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Forestry for Carbon Sequestration

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Abstract

In this paper, we develop a carbon sequestration model to estimate and determine the carbon dioxide content of forests. Specifically, combing with the proposed range of decision model and transition point conditions between forests, we convert the assessed value of forest into carbon sequestration and overall economic model. By setting decision variables and constraints, we get a Regarding the function of the carbon sequestration network system, we then performed a computer solution to apply our model to various forests, and combined with the data found, predicted the amount and location of carbon dioxide that forests and products can store for more than 100 years.

Keywords

Carbon sequestration, forest management models, simulated annealing.

1. Introduction

Carbon dioxide in plants (especially large plants like trees), soils, and water environments. Thus, forests are integral to any climate change mitigation effort. Forests sequester carbon dioxide in living plants and in the products created from their trees including furniture, lumber, plywood, paper, and other wood products [1]. These forest products sequester carbon dioxide for their lifespan. Some products have a short life span, while others have a life span that may exceed that of the trees from which they are produced. The carbon sequestered in some forest product scombined with the carbon sequestered because of the regrowth of younger forests has the potential to allow for more carbon sequestration over time when compared to the carbon sequestration benefits of not cutting forests at all. At the global level, forest management strategies that include appropriate harvesting can be beneficial for carbon sequestration [2]. However, overharvesting can limit carbon sequestration. Forest managers must find a balance between the value of forest products derived from harvesting and the value of allowing the forest to continue growing and sequestering carbon as living trees. In doing so, they must consider many factors such as age and types of trees, geography, topography, and benefits and life span of forest products [3]. The concerns of forest managers are not limited to carbon sequestration and forest products. They must make forest management decisions based on the many ways their forest is valued. These may include, but are not limited to, potential carbon sequestration, conservation and biodiversity aspects, recreational uses, and cultural considerations.

Climate change presents a massive threat to life as we know it. To mitigate the effects of climate change, we need to take drastic action to reduce the amount of greenhouse gases in the atmosphere [4]. Simply reducing greenhouse gas emissions is not enough. We need to make efforts to enhance our stocks of carbon dioxide sequestered out of the atmosphere by the biosphere or by mechanical means. This process is called carbon sequestration.

However, in this paper, we have established a carbon sequestration model to estimate and determine the carbon dioxide content of forests. We have established the carbon sink network system structure and modeled through the connections between the points, thereby transforming the problem into a planning problem. The optimal solution and pipe network

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layout are obtained by simulated annealing method, and the most effective forest management plan is given smoothly.

2. A carbon sequestration model

According to the data, we have drawn a map of the total carbon dioxide emissions of each country as follows in Fig.1 and Fig.2.

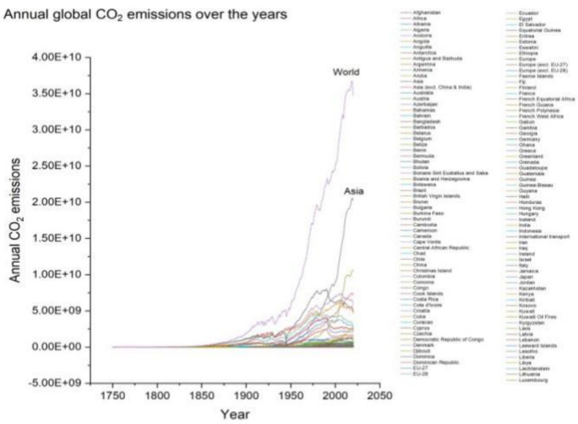

Figure 1 Global CO_2 emissions by country

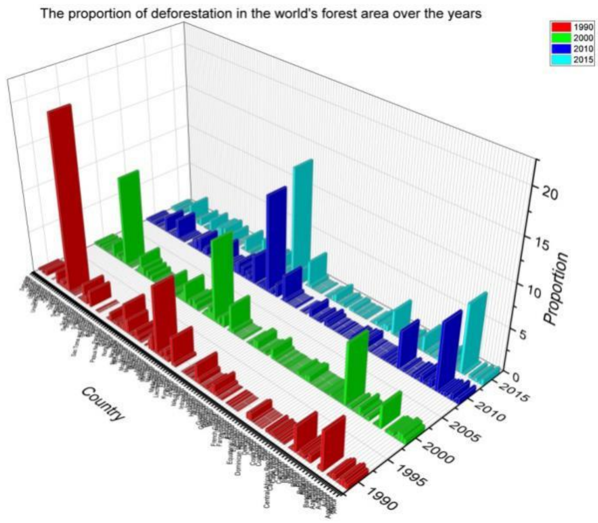

Figure 2 Proportion of global deforestation resources

From Fig.1, it can be seen that Asia's carbon emissions are currently significantly lower than the world average. Fig. 2 shows the relationship between the mass flow rate of CO_2 pipeline transportation and the transportation cost per unit distance. It can be found that the higher the mass flow rate, the lower the transportation cost per unit distance, and it tends to be stable after the mass flow rate reaches.

We simplify the cost optimization problem of carbon sequestration network system into the optimization problem of CO_2 pipeline construction and transportation cost, which is shown in Fig.3. In this simplified optimization problem, there are one CO_2 source point and one CO_2 sink point, which are connected by transportation pipeline [5]. When CO_2 emitted from one source point is transported, it can pass through other source points and then reach the destination sink point, so it is necessary to establish a connected graph covering all nodes (including all source points and some sink points). Therefore, we can roughly give a formula for calculating the transportation cost per unit distance of CO_2:

$$\frac{d_{pi}20Mt}{y}C_{tr} = G/Q_i \tag{1}$$

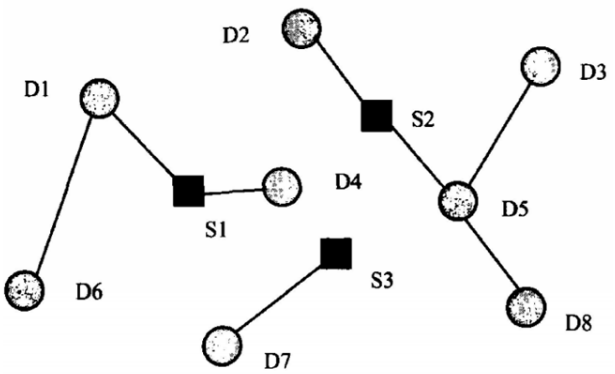

Figure 3 Schematic diagram of carbon sequestration network system

The objective function is the sum of the pipeline distances connecting all source points and selected sink points, which can be expressed as:

$$\text{Min Z} = \sum_{i,j\in D} Y_{ij}, c_{ij} \tag{2}$$

3. Solution algorithm

For the spanning tree of a network, the sum of the weights of all its edges is defined as the weight. The Minimum Spanning Tree (MST) problem is to find a spanning tree to minimize, which can be expressed as:

$$GTw(T)Tw(T) = \sum_{e\in E(T)} w_{ij} GT^* w(T^*) \tag{3}$$

Aiming at the problems in this paper, we design an improved algorithm.

$\forall Y_{ij} = 0 Y_{ij} = 1$Step 0, and calculate the distance from each source point to each potential sink point respectively, find the two points with the shortest distance, connect them, and make the corresponding.

$Y_{ij} = 1$ Step 1 calculates the distances of the remaining unconnected source points to each potential sink and connected source point, finds the two points with the shortest distances, connects them, and makes the corresponding.

Step 2 Repeat Step L until all source points are connected. Through the above calculation process, we can find the optimal solution of the objective function and the corresponding network connectivity.

In this algorithm, random factors are introduced in the search process, and a random acceptance criterion is used to accept the deteriorated solution to a limited extent, and the probability of accepting the deteriorated solution gradually approaches 0, which makes it possible for the algorithm to jump out of the local optimal solution and find the global optimal solution, and ensures the convergence of the algorithm, which can be expressed as:

$$P = \begin{cases} 1 \\ \exp\left(-\frac{E(X_{\text{new}})-E(X_{\text{old}})}{T}\right) \end{cases} \tag{4}$$

$$ifE(X_{\text{new}}) < E(X_{\text{old}}) ifE(X_{\text{new}}) \geqslant E(X_{\text{old}}) \tag{5}$$

The optimization object of simulated annealing algorithm is the selection of sink points, that is, the actual sealed points are selected from the optional sink points. After the sink is determined, the connection method between the source point and the selected sink is determined by the lower minimum spanning tree algorithm.

To show the applicability of the above model, we consider a carbon sequestration network consisting of 16 CO_2 emission source points and 6 potential sequestration points, as shown in Fig. 4, and the location coordinates of all nodes are shown in table 1.

Table 1 Location coordinates of 16 CO_2 emission sources and 6 potential sequestration points

Node	1	2	3	4	5	6	7	8	9	10	11
CX	1.3	2.2	3.1	2.9	3.8	4.9	4.6	7.6	6.7	8	9.4
CY	6.2	13.2	1.1	7.8	4	6.2	11.9	8.8	13.8	3.3	11.9
Node	12	13	14	15	16	17	18	19	20	21	22
CX	10.3	10.2	12.1	12.4	13.7	4.3	6.2	7.4	8. 1	11.9	13.2
CY	6.6	10. 9	3	8.7	13.2	7.7	3.1	7. 1	13.5	4.3	10.8

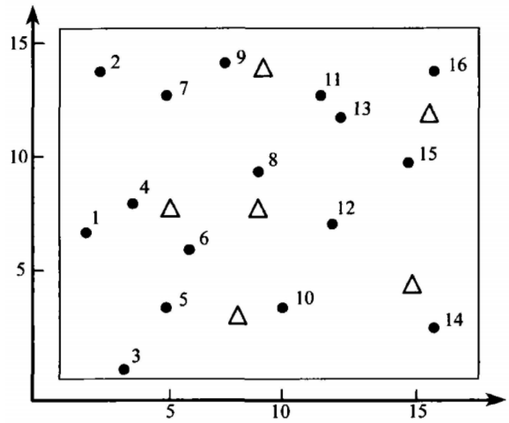

Figure 4 Layout of carbon sequestration nodes of an example

Table 2 Object function value and running time under the number of storage points

Number of sealed points	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$k = 5$	$k = 6$
Objective function value	26. 8463	24. 7410	22. 8713	22. 8713	21. 2408	33. 3988
Running time	8.3004 sec	8.2382 sec	8.7098 sec	10.6593 sec	11.8246 sec	0.0356 sec

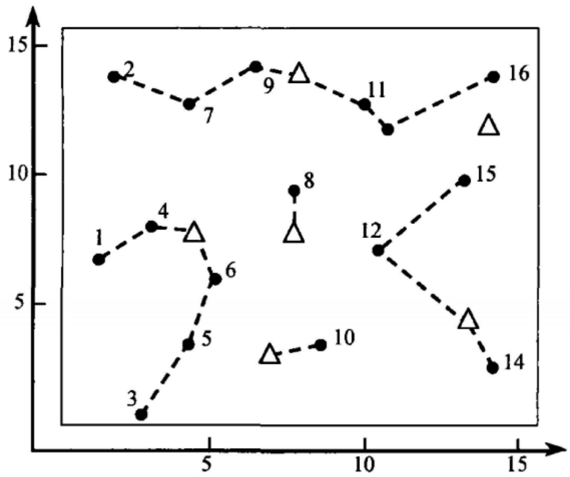

Figure 5 Pipe network layout of optimal solution

Using Matlab 7.1 program, set the algorithm parameters: iteration times, cooling rate, when the temperature drops to terminate the calculation. When running the algorithm program, take the value () in turn, and get the objective function value and running time in each case as shown in table 2. From table 2, the optimal number of storage points in this example is obtained, and the objective function value is 21.2408. The complete pipeline layout scheme is shown in Fig. 5.

In order to verify the effectiveness of the algorithm, this paper compares the calculation results optimized by this algorithm with CPLEX, a commercial operations research software. See table 3 for the comparison results.

Table 3 Comparison of calculation results between this algorithm and CPLEX

Method	Simulated annealing algorithm	CPLEX
Objective function value	21.2408	21.2408
Running time	11.8246 sec	30.1764 sec

So far, we have established a forest management plan, and we agree that the carbon sequestration model we have established is well compounded and that we should improve energy efficiency, use of alternative fuels and energy sources, and carbon dioxide capture and storage technologies [6].

This paper mainly considers the overall economy of carbon sequestration network from the perspective of cost. The decision models for forest management plans can be expressed as:

$$Min\ NPV = \sum_{t \in T} \left[I_t + C_t^{\text{CO2 flow}} - R_t^{\text{eor}} - F_t^{\text{yield}} + C_t^{\text{penalty}} \right] \cdot (1+i)^{-t} X_{pt} tp Y_{pqt} tdis_{pq} \tag{6}$$

The construction investment of carbon sequestration network system mainly refers to the construction cost of carbon capture equipment and carbon dioxide transportation pipeline during the investment construction period. Indicates whether carbon capture devices are established at points in Phase I, and whether connecting pipes are established between bright spots in Phase I. Indicates the distance between two places.

$$\begin{aligned} I_t &= \text{InvestCCS}_t + \text{InvestPipe}_t \\ &= \sum_{p \in P} \text{InvestCCSCoef} \cdot \text{CO2 Emission}_{pt} \cdot X_{pt} \\ &\quad + \sum_{pa \in P} \sum_{pb \in P} \text{InvestPipeCoef} \cdot \text{dis}_{pa\text{pb}} \cdot YP_{pa\,pbt} \\ &\quad + \sum_{pa \in P} \sum_{q \in Q} \text{InvestPipeCoef} \cdot \text{dis}_{paq} \cdot YQ_{paqt} \end{aligned} \tag{7}$$

The operating costs of carbon dioxide sequestration include the energy consumption of CCS equipment to capture carbon dioxide, the compression and transportation costs of carbon dioxide (in the previous chapter, this part of the cost has been reasonably equated with only the length of the pipeline), and the sequestration costs of carbon dioxide at the sequestration site [7]. Carbon dioxide is captured at the emission site and transported to the storage site through pipelines for storage. CO_2Yieldpat is the amount of carbon dioxide reduced by the first emission source and the amount of carbon dioxide collected by the first sequestration site.

$$
\begin{aligned}
C_t^{\text{Co2 flow}} &= \text{CCapture}_t + \text{CTrans}_t + \text{CSeal}_t \\
&= \sum_{pa \in P} \text{CaptureCostCoef}_p \cdot \text{CO2Yield}_{pat} \cdot XX_{pat} \\
&+ \left(\begin{aligned} &\sum_{pa \in P} \sum_{pb \in P} \text{TransCostCoef} \cdot \text{dis}_{papb} \cdot YYP_{pa\,pbt} \\ &+ \sum_{pa \in P} \sum_{q \in Q} \text{TransCostCoef} \cdot \text{dis}_{pa\,q} \cdot YYQ_{pa\,qt} \end{aligned} \right) \\
&+ \sum_{q \in Q} \text{SealCostCoef} \cdot \text{CO2Seal}_{qt}
\end{aligned} \tag{8}
$$

The income of enhanced oil recovery (EOR) is related to the current crude oil price, and the enhanced oil recovery effect will not be produced until the carbon dioxide storage reaches a certain scale critical point, which can be expressed as:

$$
R_t^{eor} = \sum_{q \in Q} \left(\text{OilPrice}_t \cdot \text{WhetherOil}_q \cdot \sum_{t \in T} \text{CO2Seal}_{qt} \right) \tag{9}
$$

The CO_2Priccet can be expressed as:

$$
F_t^{yield} = CO2Price_t \cdot \sum_{pa \in P} \text{CO2Yield}_{pat} \cdot XX_{pat} \tag{10}
$$

The carbon dioxide emissions can be expressed as:

$$
C_t^{\text{penalty}} = PenaltyCostCoef \cdot risk_t \tag{11}
$$

In the carbon sequestration network system, the carbon dioxide emitted from all emission points should be collected to the sequestration site for sequestration, which can be expressed as:

$$
\sum_{pa \in P} \text{CO2Yield}_{pat} = \sum_{q \in Q} \text{CO2Seal}_q t \tag{12}
$$

where

$$
\sum_{t \in T} \text{CO2Seal}_{qt} \le \text{maxcap}_q \tag{13}
$$

$$
\sum_{q \in Q} YYQ_{pa} qt \le 1 \tag{14}
$$

$$
\sum_{pa \in P} \sum_{pb \in P} YYP_{pa\,pbt} + \sum_{pa \in P} \sum_{q \in Q} YYQ_{pa\,qt} = \sum_{pa \in P} X_{pat} \tag{15}
$$

Find relevant data and solve it with a computer, we calculate the amount and location of carbon dioxide sequestered in China for over 100 years, which is shown in table 4.

Table 4 China's large-scale sequence point for carbon dioxide

Sealing point	Latitude	Longitude
Daqing Oilfield	46.62	125.02
Changqing Oilfield	36.35	107.16
Shengli Oilfield	37.47	118.5
Tarim Oilfield	41.79	85.98
Xinjiang Oilfield	45.61	84.85
Southwest oil and gas field	30.13	105.09

Yanchang oil mine	36.7	110
Liaohe Oilfield	40.85	122.22

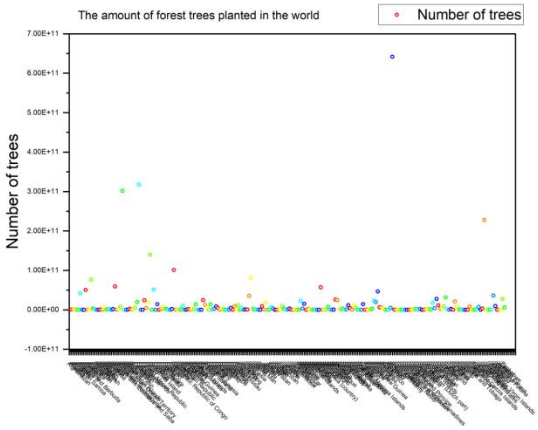

Figure 6 Number of trees planted in the world's forests.

In Fig.6, we can intuitively see the situation of tree planting in the world's forests. Therefore, studying the effects of tending measures of different thinning intensities on the growth, natural regeneration and understory vegetation diversity of plantations can help plantations to achieve scientific management, maintenance and restoration of the inherent functions of stand ecosystems, and to achieve stability, efficiency and sustainability.

4. Conclusion

In this paper, we investigate the algorithmic design of forest management plans. By combining the characteristics of carbon dioxide sequestration, a mathematical model with minimum cost as the objective function is established, and simulated annealing algorithm is used to solve the model. In addition, modeling of the entire carbon capture storage network was completed. On the basis of the research on the carbon sink capture and storage network system, all links from carbon dioxide capture to final storage are considered, which are mainly divided into three links: capture, transportation and storage, and a comprehensive carbon sink and storage system is established.

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