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The Forest of Claytor Nature Center as a Carbon Offset; Assessing the Sequestration Potential and Socioeconomic Implications

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Project Summary

Cap and trade programs limit the amount of emissions an organization can produce. To neutralize unavoidable emissions, organizations can purchase carbon offsets from the carbon market. The ability to quantify greenhouse gas emissions offsets in forests increased the urgency and popularity of the carbon market because carbon dioxide (CO2) has a large role in climate change. The University of Lynchburg's Claytor Nature Center's 332-acre forest could be a viable revenue source because of its ability to remove CO2 from the atmosphere. In this research, the potential number of annual offsets from Claytor Forest was measured through a manual biomass survey. I assessed tree quantity, size, height, and species in 1/10-acre samples and used existing biomass equations to calculate how much profit the forest could bring to the university and which tree species are best to plant for maximum profit and emissions reductions. A cost benefit analysis of this forest offset project was conducted because the school previously purchased credits from the market to be considered "Carbon-neutral." Instead, forest generated offsets will be purchased from the university by others seeking neutrality. This research is important because the school is experiencing a budget deficit and with the utilization of Claytor Forest the university could overcome financial struggles and be motivated to reduce our emissions directly. Campuses and communities can play a large role with the strategic environmental planning of their land. With the exponential growth of carbon's economic value, I also assigned economic value to Claytor Forest's community benefits and global impact since the forest provides a variety of significant services beyond GHG emissions removal. This research assigns economic worth to land that previously only had intrinsic value and allows everyone to grasp the positive impact of every single tree in the global fight against climate change. This research investigates and offers potential solutions to three key questions. Can the biomass of Claytor forest offset a

considerable amount of the University's emissions to help retain carbon neutrality? Will the revenue of the carbon offsets be able to support the school during the financial deficit? Is the carbon market an appropriate method to mitigating climate change?

Rationale

This research quantifies the value of Claytor Nature Center and other similar forested areas. Carbon sequestration can be used to offset an organization's carbon footprint internally or can be sold on the carbon offset market for others to use as emission reduction credit. This research will help developers understand the significance of the land they are urbanizing, or it can help landowners know which tree species to plant in their communities or campuses to offset their carbon footprint. Carbon sequestration is the key to achieving a global warming rate under 1.5 degrees Celsius. Carbon sequestration addresses the issues of deforestation, climate change, and urban sprawl. All three issues urgently need more attention than ever because of the worsening effects of climate change. This paper addresses the effectiveness of the market as a climate change solution or conservation method through counterarguments. Financially, revenue from the offsets can generate many opportunities for the school at any time with the use of a Conservation Stewardship Program contract. Currently, The University of Lynchburg suffers from a budget deficit that limits important resources for students and faculty. Campus forest projects are not a popular research topic, although higher education institutions are beginning to take bold green steps. This solution is cutting edge and progressive for institutions financially struggling.

Acknowledgements

At Claytor Nature Center, I had assistance from Dan Miles and Dave McCollum during data collection. Director Jennifer Wills aided in providing additional details on Claytor. At the University of Lynchburg, my thesis advisor Dr. Laura Henry-Stone reviewed and guided this process alongside other committee members.

Introduction

Our planet has been facing a dramatic increase in greenhouse gas emissions that are accelerating widespread climate change. The common greenhouse gasses -- carbon dioxide, methane, and nitrous oxide -- are all emitted by the burning of fossil fuel and by agriculture. The exponential increase of these gasses inhibits the homeostasis process -- the greenhouse effect -- which maintains Earth's temperature. These gasses trap solar radiation in the atmosphere, yet the gasses cannot be sequestered at the rate they are being emitted compared to pre-industrial levels. Governments and organizations are acting now because climate change threatens human rights, food sources, the global economy, and wildlife. Developed countries are becoming aware of the suffering populations around the globe and taking steps to decarbonize.

Atmospheric carbon is absorbed through photosynthesis and is deposited in forest biomass, tree trunks, branches, and roots. The Earth's forests and oceans are the greatest carbon sinks available. A forest is considered a carbon sink if it absorbs more carbon than it emits. Typically, forests absorb twice as much as they emit (Harris and Gibbs, 2021). Carbon dioxide (CO_2) is emitted as trees die or are cleared. Therefore, if we continue to deforest and use fossil fuels, a positive feedback loop is created, increasing the global warming effect because atmospheric CO_2 emissions increase, and sequestration decreases. Harris and Gibbs found that the world's forests emitted an average of 8.1 billion metric tons of CO_2 each year due to deforestation and disturbances, while the forests absorbed 16 billion metric tons of CO_2 per year (2021). This relationship is called "carbon fluxes" (2021).

One way to control emissions in each country is by implementing a cap-and-trade program, which allows the government to cap how much a company or group can emit. If the company does not emit all that they are allowed, they receive *credit*. If a company cannot remain under their cap, they must buy credit from the companies with unused or leftover emissions to stay within the threshold. This system places a price on carbon, rewards sustainable businesses, and allows trading of carbon credits. The carbon market is currently gaining importance as the interests in incentives for clean energy and carbon storage have grown exponentially. In the United States there are two types of carbon markets because the cap-and-trade system is not nationally adopted. California and New England states are the only governments that implement statewide regulation, making it a compliance market in which everyone must follow their allowances per law. The second type, for the rest of the United States, is the voluntary market. Participation is optional and participants may choose to buy credit to reduce their footprint or register a carbon offsetting project that will produce revenue while reducing their footprint (Carbon Credits, 2022).

Carbon neutrality means the annual net emissions equal zero through energy saving or offsetting initiatives. The University of Lynchburg claimed carbon neutrality for the 2019-2020 academic year, becoming the first carbon neutral university in Virginia. After successes in conservation and reducing consumption, the school noticed that neutrality could easily be reached by purchasing offsets from a renewable energy provider. Dr. Michael Craig began inventory for the university's emissions and analyzed the benefits of purchasing offsets. Dr. Craig used computer programs SIMAP and iTrees to collect these data and roughly estimated the potential offset value of Claytor before leaving the institution shortly after. Because of his research, the school was able to claim neutrality, and I am furthering his study. The 2019-2020 year was the only year offsets were purchased, therefore no longer maintaining neutrality. Purchasing them comes at a high cost because the University is expected to have a significant level of unavoidable net emissions every year. Since 2019, Lynchburg has struggled financially like many other higher education intuitions post-pandemic. Tuition increased, job positions and hours were cut, and organization funding was tight, putting sustainability investments on the back burner as well. The financial crisis and sustainability mission can be remedied with the carbon sequestration of Claytor Nature Center, which will ideally generate enough offsets so that the university will not need to purchase from the carbon market.

The intended outcome of this research is a verified carbon offset project registered through the American Carbon Reserve, a private voluntary greenhouse gas (GHG) registry. The American Carbon Reserve (ACR) is one of the most common voluntary carbon offset registries in the United States and is ideal for college campus projects like this, Colgate University is setting the standard. In 2019, the University of Lynchburg emitted a total of 6,458.99 MT CO_2 (Craig, 2019) requiring the use of offsets to reach the target neutrality. One option to reach neutrality is forest management of the 350 forested acres at Claytor Nature Center. Claytor Forest is converted farmland which has been growing for at least 60 years. To test this proposal, a forest survey was conducted following ACR and USDA protocol using biomass equations required to calculate the gross carbon stock in Claytor forest. Each metric ton of carbon dioxide (MT CO2) stored in Claytor was absorbed from the atmosphere to grow each individual tree. Each MT CO2 has monetary value and contributes to retaining carbon neutrality.

Methods

Of the multiple ACR approved methodologies for GHG removal, the Claytor forest project is classified as "Improved Forest Management (IFM) on Small Non-Industrial Private Forest Lands" (any land that has from 40 acres to 5,000 acres of forest). The Claytor Nature Center property fulfills the applicability conditions for ACR IFM sites. In order to register a forest with ACR, a statistically unbiased sample of inventory plots within the project boundary (project-level inventory) is conducted to derive baseline inventory data. Project-level inventories should optimize carbon stock estimates each year from the baseline (American Carbon Registry, 2021). The ACR IFM is designed to increase emission reductions resulting from forest projects by exceeding the baseline forest management practices. These management practices will be discussed in a later section. A manual forest survey of the 350 forested acres of Claytor Nature Center included 10 plots each representing the surrounding 35 acres to quantify aboveground baseline carbon stock. Facilities Manager, Dan Miles, suggested the plot locations using his knowledge of the different forest types across the property to get an accurate representation. Carbon stock is quantified by calculating total tree volume, then biomass, and converting biomass into carbon dioxide.

The 10 plots were selected using a spread of different forest types found on the property. Therefore, the 10 plots were extrapolated to represent the 350 forested acres. Each plot was 1/10 acre defined by a 37.5 ft tape staked at the center point. The end of the tape was flagged every 45 degrees, creating 8 boundary points. Within the plot, research volunteer Dave McCollum aided with tree identification. Parameters needed for calculations included: diameter at breast height (DBH), tree height, percent cull, and species name for every tree within the plot. These parameters were recorded on paper at the site and then transferred to an electronic spreadsheet where FIA species number was found for each species, needed for biomass equations.

Appropriate biomass equations are published by the USDA Forest Service in Methods and Equations for Estimating Aboveground Volume, Biomass, and Carbon for Trees in the U.S. Forest Inventory (Woodall et al., 2011). This methodology from the Northern Research Station is the universal approach for carbon registries. The gross volume of each individual tree was calculated using species-specific calculations for the Southern region with species-specific coefficients found in the supplements of Woodall et al, (2011). The percent cull of each tree was subtracted from the gross volume to find the individual sound volume. Merchantable biomass is found adding the biomass of the bole and other tree components including the stump, top, and branches. For each separate equation the weight of water (62.4lb) and specific gravity of wood found in the supplements of Woodall et al, (2011) become coefficients. The last two volumes needed for aboveground biomass include stump and top and branches. For these 2 volumes, an adjustment factor is calculated separately for each tree called CRM (Component ratio method). The sum of the bole, stump, and top and branches biomass in each plot was used to find the average biomass per acre. The methodology included example equations for clarification and the data input from Claytor Forest was regularly examined for calculation errors.

$$\text{Volume} = b_0 + b_1 x_1^2 x_2 \qquad x_1 = \text{dbh} \; x_2 = \text{height}$$

Total Bole Biomass= bole wood biomass + bole bark biomass

CRM Adjustment Factor= Total bole biomass / MST (Jenkins, 2004)

Total Stump Biomass= stump bark biomass + stump wood biomass

Top and Branch Biomass= (Aboveground Biomass- MST- Stump Biomass- FOL) CRM

Total Aboveground Biomass (lbs) = Bole + Stump + Top and Branches

$$\text{Total Carbon (lbs)} = \text{Biomass} * 0.5$$

$$\text{Total Carbon (MT)} = \text{Total Carbon} / 2204.62$$

$$\text{Total } CO_2 \text{(MT)} = \text{Total Carbon} * 3.667$$

Results

The biomass conversions indicate that the Claytor Nature Center Forest stand currently sequesters a total of 46,833.13 MT CO_2. This total represents approximately 50 years of forest growth from agricultural land conversion. That is an average of 133 sequestered MT CO_2 per acre as of the 2022 year. The map in Figure 1 displays the 10 plot locations and the total CO_2 in the surrounding 35 acres. Table 1 below includes a plot description for comparison and the annual sequestered CO_2. Annual sequestration is the key measurement used for carbon credits, and this value will increase each year because of forest growth in combination with ACR's Improved Forest Management protocol.

Based on the species make up and geological factors of the property the annual sequestration rate is 1,229.2 MT CO_2 with increased carbon stock from the baseline included. The 1,229 annual offsets are equivalent to the emissions of 265 gasoline vehicles driven for a year. This rate is concluded by dividing the carbon stock of each individual tree by its age and averaging it with the iTrees model estimate rate. The iTrees website calculates annual estimates based on canopy cover found in satellite imagery. The average of these rates is used because dividing the tree by its age does not account for the future growth projected for the forest which iTrees takes into consideration. Using the iTrees website, the estimated total carbon stored in trees according to satellite imagery analysis was 44,145.4 MT CO_2 (Craig, 2019). This estimate is 2,738 MT off the likely more accurate calculated total.

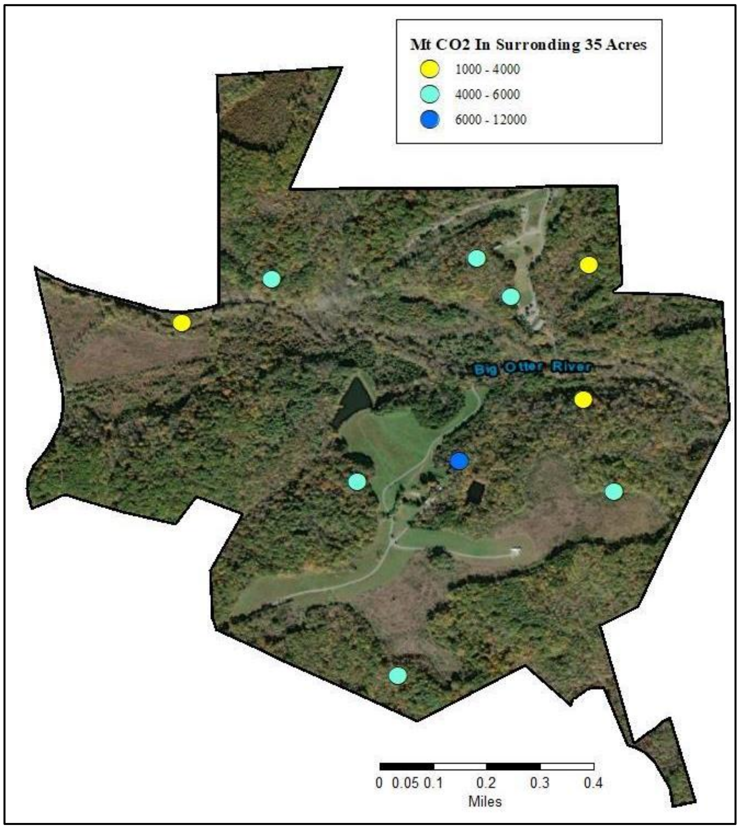

Figure 1. Total Sequestered CO_2 by Plot Throughout Claytor forest.

Table 1	**MT CO_2**	**MT CO_2 Annual 2022**	**Description**
Plot 1	11,019.68	82.42	Severe Eroded Old Field, Mesic
Plot 2	4,026.40	96.34	Former Crop Rows
Plot 3	4,094.25	73.61	Former Crop Rows, Regenerating
Plot 4	5,477.77	52.38	Pine Plantation
Plot 5	2,181.53	33.31	Severe Eroded Old Field
Plot 6	4,105.75	81.30	Wetland
Plot 7	3,527.49	52.52	Former Crop Rows, Mesic
Plot 8	5,154.11	80.94	Hardwood
Plot 9	1,487.60	30.74	Wetland
Plot 10	5,808.56	68.98	Old Growth Hardwood
Total	46,883.13		

The land management plan of Claytor Nature Center that is being developed will include a portion on carbon sequestration which will be discussed later. The data displays which tree species have the greatest carbon capacity compared to a different species at the same DBH. The species with the greatest carbon capacity should be planted for further forest management practices to optimize carbon stock from the baseline. Figure 2 taken from Jenkins et al. (2004) graphs the aboveground biomass of different tree species calculated with the same methodology used in Woodall et al. (2011). Data points from the Claytor forest survey are added to the graph represented by X's. The calculations from the Claytor study show correlation with the analysis compiled from 2,600 biomass equations.

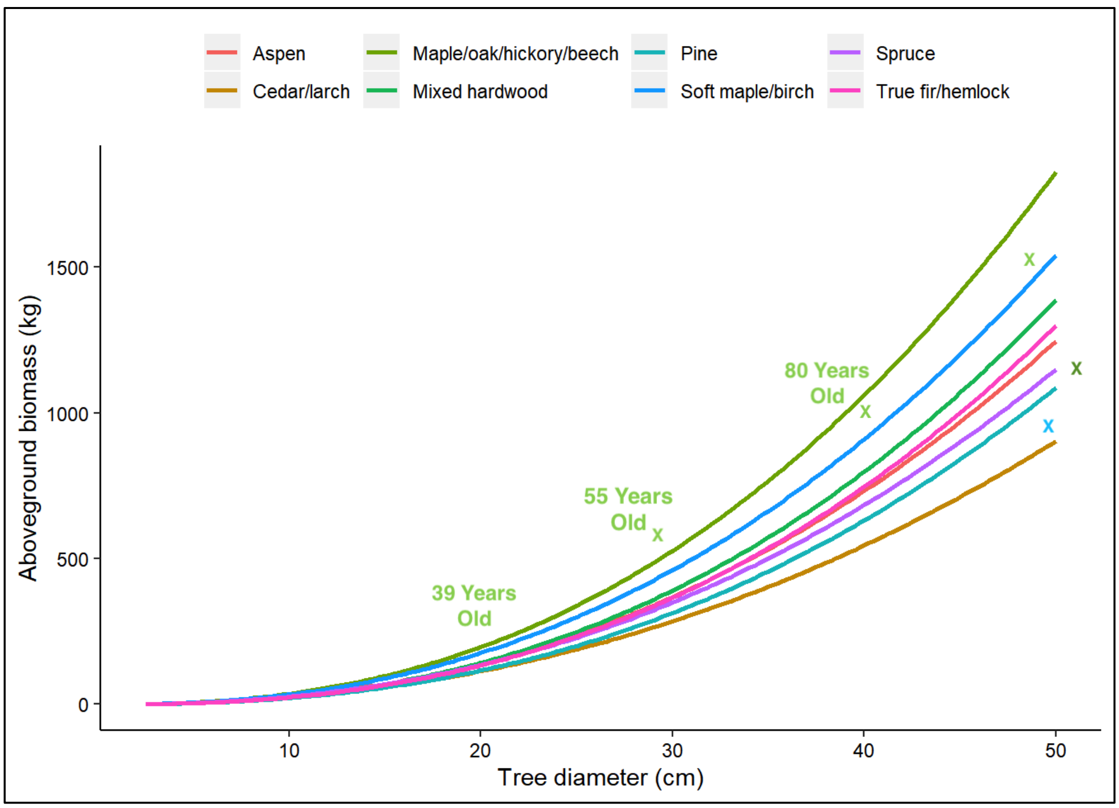

Figure 2. Jenkins et al. (2004) Total aboveground biomass compilation with data from Claytor Nature Center forest survey.

The significant differences between the species groups are revealed in the mature life phases. The maple/oak/hickory/beech group demonstrates the greatest biomass capacity at any given diameter. Within this group, the white oak consistently had a greater biomass than the hickory tree of equal size according to the data. Figure 2 is not detailed enough to display this observation made from the collected at Claytor (Figure 3). White oaks are the ideal species to optimize carbon stock of a forest. These trees are useful for community and urban planning outside of campuses as well. Factors responsible for this difference are specific gravity of bark and wood, bark percent volume, and foliage ratio.

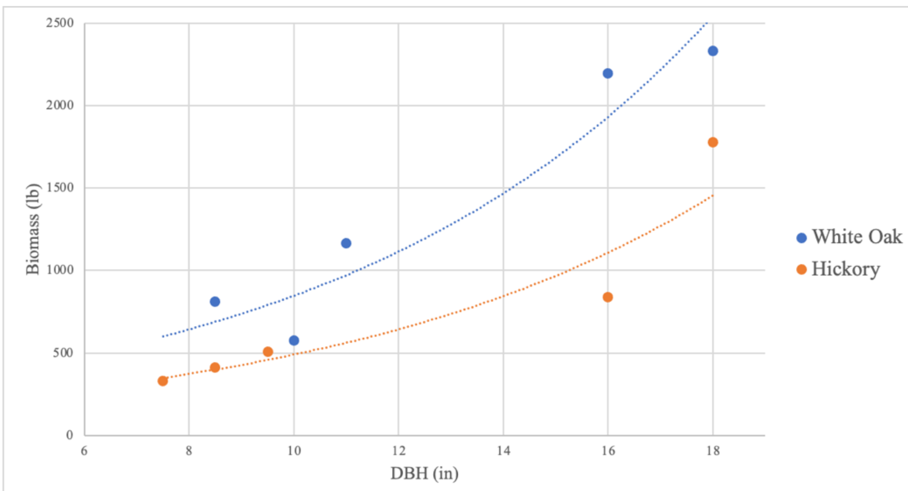

Figure 3. Biomass Comparison between White Oak and Hickory trees at different diameters at Claytor Nature Center.

The non-linear relationship seen in Figure 2 is also important for forest management practices because it should be noted that there is an exponential increase in biomass in the 30-60 cm diameter period versus the 0-30 cm period. The aboveground biomass begins to increase at a greater rate than the following year in its mature phases creating the non-linear increase. On the other hand, diameter growth and age are a linear relationship meaning the diameter increase remains constant throughout a tree's life. The increasing rate of biomass growth is not caused by an increasing rate in tree size each year. Therefore, mature trees should remain in the forest as opposed to selective logging and new growth. For ACR IFM projects, new trees will be planted but remaining trees should remain standing because that level of high carbon dioxide storage cannot be reached at an earlier age.

Cost Benefit Analysis

The scenario to which we are comparing the forest offset project is buying necessary offsets from the voluntary market, Collegiate Clean Energy, at $7 per offset. Records show in June 2021, the sale agreement between the university was 4,900 offsets at $7.00 per offset. Table 2 illustrates the total cost of 3 scenarios on an annual and 10-year basis. These would be the University of Lynchburg's expenses if they were to sell offsets annually through the American Carbon Registry. Table 2 shows that the project's costs are cheaper than the alternative cost of purchasing offsets. The project's cost outweighs the benefits in this case because of the additional full-time position. The full-time position is needed for this project because of the standards required by ACR. The amount of data and maintenance that is needed for verification is much greater than what an existing faculty or staff member can add on to their workload. It is important that the University creates a full-time sustainability coordinator position but in this case after the project is registered the need for this role decreases. It is possible that after five

years of paying a $20,000 salary, this cost can be removed from the analysis and the majority of revenue becomes profit. However, this position could be justified long-term by taking on other important duties. The annual ACR verifier fee is $0.15 per MT CO_2 for activation. The fee for verifying returning offsets is $0.02 per MT CO_2 each following year. There will be costs associated with implementing IFM such as equipment, seeds, and other supplies but this cannot be estimated now.

If selling the offsets becomes cheaper than the former scenario, the University of Lynchburg will save money. The cost benefit analysis only represents the monetary value of the forest for this purpose. Other values will be discussed later. Offsets in the voluntary market range from $4-$8 per ton. Using these projected values, the revenue after a ten-year period would be in the range of $51,626.40-$103,252.80. It is also very likely that the value per ton will increase over time as the market becomes more popular, which is attractive because the school is recovering from a $12 million budget deficit (Robinson, 2022).

Table 2. Estimated Annual Costs and Benefits of Pursuing Forest Offset Project			
	Selling offsets @$4/ MT	**Selling offsets @$8/ MT**	**Buying Offsets @$7/MT**
Labor Costs	$20,000	$20,000	
Verifier Fees	$229	$229	
Total Cost	**$20,229**	**$20,229**	$34,300
Annual Offsets	**1,229**	**1,229**	4,900
Total Benefits	**$4,916.80**	**$9,833.60**	$0
Educational Value	Not Quantified		
Annual Net Cost	$15,313	$10,396	$34,000
Annual Net Cost with CSP	$0		
Revenue after 10 years	$ 51,626.4 - $ 103,252.80		($343,000)

The reason behind purchasing offsets was to attain carbon neutrality because President Morrison-Shetlar signed the 2021 Presidents Climate Commitment, a nationwide commitment to sustainable higher education. Attaining carbon neutrality has no economic benefit either but was a choice made to reduce our emissions. Generating carbon offsets would be a sustainable business investment regardless of the profit since it contributes to a greater cause and image. Selling 1,229 offsets and increasing annually as opposed to purchasing 4,900 offsets annually is the ideal scenario. Another option would be to register Claytor Nature Center as an offset project through ACR and retain them to offset the school's emission instead of selling. This way we reduce our footprint without buying or selling. In 2019, the university had a total emission of 6,458.99 MT CO_2. The 1,229 MT CO_2 is approximately enough to neutralize scope 1 and 2 emissions (2,274 MT CO_2). The majority of annual emissions come from scope 3 (indirect emissions) like commuting. As the university works to reduce their direct CO_2 emissions carbon neutrality may be retained through the use of Claytor Forest. Scope 3 is not yet required for reporting which is why we were able to be carbon neutral with 4,900 offsets. It is in the schools best interest to sell the offsets for profit instead of internally using them because we should work to reduce our carbon footprint directly.

There is a possibility for all the costs to be funded with federal money. The Inflation Reduction Act offers S3.25 billion of funding to similar projects through the Conservation Stewardship Program (CSP) signed by the Biden administration. In the state of Virginia in the year 2021, 152 CSP contracts were issued. 119 of the 152 contracts involved "forest stand improvement." The average acreage of the projects is 400 acres, and the average contract value was $65,000 (USDA, 2023). The size and funding of the Virginia CSP contracts are very similar to the proposed Claytor Nature Center project. These records were prior to the IRA enactment meaning this funding will be more accessible than before and can cover the costs needed to register the offsets. This is the ideal scenario because the CSP funds many different methods of forest "enhancements" that Claytor is already enacting such as pollinator gardens.

The third option includes using Claytor as a timber stand and selling the wood. This has not been heavily considered by the administration because of the conservation easement and has no environmental value. The online software Landscape analyzes satellite data similar to iTrees for carbon and timber value. The value calculated by Landscape was estimated to be $712,144 in total timber value. This is obviously a one-time transaction, and more revenue is generated from annual selling of offsets overtime. Claytor Nature Center also brings in gross $72,500 annually from events and other sources. This income is made possible by the beauty of the forest and will outweigh the benefit of the total timber value overtime. Despite the large number, offsets and events revenue will bring in more money than timber. The monetary value of other forest attributes will be discussed later but do not contribute to the cost-benefit analysis but simply justify the worth of our natural resources.

Growth of the Market

The increasing growth of the carbon market should be considered during this investment. If the cost per ton of carbon generated from forestry is not yet attractive, the future will reveal patience pays well. According to the ACR IFM model, Claytor Forest would generate a $4,916.80-9,833.60 range per year accumulating to $51,626.40-$103,252.80 (Table 2) over a ten-year period. This increase reflects the improved management of the forest that increases the amount of carbon offsets each year from the baseline. Additionally, each offset increases in value every year that the market grows on top of the increase in total offsets. This will make revenue $20,650 per year if the value per offset doubled to $16. The amount of carbon offsets transacted in 2016 represented 63 million tons of carbon, in 2019 transactions represented 104 million tons of carbon globally (Carbon Credits, 2023). In 2019, the value of the market was valued at $211.5 billion (Worford, 2022). From 2019 to 2021 the market quadrupled in size and would continue to grow 20-200x by 2030 (Carbon Credits, 2023). Between 2020 and 2021, the global carbon pricing revenue increased by 60% and seven more countries implemented carbon tax or trading systems as a sustainable society becomes more desired (World Bank, 2022). Investments in voluntary carbon projects grew from $7 billion in 2021 to $10 billion in 2022 and transactions represented 255 million tons of carbon in 2022 (Carbon Credits, 2023). According to Bloomberg the carbon market will reach $2.4 trillion by 2027 and increase fifty-fold by 2050 (Henze, 2023). During this forecast period, communities are expected to transition to a sustainable economy and environmental policy will take a higher priority. Stricter regulations raise the price of carbon. In future years "forestry will hold the largest carbon credit market increase during the forecast period" (Woford, 2022). This is good news for investors but also the global ecosystem because the loss of forest accounts for 20% of global carbon emissions (Woford, 2022). To conclude, Claytor forest as a carbon offset should be preserved soon due to the expected increase in offset value over time, making it a considerable source of revenue for the University of Lynchburg with the CSP contract.

Other Ecosystem Services

The carbon market is one example of how there is an economic benefit in protecting our natural resources. Most of sustainable initiatives seem unattractive because of the myth that they are too expensive. Studies show that investing in conservation and energy saving projects saves more money in the long run. The Deloitte Global Turning Point Report found that ignored climate change impacts would cost the United States $178 trillion by 2050 (Pradeep et al., 2022). Each year, we lose $2.5-4 trillion in land ecosystems services that benefit human welfare globally (Sukhdev, 2010). This is because outside of carbon offsets, the forest provides many other benefits that are needed for survival and typically overlooked in developed countries. The carbon market monetizes the air purification qualities of forests like Claytor. The prices of other atmospheric offsets have been calculated for Claytor in the iTrees system. There is $2,072 of value in pollutants removed annually by Claytor such as CO, NO2, O3, and PM although there is no robust market for these benefits (Craig, 2019)

Claytor Nature Center brings in $72,500 annually in gross revenue from events such as weddings. The event venue is attractive because of the natural aesthetic provided by the forest. Recreation and camping at Claytor also creates some revenue but not of comparable size to the events revenue. The property is also home to a variety of wildlife that support the Blue Ridge ecosystem in many ways. A major benefit of forest is the ability to reduce stormwater and erosion which decreases the risks of floods. It estimated that each lost hectare of forest cost roughly $2,000 in flood damages (Columbia Climate School, 2022). According to this study, without Claytor, it would cost the Bedford community at least $300,000 in flood damages per year, considering it is not very developed. The root system of this forest also purifies the stormwater runoff before it reaches the James River watershed. The cost of flood damage and global warming far exceeds the cost of avoiding deforestation. This is to demonstrate why monetizing ecosystem services helps the public understand such inherent values. It is important to note that all should participate in these markets although carbon offsetting is not the most important benefit of the forest simply because it has an economic market.

The Market as Conservation Method

Deforestation needs to decrease exponentially and rapidly. Current forest protection policy is not an adequate form of prevention in today's society. As previously mentioned, forests release carbon when they are cut down, but this means less carbon from other sources can be absorbed from the atmosphere. Because deforestation is a positive feedback loop the impacts of climate change will become more severe. From 2001 to 2021, the United States lost 44.3Mha of tree cover, equivalent to a 16% decrease in tree cover and 17.2Gt of CO_2 emissions (Global Forest Watch). In 2021, the world lost 3.5 million hectares of tree cover, equivalent to the size of Saudi Arabia and 2.5 million Claytor forests, and emissions equivalent to the annual fossil fuel emissions of India (Schonhardt, 2022). The carbon market alongside other methods must urgently be enforced and standardized to buffer this because of all the forest's benefits mentioned above.

Effectiveness of the Market

Is the carbon market an appropriate method to mitigating climate change? For at least 60 years, Claytor forest has been absorbing carbon through photosynthesis, but the University of Lynchburg's emissions will remain the same before and after the offset project if energy consumption is not reduced. Forestry offsets prevent deforestation which is a source of carbon emissions but do not remove more emissions from other sources after registration. If deforestation ends tomorrow lifestyle changes are needed to remain under 1.5 degrees warming. Therefore, if all land was registered into the ACR, revenue would be generated but this would allow the corporations to continue as usual and the impacts of climate change would continue to worsen. This criticism of the voluntary market is why forest management must be improved. The project will not qualify if carbon stock does not increase from the baseline. The additional trees make emissions removal more effective which is revealed by positive indicators. "Research shows that carbon trading policies have reduced the energy consumption of regulated industries in pilot areas by 22.8% and CO_2 emissions by 15.5%," (He & Song, 2022). Even though wealthy firms who pollute the earth can appear sustainable by purchasing credits, this market pushes global warming into the spotlight and makes similar initiatives more common. It is not the solution to climate change but it is a great way to access activism in the business sector or anyplace outside of the scientific community.

The second critique of the carbon market is the quality of the offsets. The supply of forest offsets is abundant, but the prices cannot be valued too low. The market can only grow if the demand keeps up with supply. A combination of forestry offsets (cheap) and removal technology (expensive) will be needed to maintain this balance. With low offset prices the quality of offsets will be questioned. Corporations could reach their sustainability goals but there would be little incentive to participate from landowners (Carbon Credits, 2023). If the price per ton is over $100 there would not be concerns over quality. Although, with corporations less willing to purchase offsets they would focus more on reducing their own gross emissions. More expensive offsets create an ideal scenario with corporations independently reducing their energy consumption.

Future Opportunities

The end goal of a verified project will take the work of other faculty and students. Once the additional labor is created the verification process will soon be complete. After Claytor Nature Center is registered in the carbon market, future students can learn more about this topic and further this research. There is carbon sequestration potential below the ground in roots and even soil. The carbon offsets below ground can be calculated and added to Claytor's annual offsets for additional revenue. Calculating belowground biomass is not mandatory by the ACR but could be an entire thesis since the time was not available during this research. The additional labor can also take form in a student internship for credit that is paid for in their semester's tuition. This would be a great opportunity for students to gain forestry experience by maintaining and managing Claytor forest. The land management practices discussed with Jennifer Wills include switchgrass planting, pine removal, white oak planting, and others to be determined.

Many other research projects at Claytor alongside the carbon offset potential will contribute to Claytor's Land Management Plan. This plan is currently in progress and aims to be as robust as possible for staff, visitors, and students.

In order to gather the data of increased carbon stock each year, new biomass needs to be calculated. The ACR offers multiple methods to measure increased carbon stock from the baseline. The most popular method is using LIDAR satellite data which is too costly for this scale of project. Manual data collection is free of cost. It would be ideal to create an adaptable spreadsheet so when new forest data is entered, the calculations will automatically compute as opposed to conducting the complex series of equations for every new tree. This is possible although the USDA is releasing new methodology to replace Woodall's 2010 version. I communicated with Christopher Woodall to access the new methods but they were not ready before the project deadline. The new methodology will include the same math but in a simple format to make the process much more efficient. When the new methodology is released in summer 2023, staff and students will use that instead. The next step of this research is to gain the interest and approval of the administration. There is no downside to the investment but it is not clear what level of concern the president or business office holds towards sustainability.

Recommendations and Conclusions

To the President and VP for Business and Finance, I suggest that the University of Lynchburg pursues this project and begins registration in the American Carbon Registry. The school should apply to the Conservation Stewardship Program to receive funding for all associated costs. It is likely that we will receive the contract and all the revenue from selling offsets becomes profit. It is even more likely that the selling price of carbon offsets will increase as the market continues to grow. The associated cost will include labor in the form of a new full-time sustainability position. This position will have other tasks on campus sustainability outside of the carbon offset project. The funds generated from the annual offsets can serve many purposes. The institution should use the profit from Claytor Forest to fund sustainable endeavors because we are falling behind in higher education sustainability since green projects are not in the budget. It is important that all higher education institutions take steps to offset their emissions and create an eco-friendly space for all. A good way to ensure Claytor Forest is increasing the annual carbon stock is by planting white oak trees which have the greatest biomass capacity per inch of diameter. In hindsight, I would suggest a greater amount and size of the forest survey plots, time permitting. More larger plots in addition to the 10 selected will provide a greater representation of the forest make up. As climate change is an urgent issue, the University of Lynchburg has no reason to not pursue an offsetting project using government funds and an already existing forest.

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