Problem Chosen	2022	Team Control Number
E	ICM Summary Sheet	2214280

As a result of climate change, **greenhouse gases** and carbon dioxide have become increasingly persistent within the atmosphere. Forest management plans, implemented by forest managers, are key to reducing the amount of CO_2 within the atmosphere, through **carbon sequestration** by the **biosphere**. Utilizing existing statistics of forests, we can find the estimated yearly potential carbon sequestration, form models, and apply said models to real world forests and forest management plans.

First, we establish variables that contribute towards the sequestration of carbon dioxide which will the be used to estimate the average current amount of carbon sequestration of trees in a forest. Once we know this, we can find the average amount of carbon sequestration of the entire forest in which the model is applied. This model will later be used to create a method of calculation to predict the amount of carbon sequestration over a significant period of time.

Next, we create a **decision model** in order to help forest managers meet their goals. The first step of this is to create a decision model template, and research the most influencing factors that contribute to the key decisions made in the development of a forest management plan. Previously existing decision model templates are exceedingly helpful in the development of our Decision Model [Von Halle and Goldberg, 2009]. Considering the level of subjectivity of the previously mentioned factors, it is necessary to weigh the decision criteria. This is done by ranking and categorizing the criteria.

Once the Carbon Sequestration Model and Forest Management Plan Decision Model are complete, we apply them to various forests where deciding variables of stands are known and available. This reveals the complexity that goes into forests plans, especially to each specific forest. Finally, we choose our forest, Cedarville State Forest, where the inclusion of harvesting for some stands would be beneficial. Here we test the effectiveness of our model, evaluating its strengths and weaknesses, looking at the forest management plan from 2016-2116. Our models work well, and while flawed due to availability issues with information surrounding stands, we accurately implemented our plan.

Contents

1 Introduction

1.1 Background

In the United States, forests occupy approximately 740 million acres, making up about one-third of the country [Climate Impacts on Forests, 2016]. The forests in our communities provide copious benefits and services to society, including clean water and air, recreational uses, wildlife habitat, carbon storage, climate regulation, and a variety of forest products [Climate Impacts on Forests, 2016].

A changing climate has the potential to worsen many of the threats to forests through changes in temperature, rainfall, weather, and other factors [Climate Impacts on Forests, 2016]. It also inhibits forests' ability to sequester carbon dioxide, by making it increasingly difficult to simply maintain current or previous levels of carbon stocks [Ontl et al., 2020]. **Carbon Sequestration** is the process of capturing and storing CO_2 from the atmosphere. The **biosphere** is defined as the areas on the earth where things can live.

A diverse set of cultural values and symbolic functions are associated with forests, and are as numerous and diverse as the communities and cultures that surround them [Falconer and Koppell, 1990]. This is especially true in places such as South Africa. Physically, sentimentally, and spiritually, forests have defined the environments of communities in regions of the world throughout time [Falconer and Koppell, 1990]. To change a forest is to change the environment, as seen in the earliest forms of Native American and Aztec culture. This can heavily influence practices surrounding forest care and the ways in which a forest is valued within a community [Falconer and Koppell, 1990].

Taking all of these elements into consideration, it is easy to see how difficult it is for forest managers to decide what forest management plan to incorporate. The factors necessary for a forest manager to keep in mind are Conservation and Biodiversity Aspects, Cultural Considerations, Potential Carbon Sequestration, and Recreational Uses. At times, Economic Sustainability can also play a large role in the decision-making process [Division of Forests and Parks, 2001].

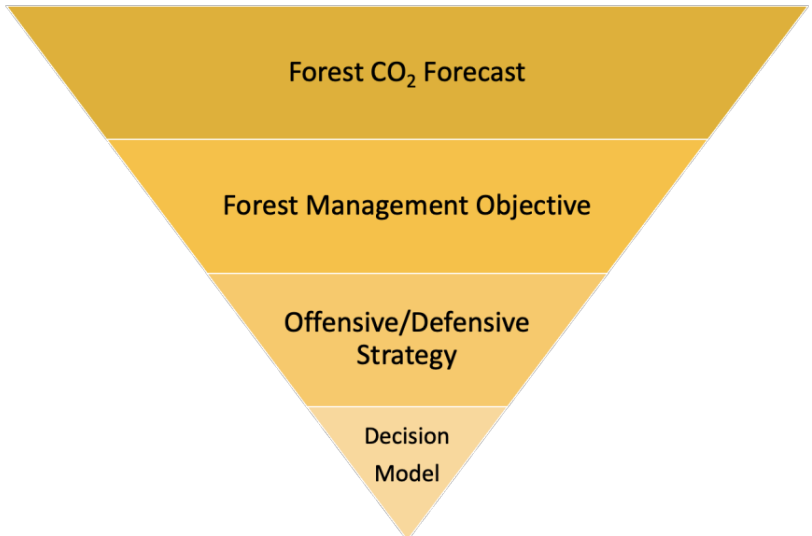

Figure 1: Carbon Sequestration Model

[Toochi, 2018]

1.2 Restatement of Problems

In order to guide forest managers in their decision-making process, we were required to create a Carbon Sequestration Model and apply it to a forest to determine what forest management plan was most effective at sequestering carbon dioxide. In addition, we built a Decision Model to incorporate real world factors, with respect to how forests are valued and carbon sequestration. We then applied our models to various forests until we found a forest that would benefit from the inclusion of harvesting. We predicted the amount of carbon dioxide that the forest, and its products, would sequester over a hundred years, and wrote a timeline for transitioning from the existing management plan to a newly improved one. We also wrote a newspaper article to persuade the local community about the benefits of harvesting stands in their forest.

1.3 Overview of Work

Our intention was to create a basic model that would inform forest managers on the amount of CO_2 being sequestered in their forests, both now and in the future, and to guide them on what decisions to make, in their forest management plans, in order to maximize the amount of carbon dioxide being sequestered in their forests. We first defined carbon sequestration and became familiar with the concept, researching how forests benefit communities and their overall importance. We then built a model to calculate the amount of carbon being sequestered per acre per year in a forest. Applying this to forests in the present time and then modeling the amount of carbon sequestration a hundred years in the future, we took the percentage change and used that to decide where to harvest trees in the forest. We applied this model, to two forests, one which the model would recommend harvesting and the other which we would not recommend harvesting. The second forest being a hypothetical forest to represent an application where all of the necessary information is available.

For the forest we recommend harvesting, we built a decision model to incorporate real-world factors into their decision-making process. For the Decision Model, we established our aim: To inform forest managers of the best use of a forest using potential carbon sequestration and the various ways in which forests are valued [Grand and Whittingon, 2022]. During this process it became necessary to define what a decision model is, being an intellectual template for perceiving, organizing, and managing the business logic behind a business decision [Von Halle and Goldberg, 2009]. This template is popularly used in corporate businesses and is easily applied to the purposes of our model [Kelly, 2006].

We also drew inspiration for our Decision Model by observing the basic step-by-step process for decision making [Daft, 2009]. From there, we did research on what factors influence forest action and how much of an impact each factor has on forest management. This allowed us to rank the factors from most influential or important to having the least impact, along with categorizing the decision criteria as internal or external factors. Taking into consideration the research already done, we began discussing the key decisions as part of the process in choosing a forest management plan. In the end, we decided the key decisions are:

- Form a beneficial balance of harvesting and monitored natural growth of forests [Houdyschell, 2006].
- Prevent disturbances that negatively impact the health and productivity of forests.
- Rehabilitation of forests and wildlife impacted by large-scale disturbances.

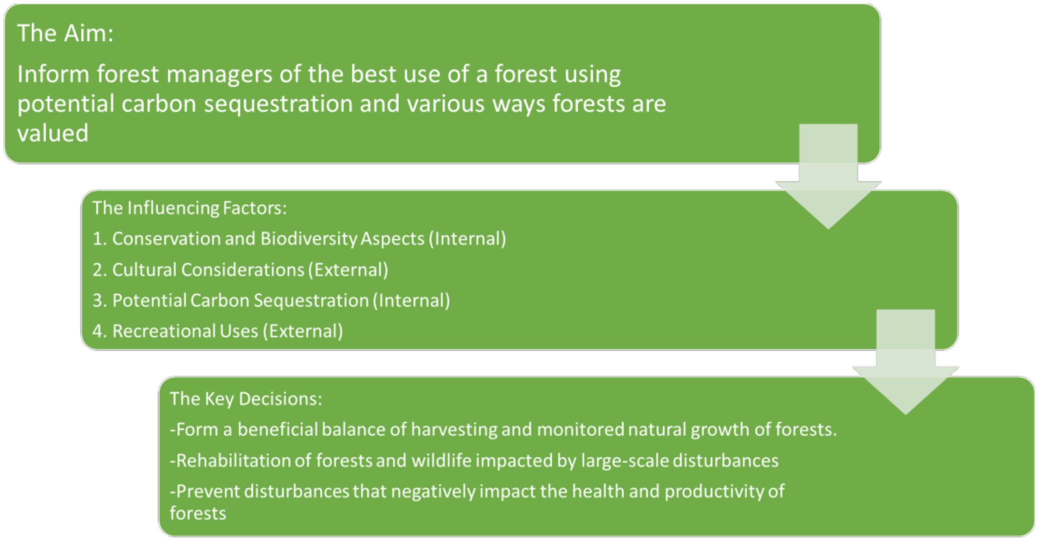

Figure 2: Forest Management Decision Model

2 Factors of Forest Management

2.1 Strategies of Forest Managers

The influencing factors of forest management in the decision model were derived from strategies of forest managers [Ontl et al., 2020]:

1. Maintain or increase extent of forest ecosystems.
2. Sustain fundamental ecological functions.
3. Reduce carbon losses from natural disturbance.
4. Enhance forest recovery following disturbances.
5. Prioritize management of locations that provide high carbon stocks across the landscape.
6. Maintain or enhance existing stocks of carbon dioxide while retaining forest character.
7. Enhance or maintain carbon sequestration capacity through significant forest alterations.

2.2 Influencing Factors

The influencing factors for the Decision Model are:

1. Conservation and Biodiversity Aspects
   - Fire Protection
   - Forest Care
   - Rehabilitation from disturbances
2. Cultural Considerations
   - Historical Significance
   - Sentimental Value
   - Religious Beliefs or Spiritual Connection
3. Potential Carbon Sequestration
   - Isolation of CO_2 by trees
   - Percentage change over the course of the projected 100 year timeline
4. Recreational Uses
   - Hiking Trails and Biking Trails
   - If there are rivers, kayaking and other activities
   - Camping

2.2.1 Internal vs. External

Internal factors are inlying forces and conditions present within, while external factors are outside forces that have the potential to impact the subject [Von Halle and Goldberg, 2009].

For our Decision Model, the internal factors were:

- Conservation and Biodiversity Aspects
- Potential Carbon Sequestration

For our Decision Model, the external factors were:

- Cultural Considerations
- Recreational Uses

3 General Assumptions and Justifications

When applying our Carbon Sequestration Model to the Cedarville State Forest, we were only able to get full average height data for stands 1, 2, 4, and 10 [Stupak, 2016]. Due to the absence of data for the remaining stands, we took the average height using only a percentage of the trees in the stand with the available data. Though this is a flaw of our model, we are assuming that this missing data does not significantly skew the height, and thus, the Carbon Sequestration Model. When applying these models to the forests, we based it upon a 100 year timeline as the benefits of harvesting are long-term, not short term [Pukkala, 2017]. We are only considering trees as products of the forests as we assume that the carbon sequestration gathered by smaller plants is negligible. In reference to our math model, we use the coefficient .25 and .15 to find the above ground weight as it is an average of trees, based on diameter. In addition we disregard stand 10 as it is an outlier.

In our ranking of the decision criteria, we made the assumption that if each factor is high then in theory the order of importance is as follows:

1. Conservation and Biodiversity Aspects
2. Cultural Considerations
3. Potential Carbon Sequestration
4. Recreational Uses

We also made the assumption that Cultural Considerations' and Potential Carbon Sequestration's rankings can be interchangeable, depending on the priorities of the surrounding community [Hall, 1981]. We excluded Economic Sustainability from the influencing factors of the Decision Model as it was too specific in its application. We assumed that the community of the forest, in which the Decision Model is applied, has the economic ability to sustain its forest management plan.

4 Carbon Sequestration Math Model

In order to determine whether to harvest trees in a forest, we used a formula to calculate the current amount of carbon dioxide all stands in a forest are sequestering in the present moment. We then use the formula to estimate the amount of CO_2 being sequestered in a hundred years, and use the percentage change to inform forest managers of the best plan possible. We do this using the following equations [Toochi, 2018]. We start by taking the average diameter breast height, *dba* (in inches), of the stand. This is the standard of measure for a trees diameter, taken 4.5 feet above ground [Liu et al., 2018]. We also take the average height, h (in ft) to get the above ground weight of the tree, W_a. If the diameter is less than 11 inches:

$$W_a = .25d^2h$$

If the diameter is greater than 11 inches:

$$W_a = .15d^2h$$

Since a trees root system is, on average, 20% of a trees weight, to calculate the full green (or wet) weight of the tree we:

$$W_g = 1.2W_a$$

Since a tree is 27.5% moisture, and only the dry matter sequesters carbon, we must isolate it:

$$W_d = .725W_g$$

The carbon content of a tree is generally 50% a trees volume, to get the carbon weight:

$$W_c = .5W_d$$

The atomic weight of Carbon is 12.001115amu and the atomic weight of Oxygen is 15.9994amu. Thus, the weight of CO_2 is:

$$C + 2 * O = 43.999915$$

The ratio of CO_2 to C is:

$$43.999915/12.001115 = 3.6663$$

To find the weight of the carbon dioxide sequestered in the tree:

$$W_{cd} = .36663W_c$$

Now, the amount of carbon a tree can sequester a year is dependent on the trees age, to get this factor we divide by the age a:

$$W_{seq} = \frac{W_{cd}}{a}$$

We now need to extrapolate the data for all the trees in a stand. To do this, we take the amount of trees per stand, D and the total acres in the stand, A.

$$T_t = DA$$

Finally, to get the total amount of carbon sequestration per stand per year:

$$Tseq = T_t W_{seq}$$

We now have the total amount of CO_2 being sequestered in a forest per stand, in lbs, in a year. To apply this model over a hundred years, we used the two main factors in how much carbon a tree can sequester, the diameter growth, and age. To find the diameter growth over a hundred years we took the given information, the length of time on average a stand would take to grow two inches, and extrapolated the data. Reapplying the equation with these two factors changed gives us an idea of how much more carbon the forest will be sequestering in a hundred years. We then take the percent change of the current (V_1) and future carbon (V_2) sequestration:

$$\frac{V_2 - V_1}{|V_1|} x100$$

in order to help forest managers decide how to maximize the use of their forest. The reason we use average percentage change as our deciding factor is that the many factors that affect carbon sequestration, vary greatly from forest to forest and what is a small amount of carbon sequestration for one forest, may be an unrealistic number for another to reach. Though this model does not include other factors, such as change in height, we feel it does give an accurate estimate of the carbon sequestration over a hundred years.

5 Application of Models

5.1 Application to a Young-Growth Forest

We first applied the model to a hypothetical 25-year old forest located in the Pacific North West, with high cultural significance. This site is, therefore, vulnerable due to the cultural value held by the community, causing forest managers to have exceedingly low-risk tolerance. We did this due to the desire to show a contrast to the next forest, in which the model would recommend some harvesting of trees. As Douglas Fir trees are one of the most common tree species in that area, we used this species for our hypothetical forest [Northwest, 2021]. To model the carbon sequestration, we averaged diameter breast height (in.) and height (ft.) for Douglas Firs in the Pacific Northwest [Poudel et al., 2018]. We also averaged diameter growth rate for Douglas Firs and used that data for our model [Zumrawi et al., 1993].

PNW Douglas-Fir Forest	
Diameter Breast Height (dbh)	13.64
Height (h)	85.67
Age (a)	25

Figure 3 Douglas Fir Average Data

The results show a change from 10676.38 to 19142.42 lbs of carbon being sequestered a year in the forest. In other words, a 79.3% increase in carbon sequestration over the hundred year time period.

5.2 Application to Cedarville State Forest

In this instance, we will first look at the information provided by the Maryland Department of Natural Resources in the report for the action of the Cedarville State Forest [Stupak, 2016]. From this, we obtained the data for each stand. We then, using the equation above, took the total carbon sequestration per year for each stand in lbs. We then take the percent change of each stand and the average percent change for all stands. Due to stand 10 being an outlier, we have excluded it from the model as to not skew results.

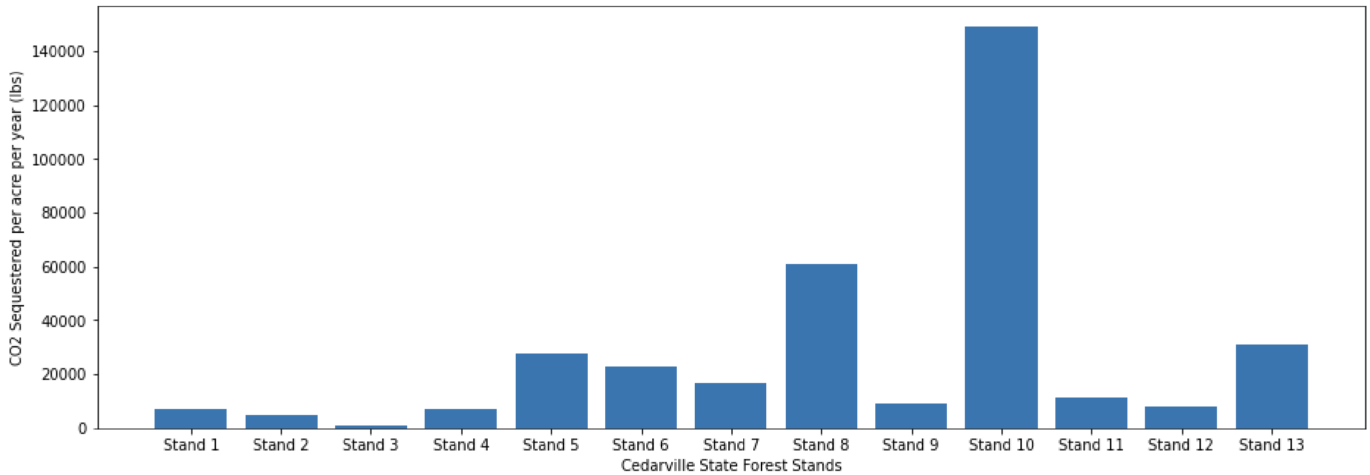

Figure 4 Cedarville State Forest Stands (2016)

Carbon Sequestration (lbs) a year per stand			
Stand Number	2016 (Year)	2116 (Year)	Percentage Change
Stand 1	5413169.79	10912040.42	101.6%
Stand 2	5063304.07	9877763.56	95%
Stand 3	80411.50	186396.94	131.8%
Stand 4	1983712.42	3559640.20	79.4%
Stand 5	10071741.70	12308646.77	22.2%
Stand 6	5740207.12	7562471.31	31.7%
Stand 7	1998710.66	1925757.94	3.6%
Stand 8	10372432.94	32527949.69	213.6%
Stand 9	149239.45	270315.20	81.1%
Stand 11	1116451.79	3205841.72	187.1%
Stand 12	4310068.41	8423441.26	95.4%
Stand 13	622069.85	1625061.49	161.2%
Total	46921519.7	92385326.5	96.9%

Figure 5 Cedarville Forest CO_2 Percent Change

The recommendation is to then harvest any stands that fall below the average percent change. In other words, the carbon sequestration model, would recommend harvesting trees from stands 2, 4, 5, 6, 7, 9, and 12, and would recommend a focus on maintaining carbon stocks for all other stands.

According to the Management Recommendations section of the report, most of the central goals revolve around preserving existing wildlife and terrain [Stupak, 2016]. This involves avoiding disturbances to non-tidal wetlands, retaining dead woody debris on the forest floor for wildlife habitats, and retaining rain-water absorption [Stupak, 2016]. The original forest management plan prioritizes preventing environmental impact from external developments to the existing ecosystem within the Cedarville State Forest [Stupak, 2016]. In comparison, our Carbon Sequestration Model and Decision Model were created with the goal to prioritize decisions that impact carbon sequestration specifically, while considering the other ways in which forests are valued. In the application of models to this forest, we used key decisions and strategies in order to recommend a new forest management plan that would take into account the preservation of wildlife and plant life, community priorities, recreational use of the forest, as well as considering the goals for maximizing carbon sequestration.

When applying the Forest Management Decision Model to the Cedarville State Forest, we implemented a number of steps in order to form a forest management plan:

1. First, you must look at site-specific areas in the forest canopy, observing stands that fall shorter than others to determine potentially unhealthy areas.

2. Once these areas are identified, look for abnormalities in the growth form of trees in the stand to make confirmation of unhealthy areas in need of reforestation.

3. Lastly, observe life circles of trees in the stand to confirm specific unhealthy trees to harvest.

We also formulated questions to ask when making a harvesting decision:

- Does the forest manager have a high or a low risk tolerance? For example, a forest manager with a lower risk tolerance might not be willing to harvest trees in an under stocked stand or forest, regardless of percentage change displayed in the Carbon Sequestration Model.

- Is the site under stocked, overstocked, or fully stocked? This will tell us in what stands we should recommend harvesting.

- How vulnerable is the forest in question? For instance, is the site susceptible to climate change? What sort of cultural value does it have, if any?

Cedarville is a great example where harvesting is necessary to promote the health and productivity of the forest, especially seeing as how factors such as cultural considerations and recreational uses have minimal importance in the decision-making process of forest management [Stupak, 2016]. In addition, the majority of the stands in the forest are overstocked meaning it is less vulnerable to the negative short-term effects of harvesting and thinning. For example, stand 1 is overstocked at 126% making it an ideal site to consider harvesting, but its percentage increase in sequestration of carbon dioxide is over 96.9%, negating consideration of this stand for harvesting [Stupak, 2016].

The conditions of Cedarville, including the lack of offensive forest care in recent years, forms great potential for highly successful reforestation, conservation, and rehabilitation where needed [Stupak, 2016]. So, therefore, our recommendation to forest managers at Cedarville State Forest, based upon the Decision Model, is to harvest trees from stands 4, 5, 6, and 7, as their carbon sequestration has the lowest percentage increase of the stands in the forest in the projected timeline of the next 100 years. We also recommend, the consideration of harvesting trees from stands 3, 9, and 12, in order to:

1. Form a beneficial balance of harvesting and monitored growth of forests

2. Prevent disturbances that negatively impact health and productivity of forests

3. Rehabilitation of forests and wildlife impacted by large-scale disturbances.

According to the Decision Model:

- Recommendation to Harvest: 3, 4, 5, 6, 7, 9, and 12.

- Recommendation to sustain and enhance levels of carbon sequestration: 1, 2, 8, 11, and 13.

1. We do not recommend harvesting trees from stand 1, despite it being greatly overstocked, due to its high percentage increase of carbon sequestration over the course of the projected 100 year timeline. In addition, due to stream and wetland buffers, proper harvesting and thinning in this stand would prove to be difficult [Stupak, 2016].

2. Though it contradicts the Carbon Sequestration Model, we do not recommend harvesting trees from stand 2 as its site growth potential is good and the average age of trees is moderate. This is key to forming that beneficial balance of harvesting and monitored growth of forests [Stupak, 2016].

3. We recommend harvesting trees from stand 3 as its site growth potential is poor and the trees in the stand, on average, are older [Stupak, 2016].

4. In agreement with the Carbon Sequestration Model, we recommend harvesting trees from stands 3, 4, 5, 6, and 7. Their percentage change in carbon sequestration is below the average, making it necessary to reforest those areas [Stupak, 2016].

5. We recommend monitored growth of trees in stand 8, and sustaining levels of carbon stocks as the trees in this stand are, on average, especially young [Stupak, 2016].

6. We recommend harvesting trees in stand 9 as it is below the average of carbon sequestration percentage change in 100 years, and it is highly overstocked [Stupak, 2016].

7. We do not recommend harvesting trees in stand 11 as its site growth potential is excellent, meaning it would be extremely high risk to harvest trees in a stand that is so healthy [Stupak, 2016].

8. In agreeance with the Carbon Sequestration Model, we recommend harvesting trees in stand 12 as its ages are relatively uneven and its percentage change in the CO_2 Model is below the average of 96.9% [Stupak, 2016].

9. We do not recommend harvesting trees in stand 13, due to its ages being in the zone for prime carbon sequestration [Stupak, 2016].

5.2.1 Transitional Strategy

Assuming, for Cedarville State Forest, the best forest management plan involves adding a ten year period in between harvests, we have created a strategy to transition between the current and the new forest management plan. In order to ensure that the transition between the current and the new forest management plan is as smooth as possible, we have favored a multi pronged approach. This will ensure stability within the ecosystem.

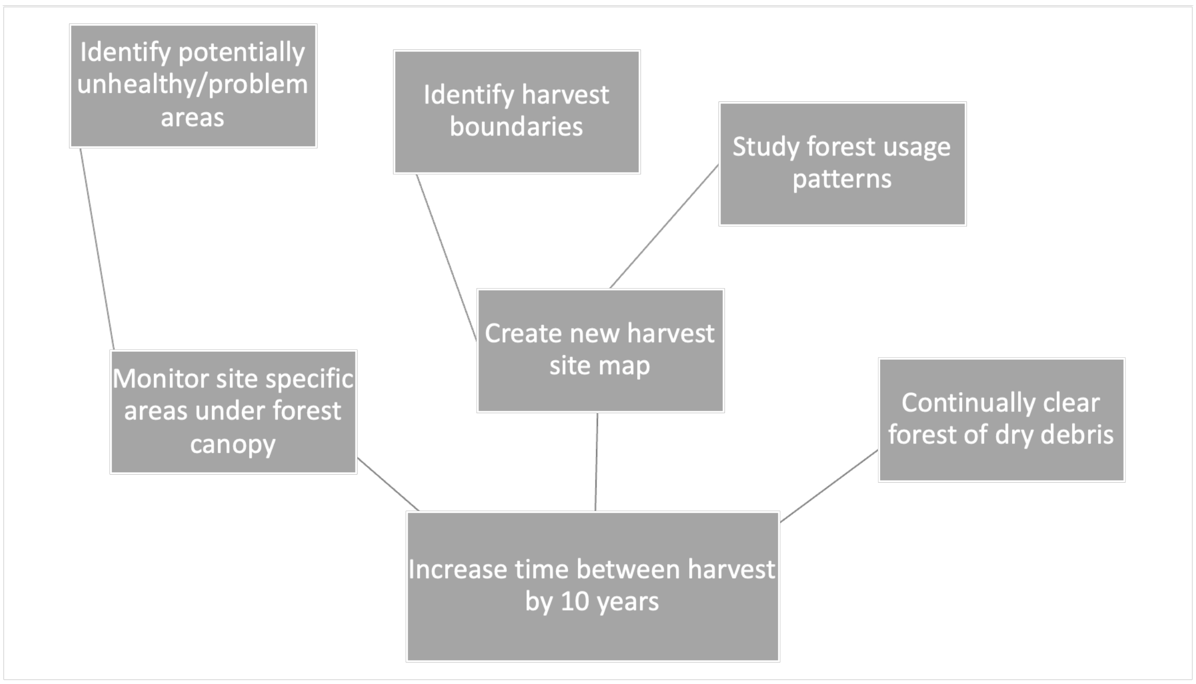

Figure 6 Transitional Strategy

First, we would recommend identifying any potential problem areas. Once identified, the trees in those areas should be monitored for abnormal growth or the appearance of pests. In addition, forests managers should study forest usage patterns and identify new harvest boundaries to create new harvest maps that will be relevant for the new time frame. Last, forests should be continually cleared of dry debris to mitigate the risks of wildfires.

6 Newspaper Article: Harvesting In Cedarville State Forest

Cedarville State Forest is exceedingly important to its surrounding community, as seen through its determined attempts to sustain and prevent disturbances of natural wildlife and its habitats [Stupak, 2016]. While it is important to prevent large-scale and small-scale disturbances within forests, it is also important to maintain care of these forests [Climate Impacts on Forests, 2016].

The idea of harvesting, which is cutting down trees and creating forest products from them, tends to have a bad reputation in the field of forestry due to negative short-term effects. Natural growth of forests and its ecosystem are healthy actions to take, but without harvesting dead and unhealthy trees will continue to occupy space within the forest where you could be reforesting and rehabilitating areas subject to disturbances [State of California, 2015].

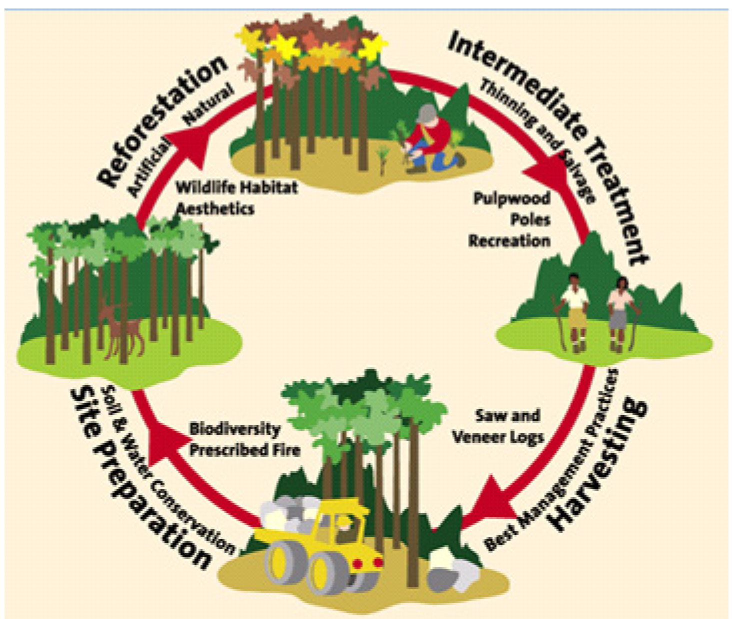

Figure 7: Cycle of Forests

[Oregon Loggers, 2022]

The long-term benefits of harvesting the unhealthy trees within forest stands far out-weigh that of the negative short-term effects. A weak and older forest becomes a carbon sink, where its stands emit more carbon dioxide than it stores [Pukkala, 2017]. Stands are clusters of trees in a specific that are uniform in species composition, site, age, arrangements, and condition [Mercker, 2017]. Harvesting helps to maintain overall health levels within forests and remove CO_2 from the atmosphere [Ontl et al., 2020].

While it would undoubtedly be risky for the forest to harvest healthy and strong trees, there are procedures in order to determine which trees are unhealthy or dead. Practices such as harvesting and commercial thinning allow for more space to replant new healthier trees to improve the state of the forests' ecosystem [Ontl et al., 2020]. The use of these practices create productive forest lands that are more resilient to drought, fire, and other natural disturbances.

Harvesting can also help to rehabilitate wildlife that has been negatively impacted from external development, such as disturbance from recreational human activity of the community. While most do not consider how this sort of activity can effect forests, the health and prosperity of wildlife is key to maintaining a thriving ecosystem. Harvesting helps to create a less hostile environment for animals, insects, etc. to live in.

7 Sources

References

[Climate Impacts on Forests, 2016] Climate Impacts on Forests (2016). http://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-forests_.html#:~:text=The\%20productivity\%20and\%20distribution\%20of,land\%20development\%20and\%20air\%20pollution.

[Daft, 2009] Daft, R. L. (2009). *Principles of Management*. South-Western, Cengage Learning India Pvt. Limited.

[Division of Forests and Parks, 2001] Division of Forests and Parks (2001). Sample Forest Management Plan. Technical report.

[Falconer and Koppell, 1990] Falconer, J. and Koppell, C. R. (1990). The Major Significance of 'Minor' Forest Products. The Local Use and Value of Forests in the West African Humid Forest Zone. Technical report, FAO, Roma (Italia).

[Grand and Whittingon, 2022] Grand, L. and Whittingon, T. (2022). Forest Management Planning. http://knowyourforest.org/learning-library/forest-management-planning#:~:text=A\%20plan\%20can\%20help\%20you,green\%20certification\%20for\%20your\%20forest.

[Hall, 1981] Hall, T. (1981). Forest Management Decision-Making: Art or Science? *The Forestry Chronicle*, 57(5):233–238.

[Houdyschell, 2006] Houdyschell, W. H. (2006). California Cooperative Forest Management Plan.

[Kelly, 2006] Kelly, A. (2006). *Maintenance Systems and Documentation*. Elsevier.

[Liu et al., 2018] Liu, C., Xing, Y., Duanmu, J., and Tian, X. (2018). Evaluating different methods for estimating diameter at breast height from terrestrial laser scanning. *Remote Sensing*, 10(4):513.

[Mercker, 2017] Mercker, D. (2017). *A Glossary of Common Forestry Terms*. University of Tennessee Institute of Agriculture.

[Northwest, 2021] Northwest, P. (2021). Native Plants PNW: An Encyclopedia of the Cultural and Natural History of the Northwest Native Plants. http://nativeplantspnw.com/.

[Ontl et al., 2020] Ontl, T. A., Janowiak, M. K., Swanston, C. W., Daley, J., Handler, S., Cornett, M., Hagenbuch, S., Handrick, C., McCarthy, L., and Patch, N. (2020). Forest Management for Carbon Sequestration and Climate Adaptation. *Journal of Forestry*, 118(1):86–101.

[Oregon Loggers, 2022] Oregon Loggers (2022). Steps to Manage the Life of an Oregon Forest. https://www.oregonloggers.org/Forest_About_FullCycle.aspx.

[Poudel et al., 2018] Poudel, K. P., Temesgen, H., and Gray, A. N. (2018). Estimating Upper Stem Diameters and Volume of Douglas-fir and Western Hemlock Trees in the Pacific Northwest. *Forest Ecosystems*, 5(1):1–12.

[Pukkala, 2017] Pukkala, T. (2017). Does Management Improve The Carbon Balance of Forestry? *Forestry: An International Journal of Forest Research*, 90(1):125–135.

[State of California, 2015] State of California (2015). Five Year Review of Forest Action Plan- Update Report. Technical report.

[Stupak, 2016] Stupak, Bryan J., G. R. E. A. J. E. (2016). Cedarville State Forest Stewardship Plan. *Maryland Department of Natural Resources, Forest Services*.

[Toochi, 2018] Toochi, E. (2018). Carbon Sequestration: How Much Can Forestry Sequester CO2. *For. Res. Eng. Int. J*, 2(3):148–150.

[Von Halle and Goldberg, 2009] Von Halle, B. and Goldberg, L. (2009). *The Decision Model: A Business Logic Framework Linking Business and Technology*. CRC Press.

[Zumrawi et al., 1993] Zumrawi, A. A., Hann, D. W., et al. (1993). Diameter Growth Equations for Douglas-fir and Grand Fir in the Western Willamette Valley of Oregon.

8 Appendix

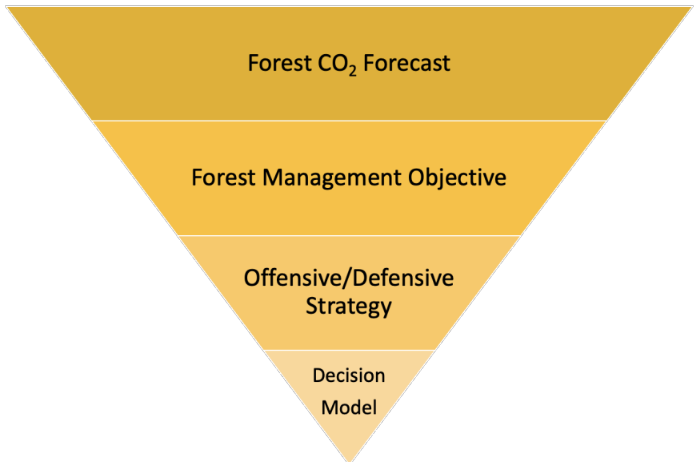

Figure 1: Carbon Sequestration Model

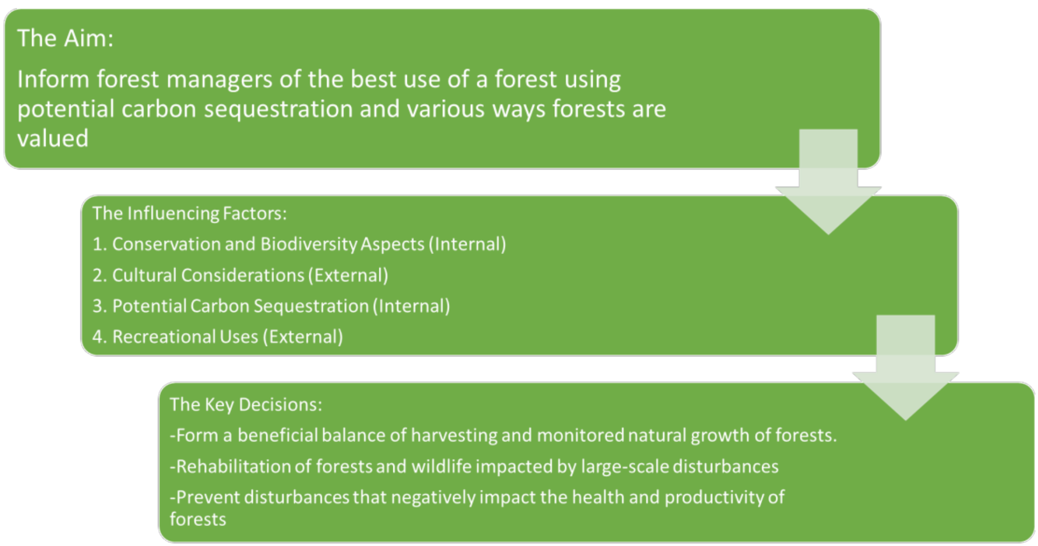

Figure 2: Forest Management Decision Model

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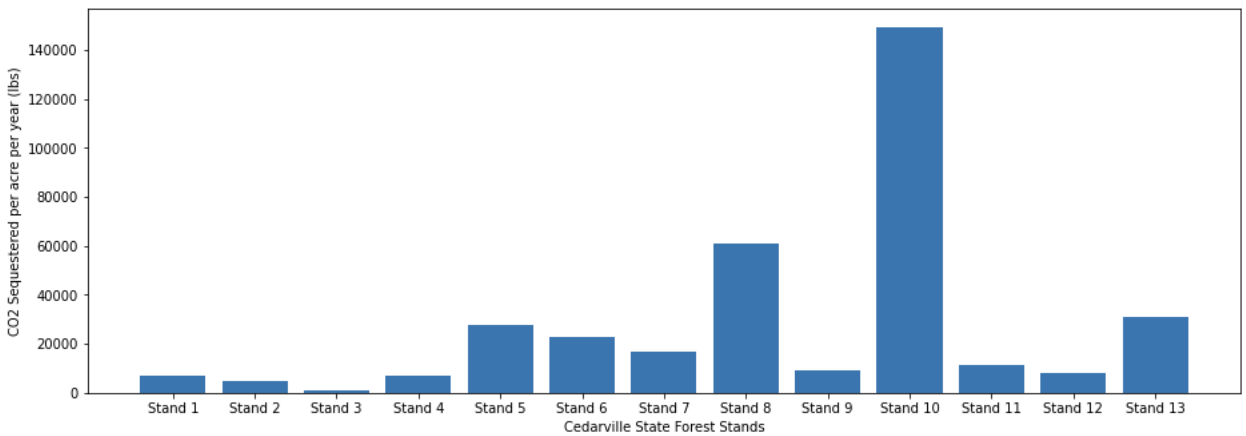
Figure 3 Douglas Fir Average Data



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Stand 6	5740207.12	7562471.31	31.7%
Stand 7	1998710.66	1925757.94	3.6%
Stand 8	10372432.94	32527949.69	213.6%
Stand 9	149239.45	270315.20	81.1%
Stand 11	1116451.79	3205841.72	187.1%
Stand 12	4310068.41	8423441.26	95.4%
Stand 13	622069.85	1625061.49	161.2%
Total	46921519.7	92385326.5	96.9%

Figure 5 Cedarville Forest CO_2 Percent Change

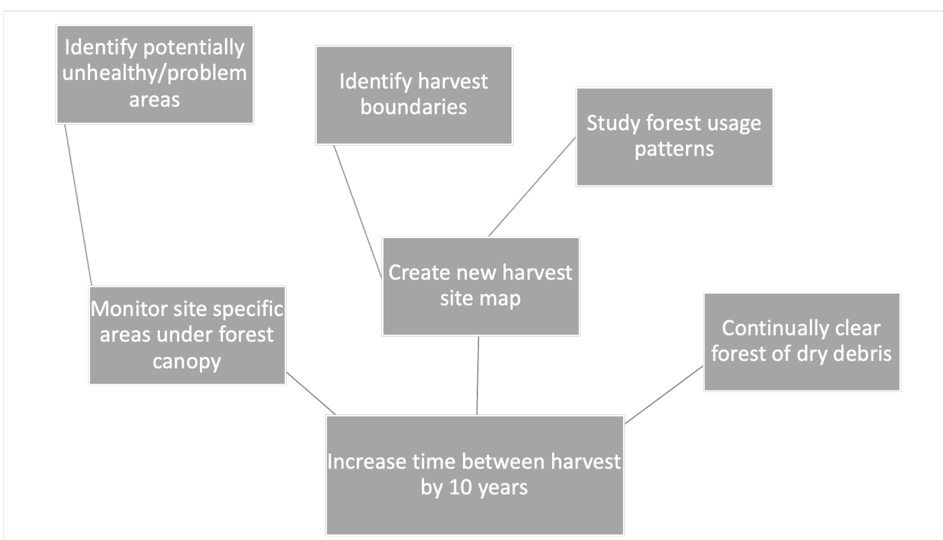

Figure 6 Transitional Strategy

Figure 7: Cycle of Forests

[Oregon Loggers, 2022]