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Carbon Storage and Sequestration Forecast for Campus Trees Threatened by Exotic Invasive Plants: Meeting the Campus Carbon Commitment

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Abstract

This study examined the impact of the lack of control of exotic invasive plants on UNCA's carbon budget, building upon earlier research conducted in the university's Biology and Environmental Studies departments. Urban forests can play an essential role in providing sinks for atmospheric carbon. Carbon stored by urban trees is threatened to be rereleased in the atmosphere by the presence of exotic invasive plant species. Invasive plants can exacerbate the impact of climate change by killing trees, causing release of carbon stored therein. On the UNCA campus, without proper management, exotic invasive plants will contribute to the death of urban trees. This study uses i-Tree Eco software to model carbon storage and sequestration in UNCA's urban forests with and without adequate management of invasive plants. Five plots were chosen on south campus that were heavily invaded by species such as English ivy (*Hedera helix)* and Oriental bittersweet (*Celastrus orbiculatus)*. For each tree species, a database was then created quantifying the amount of carbon trees in the plots are projected to store and sequester through 2050, the target date for campus carbon neutrality, if invasive plants were not adequately managed. Zero dieback was assumed from other factors. This created a theoretical maximum of carbon storage and sequestration for each year over the next 27 years. The research employs forecasting and modeling to determine the effect of controlling invasive plants on helping meet the Campus Carbon Commitment. The results of this study provide insight into the

importance of controlling invasive plant species as a means of mitigating climate change.

1. Introduction

According to the IPCC (2023), increasing atmospheric carbon dioxide levels are causing the global climate to warm. The global temperature is expected to increase 1.5 degrees Celsius more than pre-industrial temperatures between 2030 and 2053. (IPCC,2023). Carbon dioxide makes up the majority of greenhouse gas emissions mainly from fossil fuel combustion (Schneider, 1989). Urban areas specifically have been shown to contribute more than rural areas to climate change with higher use of fossil fuels (Nowak, 2000). Universities in particular account for around 2% of carbon emissions in the US (Sinha et al. 2010). As a response to the threat of climate change, many universities have increased on campus sustainability programs and committed to reduce carbon emissions (Second Nature 2018). As of 2018, 372 universities pledged to be carbon neutral by the year 2050 (Second Nature 2018). University of North Carolina Asheville (UNCA) signed the Campus Carbon Commitment, which pledges the university to reach carbon neutrality by 2050 (Ormsby et al. 2021)

Previous studies have shown that trees in urban forests, as well as urban vegetation, can have a variety of benefits including stormwater management, atmospheric pollution removal, and microclimate regulation in cities (Bolund and Hunhammar, 1999). Terrestrial forests offset around 15% of US fossil fuel emissions (Woodall et al. 2015). Literature in forestry has shown managing forests in order to maximize carbon storage is paramount to aid in natural climate solutions (Todd et. al 2019). More recent studies examined urban trees as a mechanism for carbon storage and sequestration, specifically on university campuses. One study done at the University of Georgia found that trees on their main campus stored about 3,450 tons, (SD-65) of carbon with an annual sequestration rate of 65 metric tons (mt) (Fox et. al, 2020). A similar study was done at the University of Pennsylvania, where the researchers found that urban trees on their main university campus sequestered 11 mt/ha of carbon (De Villers, 2014). A previous study done at UNCA calculated that there was 125.6 mt/ha of carbon in one of forested areas owned by UNCA- similar to the study site used in this research.(Keller,2022)

While urban forests and trees on university campuses can provide ecological services, they are often poorly managed. Invasive plant species present a significant challenge to urban ecosystems, including urban trees and their carbon sequestration potential. When a tree dies and decomposes, it goes through a process known as heterotrophic respiration. This is where stored carbon in the woody tissue of the tree is re-released into the atmosphere (Hammon et al. 2011). In many urban areas, invasive species take over green spaces. This biological invasion dramatically decreases native biodiversity (Vilà, Montserrat, et al., 2011). Disturbances in forests have been shown to decrease the maximum amount of carbon storage and make using forested areas to offset emissions less effective. (McKinley, Duncan C., et al 2011) Removal of invasive plant species is part of a suite of viable climate solutions that are important both to maintain native ecosystems and encourage the overall health of trees in order to promote terrestrial carbon storage. (Westbrooks, Randy G, 1998)

This study adds to the recent literature quantifying the current carbon storage and projected carbon sequestration of urban trees through a case study on UNCA's south campus. This study forecasted carbon storage and sequestration of a sample area in a forested area of UNCA's campus over the next 27 years. Carbon storage and sequestration was estimated using I-Tree Eco software. This is a software created by the United States Forest Service that employs allometric equations to provide estimates of the urban forest structure.This study is part of a larger project at UNCA and builds on previous work. A previous study was conducted in 2022, quantifying current carbon storage and sequestration in the same study plots used during the course of this study. Previous data was used to further assess the current threat of invasive woody vines and other invasive plant species to the trees in this area in order to contextualize the urgent need for resources devoted to removal of invasive plant species to maintain the health and carbon stock potential of UNCA's urban forested properties.

2. Methods

2.1 Site description

The study site is located in the Blue Ridge mountains on UNCA's campus. UNCA's campus includes a small urban forest on the south campus that serves as a green space with walking trails and parking lot access (Fig 1). Invasive plant species have taken over much of the forest due to high levels of disturbance and anthropogenic activity. Five plots within the site area were selected in areas most highly threatened by invasive species along the main walking trail. A center point was determined for each of the plots and measured 10.0 meters out to the four corners at the perimeter of each plot. Each plot was designed to be an area of 400 square meters (0.04 hectare).

Fig.1 Map of plots selected on UNCA's south campus

2.2 Data collection

Background data for the five plots was collected during 2022 and published in a previous study. (Meyers,2022) This data was used in this study to calculate carbon storage and sequestration results through 2050. During this previous study, within each plot, all native trees larger than 2.5 cm diameter at breast height (DBH) were manually identified to the species and recorded. The DBH of these trees were then measured and recorded. Trees that measured below 2.5 cm DBH were not included in the final data set nor were invasive trees-118 trees in total were measured but some were excluded from the final data set (mostly due to being dead) bringing the total down to 106 trees. All invasive plant species on and within 1.0 meters of the tree were identified and recorded as well as a visual estimate of the percent of the tree covered in invasive species. A subjective scale was created to rate the threat that each tree faced based on the presence of invasive plant species. A numerical value between 0-6 was then assigned to each tree based on the percent of the tree that was covered with invasive species.(Table 1)During the data collection process, the research team cut invasive vines on the trees measured with loppers or garden shears. A cut and paint method was then used– applying Triclopyr to the cut vine in order to kill the invasive plant.

Description	**Rank**
No invasives present within 1.0 meter radius of tree	0
Invasives present within 1.0 meter of tree but not on tree	1
Invasives covering 0-25% of tree	2
Invasives covering 25-50% of tree	3
Invasives covering 50-75% of tree	4
Invasives covering 75-100% of the tree	5
Tree is dead	6

Table 1. Risk assessment scale. This scale was used as an objective measurement to assess the level of risk each tree faced due to invasive species. (Meyers, 2022)

2.3 Data analysis

Previous research calculated the amount of carbon stored and carbon sequestered in the trees located in each of the five plots based on a 30% annual dieback rate. (Meyers, 2022) This study used the previously recorded DBH measurements and invasive plant threat values to simulate what carbon sequestration and storage would look like over the next 30 years with no invasive plant species present in the area. To understand the maximum carbon sequestration and storage potential in these trees, a catalog of each tree species present in the plot was created, assuming that each tree started at a DBH of 2cm. Following this, i-Tree Eco software was used to forecast each tree species measured in the five plots for the duration of 100 years assuming zero percent dieback. This database was then used to calculate carbon storage and sequestration in all five plots assuming that all trees over the next 27 years face zero die back. This database created a catalog of carbon storage in each tree species over the next 27 years. This data was then matched to trees in the existing plots based on species and recorded DBH. Twenty-seven years was used in order to model carbon storage through the year 2050, which aligns with the year by which UNCA plans to be carbon neutral. This forecast was done to model carbon storage and sequestration when all invasive plants are removed from the area.

3. Results

Previous researchers found that of the 106 trees rated on the subjective scale for invasive plant severity, only 4 trees received a rating of zero. These non-threatened trees account for only about 3.8% of the total trees in the survey. This score indicates there were no invasive plants present within 1.0 meter of the base of the tree. The remaining 96.2% of the trees that were assessed received a rating between 1-6, indicating the risk of invasive species was present.(fig.2)

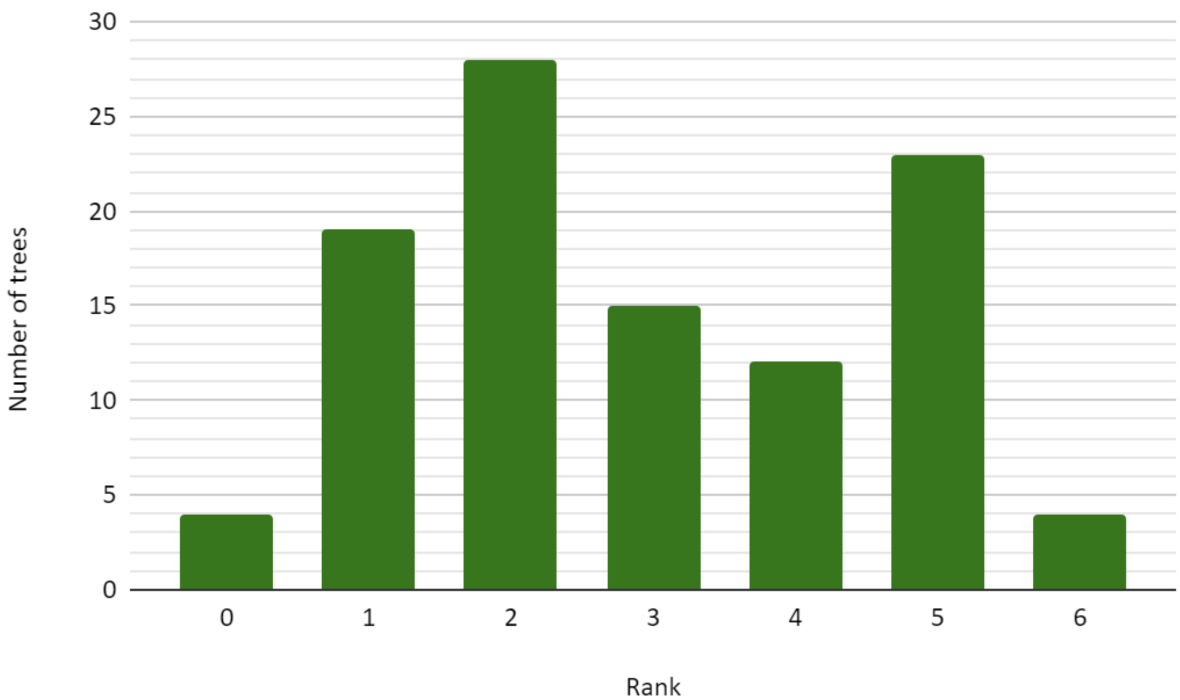


Fig.2 Number of trees that received each of the ratings for invasive species presence (Meyers, 2022)

The most prevalent invasive species present in the study area were Oriental bittersweet (*Celastrus orbiculatus)* and English ivy (*Hedera helix)*. The former makes up 22.3% of the invasive species surveyed in the area. English ivy (*Hedera helix)* made up 19% of the total invasive plant species present. Poison Ivy (*Toxicodendron radicans*) made up 14% of the total population of invasive species present.(fig.3) Although Poison Ivy (*Toxicodendron radicans*) is native to the area, high anthropogenic disturbances allow this species to become invasive in some cases and threaten biodiversity similar to an exotic invasive plant species. Due to the nature of Poison Ivy (*Toxicodendron radicans*) in the south campus forest, this was included in the data set.

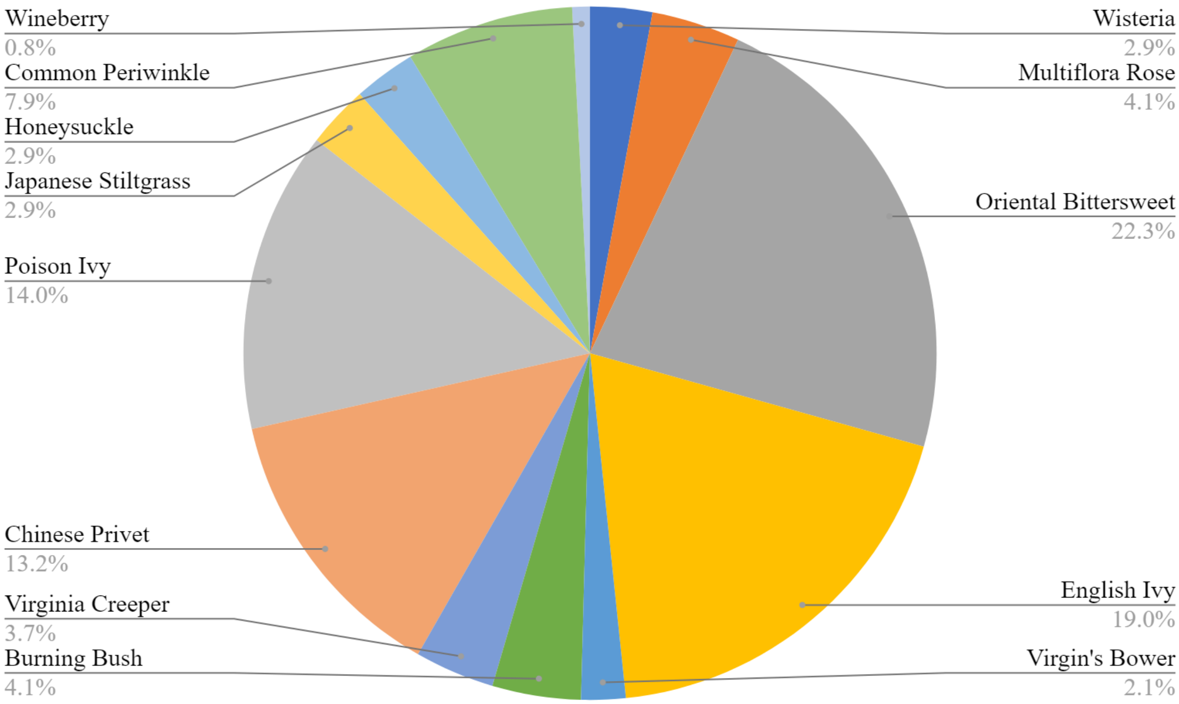


Fig.3 Abundance of invasive plants surveyed by species (Meyers, 2022)

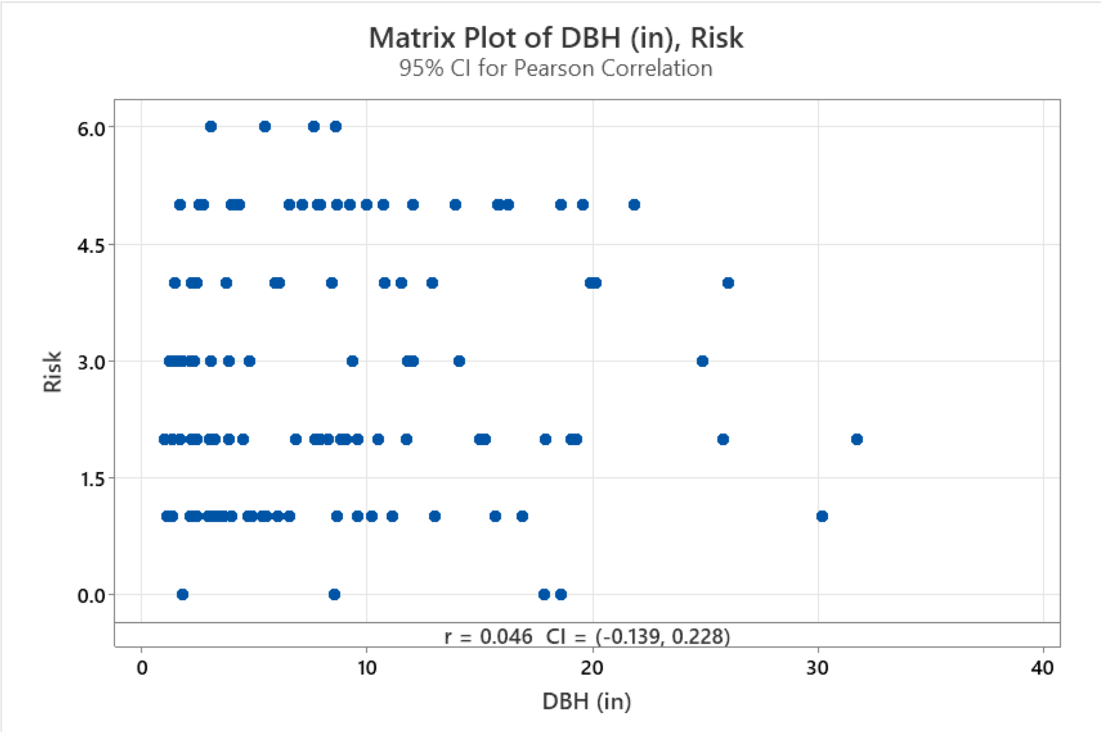
During 2022, twenty species of native trees were identified within the five plots. The most abundant species being Eastern White Pine *(Pinus strobus)* and Black Cherry *(Prunus serotina)*, which collectively make up 35.82% of the trees in the data set. (Table 2)

Species name	Percent population
Black cherry *(Prunus serotina)*	17.92
Eastern white pine *(Pinus strobus)*	17.92
Black haw *(Buteogallus anthracinus)*	13.21
Boxelder *(Acer negundo)*	7.55
Tulip poplar *(Liriodendron tulipifera)*	6.6
White hickory *(Carya tomentosa)*	4.72
Southern red oak *(Quercus falcata)*	4.72
Redbud *(Cercis canadensis)*	3.77
Mulberry *(Morus alba)*	2.83

White ash *(Fraxinus americana)*	2.83
Shagbark hickory *(Carya ovata)*	1.89
White oak *(Quercus alba)*	1.89
Black ash *(Fraxinus nigra)*	1.89
American hazelnut *(Corylus americana)*	0.94
Sweet birch *(Betula lenta)*	0.94
Flowering dogwood *(Cornus florida)*	0.94
Red maple *(Acer rubrum)*	0.94
Pignut hickory *(Carya glabra)*	0.94
Blackjack oak *(Quercus marilandica)*	0.94
Scarlet oak *(Quercus coccinea)*	0.94
Total number of trees	**106**

Table 2. Abundance of trees sampled by species (Meyers,2022)

During the previous study conducted in the five plots, a correlation between DBH of the trees and the level of invasion was considered. This was plotted and no visual correlation was found between the two variables. To verify this, during this study, a linear regression was done for DBH and level of invasion. The P-value of this was 0.627. A very slight positive relationship was found, but not significant. A correlation test was also run on the two variables. The r value for this test was 0.046. No significant correlation was found between DBH and level of invasion. (Fig.4)



(Fig.4) Plot of correlation between DBH and level of invasion for each tree

Previous research found that in fall 2020, these five plots stored 26.27 metric tons of carbon (Meyers,2022) This previous study also found that these plots sequester carbon at a rate of 0.895 metric tons per year. This study's forecast model predicted that these same plots will store 15.7 additional metric tons of carbon by 2050. This is a total of 41.97 metric tons. (Table 3).

	Carbon storage (metric tons) by 2050	**Carbon sequestration (metric tons) in 2050**	**Number of trees in plot**
Plot 1	10.77	0.27	19
Plot 2	9.85	0.34	35
Plot 3	3.48	0.10	10
Plot 4	8.92	0.24	19
Plot 5	8.95	0.23	23
Total	**41.97**	**1.18**	**106**

Table 3. Predicted carbon storage and sequestration in each of the five plots

A few similar studies have been conducted at other universities in the southeast region. Based on the 5 sample areas, it was estimated that the carbon storage in all of the trees on the south campus forest have the potential to store 257.5 mt/ha of carbon by the year 2050, based on the 5 plots we sampled. One of the previous studies conducted at UNCA found that trees on main campus currently store 125.6 mt/ha of carbon (Table 4) (Keller,2022). Assuming that these plots are representative of the south campus forest area, it would be estimated there are around 525 trees per hectare. Under this assumption, it would be estimated that there is a theoretical maximum of 209.85 mt/ha of carbon storage possible in 2050. Using the measure tool on Google Maps a larger area was outlined using the existing trail system as the outermost boundary. It was estimated that this larger area of south campus forest area is 5.57 hectares (ha). From this it was assumed that the area within the trail system in south campus forest would have the maximum potential to sequester 1,168.87 mt of carbon in 2050.

	University of North Carolina Asheville (Meyers,2022)	**University of North Carolina Asheville (Keller 2022)**	**University of Georgia (Fox et. al 2020)**	**University of Pennsylvania (Bassett 2015)**
Area	0.2 ha	35 ha	94.1 ha	64.7 ha
Tree density	525 trees per ha	1,046 trees per hectare	73.5 trees per ha	62.3 trees per ha
Carbon Storage	131.5 mt/ha	125.6 mt/ha	36.6 mt/ha	11 mt/ha

Table 4. Comparison of area, tree density and carbon storage found in similar studies

The twelve trees with the largest DBH measurement in the data set included three Tulip poplars *(Liriodendron tulipifera)***,** two Southern Red Oaks *(Quercus falcata)*, one blackjack oak *(Quercus marilandica)*, one scarlet oak *(Quercus coccinea)*, one black cherry *(Prunus serotina)*, and one boxelder *(Acer negundo)*. These twelve largest trees, 11.3% of the total number of trees, are predicted to account for 35.4% of the total carbon stored within the five plots in 2050. Previous research showed that these trees currently store 14.23 metric tons of carbon (Meyers,2022). This study projects that these twelve trees have the potential to store 8.94 more metric tons of carbon over the next 27 years. (Fig.5) Using the estimate that the entire south campus forest has a maximum potential of 1168.87 mt of carbon storage in 2050, we can assume 35.4% of that carbon storage will be held in the 11.3% of the largest trees in 2050. This would mean the 12 largest trees would have a maximum carbon storage potential of 413.78 mt in 2050.

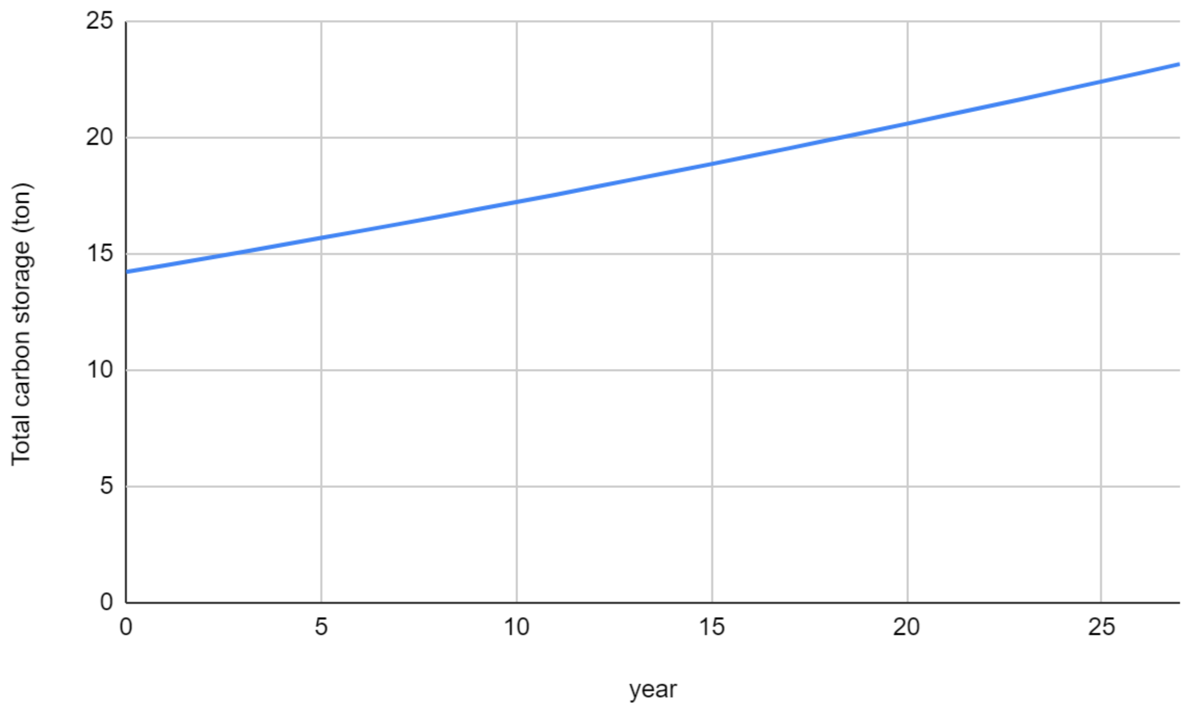


Fig.5 Total carbon storage over the next 27 years in the twelve largest trees

4. Discussion

An alarming amount of invasive species were noted in UNCA's south campus forest. 96.2% of the trees we surveyed were threatened by invasive species, accounting for a large majority of trees in this study. Even considering the small portion of trees that received a 0 on the subjective scale, the severity of the nearby infestation makes it likely that these trees will become threatened in the near future. These invasive species degrade the natural habitat and threaten the carbon storage potential in the south campus area.

This study estimated that there is a maximum carbon sequestration potential of 257.5 mt/ha in the south campus forest area. This assumes a theoretical maximum. In this case, simulating the maximum carbon sequestration potential if all trees in the south campus forest stay at optimum health over the next 27 years. Given the severity of the infestation of invasive plant species in the area, these trees will not likely survive without intervention. The carbon they hold will likely be re-released into the atmosphere. Further contributing to climate change. The loss of these trees would also not allow UNCA to use this area as a carbon offset in order to reach carbon neutrality by 2050. This study gives a rough estimate of carbon storage per hectare in 2050 based on the assumption that the five plots were representative of the south campus forest. Due to species variation and size variations, satellite and GIS data would need to be used in the future to acquire a more accurate estimate. It would also be necessary to acquire a more accurate estimate of the total area in the entire south campus forest.

In comparison to the studies conducted at the University of Georgia and the University of Pennsylvania, both studies conducted at UNCA show more trees per hectare. Both studies at UNCA also show greater carbon storage than the other two universities. This could be due to the nature of the study sites. University of Georgia and the University of Pennsylvania both were conducted on highly urban trees on the main campus of their respective universities. This meant that the study areas came into contact with urban features such as buildings and sidewalks. On the other hand, both UNCA studies were conducted in more forested areas.

Due to time and resource constraints, there are several variables that need further research. There is a lack of current research available on the time frame that invasive woody vines cause trees to die. Due to lack of existing scientific literature in the area, the rate that invasive plant species would kill the trees was unable to be determined. It is suggested that future studies seek to better understand the interactions between native trees and invasive species, as well as how fast invasive species grow in their habitat. It is also suggested that research detailing the rate at which invasive species can cause tree mortality. Another area to look into would be the amount of carbon stored in the soil and what effect the presence of invasive plant species have on both soil health and the maximum amount of carbon storage. In order to begin to mitigate the effects of invasive plant species on UNCA's campus and preserve tree's ability to store and sequester carbon, the Invasive Plant Management Club should continue to be active in removing invasive species on campus. Resources should be allocated by the university in order to aid in invasive species mitigation and continue to protect urban forests on UNCA's campus.

This study explored a theoretical maxim of carbon storage and sequestration through 2050 on a portion of UNCA's forested property. Given the severe level of invasion in this areas, it is likely that these trees will be killed or severely damaged over the next 27 years. This damage caused by invasive species present in UNCA's south campus forest will almost certainly reduce carbon storage in these trees. There is an urgent need for invasive plant management on UNCA's campus in order to protect carbon storage potential in trees. This study also found that the largests trees in UNCA's urban forest area on south campus make up a large percent of carbon storage. The 12 largest trees made up 35.4% of the total carbon storage in the five plots projected for 2050. This highlights the need for prioritization of proper management of the largest and oldest trees on UNCA's campus in order to maximize carbon storage potential. The case study done on south campus can be applied to other areas of campus when considering management of UNCA's trees.

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Sources

Alison Ormsby, Jackie Hamstead, Dan Croisant, Evan Couzo, Kelsey Hall, India Appleton, Ally Fouts, Corey McVay, Anna-Lisa Keller, Lindsey Nystrom, Mae Tesh, Julia Weber, J. Zimmer, “Addressing Campus Greenhouse Gas Emissions: Climate Action Plan,” *UNC Asheville’s Office of Sustainability* 1, (2021): 1-29.

Bolund, Per, and Sven Hunhammar. "Ecosystem services in urban areas." *Ecological economics* 29.2 (1999): 293-301.

De Villiers, Charl, et al. "Carbon sequestered in the trees on a university campus: a case study." *Sustainability Accounting, Management and Policy Journal* 5.2 (2014): 149-171.

Fox, William, et al. "Estimating carbon stock of live trees located on the main campus of the university of georgia." *Journal of Forestry* 118.5 (2020): 457-465.

Harmon, M. E., Bond‐Lamberty, B., Tang, J., & Vargas, R. (2011). Heterotrophic respiration in disturbed forests: A review with examples from North America. *Journal of Geophysical Research: Biogeosciences*, *116*(G4).

Hoesung, Katherine, et. al. “Climate Change 2023 synthesis report.” *International Panel on Climate Change* (2023)

Anna-Lisa Keller, “Inventorying University of North Carolina Asheville’s Forested Properties to Assess Carbon Stock,” *University of North Carolina Asheville Journal of Undergraduate Research* (2022),

McKinley, Duncan C., et al. "A synthesis of current knowledge on forests and carbon storage in the United States." *Ecological applications* 21.6 (2011): 1902-1924.

Meyers “Carbon Sequestration in the Face of Invasion: Invasive Species as a Threat to UNC Asheville’s Carbon Stock” *University of North Carolina Asheville Journal of Undergraduate Research*.(2022)

Nowak, D. J. "The interactions between urban forests and global climate change." *Global climate change and the urban forest* 31 (2000): 44.

Ontl, Todd A., et al. "Forest management for carbon sequestration and climate adaptation." *Journal of Forestry* 118.1 (2020): 86-101.

Schneider, Stephen H. "The changing climate." *Scientific American* 261.3 (1989): 70-79.

Second Nature . 2018. *Second nature: 2017–2018 impact report.* Tech. Rep. Boston, MA. 21 p

Sinha, Parikhit, et al. "Greenhouse gas emissions from US institutions of higher education." *Journal of the Air & Waste Management Association* 60.5 (2010): 568-573.

i-Tree Canopy. i-Tree Software Suite v5.x. (n.d.).itree tools.org.8 May 2023

Vilà, Montserrat, et al. "Ecological impacts of invasive alien plants: a meta‐analysis of their effects on species, communities and ecosystems." *Ecology letters* 14.7 (2011): 702-708.

Westbrooks, Randy G. "Invasive plants: changing the landscape of America." (1998).

Woodall, Christopher. "US forest carbon accounting framework." *General technical report NRS; 154* (2015).