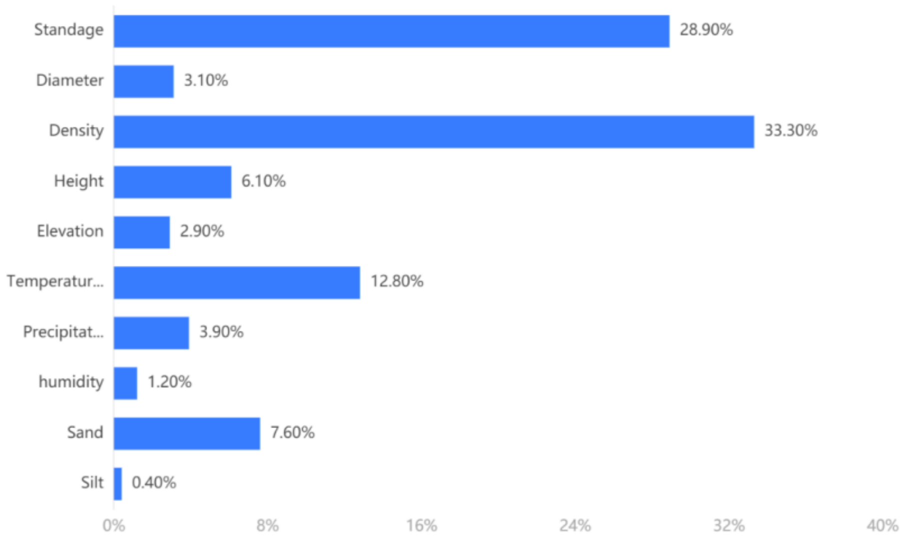

Figure 1: The importance of ten characteristics

From the decision tree regression model, it can be seen that stand density, stand age, temperature, and soil sand content are the four indicators that have the greatest impact on the forest ecosystem. Therefore, when doing forest management, it is necessary to analyze the above indicators for specific tree species to achieve the maximum utilization of the forest ecosystem.

2.2. Calculation of carbon sequestration of forest products

To design a scheme to sequester the most CO_2 through forest management, here we propose the concept of a logical tree, which does not exist, but, to clearly show the forest management process, we assume that the currently analyzed forest ecosystem is a tree, which has a growth cycle *T* (that is, the cycle of our forest management scheme), and in time *T*, the net productivity of the tree shows, so to make better use of its carbon sequestration, we can choose to cut it down at some time *t*.

However, after cutting it down, we cannot plant another tree immediately, considering the land restoration and climate, we need to wait for t_1 time, so the tree is replanted at time $t+t_1$ (taking into account the planting state of the tree, here we assume that the tree is planted. The tree was planted at $t+t_1$ (taking into account the planting status of the tree, here we assume that the tree was planted with the initial age),

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and the cut tree was taken for forest products, and the whole flow chart is shown in Fig 2.

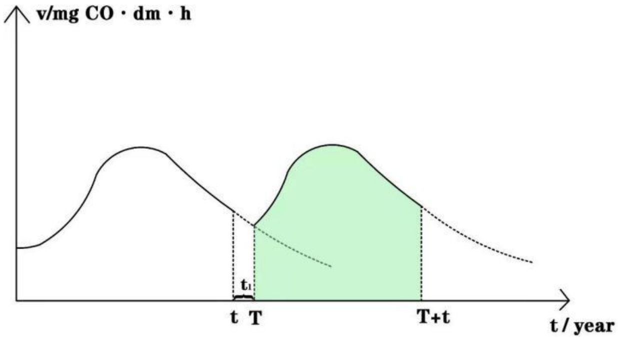

Figure 2: Program flowchart

Here, we consider the net productivity NEP_T of large trees between being planted and felled in a forest management cycle as the product of the annual net productivity predicted by the decision tree regression model and time t.

$$NEP_T = NEP\ t \tag{5}$$

And since only carbon sequestration is considered while ignoring economic and other public good impacts other than carbon sequestration, we used an optimal harvesting model that takes into account forest heterogeneity differences, i.e., all trees must be larger than a particular diameter before they are allowed to be cut. Here, the trees felled each year are summed into this one large tree, and the net productivity and recovery time affected by the felled trees are treated here as the recovery time t_1.

$$t_1 = T\,(C_T / C_S) \tag{6}$$

At this point, we can also get the management cycle $T = t + t_1$ for the whole forest, but this is not a good solution to the forest management problem. After trying, we decided to take the weighted average use time of these forest products, such as furniture, tableware, and handicraft items, as the management cycle T of the forest, which means that T may be a constant at the beginning, but with the transformation of forest products, we can update the forest management cycle T appropriately according to the weight of carbon stock in the forest products.

The carbon stock of the felled tree in period T is not considered as the carbon stock of the forest product, here we also need to consider the *loss* rate in processing and the carbon content of the wood C, so we get the carbon stock of the forest product F_{PC}.

$$F_{PC} = C_T\ loss\ C \tag{7}$$

Finally, we derive the carbon sequestration CS of the entire forest from the NEP predicted in the decision tree regression model and the carbon sequestration of forest products we calculate at this point.

$$CS = NEP\ t - F_{pc} \tag{8}$$

After finishing, it can be deduced that

$$CS = T\,[NEP - (NEP/C_S + loss\ C)C_T] \tag{9}$$

In other words, the fewer trees are cut down in the whole forest management cycle, and the longer the use cycle of forest products, the stronger the carbon sequestration capacity of the whole system. In addition, when the loss of forest products processing is much smaller than the net productivity of the whole system, expanding the NEP value of the forest system by each indicator can also achieve the purpose of expanding the total carbon sequestration of the forest system.

2.3. Carbon curing model testing

To better answer the question of how much CO_2 is expected to be sequestered by the forest and its products over time, we selected data from a forest here and then used our carbon sequestration model to predict its carbon sequestration value C_S over a forest management cycle T and then propose forest management options for it.

Here we extracted data from a forest in a temperate continental climate and then predicted the net productivity of that forest using a previously trained decision tree regression model.

We then queried that the main tree type of this forest is broadleaf deciduous forest, and based on its forest products and use, we finally calculated its forest products carbon sequestration using a carbon sequestration model. Based on the optimal harvesting model for forest heterogeneous age differences, our recommendations for the management plan of this forest are:

i. Provide timely feedback on forest changes over time by felling trees once a year to remove old trees with low net productivity due to forest age.

ii. Minimize the interval between tree planting after felling to increase the overall net productivity of the forest.

iii. In the above calculation, we found that the duration of use of this forest product is short, so we should adjust the type of forest product or processing method to increase its duration of use and thus improve the overall efficiency of carbon sequestration.

iv. In the analysis of ecosystem net productivity, stand density, temperature, and soil content also have a significant impact on the net productivity of trees, so it is necessary to select suitable tree types according to the climate, and forest managers should adjust the stand density to optimize the overall carbon sequestration efficiency.

3. Conclusion

Carbon sequestration in forests has always been a hot issue of concern. In this paper, we construct a carbon sequestration model with decision tree regression prediction and forest product carbon sequestration as sub-models, which can accurately calculate the amount of carbon dioxide absorbed by a forest in a forest management cycle, and correlate the forest management cycle with the weighted forest product use time, which can better influence the forest management cycle through the transformation of forest products and even the change of forest tree species.

Ideally, we would like to see the forest develop comprehensively, but in practice, the forest has to make trade-offs between carbon sequestration value, economic value, and ecological value, and then decide the development direction of the forest by taking into account the climatic factors, geographic factors and people's living standards in the area where the forest is located. When the forest manager has a clear demand or the forest management cycle needs to be changed, the weighting indicators of carbon sequestration value, economic value, and ecological value can be adjusted appropriately to decide the development direction of the forest.

Through this model building and solving, as well as the testing process, we also deeply understand the real meaning of environmental governance, which is neither to pursue the maximization of one indicator nor to deny the role of one indicator comprehensively, but to make a trade-off between them, so that the forest can steadily develop in a better management scheme and better play its role for the benefit of human beings.

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