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To Plant or to Preserve: Comparing the Carbon-Capture Potential of Planting New Trees Versus Preserving Existing Forest

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Abstract

As climate change has heightened in recent years, awareness and action to reduce global carbon dioxide (CO_2) emissions have increasingly focused on planting trees for their ability to sequester and store carbon over time. Notable tree-planting efforts include the One Trillion Trees campaign and Coldplay's world-tour partnership with One Tree Planted where one ticket purchased equals one tree planted. This research examines tree-planting initiatives through a critical lens, seeking to determine if planting trees is an effective method to offset CO_2 emissions when compared to preserving existing forests. For local application, 26 acres of mature oak-hickory forest in the US Forest Service Southside Project logging project in the Nantahala National Forest were analyzed. Tree density of this area was estimated using available LiDAR data and age classes were obtained from USFS data. i-Tree Eco data was used to model current carbon storage and sequestration data of the forest and then to forecast its carbon data into 2050. Subsequently, the growth of a newly planted 26-acre forest with the same oak-hickory forest species was modeled and similarly forecasted into 2050. Through comparison, it was revealed that the existing forest has greater potential to store and

sequester carbon now and into 2050. This research highlights the importance of preserving existing forests for the continued mitigation of current and future CO_2 emissions.

1. Introduction

Human activity has dramatically altered the global climate. Whether it be from the combustion of fossil fuels for energy production or deforestation for agricultural and urban development, atmospheric concentrations of greenhouse gases have increased exponentially since the Industrial Revolution (McKinley et al., 2011). Carbon dioxide (CO_2) is a primary greenhouse gas that, when emitted, resides in the atmosphere for long periods of time and traps heat, thus contributing to the global greenhouse effect (Schneider, 1985). Unless urgent action is taken to reduce CO_2 emissions, global temperatures will continue to rise and ultimately worsen climate change in the coming decades (Kirschbaum et al., 2024).

As the effects of climate change become more unavoidable, the search for solutions to reduce global CO_2 emissions has dominated public discourse. Since government policies often struggle with implementation or gaining public favor, voluntary carbon offsets have become an appealing solution for individuals or organizations to reduce their environmental impact without taking direct action (Kirschbaum et al., 2024). Carbon-offset projects either use ecological or technological methods to reduce greenhouse gas emissions, which can then offset, or compensate for, the emissions produced by the individuals or organizations hoping to control their impact (McKinley et al., 2011). Natural ecosystems are most often utilized to offset emissions, as plants sequester atmospheric CO_2 through photosynthesis and store the carbon as biomass and in soils (Fleischman et al., 2020; Goh, 2017).

Recent years have shown a surge in carbon-offset projects focused on forest ecosystems. Efforts include afforestation–planting trees in unforested areas–, reforestation–replanting trees in depleted forests–, and conservation–protecting existing forests. Sentiments have shifted towards forests and tree-planting for a number of reasons. Forests are above ground, meaning they are highly visible and their carbon storage and sequestration can be easily measured (Fleischman et al., 2020). Forests also might hold more cultural significance for many people compared to other ecosystems, so their protection and regeneration might be more strongly advocated for (Fleischman et al., 2020). Planting new trees can offer a simple, less-controversial solution to reducing emissions that can ultimately garner stronger support from the public (Kirschbaum et al., 2024). Utilizing trees as carbon offsets also poses a unique financial mechanism: the amount of trees planted by a carbon-offset project can equal the amount of money donated by an individual or organization (McKinley et al., 2011).

This rise in tree-planting popularity can in large part be attributed to a scientific study that circulated the media in 2019. The study claimed that the planet has room for 1.2 trillion trees and that planting trees is “our most effective climate change solution to date” (Bastin, 2019). Scientists quickly responded with their criticisms–noting that the numbers were overinflated, not enough ecological factors were accounted for, and planting new trees requires significant space, time, and effort–which led authors of the study to take accountability and correct their mistakes, but attention towards tree-planting persisted nevertheless (Greenfield, 2021). In 2020, the World Economic Forum–a non-governmental international organization–launched the One Trillion Trees initiative that aims to plant one trillion trees by 2050; this initiative offers companies in the private sector an opportunity to offset their emissions through financial contributions to tree-planting projects (World Economic Forum, 2023). The Republican Party of the United States, most notably former president Donald Trump, caught wind of this initiative and fully supported its mission while still advocating for the progression of national fossil-fuel production (Joselow, 2023).

Planting trees has also become an appealing carbon offset for events that host a large number of people. Live-music events, like concerts and festivals, generate a large amount of emissions from fan travel, energy generation, and waste production; a study from 2010 found that live-music events in the UK emit approximately 400,000 tons of CO_2 equivalent per year, with the highest contribution (43%) coming from fan travel (Bottrill et al., 2010). To mitigate this impact, influential artists and bands can encourage venues and fans to adopt more sustainable practices (Connolly et al., 2016). The impact of fan travel is more difficult to control, however, so further action is necessary to offset these emissions; artists and bands can bundle an individual ticket price with the price it takes to offset the emissions associated with that ticket (Connolly et al., 2016). Coldplay has most recently pledged to plant one tree per one ticket sold for their Music of the Spheres world tour, which began in 2022 and will extend to the end of 2024 (Chaplin, 2021). For this pledge, Coldplay is working with One Tree Planted, a non-profit that specializes in reforestation efforts across the globe (Chaplin, 2021).

Successful tree-planting initiatives can certainly sequester atmospheric CO_2 and provide many social, economic, and environmental benefits; it is worthwhile, though, to examine these initiatives in a critical lens. Preserving existing forest is a method that can be used to offset carbon emissions, but is often lower in priority and less advertised in comparison to afforestation or reforestation. This research applies the concept of planting new trees versus preserving existing forest on a local scale, using data from a logging project in North Carolina to determine which method has greater potential to store and sequester carbon over time. The hope for this research is to support the prioritization and necessity of preserving existing forests as a method to effectively, and urgently, assist in climate-change mitigation.

2. Methods

2.1. Site Description

The Southside Project is located in the Nantahala National Forest in North Carolina. This project proposes forest-management actions– such as timber harvest, commercial sale, and regeneration– for compartments within the Nantahala Ranger District, spanning the southeastern region of Macon County and the southernmost part of Jackson County (Figure 1). The project's analysis area is approximately 29,090 acres, including 18,944 acres of National Forest System lands; elevation ranges from 1,950 feet to 4,900 feet, and the most prevalent plant communities are montane oak-hickory forest, acidic cove forest, and chestnut oak forest (Forest Service, 2019). This study examines unit 35/41, a 25.79-acre portion of the Southside Project at Brushy Mountain (Figure 2). Unit 35/41 is an old-growth hardwood forest that serves as a wildlife corridor between the Terrapin Mountain and the Ellicott Rock Wilderness (Chattanooga Conservancy, 2017). The Southside Project proposes the timber harvest of unit 35/41 to create early successional habitat and construct a road on top of Brushy Mountain (Forest Service, 2019; Chattanooga Conservancy, 2017).

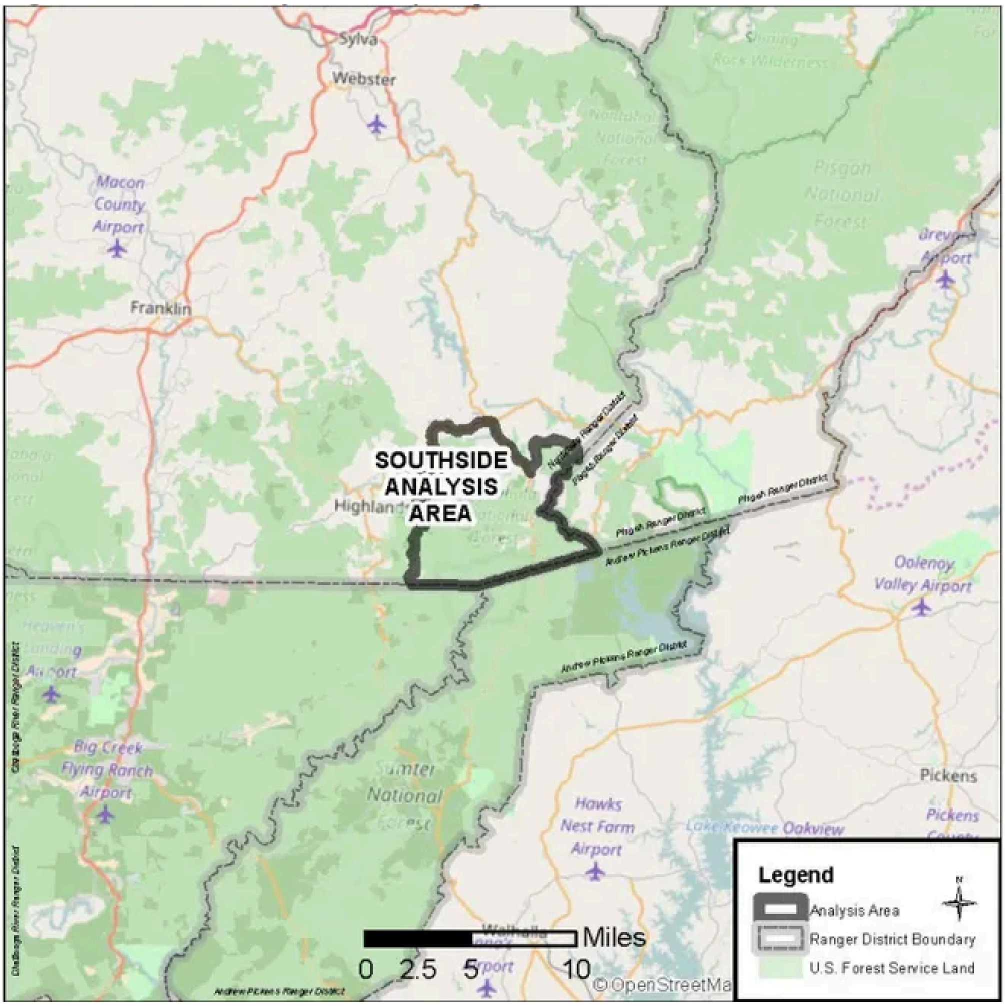

Figure 1. Vicinity map of the Southside Project, including the analysis area of the project, the ranger district boundaries, and the surrounding U.S. Forest Service lands. (Forest Service, 2019).

Figure 2. Google Earth map showing unit 35/41 (the left-most area in yellow) and the adjacent unit 35/42 (the right-most area in yellow) on top of Brushy Mountain (MountainTrue, 2022).

2.2. Data Collection

To determine the carbon-capture potential of unit 35/41, the distribution of trees in the area needed to be understood first. Throughout the research process, we were in contact with Josh Kelly, public lands biologist for Asheville non-profit MountainTrue, and Nick Holshouser, self-employed, who provided us with helpful information and data regarding the Southside Project. Holshouser, a GIS specialist, obtained LiDAR data of unit 35/41 and developed an online tool that cut the unit into a total of 129 six-meter-wide slices so that individual trees could be easily counted (Figure 3). From Holshouser's tool, the rough estimation of the tree density of unit 35/41 was used for further data analysis.

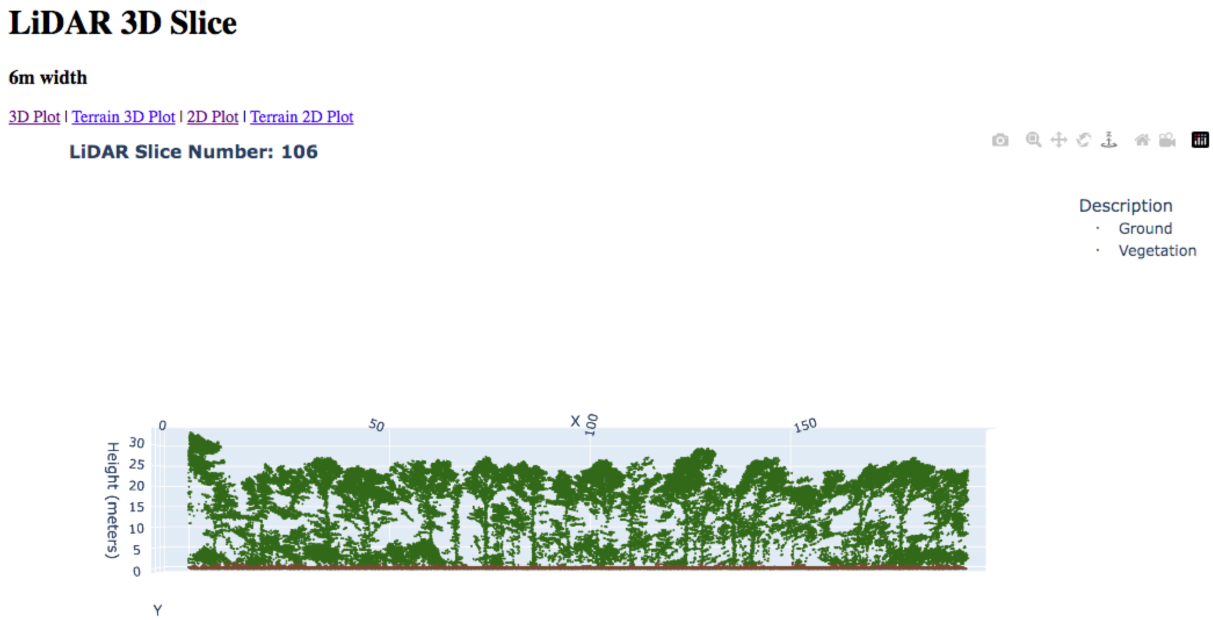

Figure 3. Example of a six-meter-wide LiDAR slice of unit 35/41. This tool offers features to draw, zoom, and take away ground and/or vegetation layers. It can also change views from 3D to a flattened 2D to Terrain, which visualizes the slice’s elevation.

Other data pertaining to the trees in unit 35/41 was sparse, so many assumptions were made based on the data that was available. Data was obtained from the US Forest Service on the number of acres in the Southside Project by age class (Figure 4). Age class is an interval used by the US Forest Service to classify the age range of an aggregation of trees (US Forest Service, n.d.). Though the carbon-capture potential of old-growth forests might be significant, the old-growth status of unit 35/41 had to be ignored for data analysis and it was assumed that the unit contained the same range of age classes in Figure 4. This assumption was made because there was no data that corresponded to the ages or DBHs of unit 35/41 itself. It was also made based on the fact that remaining old-growth trees in this area are typically small for their age, as they grow more slowly and have less DBH per year than an average tree due to harsh, hyper-local growing conditions (Personal communication, Josh Kelly, Public Lands Field Biologist, MountainTrue, Asheville, NC, January 23, 2024); i-Tree does not properly account for this, so if the approximate ages of the old-growth trees were used, the resulting carbon data would be significantly overestimated since i-Tree would calculate that the trees have faster growth and greater DBHs than they would in reality. The LiDAR data was used for this area to estimate trees per acre because it was the best and only data available.

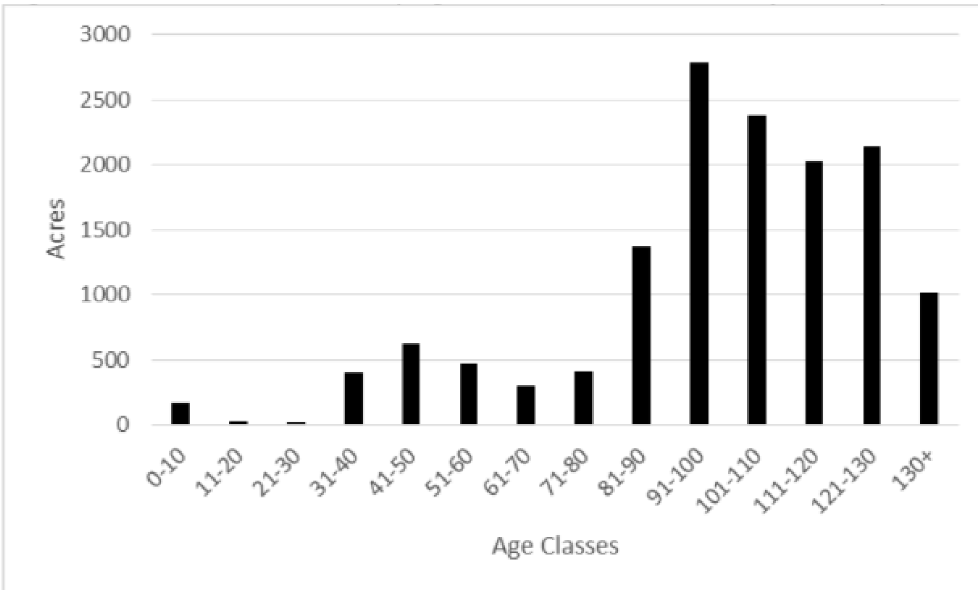

Chart developed from the Forest Service's FSVeg Database, last accessed December 2017.

Figure 4. Number of acres by age class in the Southside Project analysis area (Forest Service, 2019).

Along with the age of a tree, diameter at breast height (DBH) is necessary to determine carbon-capture potential. Previous research conducted at UNC Asheville measured the DBH of various tree species native to North Carolina and recorded those values into the i-Tree Eco software to calculate the trees' current carbon storage and annual carbon sequestration (Meyers, 2022; Given, 2023). The cataloged data includes seven tree species that can be found in montane oak-hickory forest, a dominant community in the Southside Project (Virginia…, 2021); since there was no data that accurately encompassed the range of tree species found in unit 35/41, we assumed it to be the seven oak-hickory species and used their data for analysis (Table 1).

Species Name
White pine *(Pinus strobus)*
Tulip poplar *(Liriodendron tulipifera)*
Pignut hickory *(Carya glabra)*
White hickory *(Carya tomentosa)*
Southern red oak *(Quercus falcata)*
White oak *(Quercus alba)*

Red maple *(Acer rubrum)*

Table 1. List of seven oak-hickory tree species included in i-Tree Eco catalogs.

2.3. Data Analysis

Analysis of all data mentioned above was completed through Excel. The goal was to match the i-Tree Eco catalogs of the seven tree species to the USFS bar chart and the LiDAR data to result in the estimation of the total carbon storage and annual sequestration of trees in unit 35/41. The USFS age class data was first used as a basis for determining the DBH and closest carbon values for each tree species; the DBH growth rate of each tree (found in the i-Tree catalog) was multiplied by the midpoint age of each age class, resulting in the approximate DBHs of a particular tree species per age class. The carbon storage and carbon sequestration values in i-Tree Eco are calculated based on DBH, so we matched the approximate DBH calculations to the closest lower DBH value in the catalog to find the estimated carbon storage and sequestration values per age class for each tree species.

Those carbon values then needed to be fit to the size of our unit: 26 acres. From the USFS data, the number of acres in each age class was estimated and each was summed, and then each age-class's acreage value was divided by the grand total to get the percentage of total acres in each age class in the whole Southside Project. The next important step was to find the number of trees per acre; this could be accomplished through the estimated tree density from the LiDAR data of unit 35/41. The total number of trees (6297) was divided by 26 to find the approximate number of trees per acre (242.2). The approximate number of trees per acre was then multiplied by the percentage of total acres in each age class, the result of which was divided by 100 to get the approximate number of trees in each age class for unit 35/41. Then the approximate number of trees in each age class was multiplied by the corresponding carbon storage and carbon sequestration values for each tree species' age class; the resulting values were all summed to obtain the total carbon storage and annual sequestration of 26 acres of a particular tree species– there was no accurate depiction of the distribution of tree species per acre, so it was assumed that the distribution of trees would be the average of the total carbon values of each species. Using the same assumption for tree density per acre, the carbon values of each species were forecasted into 25 years (to simulate effects in 2050) using data from the existing i-Tree Eco catalog. The totals were then averaged for best representation.

It was then necessary to simulate the effects of planting new trees of the same species and acreage for further comparison. The goal was to understand the effects of new tree growth in 25 years, so data was used that corresponded to age class 21-30 since its midpoint age is 25.5. With the available data it had to be assumed that only one species and would grow in 26 acres, so the number of trees per acre (from the

LiDAR data) was multiplied by the carbon values (from the i-Tree Eco catalog) of age class 21-30, resulting in the total carbon storage and sequestration of new tree growth of each species after 25 years. This result also assumes that the total number of trees planted would survive to 25 years. These values were also averaged for most effective comparison to the existing forest totals.

3. Results

Through data analysis, it was determined that unit 35/41 contains approximately 6297 trees within its 26 acres, with approximately 242.2 trees per acre. It was assumed that unit 35/41 hosts the entire range and distribution of age classes per acre, and through this it was found that the majority of trees in this unit are classified by older age classes.

To rank the total carbon storage for each species in the existing forest now, tulip poplar is the highest, white pine is in the middle, and white oak is the lowest (Figure 5); for total carbon sequestration, tulip poplar is the highest, southern red oak is in the middle, and white oak is the lowest (Figure 6). On average, the existing forest can currently store 164.8 tons of carbon per acre and can annually sequester 3.7 tons of carbon per acre (Figures 5 & 6). Figures 7 & 8 show the range of total carbon storage and sequestration for the existing forest forecasted into 2050. To rank the total carbon storage of the existing forest in 2050, tulip poplar is the highest, southern red oak is in the middle, and white oak is the lowest (Figure 7); similarly for carbon sequestration, tulip poplar is the highest, southern red oak is in the middle, and white oak is the lowest (Figure 8). On average, the existing forest in 2050 can store 236.5 tons of carbon per acre and can annually sequester 5.1 tons of carbon per acre (Figures 7 & 8).

After modeling the new 26-acre forest in 2050, it was revealed that, for every species, the total carbon storage and sequestration values of the existing forest now and in 2050 were significantly higher than the values of the growth of new trees. To rank the seven species each modeled in the new forest for total carbon storage, red maple is the highest, white pine is in the middle, and white oak is the lowest (Figure 9); similarly for total carbon sequestration, red maple is the highest, white pine is in the middle, and white oak is the lowest (Figure 10). On average, the new forest in 2050 can store 6.8 tons of carbon per acre and can annually sequester 0.6 tons per acre (Figures 9 & 10). Figures 11 and 12 compare the carbon values of the existing and new forest in 2050, which reveals that existing forest has much greater potential to store and sequester carbon in 25 years; Figure 11 demonstrates that the existing forest will store thirty-five times more carbon per acre than the new forest, and Figure 12 shows that the existing forest will annually sequester eight-and-a-half times more carbon per acre than the new forest.

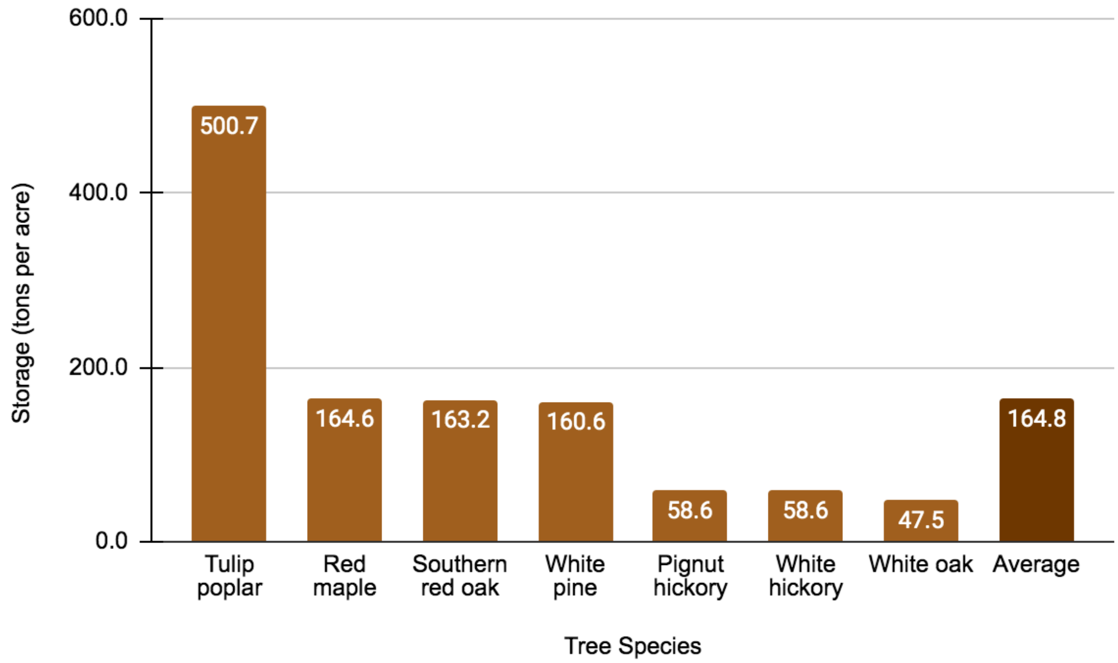

Figure 5. Total Carbon Storage (tons per acre) of Existing 26-Acre Forest by Tree Species Now.

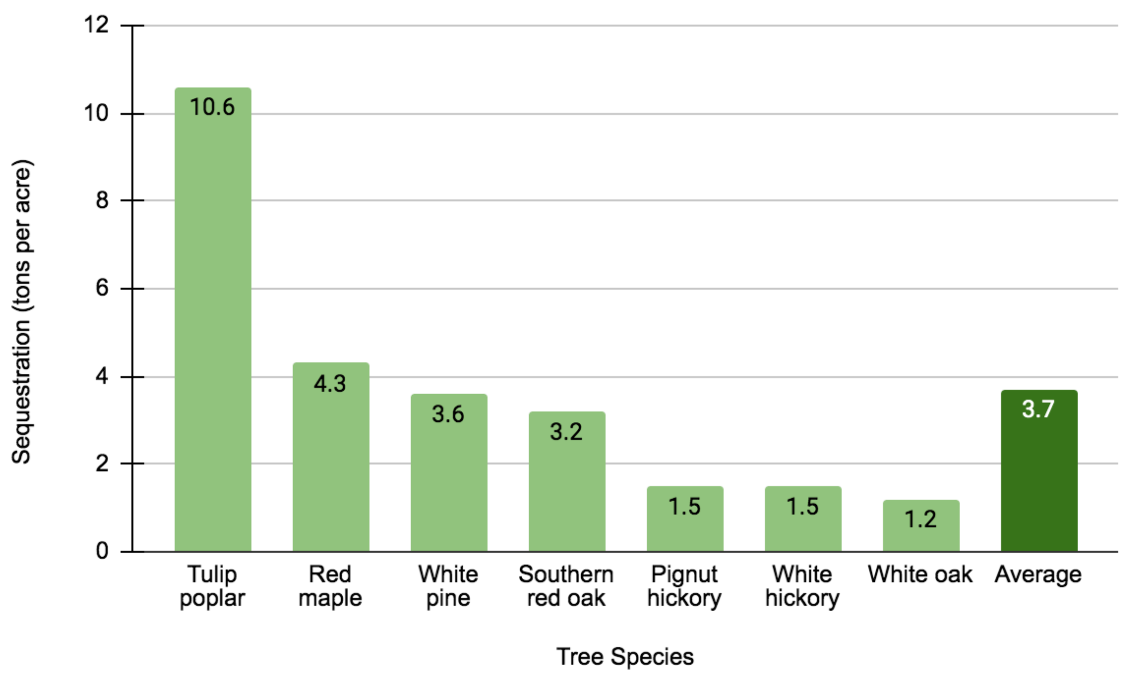

Figure 6. Total Carbon Sequestration (tons per acre) of Existing 26-Acre Forest by Tree Species Now.

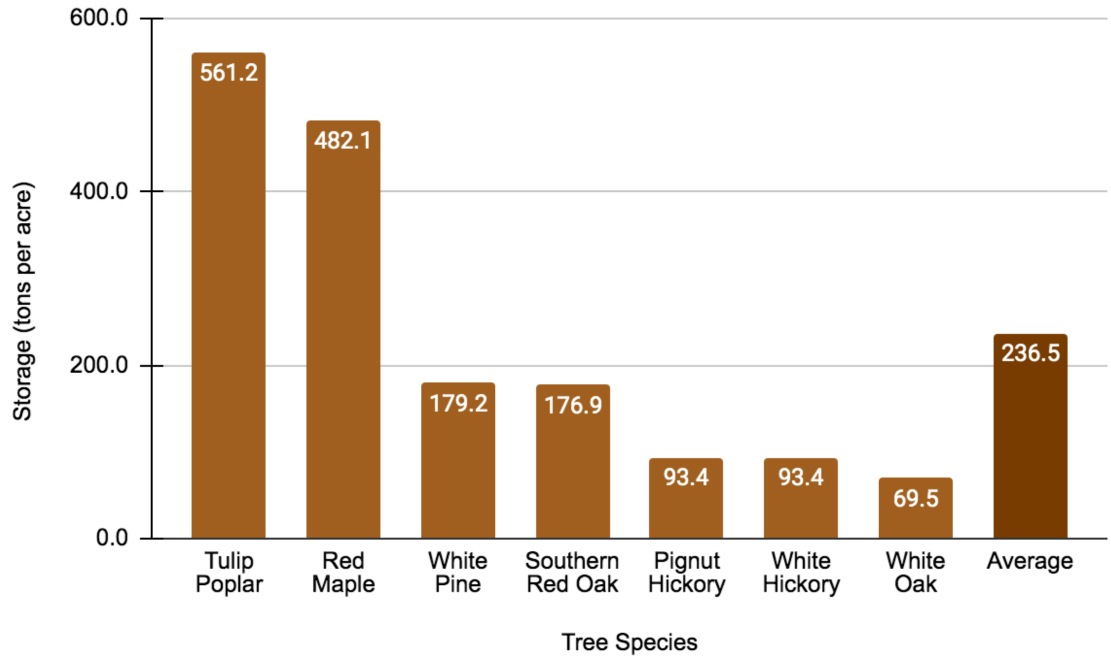

Figure 7. Total Carbon Storage (tons per acre) of Existing 26-Acre Forest by Tree Species in 2050.

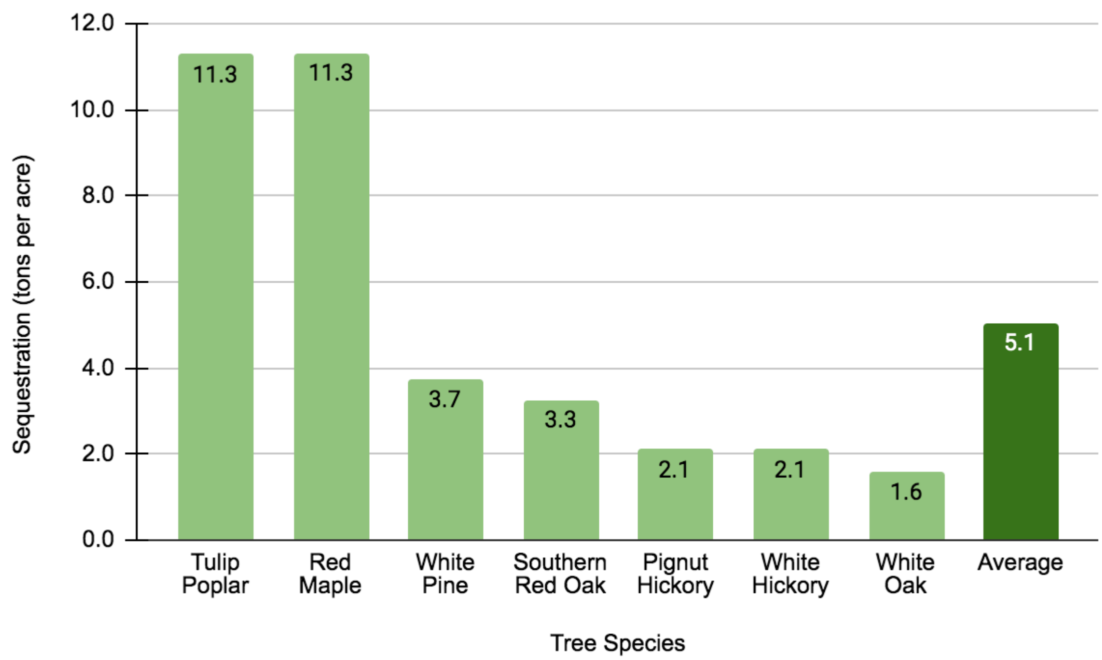

Figure 8. Total Carbon Sequestration (tons per acre) of Existing 26-Acre Forest by Tree Species in 2050.

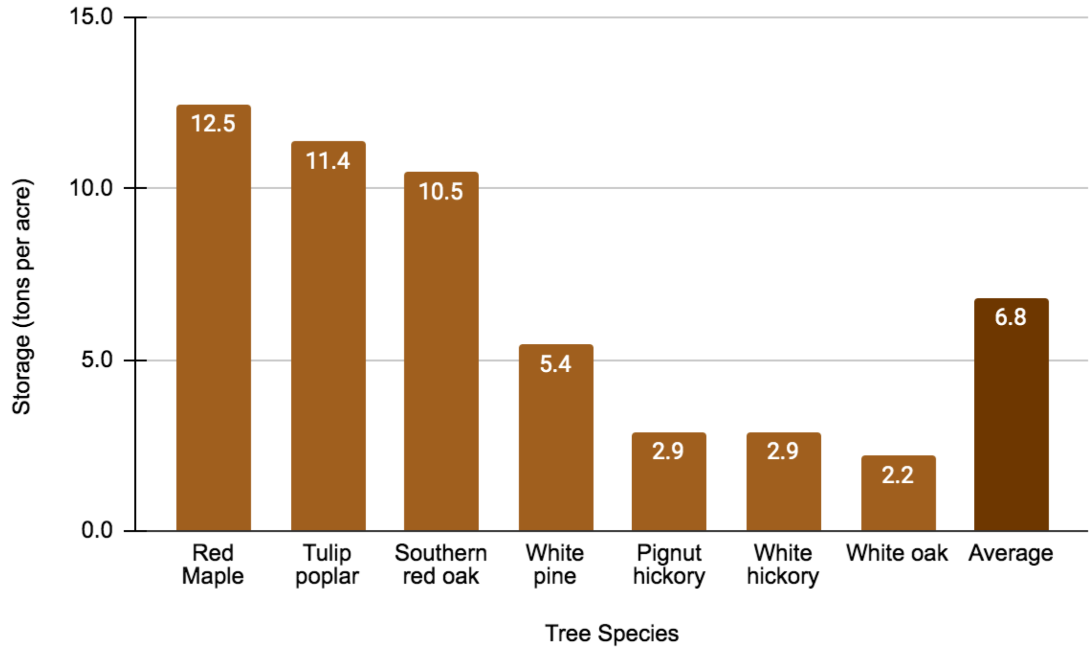

Figure 9. Total Carbon Storage (tons per acre) of New 26-Acre Forest by Tree Species in 2050.

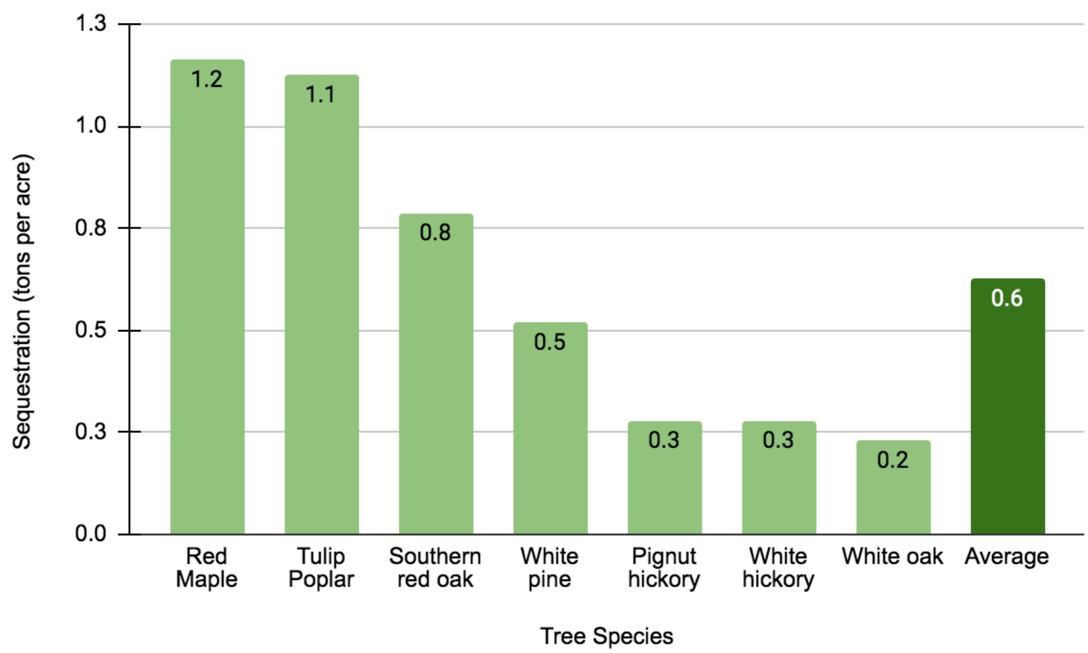

Figure 10. Total Carbon Sequestration (tons per acre) of New 26-Acre Forest by Tree Species in 2050.

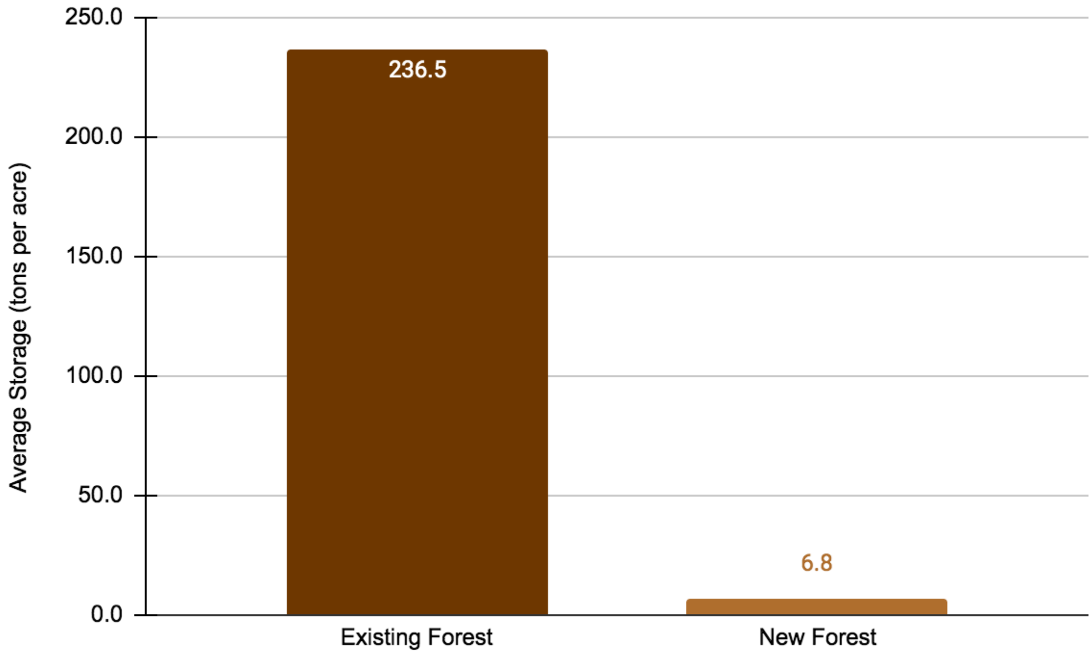

Figure 11. Comparison of Average Carbon Storage (tons per acre) of Existing and New 26-Acre Forest in 2050.

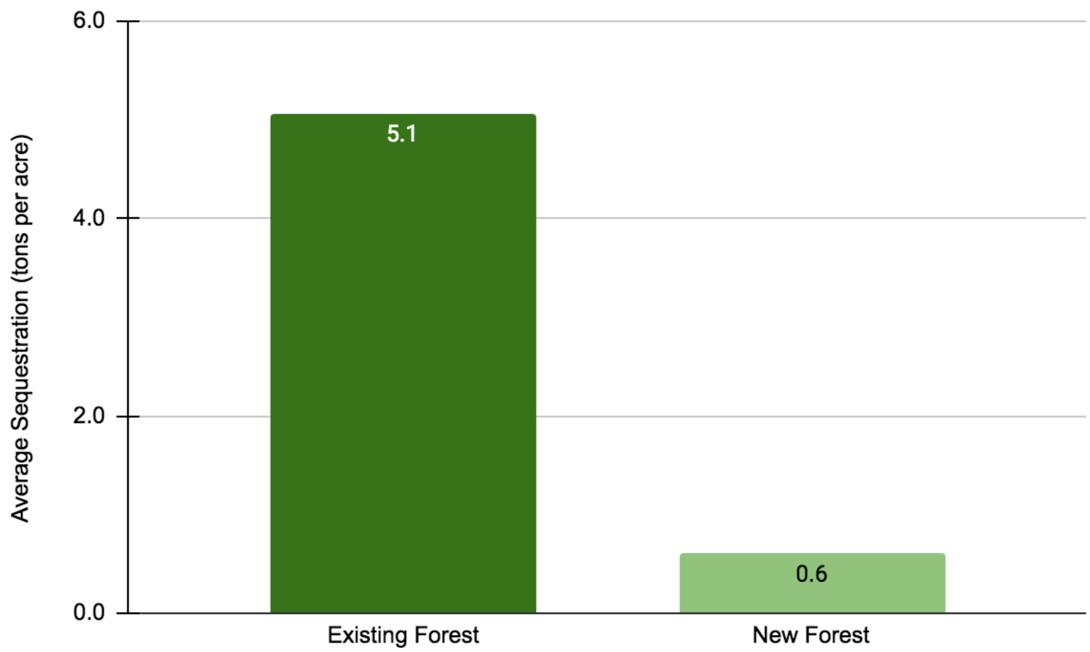

Figure 12. Comparison of Average Carbon Sequestration (tons per acre) of Existing and New 26-Acre Forest in 2050.

4. Discussion and Conclusions

The above findings confirm the initial hypothesis of this research: preserving the existing forest of unit 35/41 has significantly greater potential to store and sequester carbon now and over time when compared to planting new trees in the same 26-acre area. This can be due to a number of factors. The most evident factor in the data is that the existing forest has a much wider range of age classes, which includes the older age classes which have the ability to store and sequester much more carbon than the younger age classes. The findings of this research support that growing only one type of age class in a 26-acre forest will inevitably lead to lower carbon storage and sequestration– this reiterates the importance of maintaining existing forests for a diversity of age classes to reach optimal carbon storage and sequestration values.

Logging an existing forest with a diverse range of ages, especially with mature trees, will not only release carbon back into the atmosphere as the trees lose their ability to store and sequester, but also reduce the overall carbon stock stored in the forest biomass (Goh, 2017). Replacing that mature, diverse forest with new trees will actually result in a net increase of atmospheric CO_2 for the time that it takes those new trees to reach adequate maturity; the time-lag in receiving carbon storage and sequestration benefits for new trees means that it could take several harvest intervals to reach what the mature forest had stored and sequestered–even with productive tree species (McKinley et al., 2010). This time-lag can be visualized in the figure below, where researchers at MIT used ClimateInteractive's EnROADS simulator to model how the planting of one trillion trees would affect global temperature over the coming decades until 2100 (Figure 13; Joselow, 2023). Figure 13 emphasizes that it takes a significant amount of time for new trees to begin capturing enough carbon to make a difference in the global climate–this also assumes that the new trees would survive to this point.

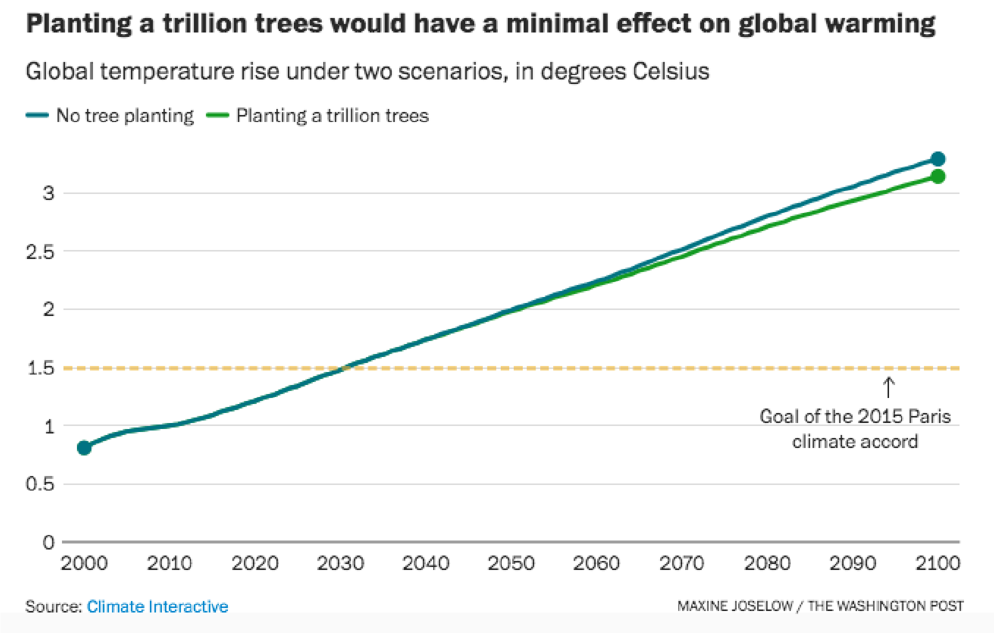

Figure 13. The effect of planting one trillion trees versus planting zero trees on global temperature from 2000 to 2100 (Joselow, 2023).

There are a variety of factors that go into planting trees, albeit successfully so all the carbon benefits are eventually reaped. Carrying out a reforestation or afforestation project requires extensive planning, evaluation, and local expertise to determine if planting the chosen tree species would benefit or harm the surrounding ecosystem (EcoEnclose.com, 2023). After planting, the trees need to be adequately monitored for many years to ensure they are growing properly to effectively carry out their offset requirements (EcoEnclose.com, 2023). Equitable distribution of projects is a large issue that tree-planting offset projects can face, as many are carried out in the Global South whereas most emissions come from the Global North (Fleischman et al., 2020). The social aspect of tree-planting projects is therefore important; maintaining a positive relationship with the local community is essential to ensure the success of a project (Fleischman et al., 2020). Since the tree-planting trend has grown so large, many governments offer incentives for planting trees which could encourage projects to clear-cut native forests and plant a variety of trees or even only one species, essentially creating a monocrop; monocrops provide little value to the surrounding wildlife and ecosystem and can disrupt the balance of soil, ultimately reducing carbon stock of the forest even more (Hua et al., 2019). Many forested areas with higher species richness have a positive relationship with carbon storage, so a diversity of species should be prioritized (Bentsi-Enchill et al., 2022).

The new-forest model in this research could potentially represent the carbon storage and sequestration of a monocrop, as each tree species was modeled separately. This model, though, is not an entirely accurate depiction of typical tree-planting efforts, as many assumptions were made and there was no accounting for the additional anthropogenic forest management activities that occur during reforestation such as fertilization, irrigation, disease and pest control, pruning, and stand thinning (Liang et al., 2022). Both models could certainly be improved for more accurate representation of the area. More precision could be brought when manually counting trees in the LiDAR data so the total number of trees could be more exact instead of a rough estimation; in turn, the carbon storage and sequestration values (which account for the number of trees per acre) would be more accurate. The distribution of tree species could also be obtained to model the real mixed forest, which would help with comparisons to other work and root our research more in reality by representing the specific area.

This research can provide a helpful framework for future efforts to improve on current inaccuracies and also apply these methods to other forested areas or similar logging projects. With more accurate data, the results derived from this framework could inform the general public as well as the USFS on the importance of preserving existing forests for their continued carbon-capture abilities. The USFS is currently being sued by the Southern Environmental Law Center for "failure to properly study the massive environmental and climate impacts" in their timber-sale evaluations (MountainTrue, 2024), so the modeling demonstrated in this research could provide more transparent information to the public and ultimately support the USFS in developing more accurate and appropriate carbon models. The value of carbon storage and sequestration should not be overlooked in an age where it is needed most; continuing to analyze the carbon-capture potential of forested areas is therefore important to garner greater evidence, awareness, and support for effective climate-change-mitigation strategies.

5. Acknowledgment

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