Optimizing Forest Harvest Cycles For Carbon Sequestration

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Objectives

For this modeling competition, our group was tasked with creating a carbon sequestration model to determine how much carbon dioxide a forest and its products can be expected to sequester over time and determines a forest management plan that is most effective at sequestering carbon dioxide. Our model aims to complete the following goals

- Develop a carbon sequestration model to find optimal harvest times for different types of forests
- Create a management plan that balances the various aspect of a forest (CERB Score)
- Identify a forest and apply the carbon sequestration model for a 100 year time span

Introduction to Carbon Sequestration Model

We can model the amount of carbon a tree holds through it's life as an sinusoidal function, taking into account previous iterations of harvest cycles. As a tree grows, the amount of carbon that it can hold increases, then hits a maximum amount, after which it decays

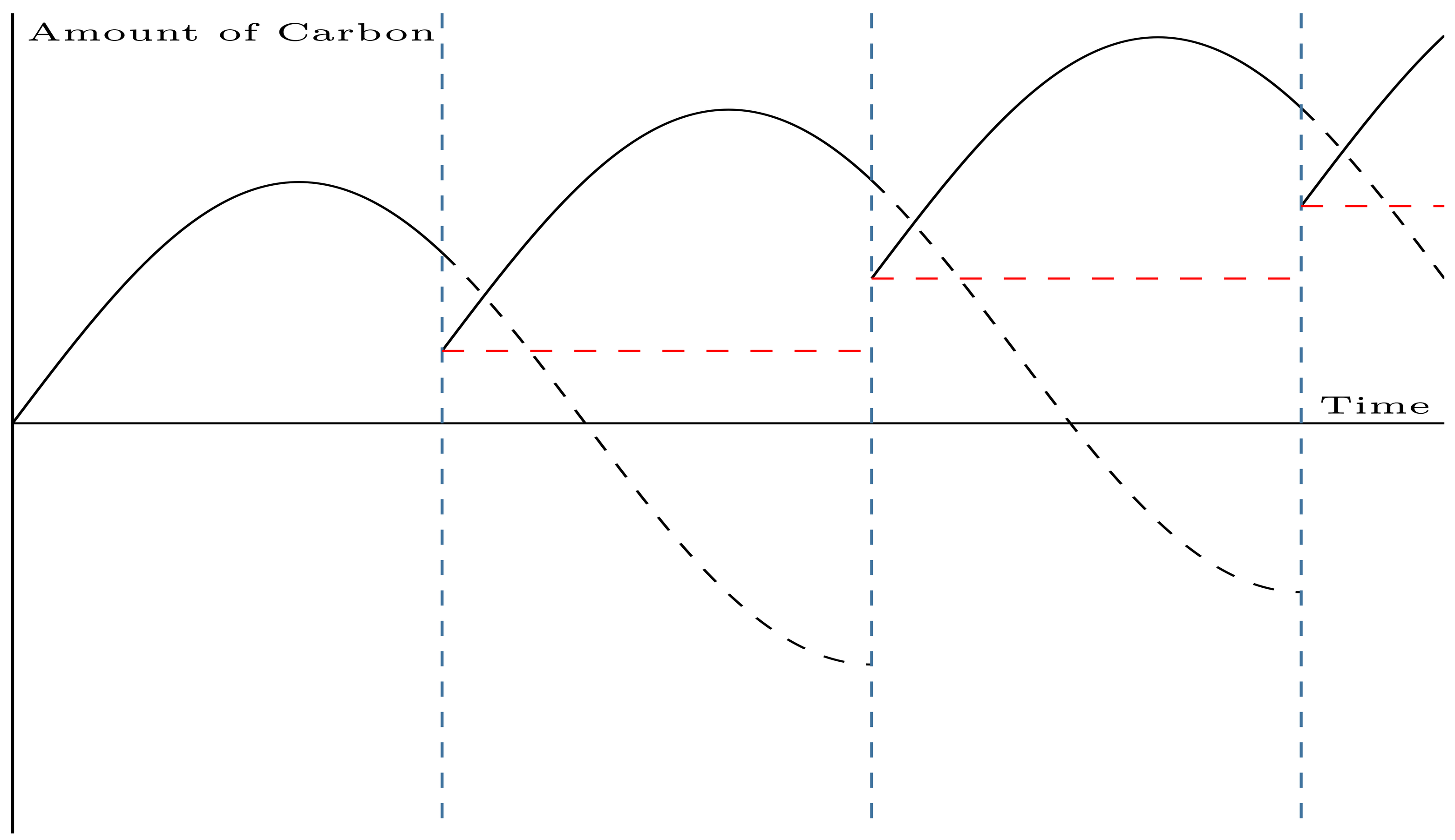

Figure 1. Carbon Sequestration Model plotted graphically

In order to incorporate the different types of forests in the world, we built three separate models: Boreal, Temperate, and Tropical

CERB Model

Four primary ways in which a forest is valued, all evaluated in U.S. dollars

- C = Value of Carbon Storage Capacity
- E = Economic Value of Forest Products
- R = Value of Recreation
- B = Value of Biodiversity

CERB Score = C + E + R + B

Value of carbon and economy are based on the forest carbon storage and the value of products from forest, respectively. Value of recreation and biodiversity were found with hedonic pricing system

Carbon Sequestration Model

Model incorporates tree density, forestry carbon rate, and lifespan, as while as accounts for the harvesting cycles for each forest

$$C = A\sigma_\alpha F_\alpha \int_{t_1}^{t_\alpha} \sin(t_\alpha - t)\,dt + \sum_{i=1}^{n} a \cdot C_{n-1}$$

where

- A is the area the forest (km^2)
- σ_α is the tree density of the forest ($trees/km^2$)
- F_α is amount of carbon sequestered per tree per year ($\frac{kg}{trees \cdot years}$)
- t_α is the lifespan of the tree ($years$)
- a is the percentage of carbon sequestered in previous cycle (30% for this model).

Results of Model

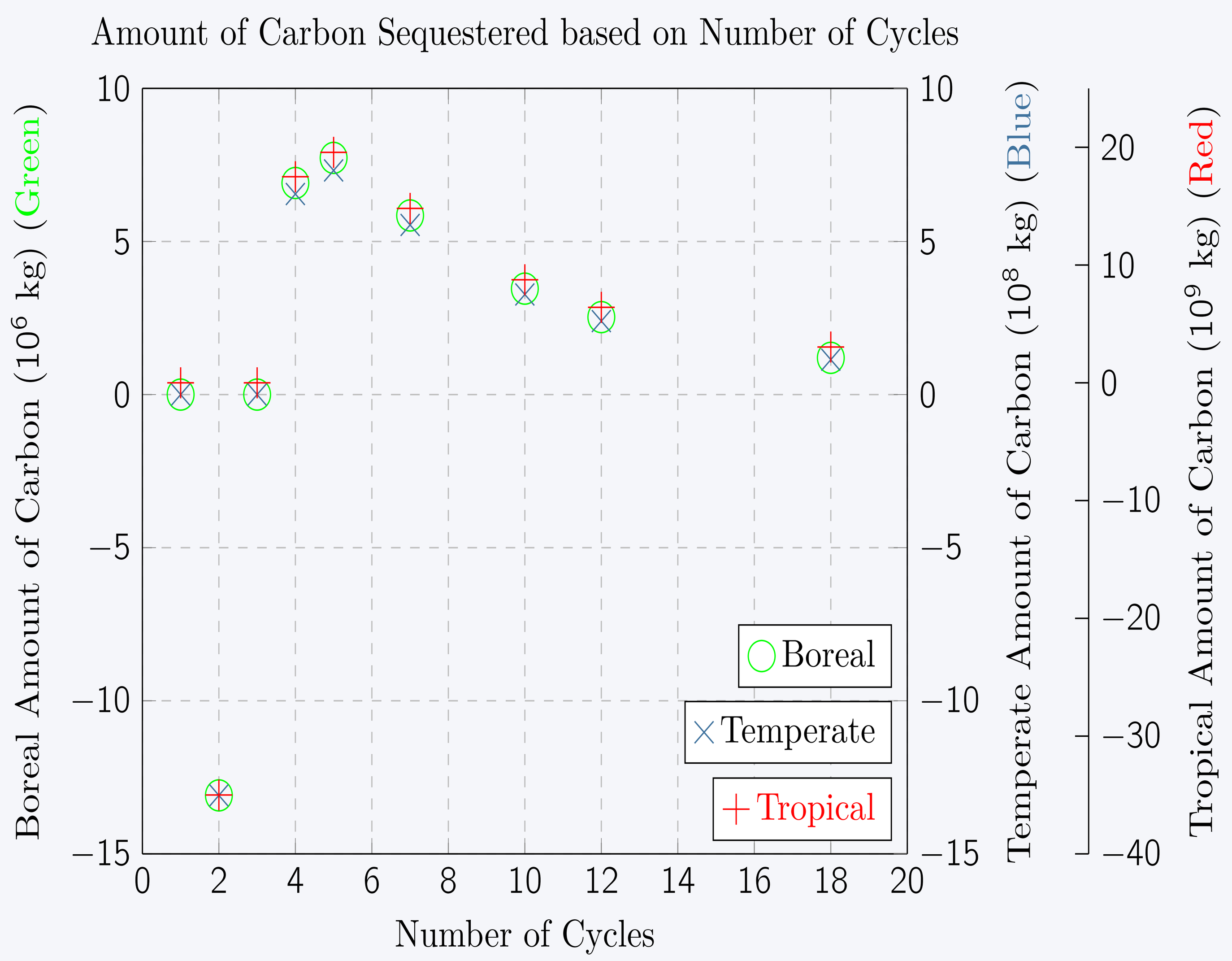

Figure 2. Amount of carbon sequestered for various cycles for boreal, temperate, and tropical forests

Analysis of Carbon Sequestration Model

All three types of forest have similar behavior, initially releasing more carbon when decomposing then reaching an maximum, before hitting a horizontal asymptote. This behavior is analogous to blackbody radiation if we disregard the first few points

$$C \propto \frac{t^3}{e^t + 1},\ 3 < t < \infty$$

Conclusion: To maximize the amount of carbon sequestered, harvest every 20 years for a 100 year time span

Management Plan based on CERB Score

To evaluate CERB scores, examine if conservation is greater market value

- C and E are value of cutting trees
- R and B are value of forest left in situ

Value Bias	Condition	Decision
C + E > R + B	C > E	Cut based on sequestration
C + E > R + B	C < E	Cut based on economic profits
C + E < R + B	R > B	Manage for recreation
C + E < R + B	R < B	Manage for biodiversity
C + E = R + B	N/A	No action taken

Table 1. Decision Plan Table

Management plan depends on type of forest and forest values, making CERB indexes differ on type of forest, which leads to the following conjecture

Maximize one of the forest's value

Application to Local Forest

Model was applied to Willamette National Forest, which gives the following CERB values over an 100 year time span

$$C = \$171,854,000,000$$

$$E = \$60,800,000,000$$

$$R = \$870,000,000$$

$$B = \$350,000,000$$

We can see that $C + E > R + B$ and $C > E$

$$C + E \Rightarrow \$171,854,000,000 + \$60,800,000,000$$
$$= \$232,654,000,000$$

$$R + B \Rightarrow \$870,000,000 + \$350,000,000$$
$$= \$1,220,000,000$$

Decision: Manage forest with regards to harvest times

Management Plan based on Application

Based on decision table, the management plan should be

- Manage forest with regards to harvesting every 20 years
- Since $C > E$, optimize based on sequestration profits
- B may be negatively impacted, causing management decisions to change
- Implementation may cause $C < E$ over time
- Transition of new strategy should be done over long period of time to prevent large shocks in the timber supply markets