Problem Chosen	2022 MCM/ICM Summary Sheet	Team Control Number
E		2200292

To hew or not to hew, that is the Question

Summary

The severe climate change due to greenhouse gases, is posing a great threat to the global ecosystem and human lives. Forest and its products can effectively mitigate this situation. At the same time, many ways that the forest is valued are hard to balance, and this makes forest managers face a dilemma. To better understand and tackle these problems, this paper focuses on the carbon sequestration and other various ways that forests are valued, and determine different forest management plans based on characteristics about each forest.

Firstly, we devise a **CS model** to evaluate the carbon sequestration of a forest. CS model is based on collected data of annual deforestation and planting rate, annual carbon stock, product recovery rate, altitude and latitude. CS model outputs the **quantity of carbon that a forest can sequestrate over a period of time.**

Secondly, we use the CS model to generate **management plans**, such as controlling tree species and harvesting age for forests, in order to sequester more carbon dioxide. Straight after that, we apply our model to two famous forests, Amazon and Siberia, analyze their current situation and give suggestions.

Thirdly, we generate **FV model** to discuss the value of forest comprehensively by considering its four aspects, which are provisioning value, regulating value, cultural value and supporting value. The sum of these four values is the overall value of the forest.

Then, we obtain the management strategies derived from FV model for forest managers to balance various value of forest. Transition points of the value of forests are defined based on the altitude and latitude of forests.

Finally, we apply our FV model to the Central American Rainforest, and we conclude that the best plan is to divide **80** harvesting areas according to industrial needs and take turns to cut. In this process, optimal harvest rate is **0.5%**, and it will sequester **88.5 billion** tons carbon over 100 years. What's more, to maximize the overall value of the forest, protecting cultural heritage, including Mayan ruins and primitive tribes, is also necessary.

Keywords: Carbon Sequestration, Forest Value, Forest Management Plan

Contents

1 Introduction

1.1 Background

Since the 1970s, global carbon emissions and economic development have basically shown a positive correlation. As the climate issue has gradually become a global consensus, countries have taken measures to control carbon emissions, and the growth rate of carbon emissions has begun to slow down. Until 2019, the growth rate of global carbon emissions has been close to zero[1]. Although some achievements have been made in emission reduction actions, the global emission reduction problem still faces severe challenges under the influence of factors such as energy structure, natural resources and carbon sink capacity.

Intact forests are known to be important global carbon sinks, and these forests mitigate climate change by absorbing carbon from the atmosphere and storing it in trees, which is known as carbon sequestration. Climate models typically predict that this tropical forest carbon sink will remain for decades.

However, according to a study in Nature, we have discovered a worrisome situation: the world's pristine tropical forests have begun to transform from carbon sinks to carbon sources. The extra carbon dioxide boosts tree growth during a warmer climate, but this effect is gradually offset by the negative effects of heat and drought, which slow tree growth and cause tree death. As a result, the ability of forests to absorb carbon has declined by 33 percent over the decades, the area of intact forests has declined by 19 percent, and global carbon dioxide emissions have soared by 46 percent[2]. Climate impacts in the tropics are likely to be more severe than expected, and the international community will need to seriously prepare for the lingering impacts of climate change.

Therefore, all countries in the world need to immediately start to manage and utilize forest resources more scientifically. Trees are known to have the greatest carbon sequestration capacity during high-speed growth at the right age, so wise harvesting to make products and regenerating young forests may be more beneficial for carbon sequestration. In this process, we need to fully consider the climatic and topographical factors in different regions, as well as the biological characteristics, durability and recovery rate of different tree species and their industrial products, so as to provide strategy with the most suitable environmental, economic and cultural values for different forest managers.

1.2 Restatement of our work

Firstly, we propose the CS model, in which six indexes including duration, latitude, altitude, protection of water and soil, forest expansion and deforestation rate are used to estimate how much carbon a forest and its products can sequester over time. Specifically, based on collected data, we obtain the complete expression.

Secondly, we apply our CS model to forests and give management plans so as to maximize carbon sequestration. Some basic strategies like controlling tree species and harvesting age as well as the rationale of these strategies are discussed. Then we give out more analysis on two famous forest areas, including but not limited to the reasons that lead to the current situation and plans to make it a change.

Thirdly, according to the four parts of the value of a forest, which are provisioning value, regulating value, cultural value and supporting value, we integrate our FV model. Each of them shows the important function of forests.

Then, we generate management strategies to maximize the overall value, and discuss transition points.

Finally, we use our model to analyze a specific forest, the Central American Rainforest, make a plan and predict the future.

2 General Assumptions and Notation

2.1 General Assumptions

Carbon sequestration is a complex and interdisciplinary problem with international significance. Relevant questions involve subjects like politics, economics, culture, human biology, ecology, geology, and many others. It is impossible to model every possible circumstance. So, we made a couple of assumptions and simplifications, each of which is properly justified.

1. Some parts of forest resources were used for pulpwood and energy production, and we assume this kind of parts does not sequester any carbon, as they change into carbon dioxide in a very short time, that is, only long-lived wood products sequester carbon.
2. We ignore the differences between countries in the first model, such as the development level. But they are taken into consider in the second model.
3. We assume all the forests that are cut down are used for human production, and we do not take natural disasters that cause deforestation into account.
4. The current statistics on forests in various regions do not take into account the distribution of specific tree species, because none of the major databases have statistics on the proportion of specific tree species in large rainforests around the world. And afforestation with selected tree species is very small compared with natural forests, we can think that the distribution differences of natural tree species in different regions can be approximated by the latitude and altitude of the region.
5. Both the photosynthesis intensity and growth rate of trees are related to the amount of precipitation in the area where the forest is located, and we know that forests can prevent land desertification and soil erosion. Generally, the deforestation and growth of forests will affect the soil and water conservation rate in the region, especially for small and medium-sized forests in monsoon climates and inland

areas. Therefore, here we use soil and water conservation rate to describe the rainfall and humidity of the environment in which the forest entity is located.[3]

6. We assume that the data obtained are accurate and reliable. Table 1 shows where our data comes from.

Database Names	Database Websites
National Bureau of Statistics of China	https://www.stats.gov.cn/
FAO	http://www.fao.org/
United Nations Data Retrieval System	http://data.un.org/
Our World in Data	https://ourworldindata.org/

Table 1: Resources of our data

2.2 Notation

Symbol	Description
t	Duration
x_1	Latitude
x_2	Altitude
x_3	Soil and water conservation rate
x_4	Forest expansion rate
x_5	Forest deforestation rate
NI	Carbon Sequestered by forests mainly influenced by nature
AI	Carbon Sequestered by forests mainly influenced by human activities
MRT	Mean residence time
FS	Forest stock
ρ	Density of wood
r	Wood recycle rate
p	Percentage of long-live wood product
E	Overall carbon sequestration
E_1	Carbon sequestration of forests
E_2	Carbon sequestration of forest products
PV	Provisioning value
RV	Regulating value
CV	Cultural value
SV	Supporting value
OV	Overall value

Table 2: Notations

3 CS (Carbon Sequestration) Model

3.1 Carbon Sequestration of forest

We think that the geographical location of the forest, like latitude and altitude, will influence the ability of carbon sequestration of a forest. At the same time, some human activities, such as lumbering and planting forests, will also make a difference.

3.1.1 Natural influence

According to the Assumption 2, for the target carbon sequestered by forests mainly influenced by nature, based on latitude and altitude.

The different latitudes where the forest is located determines the intensity and time of light it receives each year, as well as the temperature of the growing environment. The lower the latitude, the greater the intensity of light and the longer the sunshine duration, and the stronger the photosynthesis and respiration of plants. [4]

Our model unifies the results of photosynthesis and respiration into carbon uptake and emission capacity, which scientifically demonstrates the effect of latitude and temperature on the carbon uptake efficiency of forests.

The complex topography brings vertical species diversity to the forest. The higher the altitude, the lower the temperature and the thinner the oxygen content, which affects the distribution of vegetation and the density of the forest, and further affects the carbon sequestration capacity of the forest in this area.

An exponential function is established to describe the impact. Therefore, the carbon NI can be expressed as

$$NI = k_1 \cdot e^{-k_2 x_1} + k_3 \cdot e^{-k_4 x_2}$$

The graph below shows the effect of latitude and altitude on forest carbon storage capacity in our model.

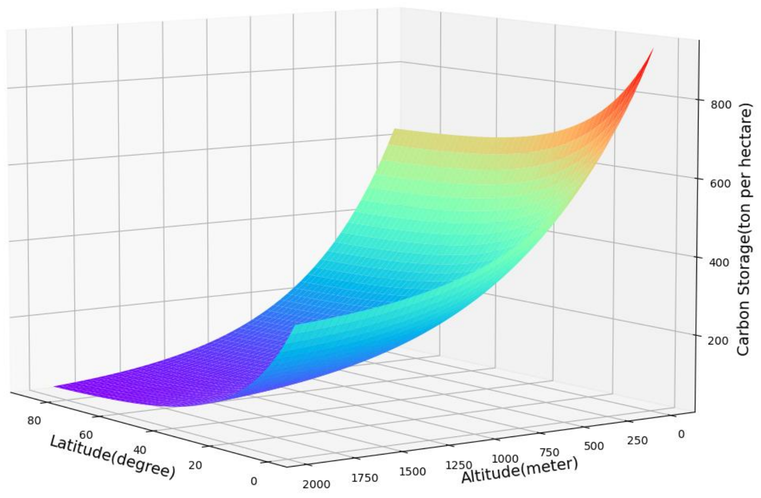


Figure 1: Effect of latitude and altitude on forest carbon storage capacity

3.1.2 Anthropogenic influence

Apart from natural factors, forest management strategies also influence carbon sequestration.

In our model, we consider the deforestation volume to be used to produce various wood products, including building materials, energy, furniture and paper.

A percentage of these products are durable products that can preserve carbon for a period of time.

For individual trees, cutting down mature trees and planting new ones can take advantage of the strong carbon storage capacity of the high-growth period. Cutting down trees converts the current tree's ability to absorb carbon into their product, and planting a new tree adds more rapid carbon uptake as it grows. For the entire forest, reasonable logging can balance the increase and loss of carbon absorption capacity.[5]

For real forests, the annual natural expansion and artificial planting only account for a small proportion. Obviously, the faster the forest area grows, the greater the increase in forest stock, and the greater the carbon absorption capacity.

The following figure shows the carbon sequestration corresponding to different cutting-down and planting rate.

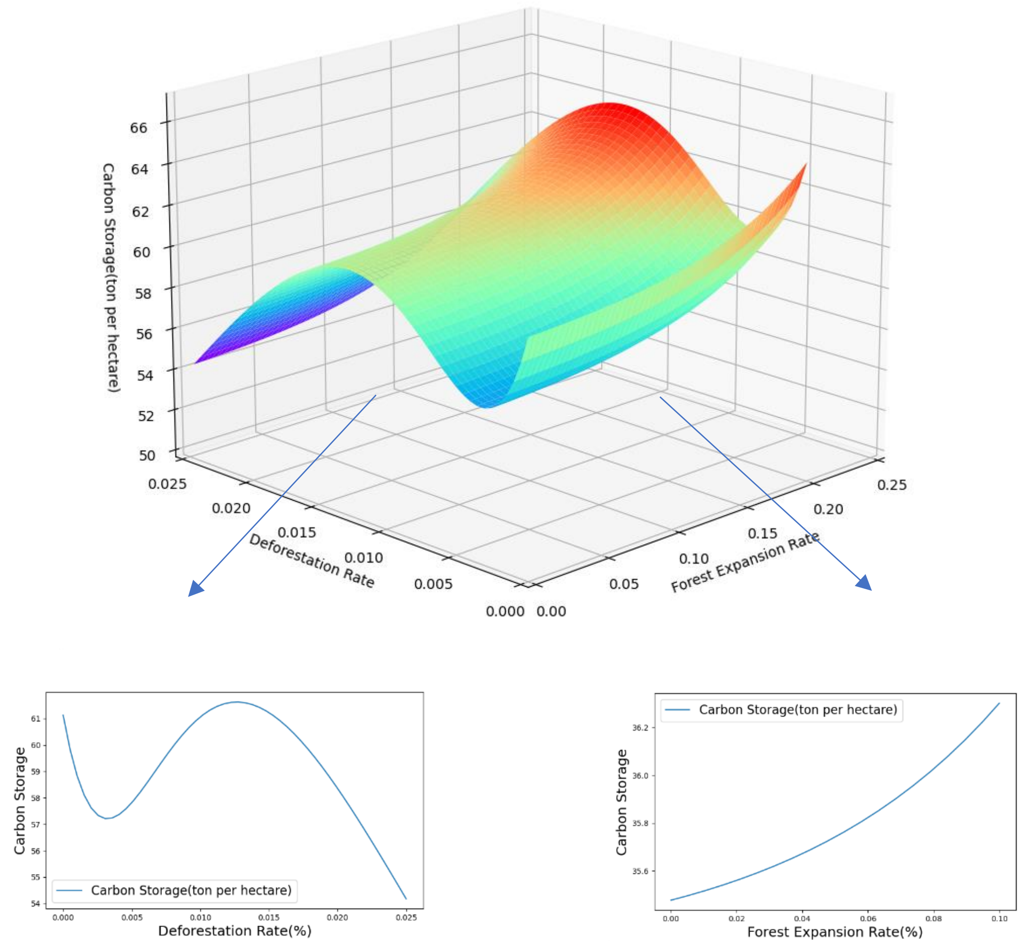


Figure 2: Carbon sequestration corresponding to different cutting-down and planting rate

Based on previous analysis, the equation below shows how carbon is affected by conservation of water and soil x_3, forest deforestation x_4, which is calculated by dividing the amount of forest cut down per year by total forest area, and forest deforestation x_5, generated by dividing the amount of forest planted per year by total forest area.

$$AI = k_5 \cdot e^{-k_6 x_3} + t \cdot (k_7 \cdot e^{-k_8 x_4} + k_9 \cdot e^{-k_{10} x_5})$$

3.1.3 Summative analysis

As we have discussed before, carbon sequestration of forests is mainly divided into two parts, that is NI and AI , which represent for carbon sequestered by forests mainly influenced by nature and human activities respectively.

So, the carbon sequestration of forests E_1 is expressed as

$$E_1 = NI + AI$$

3.2 Carbon Sequestration of forest products

3.2.1 MRT (Mean Residence Time) and Recycle Rate

Many developed and developing countries have realized that in order to combat the energy crisis and environmental pollution, waste recycling is of great importance. The United Nations also advocates and urges countries to pay attention to resource recycling, which has a positive impact on the future development of carbon sequestration.

The MRT is one of the two key parameters for estimates of carbon storage in dead tree biomass and wood products. In this study, the MRT of the wood product classes refers to the mean lifetime of the first products resulting from raw wood processing.

Our model argues that, since the quality of preserved carbon in long-term wood products is linear, improving MRT and recycling are both factors that directly affect the carbon absorption model.

The graph below shows the effect of our model in improving product recovery.

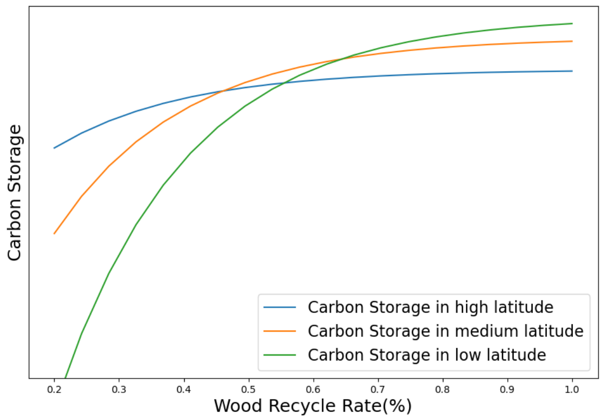


Figure 3: Effect of our model in improving product recovery

Wood furniture is one of the main uses of forests. Stevie Wilson says solid wood furniture lasts an average of 10 to 15 years before it starts to show signs of aging, such as fading or cracking. In fact, it can last for decades if properly maintained. [6]

In our study, we suppose long-lived forest products have a lifespan of 15 years, that is, MRT is 15 years.

Wood recycle rate varies from country to country, according to a website, the data of developed countries are mostly greater than 80%. In our CS model, we take 70% as wood recycle rate.[7]

3.2.2 FS (Forest Stock)

Forest stock refers to the total volume of various living trees existing in a given area of forest, and it is related to altitude and latitude, that is x_1 and x_2.

$$FS = k_{11} \cdot e^{-k_{12}x_1} + k_{13} \cdot e^{-k_{14}x_2}$$

After fitting the existing data of various countries, we get

$$k_{11} = 306.55$$

$$k_{12} = 0.053$$

$$k_{13} = 1245.17$$

$$k_{14} = 0.0052$$

3.2.3 Density and proportion of forest products

In our study, we assume $\rho = 0.5 \times 10^3\ kg/m^3$, which shows the density of wood.

About 40% of felled forests was actually processed to long-lived products . So, we take p = 40%.[8]

3.2.4 Summative analysis

$$E_2 = \frac{x_5 \cdot p \cdot FS \cdot \rho \cdot r}{MRT} \cdot t$$

where x_5 is forest deforestation index and E_2 is the carbon sequestration of forest products.

3.3 Combination of forest and its products

We have obtained the carbon sequestration of forest and its products respectively, then we define the overall carbon sequestration as below, which shows the ability of sequestering carbon dioxide.

$$E = E_1 + E_2$$

$$= NI + AI + \frac{x_5 \cdot p \cdot FS \cdot \rho \cdot r}{MRT} \cdot t$$

4 Implementation of CS Model

4.1 Basic strategies adopted for forests and their rationale

4.1.1 Controlling tree species and harvesting age

The carbon fixation activity of trees is mainly reflected in photosynthesis, which means it absorbs carbon dioxide from the air into the body, turns the carbon dioxide into organic matter and fixes it in the body. This shows that the faster the growth rate of trees, the faster the mass growth, and the stronger the carbon fixation capacity. A study in the image below visually shows that trees vary widely in their carbon uptake capacity at different growth stages:[9]

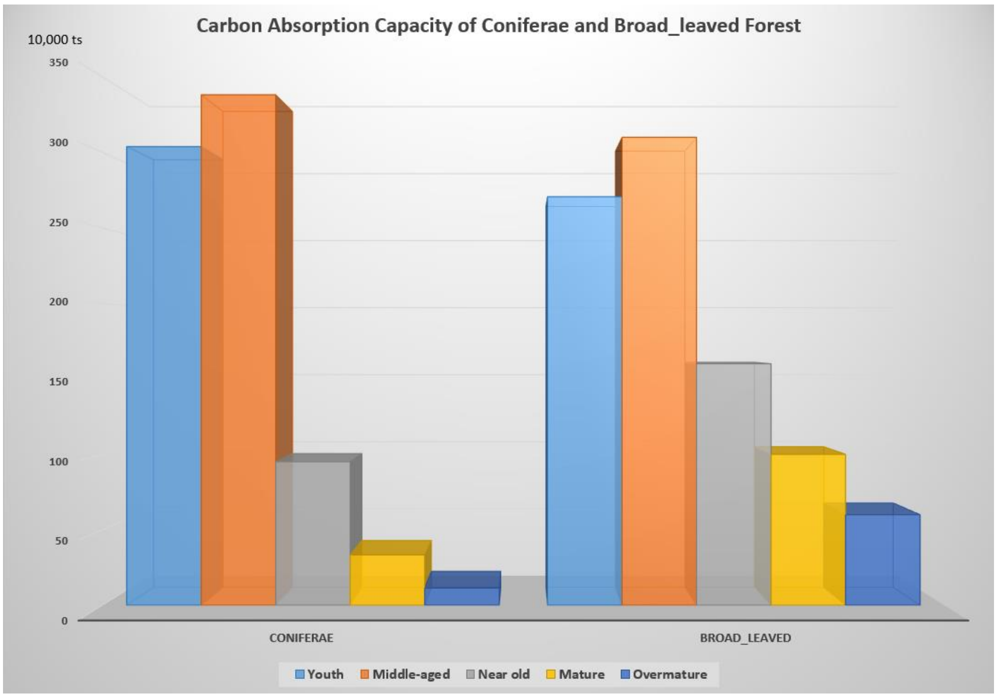


Figure 4: Carbon absorption capacity of two different tree species

The following table shows the age distribution of several common forest trees (where **Age_1** refers to **Youth, Age_2** refers to **Middle-aged, Age_3** refers to **Near Old** and **Age_4** covers **Mature** and **Overmature**):

Species	Age_1	Age_2	Age_3	Age_4	Optimal Felling Age
Cypress	<=40	41-60	61-80	>=81	81
Pinus Tabulaeformis	<=20	21-30	31-40	>=41	41
Larix	<=30	31-50	51-60	>=61	61
Spruce	<=60	61-100	101-120	>=121	121
Poplar	<=10	11-15	16-20	>=21	21

Table 3: Optimal felling age of some tree species

Based on the optimal harvesting age of the trees, we set the inverse as the annual limit of harvesting for a forest. It is impossible for human activities to deforestation of large rainforests to reach this value, but small rainforests in many areas should not exceed this limit. Otherwise, their forests would lose carbon-absorbing capacity significantly.

For plantation forests, urban green forests, and commercial forests, forest managers can adjust the proportion of different tree species, or introduce new species. However, for a natural forest with a larger total area, it is unrealistic to drastically change the distribution of tree species which is very costly.

4.1.2 Managing the amount of harvesting and planting

According to our model, controlling the amount of harvesting and planting of forests can increase the carbon sequestration efficiency of forests. Our Model1 assumes that forest managers have a lot of power to control deforestation and planting, regardless of cost.

According to global forest statistics, in today's developed wood product industry, the area of forest expansion and deforestation only accounts for a small part of the total forest area, as shown in the following figure:

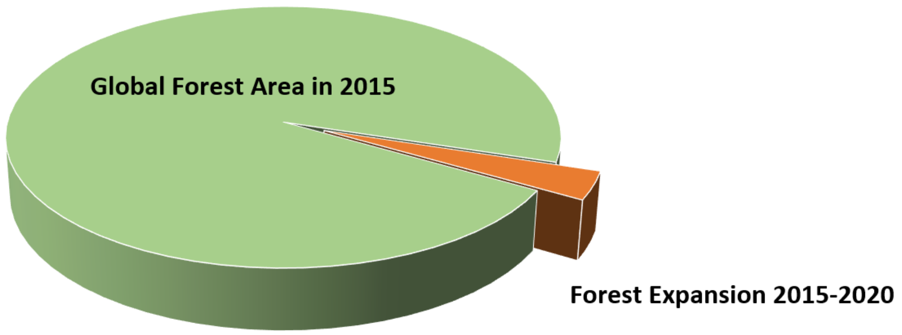


Figure 5: Area of forest expansion and deforestation from total forest area

This suggests that managers have a wide range of values to control the amount of deforestation, and we usually think that the planting and growth of forest areas is difficult.

But in reality, large-scale forest expansion is impossible.

On the one hand, the natural expansion rate of forests is limited. Big amount of the forest expansion requires a lot of cost, but the economic resources and land resources of most regions are limited. Urbanization and arable land are the main reasons for deforestation in tropical and Asian countries in the past few years. Most of the deforestation area has been converted to land for other uses, and there is only very little space for forest expansion.

In addition, this also shows that in the rainforest that has existed on the earth for tens of thousands of years, a large part of the trees has not been affected by human activities and natural damage. They have all grown to a very high age, which means they grow slowly and absorb carbon less efficiently.

Our model assumes that forest managers can not only control the amount of harvesting, but also allocate harvested areas according to our guidance. Preferentially selecting trees that are beyond the appropriate harvesting age for harvesting in the short term is highly efficient for carbon sequestration improvement.

4.1.3 Utilizing potential value of wood product recycling

People in most countries and regions have a large demand for wood products, including furniture, paper, and building materials. Many wood products are recyclable. However, different countries are affected by technology, and the recycling efficiency of products is not the same. For example, developed countries with better technology have a higher proportion of product recycling, while many developing countries cannot realize the recycling of wood resources well. The data in the graph below shows the recycling rate of wood waste in several typical countries:

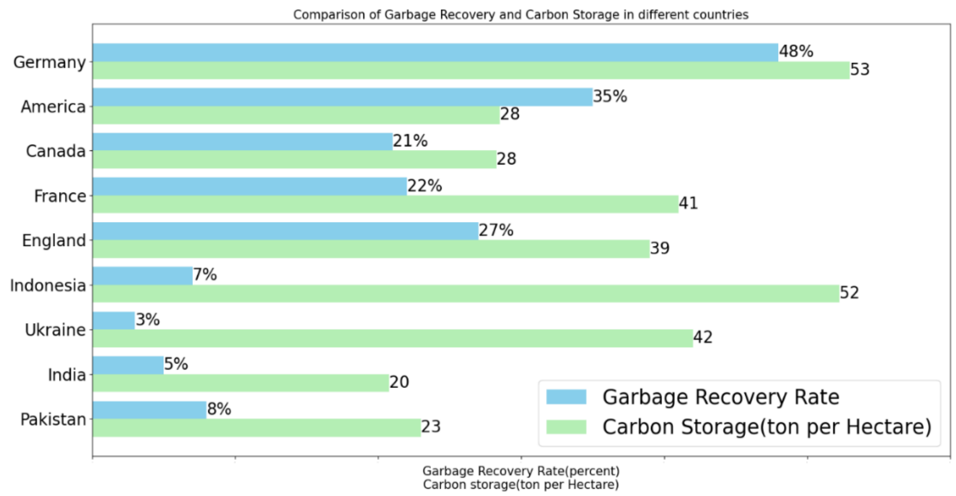


Figure 6: Recycling rate of wood waste in several typical countries

Obviously, in our CS model, we think it is feasible to increase the country's product recycling ratio, which can increase the additional carbon sequestration capacity in the product. In addition, measures such as promoting the use of clean energy, strengthening the recycling rate of paper products, and upgrading furniture technology to increase the durability will all play a role.

4.2 Model analysis on some famous forest area

4.2.1 Amazon Rain Forest: Lungs of the Earth

The Amazon rainforest is located in the Amazon Basin of South America, covering an area of 7 million square kilometers. It is symmetrical to the equator, distributed between 10 degrees north and south latitude, and the terrain is mainly plain.

Based on our model we concluded that the Amazon rainforest is now in a state of over-harvesting. If the managers of the Amazon rainforest can do the following three things, it will greatly ease its transition from carbon sink to carbon source:

a) Reduce forest harvest to **10%** per year.
b) Timely afforestation and replenishment after harvesting, and try to increase the amount of additional afforestation
c) Reasonable planning for felling, and selection of suitable and over-aged trees for felling

In addition, the Amazon rainforest contains the most abundant and diverse biological resources in the world. Some experts estimate that there are more than 75,000 species of trees and 150,000 species of higher plants per square kilometer, including 90,000 tons of plant biomass. Currently, approximately 438,000 species of plants of economic and social interest are found in the Amazon rainforest, with many more yet to be discovered and classified. However, irregular deforestation destroys the original ecology. In Brazil alone, more than 90 indigenous tribes were destroyed by colonialists in the 1900s, and centuries of accumulated knowledge of the medical value of rainforest species was lost. Native tribes continue to disappear as the territory continues to be deforested and ecologically extinct. In the future development of the Amazon rainforest, we should pay attention to protecting biodiversity and culture.

4.2.2 Siberia: Boreal Forest

The West Siberian Plain is the largest plain in Asia and the third largest in the world. It is 2,000 kilometers long from north to south, 1,500 kilometers wide from east to west, and covers an area of 2.6 million square kilometers.

The southern part is 220 to 300 meters above sea level, and the middle and northern parts are 50 to 150 meters above sea level. Although this land has an extremely cold climate, it is mostly covered by subarctic coniferous forests.

This forest is rich in pine coniferous trees, but due to the vast area and sparse population and low production efficiency, the proportion of annual deforestation and planting is particularly low.

Due to low temperature, little sunlight, and difficult development, it is very difficult for boreal forests to improve their carbon storage capacity. Newly planted trees will also grow slower here. Thus, while our model can provide idealized strategies, maintaining the status quo is one of the few options for Siberian forests.

5 FV (Forest Value) Model

When we aim at discussing the value of forests comprehensively, we often do so by looking at overall aspects. According to Millennium Ecosystem Assessment of the United Nations, four indicators are concluded, that is provisioning, regulating, cultural and supporting, which can represent the value accurately.[10]

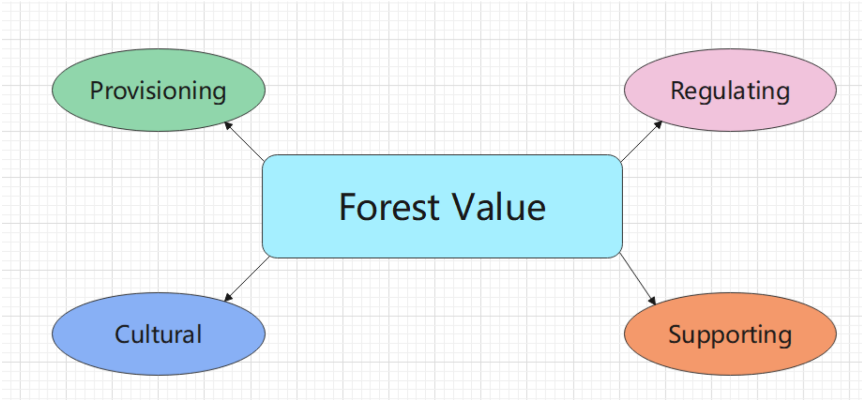


Figure 7: Brief description of FV Model

5.1 Provisioning value

Provisioning value refers to the direct demand of human beings for various products derived from forest ecosystems, such as wood, food, fuel, fiber, drinking water, and biological genetic resources.

5.1.1 Correlation with latitude and altitude

It is common knowledge that as latitude and altitude rise, biodiversity decreases, and the direct supply of the forest goes down simultaneously.

Section 3 provides us with a model of carbon uptake based on multiple factors. We can apply this model to each area and calculate the amount of deforestation that is best for that area. The following picture shows us the distribution of the major forests on earth:

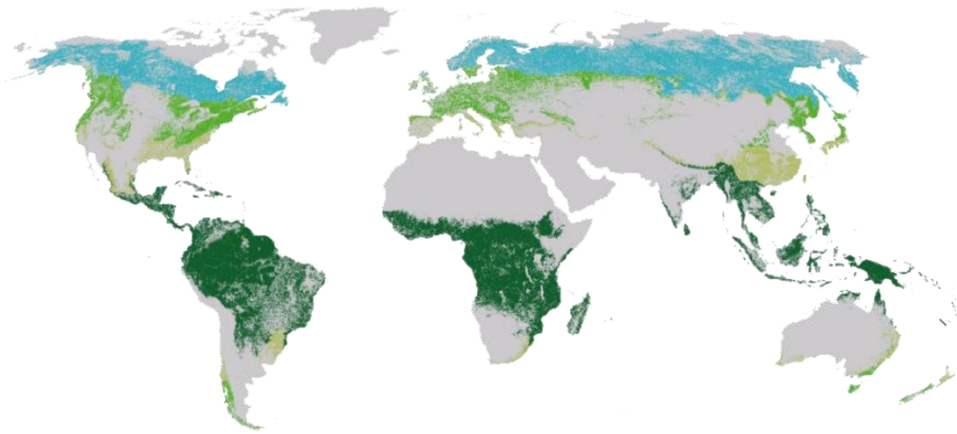


Figure 8: Forest distribution at different latitude[10]

Our mathematical model fits perfectly with the actual geographic knowledge. In low latitudes and low altitudes, the photosynthesis of forests is strong, and newly planted trees grow rapidly. This means that higher deforestation rates have a larger contribution in our carbon sequestration model. The difference is that in cold, anoxic regions at high latitudes and high altitudes, the growth rate of new plants is slower and the forest area is smaller than in lower latitudes. Taking these factors into account, our model has strong generalizability in any geographic location.

5.1.2 Correlation with deforestation

With the increase of logging, more and more forest resources are developed and used by human beings, and the amount of deforestation is positively correlated with provisioning value.

Over the past few decades, economic interests have been the main driver of human deforestation and development. Deforested forests are primarily used for industrial production, including industrial roundwood, paper, fuel, durable products, and many other uses.

From the Industrial Revolution to the present, the world's population and economy have been in a period of rapid growth for a long time. In this process, resource consumption and product demand, especially forest resources and wood products, have been increasing. However, in 2022, most countries and regions have slowed down in economic field. Their populations have stabilized, and industrial demand has stopped growing rapidly. [12]The chart below shows us the trends in the production of wood products in some countries.

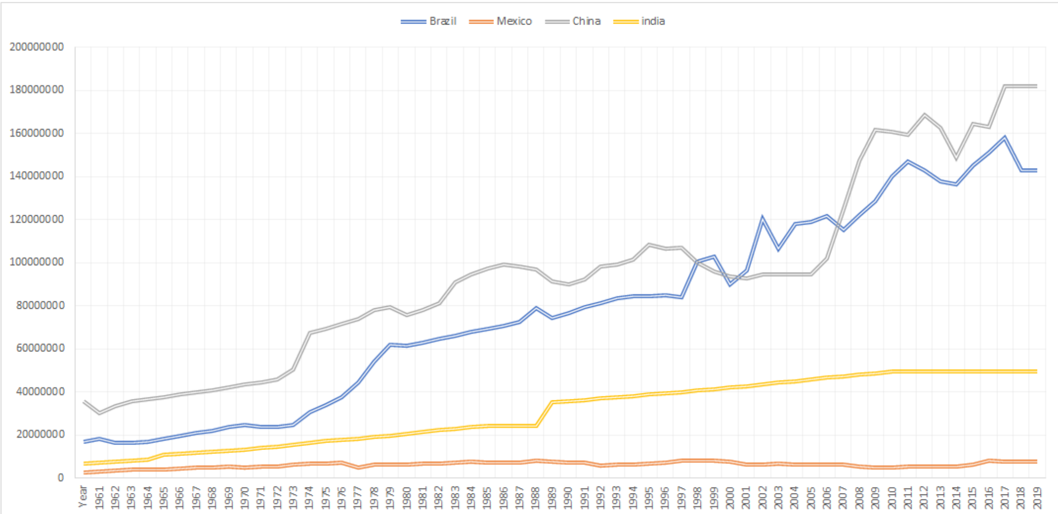


Figure 9: Production of wooden products in several typical countries

Different countries have different characteristics in industrial production, but we can assume that the demand for forest resources in most countries is consistent with our model, which means that their demand has started to level off.

Our model believes that the demand for forest resources for industrial production directly determines the basic amount of felling, which will be calculated from the growth curve of wood product production in each country. A smaller amount of felling will directly cost economic benefits. Higher deforestation, which can be used for product export, also brings economic benefits and may provide a larger contribution in the carbon sequestration model.

5.1.3 Expression of provisioning value

Based on the above analysis, we use the exponential form to obtain the following expression.

$$PV = (k_{15}e^{-k_{16}x_1} + k_{17}e^{-k_{18}x_2}) * e^{k_{19}x_5}$$

5.2 Regulating value

Regulating value refers to the benefits obtained by human beings through the natural growth and regulation of forest ecosystems, such as maintaining air quality, rainfall regulation, erosion control, natural disaster buffer and other functions to support social and economic development.

Our index protection of soil and water accurately reflect this aspect.

$$RV = k_{20}e^{-k_{21}x_3}$$

5.3 Cultural value

Cultural value refers to the non-material service benefits such as physical recovery and spiritual sublimation of human beings from the ecosystem through enriching people's spiritual life, cognitive development, brain thinking, ecological education, recreation, recreation, aesthetic appreciation and landscape beautification.

We believe that the more we invest in forests, the more we plant trees, the less we cut down trees, forests will bring us more non-material spiritual values.

Cultural value can be expressed as:

$$CV = k_{22}e^{k_{23}x_3}(1 - \frac{1}{e^{x_4}})(1 - x_5)$$

5.4 Supporting value

Supporting value refers to the basic functions of forest ecosystem production and supporting other service functions.

Some developing countries with large populations, such as Brazil, China, etc., deforest and convert them into arable land. This provides economic benefits for the local area. But in the long run, the loss of forest resources is serious, which also leads to soil erosion and land desertification in some areas.

In the previous model, we have discussed the ability of sequestering carbon, and it is one of the aspects of supporting value.

As we have considered comprehensively and there is a close relationship between carbon sequestration and supporting value, we use carbon sequestration to represent supporting value. The formula below can calculate the supporting value of a forest and its products within a certain period of time.

$$SV = NI + AI + \frac{x_5 \cdot p \cdot FS \cdot \rho \cdot r}{MRT} \cdot t$$

5.5 Overall value

The sum of these four values that we have mentioned before is the overall value of the forest, shown as:

$$OV = PV + RV + CV + SV$$

6 Implements of the Forest Value Model

In order to solve real-world forest management problems in combination with the actual situation, our model comprehensively considers various factors, including the economic benefits of forests to the region, the positive impact on carbon sequestration models, and the support of forest protection for biodiversity and soil and water conservation. In addition, many ancient primitive rainforests are inhabited by primitive tribes. With the large-scale forest development in recent years, many tribes have disappeared, which undoubtedly caused their rainforest culture to disappear with it. Our FV model will comprehensively consider these factors to provide global rainforest managers with universal strategies and solutions to maximize the benefits of forests.

6.1 Management strategies for all forests

Our model takes into account multiple factors that affect forest benefits, including the latitude, altitude, wood product MRT and recycling efficiency of the forest's location, which influences the forest's carbon sequestration model, and the demand for forest resources in the country where the forest is located which brings important economic benefits. In addition, when applied to specific forests, we also provide management strategies that combine factors such as biodiversity, soil and water conservation, and local culture.

In our management strategy, we are able to control the proportion of deforestation within a certain range, and plant the same number of trees at the same time. For other factors, we believe the MRT and recycling rates of wood products are beyond our control. At the same time, we use the form of initiatives and suggestions to enhance cultural values.

6.1.1 Harvest Increase Strategy

In general, we believe that increased harvesting of wood is mostly used for industrial production, which means that increased harvesting increases the volume of products from the forest. This is generally considered positive for economic models. Meanwhile, according to our CS Model, we believe that moderate deforestation is beneficial for carbon sequestration, but excessive deforestation obviously reduces the carbon sequestration capacity of forests.

Based on the above discussion, we believe that any forest has its transition point in our FV Model which is based on its characteristic and location. For the forests whose actual harvest rate is smaller than this value, we should offer them a harvest increase strategy in order to maximize its forest value.

6.1.2 Harvest Reduction Strategy

In general, we believe that reduced harvesting of wood leads to an economical loss directly. This is generally considered negative for our economic models. Obviously, there must be some rainforest being over-cleared right now, which is harmful for their carbon absorption capacity. Although reducing deforestation reduces economic benefits, sometimes we have to sacrifice some money for greater value.

For the forests whose actual harvest rate is larger than its transition point, we should offer them a harvest reduction strategy in order to maximize its forest value.

6.1.3 Utilize the optimal harvesting interval

In Section 4.1, we explained that trees have greater carbon uptake capacity during growth and how to calculate the optimal harvesting age for tree species. Therefore, for a large area of rainforest, we should make full use of its optimal harvesting interval. For example, for forests whose optimal harvesting age is 10, the forest manager should divide ten harvesting areas. For the next decade, forest managers select an area each year to clear and replant in it. This creates a sustainable forest cycle that maximizes its carbon sequestration capacity over its cycle.

However, small-scale rainforests may not be able to apply this strategy, especially when it needs to output a lot of wooden products. But our Forest Value Model can still give the optimal felling strategy based on this.

6.2 How to figure out the transition point

For any specific location, our FV model can provide us with an associated function. We can discretely calculate the optimal value of our FV model for each exact latitude and elevation. We use this value as the transition point for a specific forest

The figure below shows the optimal deforestation ratio for forests at any altitude and latitude to achieve the best value in our FV model.

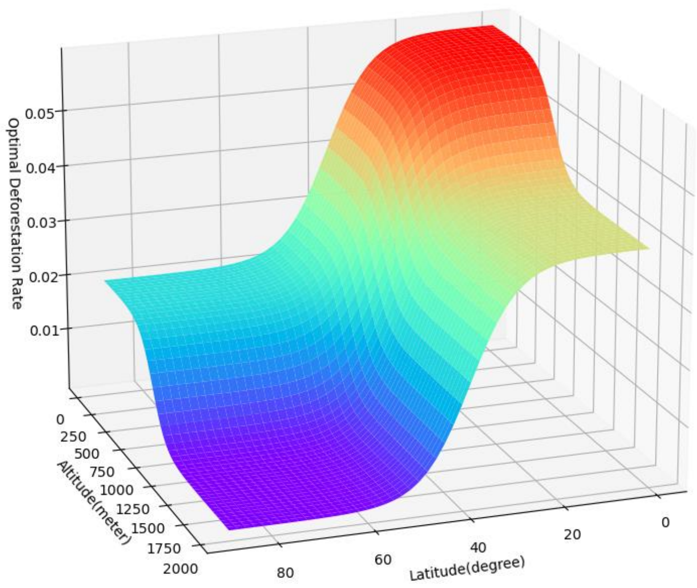


Figure 10: Optimal deforestation ratio for forests at any altitude and latitude to achieve the best value in our FV model

We use these transition points as key references to provide strategies. The strategy we provide for a particular forest is mainly to approach its transition point.

6.3 Application for actual forest comprehensive value

We take the Central American Rainforest as an example and use our Forest Value Model to provide a management plan for local forest managers.

6.3.1 Optimal Harvesting Interval of the Central American Rainforest

The graph below shows the tree species composition of the Central American rainforest.[13]

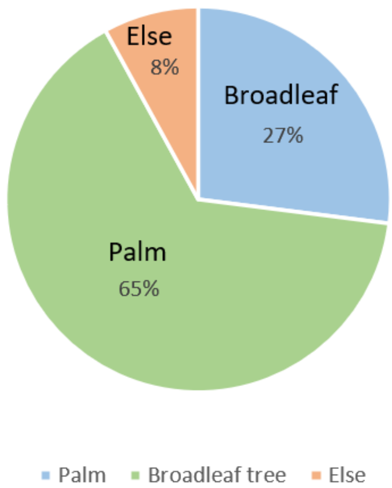


Figure 11: Tree species composition of the Central American rainforest

According to the data, the optimal felling age for tropical hardwood trees is 81 years, while palm species is 25 years.

Due to the size of the Central American rainforests, we recommend that forest managers use 81 years as the optimal logging age. We should divide 80 harvesting areas according to industrial needs. Each harvested area can supply the needs of the surrounding countries for a year.

6.3.2 Optimal harvest rates and calculation of future carbon stocks

Based on our Forest Value Model, we derived the optimal harvest rate for the Central American rainforest, which is **0.5%** of the whole forest.

Let's assume that forest managers take our strategy. Over the next hundred years, if forest managers keep optimal harvesting rates, this tropical rainforest will store 106 tons more per hectare than it does today, which is **88.5 billion tons** in total.

6.2.3 Biodiversity Value of the Central American Rainforest

Similar to the Amazon rainforest, the Mesoamerican rainforest is rich in biological resources. This rainforest has many rare species not found in the Amazon rainforest. In the process of scientific development, we recommend forest managers to preserve the original ecological environment as much as possible.

It is estimated that in addition to the planned 80 harvesting areas, 60% of the rainforest in Central America will remain. Forest managers should leave this part of the rainforest untouched. This protects the living environment of local organisms, in order to maintain biodiversity.

6.2.4 Cultural Value of Maya the Ancient

The Mayan civilization that shocked the world is located in this tropical rainforest. However, in the previous development of the rainforest, the protection of cultural heritage has been neglected. Destructive activities, including tomb robbery and oil exploration, have caused great damage to the Mayan ruins. We believe that the government should establish relevant laws to protect such cultural heritage.

There are still many primitive tribes and cannibals living in this tropical rainforest, who may even be descendants of the Maya. The exploitation of modern people is taking away their territory and is bringing them into modern society. We think they have the right to choose either way to live, and we shouldn't let their original culture disappear completely.

6.2.5 Summary of Strategy for the Central American Rainforest

- We should take **80 years** as the optimal cutting interval, and divide **80** areas into rotation for wood harvesting.

- We should take **0.5%** as the optimal harvesting rate per year.
- We should protect the species diversity of the remaining area.
- We should protect cultural heritage including Mayan ruins and primitive tribes during development.

7 Strengths, Weaknesses and Sensitive Analysis

7.1 Strengths

1) According to the distribution of various forests in the world, as well as the geographical and environmental conditions, we have selected various indicators that may affect carbon sequestration as comprehensively as possible, including environmental aspects, forest management aspects of planting, deforestation, and so on. In the process, all the indicators selected have different degrees of consideration. The comprehensiveness of the model is relatively good.
2) The applicability of the model is pretty good. We set some indicators for the established model to a definite value, that is to say, considering a specific geographic location, we use the model to find the most suitable forest management strategy for this place. We found that there are differences in management strategies in different regions, such as tropical rain forests in low latitudes and boreal forests in high latitudes, the model can output different management strategies accordingly. It can be seen that our model can better meet the specific local conditions and is universal.
3) The model is highly innovative. Most of the metrics are original and reflect team performance in a unique way.

7.2 Weaknesses

1) We do not consider the distribution of specific tree species in the statistical data of forests in various regions, because major databases do not count the proportion of specific tree species in large rainforests in the world. We assume that the distribution law of tree species has a lot to do with geographical location, and the indicators representing geographical location have been given in the previous section, however, if more accurate data on the distribution of tree species are obtained, the correctness of the model will be further improved.
2) Since there is no accurate data for the distribution of specific tree species, this is also an aspect that we have not taken into account, so that the granularity of the forest management strategy output by our results cannot be accurate to the planning of specific tree species. If a more accurate data set is obtained, we can optimize the model to add fine-grained considerations.
3) This model is based on the normal development of economy and ecology, and performs fitting and analysis within a certain range. It does not consider factors

that affect the degree of damage, such as large-scale wildfires, large-scale biological extinction, etc. Because such impacts are short-lived, and short-term changes are difficult to predict with a model suitable for long-term development, also because our model focuses on forest management rather than contingency strategies.

8 Conclusion

The construction and analysis of our model led to the several major conclusions.

We have established a mathematical model that integrates social, economic, environmental and other factors to evaluate and predict the carbon sequestration capacity and the economic benefits of forests, and use the model to find different management strategies suitable for different forests.

Our research survey found that some forests have reached saturation for carbon sequestration for a number of reasons, and their capacity to sequester carbon is declining.

In recent years, the increase in temperature caused by the greenhouse effect has exacerbated the drought in some areas, especially near the equator, and large areas of tropical rain forests in these areas have been greatly affected. [14]This weakens the intensity of photosynthesis in the rainforest, reducing carbon fixation capacity, and studies have shown that the eastern Amazon rainforest has been transformed into a source that emits more carbon than it absorbs, raising alarm bells for scientists.

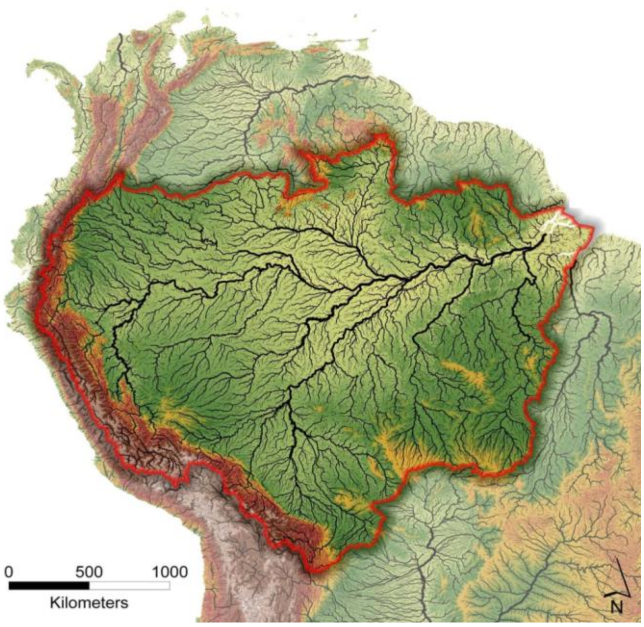
Our final conclusion is that when formulating forest management strategies, various factors such as geographical location, environmental climate, and economic and social conditions should be considered. Different factors lead to different optimal strategies for forest management. Indicators, appropriate deforestation can increase carbon sequestration and also improve the economic benefits of the region.

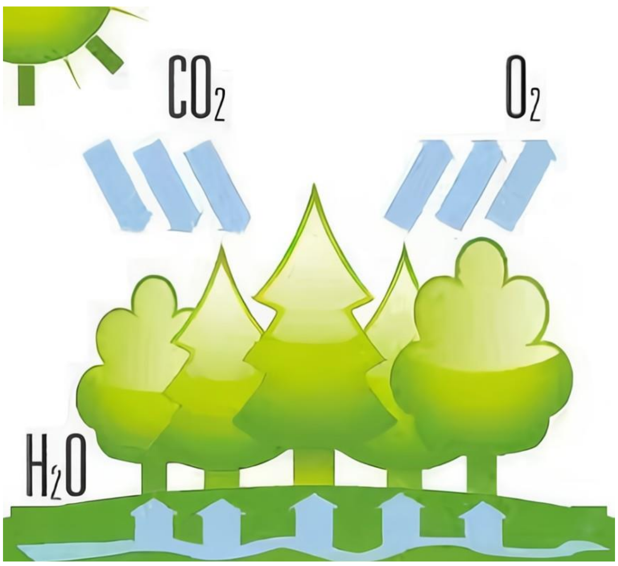
How To Manage Your Forest

WARNING:

Forests may turn into **CARBON SINKS**

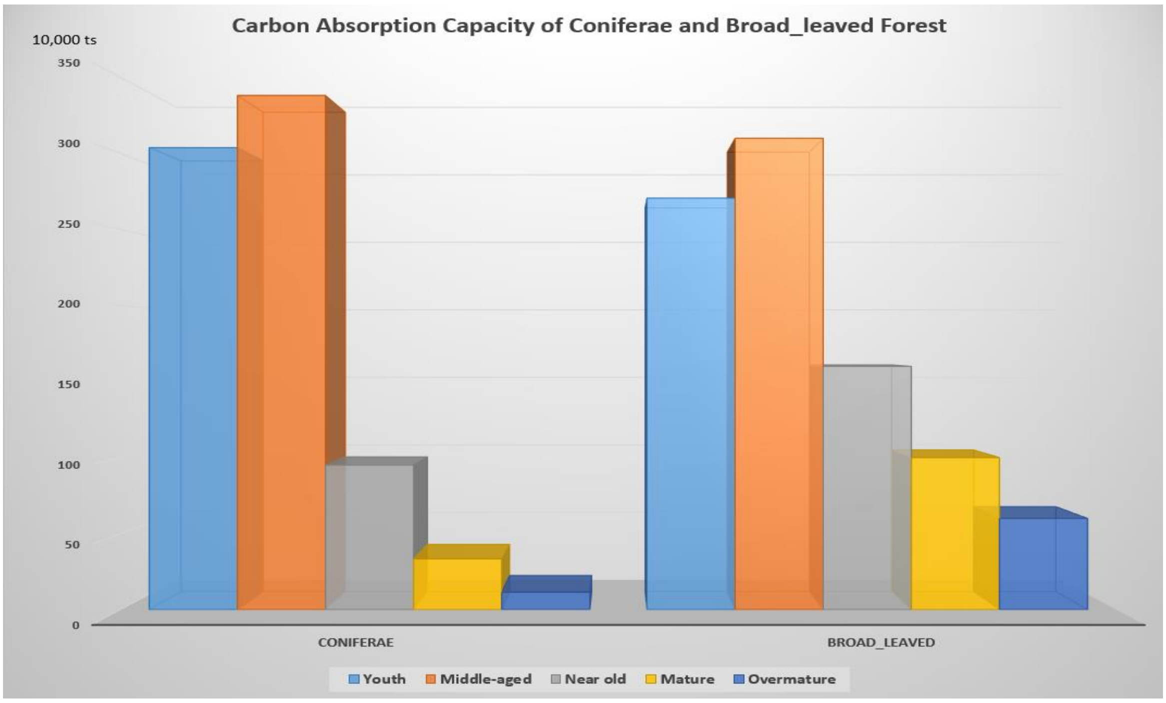
Over the past 20 years, the entire Amazon biome -- spanning Bolivia, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, and Venezuela -- has been a net "carbon sink" that has consume about 1.7 billion tons of carbon dioxide emissions. However, the part of the Amazon in Brazil emits 3.6 billion tons of carbon dioxide, more than it absorbs. The findings come from a study published on August 25 by the Monitoring of the Andean Amazon Project (MAAP), an initiative of the US non-profit organization Amazonas Conservation Society. Carbon dioxide emissions from the Brazilian Amazon rainforest, on an annual basis, are roughly three times the annual emissions from New York City, according to calculations by tracking website Carbon Visuals. Let's take a look at why parts of the Amazon are turning from carbon sources to carbon sinks.





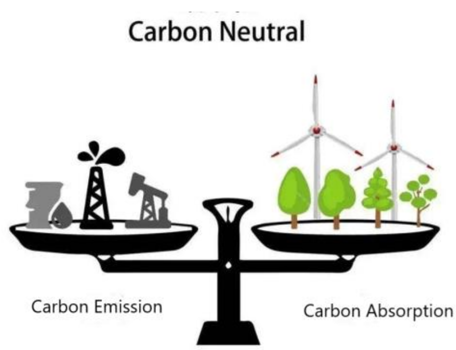
We all know that the photosynthesis of plants uses carbon dioxide as raw material to generate organic matter and provide their own growth and development. Such biological behaviors gather carbon in the atmosphere, making forests an important part of carbon sinks. There is a huge difference in the contribution capacity of carbon sequestration. The data show that the carbon sequestration capacity of growing trees is significantly higher than that of mature and over-mature trees, because during this period, plants need to perform more photosynthesis to generate and provide their own development. The organic matter of the mature or over-mature tree is far less than that of the growing tree, the intensity of photosynthesis is lower, and the carbon sink is also worse.

This table shows the difference in carbon absorption capacity of trees of different ages.



The evolution and development of the population is not a linear and unidirectional conceptual model, but a cyclic, long-term and dynamic process. In this cycle, there are inputs and outputs, gains and losses. For a forest, its Timber production can be regarded as its income, water and soil loss, abnormal tree death and other aspects can be regarded as its losses. The impact of its population, we hope to achieve a balance, this balance will not affect the normal cycle of its population, using its output to maximize the benefits, you may ask, how to make the tree population achieve an optimal carbon sink effect, yes, this is the problem we are studying. Our research shows that a certain degree of increase in deforestation has a positive effect on carbon sequestration. It can be understood that the capacity of the ecosystem is limited, and the age structure of trees If not updated in time, it will squeeze the living space of new trees and affect their normal growth and development. Therefore, we need to manually intervene in the tree age structure of the forest, reduce the proportion of mature and over-mature trees, and increase the proportion of young trees. The situation considered is not limited to ecological aspects, we start from economic, social, ecological and other aspects, comprehensively consider how to determine the best forest management strategy, appropriately increase deforestation, and output more to the production and life of human society, promoting economic and social development.

Forest managers should be aware of such problems and manage forests in real time according to conditions. Deforestation is not to destroy, but to optimize the ecology itself. This management mode is a catalyst for promoting ecological cycles and economic benefits, which not only optimizes. The population structure of forests takes into account the production and living needs of human beings to the greatest extent, so that the economy, society, and ecology are in a benign development trend and realize sustainable development in the true sense, which not only protects the earth on



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