AGRICULTURE AND FORESTRY REPORT

Anne Wong, Austyn Long, Natalie Daughtry, Scott Holden and Elea Reyna Ocampo
Project Manager: Austyn Long

North Carolina State University

Table of Contents Page #

ABSTRACT

The Earth's climate is changing much faster than we have ever experienced in the history of modern civilization. According to the IPCC, scientists have a 97 percent certainty that anthropogenic contributions to greenhouse gas emissions are the "dominant cause" of global warming since the 1950's.[4] This report analyzes how the agricultural and forestry sector can change its current strategies to combat climate change by 2030. As our population continues to grow exponentially and land use changes continue to transition from forested or pasture land into urban areas, it becomes harder to create solutions that could help with mitigating climate change. To explore solutions to this issue, this report investigates and suggests afforestation, preservation, forest management, and intercropping methods that show an overall decrease in carbon emissions and an increase in carbon sequestration in forested land and pasture land.

INTRODUCTION

Climate change is one of the most pressing problems that the world is currently facing. The general population, scientists, political and social leaders are demanding governments to invest in methods to mitigate the effects of climate change. The Intergovernmental Panel on Climate Change (IPCC) states that climate change will increase significantly due to anthropogenic effects. This report suggests specifics efforts to mitigate the effects of climate change specifically to aid the agricultural and forestry management leaders of Chatham County in making the transition to practices that encourage the sequestration of higher numbers of greenhouse gases.

Climate change will not only affect the community's local environmental and climatic characteristics but also its economic and sociological factors. The Chatham County Climate Change Advisory Committee (CCCCAC) is working to evaluate several different methods of lessening the county's carbon footprint with practices such as: applying manure on various soils, increasing digestibility of livestock, including feeding additives to inhibit methane production, and effectively composting of manure after anaerobic digestion. This report suggests more intense and effective operations in which agricultural and forested land in Chatham County contribute to carbon sequestration and carbon emissions. We will suggest practices that Chatham County can implement to increase carbon sequestration such as silvicultural practices, afforestation, including practices that will decrease carbon emissions such as precision agriculture.

We initially researched current agricultural practices in Chatham County, and evaluated the expected sequestration and emissions from these practices. Some of these practices included optimizing the nitrogen content depending on soil type, changing from traditional agricultural methods to crop rotation practices, and applying manure to land used for crop production. Using geospatial data and research on the sequestration potential of forestry and farming practices, we estimated how much carbon is currently being sequestered in the agricultural and forestland within Chatham County. This data gives us a rough estimate the changes needed over the next ten years. Using Dr. Ross Meetenmeyer's FUTURES land change projection model, along with the help of Dr. Georgina Sanchez, we have generated estimates for land use change and urban growth projections for 2030. The FUTure Urban-Regional Environment Simulation, is a "multilevel simulation" of urban-rural landscape structure that uses a "stochastic patch level algorithm… to simulate land development dynamics" (Meentemeyer, 2011). Based on the predicted changes, Chatham County is on course to lower the total amount of agricultural land as well as the total amount of forested land in the county.

In addition to FUTURES, we relied on data from Alan Franzluebbers's paper, "Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA". This paper is a comprehensive survey of soils in Texas that measures the amount of soil organic carbon stored within pastureland, forestland, and cropland, and provides averages. We used the averages from this paper to estimate the amount of carbon currently stored in Chatham County's agricultural lands.

We've found that if management does not change for pasture, crop and forestland, Chatham County will see a net loss of carbon sequestration in this land. Our goal is to provide scientifically sound management suggestions that will make up for the projected decrease in sequestration, while lowering emissions from agricultural activities. We used the FUTURES model with the carbon sequestration equation to predict quantities of carbon sequestered under each land use type, being as specific to Chatham County as possible. Forest and pastureland practices were observed as these are the largest agricultural land reserves in Chatham County, and are the ones that will remain the largest by 2030.

Based on a literature review we did on the effect of NPK fertilizers on Chinese agricultural soils, we found that adding NPK fertilizers to crops can increase their carbon storage at a depth up to 20 cm. These synthetic fertilizers applied over time can improve the growth of underground biomass, roots, and root exudates which contribute to the importance of soil C in soil. In addition, we did another literature review on the effect of protecting riparian barriers on carbon sequestration (USDA 1996). The researchers in this study found that Brazil could greatly increase the carbon sequestration with larger riparian buffers. Statistically, they found that in the 15m bound buffers, 332,824 Mg of Carbon was sequestered over 40 years. The researchers concluded that riparian areas can greatly increase carbon sequestration, and could consider applying to other parts of the world (Rheinhardt 2012). We can use this information to implement stricter riparian buffer laws around agricultural areas in Chatham County. On the other hand, there was another scientific study taken place in

Canada where carbon sequestration was measured based on tree- based intercropping in a conventional agricultural system. Compared to the sites where barley was the main crop, soil respiration was higher and soil carbon concentration increased at the sites where hybrid poplar trees were intercropped. The main conclusion is that there is greater carbon sequestration by using intercropping methods rather than pursuing conventional agricultural methods. We use this research for our recommendation to include tree intercropping in Chatham County.

Alternatively, we thought about using precision agriculture to reduce air pollution and improve energy use in robotic tractors. The results from their study showed a reduction in CO_2 emissions of almost 50% for the best case. This report showed that it is possible to combine current agricultural machines, which use International Combustion Engines for power, with new technologies that are based on clean energy sources to obtain significant reductions in the emission of atmospheric pollutants and greenhouse gases. Our last suggestion looks at how emissions can be reduced when it comes to land use. Our article suggests limiting pasture land to minimize deforestation and making livestock production more efficient. In Chatham County, forest lands contribute a majority of the carbon sinks, but at the current rate of deforestation they will not be able to continue offsetting GHG emissions.

The CCCAP's stated goal is for Chatham County to reach 100% clean energy by 2050. As a part of the proposed solution, the CCCAP plans to reduce overall greenhouse gas (GHG) emissions and increase carbon sequestration (CCCAP, 2017). This puts pressure on the agricultural and forest land sectors especially to reduce emissions and increase sequestration through better land management practices. Our suggestions are intended to support the land's natural capacity for carbon sequestration in Chatham County without impacting the agricultural and forested land's health and stability.

METHODS

Land Use Change

In order to better assess our role in Chatham County's goals, we met with Chatham County officials and discussed current agricultural practices. We then considered the expected sequestration and emissions from these practices. Current management strategies include optimizing the nitrogen content depending on soil type, crop rotations, and applying manure to land used for crop production. Our goal is to determine ways that will work in concert with current practices. After learning about current work in Chatham county, we shifted to using projections of future land change to tailor suggestions to mitigate the more specific needs of Chatham County as it continues to develop.

We then needed predictions for land use changes. With the help of Dr. Georgina Sanchez, we were able to access a single simulation run from the FUTURES land change model to project changes in land use between 2011 and 2030 (Table 1). This urban growth projection by the year 2030 is representative of land use historical patterns. Using ArcGIS Desktop, we analysed NLCD land cover raster data with the FUTURES simulation (Table 1). The National Land Cover Database (NLCD) is a “ongoing land cover model” database that is based primarily on satellite observations and ancillary data sources, such as topography, census and agricultural statistics, soil characteristics, wetlands, and other land cover maps (NLCD, 2011). Land cover data from the NLCD is categorized into Deciduous, Evergreen and mixed forests, Shrub/scrubland, Grassland/Herbaceous land, Pasture/Hay, Cultivated Cropland, Woody Wetlands, and Emergent and Herbaceous Wetlands. This report focused on the expected changes in forestland, pasture land, and cropland, so we condensed this data into total forest land, cropland, and pastureland, and analysed the changes in these three categories.

This raw data was reduced down into categories of Total Cropland in 2011 and 2030, Total Forestland in 2011 and 2030, Total Pastureland in 2011 and 2030 and Total Developed land in 2011 and 2030. Initially, we took the net change for each category of land cover. Our goal was to quantify how the carbon sequestration would change from simply altering the land cover, without implementing any of the changes.

Figure 1 shows the 2011 estimates for cropland, forestland, and pasture land in Chatham county. It was generated using the data for 2011 in the FUTURES project. Figure 2 shows the FUTURES estimates for 2030. FUTURES generates estimates by using coupled submodels that combine nonstationary drivers of land change: per capita demand (DEMAND submodel), site suitability (POTENTIAL submodel) , and the spatial structure of conversion events (PGA submodel) (Meentemeyer, 2012).

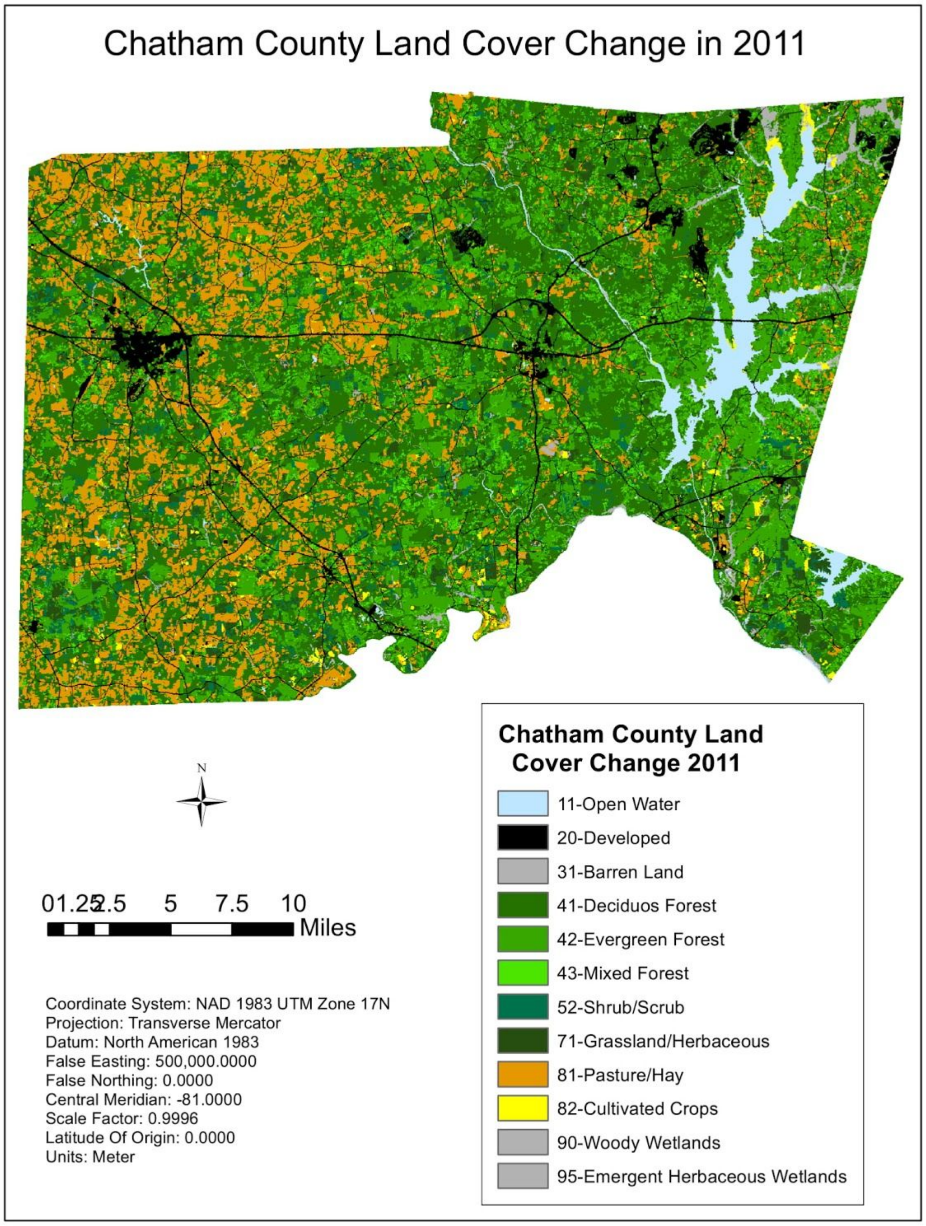

Figure 1: Figure 1 shows the 2011 projection for Chatham County's Land Cover, highlighting the forests in green, the pastureland in orange, and cropland in yellow. The black refers to developed land. The image demonstrates that most of Chatham County is forested or cropland.

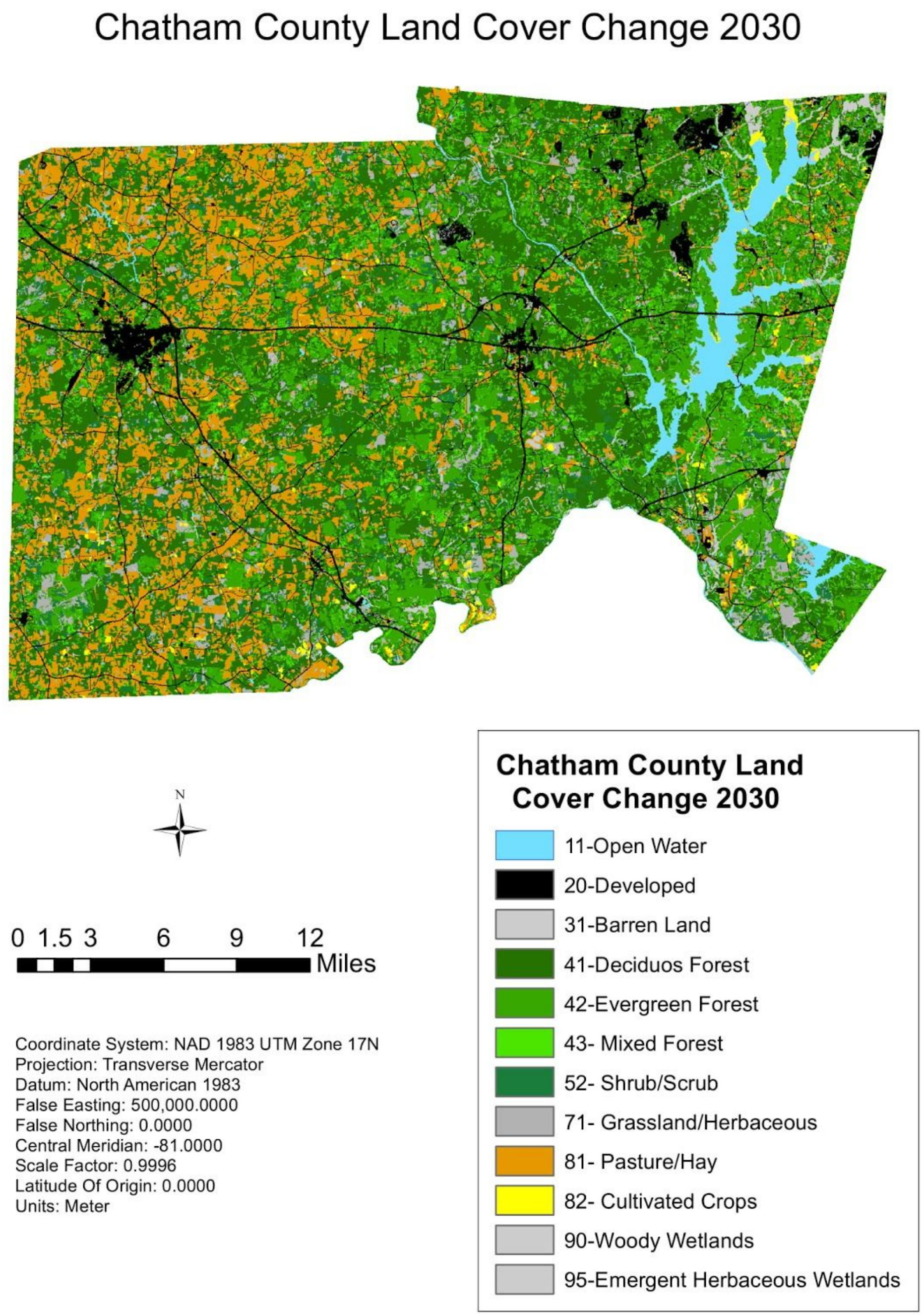

Figure 2: Figure 1 shows the FUTURES 2030 projection for Chatham County's Land Cover, highlighting the forests in green, the pastureland in orange, and cropland in yellow. The black refers to developed land. The image demonstrates that most of Chatham County will still be forested or cropland, but estimates an increase in developed land.

Carbon Sequestration

With the FUTURES analysis mentioned above and with our research on the sequestration potential of forestry and farming practices, we estimated how much carbon is currently being sequestered in the agricultural and forestland within Chatham County. We first used the 2030 and 2011 data from FUTURES to have an estimate of how much cropland, forestland, and pastureland would be lost over the 19-year gap. We then used data from Alan Franzlubebber's paper, *Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA*, on the average sequestration from each type of land cover to estimate the total carbon that would be present in the acreage of land that was changing, using the following equation (Franzluebbers, 2019):

$$\Delta\, C_{avgseq}\ (kg)\ =\ (A_{2030} - A_{2011}\ m^2) \times C_{avgseq.}(Mg \cdot ha^{-1})\ \times (\frac{1\ ha}{10{,}000\ m^2})\ \times (\frac{1000\ kg}{1\ Mg}) \quad \textbf{(1)}$$

Equation 1 demonstrates how the values were determined for the "Business As Usual" carbon sequestration data in Figures (2), (3), and (4). ΔC is the change in sequestration. A_{2030} and A_{2011} are the land areas for each value in meters squared for 2030 and 2011. C_{avgseq} refers to the mass of carbon per area in $Mg*ha^{-1}$ (Franzluebbers) and the conversion factors allow us to report the final values in kg. These are the values in Figures (2), (3), and (4). Values are rounded to three significant figures.

This calculation assumes Chatham County's agriculture maintains current practices and continues to develop. It will provide the background decline of sequestration capabilities as land loss decreases, and is generalized to southern soils as a whole. In keeping with our goal to not only quantify the current trajectory, but also to provide suggestions for how to better manage Chatham County's agriculture for better carbon sequestration, we will also provide the potential of each method we suggest to sequester carbon.

RESULTS

Land Use Change

According to the FUTURES' 2011-2030 projection, Forested land in Chatham County will decrease by 6611 square meters, Pasture land will decrease by 1962 square meters and Cropland will also decrease by only 60 square meters (Table 1). On the contrary, developed land will increase by a total of 9507 square meters (Table 1) which shows a growth in the urban area in Chatham County. Total Agricultural (Pasture and Cropland) and Forested land is expected to decrease a total of 8,633 square meters from 2011 to 2030 in Chatham county (Figure 1).

The developed land use change from 2011 to 2030 will be a total of 9507 square meters thus decreasing the area put forward agriculture.

Our results show that Chatham County is seeing an overall increase in developed land and decrease in forested and pasture land. Forested land will decrease by 0.53%, and pasture land by 0.55%. Developed land will increase by 8.12%. The total amount of agricultural land in Chatham county will decrease by 0.5% from 2011 to 2030. Table 1 outlines these changes as well. These are small changes, but when considered alongside the carbon stored in the land they point towards a net decrease in the agricultural sector's ability to sequester carbon.

Table 1 FUTURES projection for 2011 and 2030.

Land Use Type	2011 (m^2)	2030 (m^2)	Change 2011-2030(m^2)
Forestland (Total)	1240682	1234071	-6611
Pasture Land	356379	354417	-1962
Cropland	17815	17755	-60
Developed (Total)	117020	126527	9507
Total Agricultural Change	1731896	1732770	-8633

Table 1: This table shows the projections for change in land use for forestland, pastureland, cropland, and developed land. The data comes from the FUTURES Assessment. The forestland is a sum of deciduous, evergreen, and mixed forestland. We did not include shrublands and grasslands in this assessment of the land change. The total change is not large compared to the overall land areas.

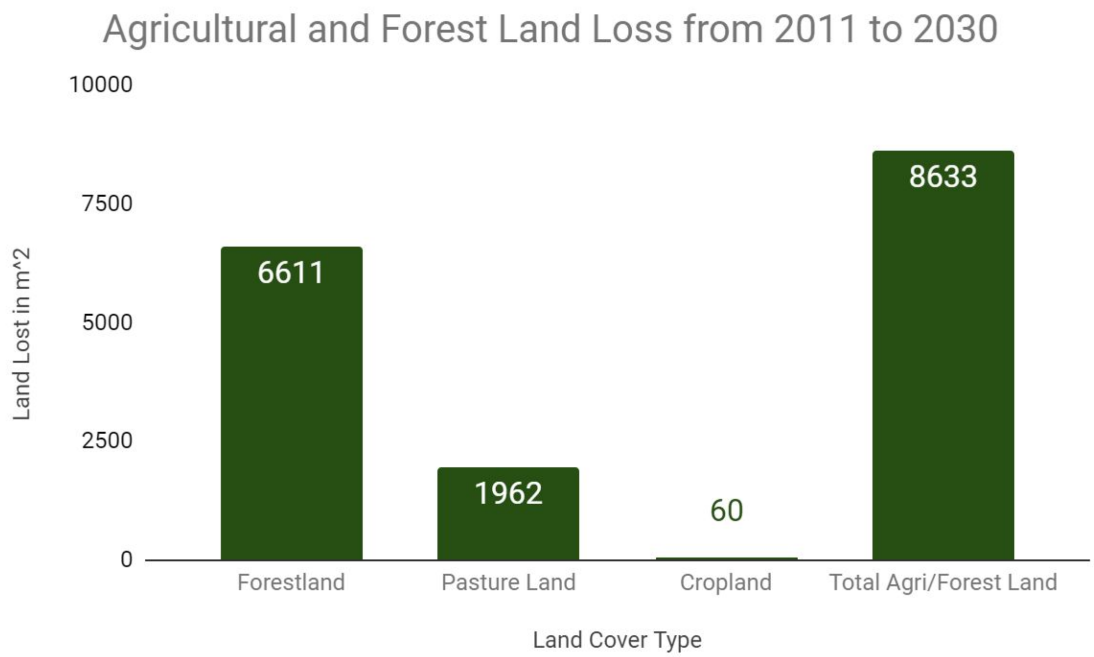

Figure 1: Predicted land area lost to development in Chatham County from 2011 to 2030. Note that losses of forestland and pasture land are occurring the most quickly. The rate of cropland decrease is the smallest, but this is more indicative of the small portion of total land in Chatham County dedicated to growing crops.

Carbon Sequestration

Based on our calculations, we expect to see a net decrease 43 Mg C per hectare (Table 2) on average across forested and agricultural land. This is considering the business-as-usual projections for land use change, and data from Table 2. The total amount of carbon sequestered from forested land will decrease by 0.533 % from 2011 to 2030. Carbon sequestered from pasture land will decrease by 0.550% from 2011 to 2030. Carbon sequestered from cropland will decrease by 0.337%. The total amount of carbon sequestered from land change will decrease by 0.535%. This is not a large decrease, but paired with Chatham County's goal of increasing carbon sequestration within the agricultural sector, this means that steps must be taken to account for the loss - Carbon sequestration will not increase by continuing the same practices.

Table 2. Carbon Sequestration calculations per Land Use Type for 2011 through 2030.

Land Use Type	**Δ Land Area (m^2)**	**C_{seq} (Mg ha^{-1})** cite franz. here	**Δ Mg C_{seq}**	**% Δ C_{seq}**
Forestland (Total)	-6611	49.9	-33.0	-0.533
Pasture Land	-1962	47.4	-9.30	-0.550
Cropland	-60	31.1	-0.187	-0.337
Total	-8633	--	-42.5	-0.535

Table 2: The land area change is taken from Table 1. The average values for Carbon sequestered are taken from Alan Franzluebber's paper, *Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA* (Franzluebebbers A. 2005). Note that these are extremely generalized values, and that the land area change is small compared to the overall land use. They are indicative of a net decrease in the ability of the agricultural sector to sequester carbon. Numbers in the change have been rounded to three significant figures based on values obtained from Franzluebbers (2005).

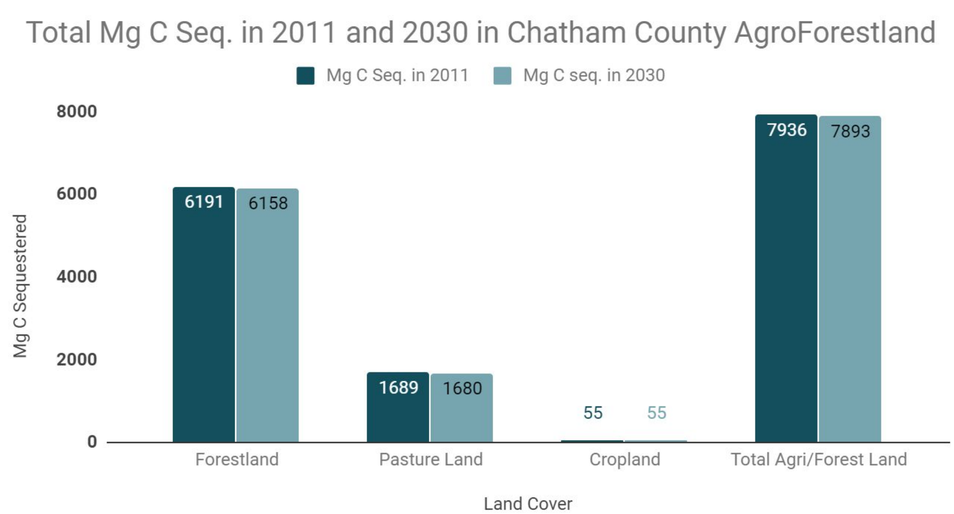

Figure 2. Total amount of Carbon (Mg) sequestered by each Land Cover type (Forestland, pastureland, Cropland, and Total Agriculture/Forestland) for 2011 and 2030. These decreases are small, (or in the case of cropland, indistinguishable). This data is not meant to be taken as exact values but rather an indicator that with a business as usual approach, Carbon sequestration will decrease.

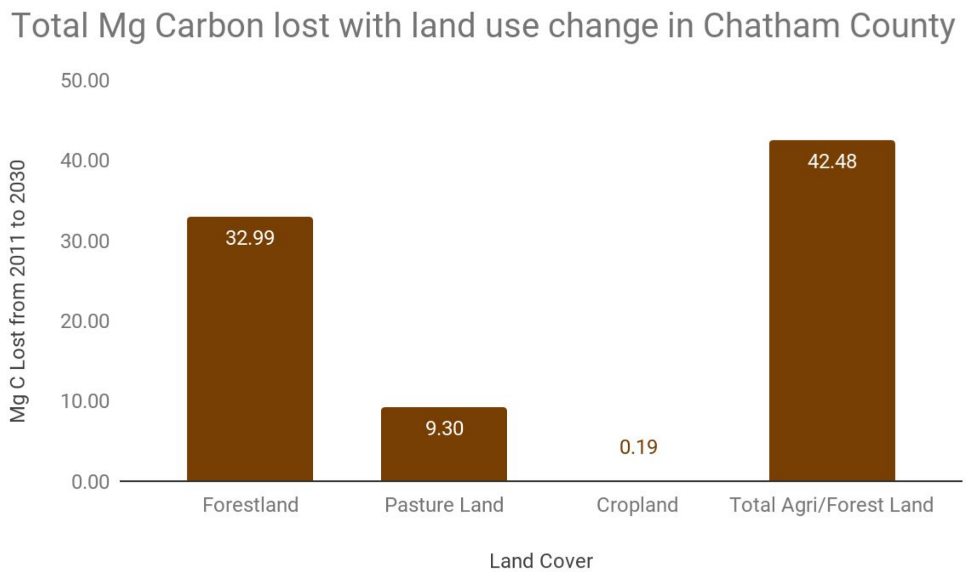

Figure 3. Total amount of Carbon lost (Mg) by Land Cover type (Forestland, Pastureland, Cropland and Total Agriculture, Forest Land and Cropland) by 2030. These are general values and indicative of general carbon sequestration lost. Data from Franzluebbers paper is used in these calculations (Franzluebbers A. 2005).

RECOMMENDATIONS

Following the business-as-usual scenario, we estimated that Chatham County will have a decrease of forested land and pasture land. Chatham County is currently reducing emissions and increasing sequestration by applying manure on various soils, increasing digestibility of livestock feed with additives to inhibit methane production, and effectively composting of manure after anaerobic digestion. The same applies to reducing nitrous oxide emissions when weather changes. These methods will increase carbon sequestration and reduce GHG emissions, but will need to be supplemented by other more intensive strategies in order to reach the goals of the CCCAP.

Currently, Chatham County has more forested lands than croplands. By 2030 the amount of carbon sequestered by forestlands will decrease from 7936 mg C to 7893 mg C (refer to Figure 3). Our recommendations focus on more efficient practices where forest and pasture land management activities to decrease carbon emissions and increase carbon sequestration, responding to the current land use patterns.

Precision Agriculture

We recommend using precision agriculture as another method in reducing GHG emissions. Precision agriculture is a site-specific management approach to farming that uses information and technology for identification, analysis, and management of spatial variability within fields, to optimize profitability, sustainability, and environmental protection (White, J. 2011). Precision agriculture practices using high-tech equipment have the ability to reduce agricultural inputs by site-specific applications, as the practices better target inputs to spatial and temporal needs of the fields, which can result in lower greenhouse gas emissions (Balafoutis A. et al, 2017).

Precision agriculture technologies (PAT), such as variable rate nutrient application, reduce the amount of fertilizer applied in modern agriculture by using technology to cover site-specific nutrient needs (Balafoutis A. et al, 2017). Reducing the amount of fertilizer use will reduce the amount of nitrous oxide (N2O) a GHG from being released from the soil microorganisms to the atmosphere which contributes to global warming. Soil microbes transform excess nitrogen in the soil that has not been taken up by the plant to nitrous oxide through the process of nitrification and denitrification (Balafoutis A. et al 2017).

Another precision agriculture technology is variable rate pesticide application which is also expected to have GHG reduction potential by reducing the pesticide application and its industrial production (Balafoutis A. et al 2017). Applying pesticides more accurately to the weeds in the field will kill off more weeds and also reduce the need to till. Reducing tillage means the soil will be able to store more carbon thus reducing carbon dioxide in the atmosphere (Balafoutis A. et al 2017).

Another precision agriculture technology is controlled traffic farming and machine guidance to limit the use of tractors to only the necessary passes through the fields avoiding overlapping with respective decrease in agricultural inputs and fuel which translates to reduced GHG emissions and lower cost of production (Balafoutis A. et al, 2017).

Incorporating precision agriculture using hybrid powered robotic tractors with internal combustion engines (ICE) would greatly reduce air pollution and energy use (Gonzalez-de-Soto, M. et al, 2016). The energy source for the hybrid powered robotic tractors was composed of batteries, a hydrogen fuel cell, and photovoltaic (PV) cells with the original ICE of the tractor to achieve a substantial decrease in fossil fuel use and a consequent reduction in the emission of pollutants (Gonzalez-de-Soto, M. et al, 2016). According to Gonzalez-de-Soto, the hybrid powered tractors with ICE reduced carbon dioxide emissions by up to 50%.

Forest Management

For forestry and pastureland management we recommend practices that follow tree-based intercropping systems. Intercropping systems, where barley and/or other crops are "intercropped" with trees, have a higher success in reducing atmospheric carbon dioxide concentrations compared to soil cropping systems (Peichl, M et al, 2006). Also, hybrid-poplar trees had the highest carbon sequestration potential followed by red oak, black walnut, Norway spruce, and white cedar respectively (Peichl, M. et al, 2006). Red oak and black walnut trees were found to have deeper roots with greater biomass and therefore higher carbon storage (Peichl, M. et at, 2006).

Pasture Management

The majority of Chatham County's agricultural lands are used for grazing. Because of this, pasture land management must be at the forefront of the efforts. Cotant and colleagues in 2001 found that "good management" of pasture land can increase the amount of soil carbon (Follet and Reed, 2010). "Good management" includes irrigation, fertilization, better grazing, improved grass species, vermicomposting, and introduction of legumes to the pasture ecology (Cotant et. al, 2001). Earthworm introduction, for instance, was shown to increase carbon sequestration by 2.35 Mg C ha^{-1} yr^{-1}, and improved grass species were shown to increase carbon sequestration by 3.04 Mg C ha^{-1} yr^{-1} (Cotant et al, 2001). The authors also determined that these effects are likely short lived and that soils equilibrate eventually. Earthworms can aerate the soil, increase surface area of organic materials, increase microbial activity, and speed up mineralization and humification (Cotant et al, 2001). To add onto this, we should switch to warm season grasses as they are heat and drought tolerant grasses. When we incorporate them in the grazing system, it decreases the grazing days, reduce reliance on costly hay, and allows pasture to rest during the summer. However, these management practices are likely a good first step to increasing the carbon sequestration capabilities of grazing land.

Moreover, we can integrate the landscape such as riparian zones or prairie strips for reducing nutrient runoff from farms, controlling erosion, and supporting pollinators. Riparian areas are one of the most productive and valuable resources in the US but are often left unnoticed. These areas include floodplains and streambanks that help control pollution and hold nutrients thus reducing sedimentation from runoff from agricultural farms (USDA). They consist of lands that occur along watercourses that affect the water quality, nutrient cycling, and terrestrial life as the water travels through. The state of a river channel can have a significant impact on water and sediment transport which contributes to climate impacts. By encouraging riparian areas, we provide food, shelter, and water for a wide range of animals between habitats.

According to Harvey, agricultural landscapes with abundant plant and tree cover serve efficient buffers for natural areas and increase carbon sequestration (Harvey 2008). Currently, Chatham County has riparian buffer requirements for the Jordan Lake watershed and to prevent oil spills, filter stormwater runoff, and slowing down floodwaters. Some examples are requiring buffers inside the Jordan Lake watershed according to Section 304 (J) of the Chatham County Watershed Protection Ordinance. They added a requirement to apply to properties that are within 2,500 feet of identified rivers.

For Chatham County, we can educate the farmers owning forested land and pastureland in providing strategies for reconciling farming and conservation (Harvey C. et al, 2008). In effect, this complies all the recommendation our group wants to focus on for the agriculture sector of Chatham County.

DISCUSSION

Our goal was to make predictions about Chatham County's carbon sequestration in a business-as-usual scenario, and use those predictions to direct our focus to the most effective management plans. The FUTURES assessment indicates a net decrease in Carbon sequestered land for Chatham County. This indicates that carbon sequestration will also decrease in Chatham County within the next decade.

The FUTURES assessment is based on factors including development rates and current land use patterns, and should be a reliable baseline. In order to make the calculations for carbon sequestration, however, many generalizations were used. First, Alan Franzuluebber's data is taken from many field sites, but these apply to soils in Texas instead of North Carolina, and while the effects can be generalized, these numbers are not meant to be exact predictions. Our calculation is also highly simplified. Because the values for the SOC paper are static, our calculation does not account for the change in carbon sequestration, and simply assumes that developed lands cease to sequester inputs. While active inputs will likely stop, the soils may continue to hold carbon. The ecosystems that did exist however will lose carbon.

Despite these uncertainties, we draw the conclusion that a business as usual approach will likely result in decreased carbon sequestration. Because of this, we strongly recommend implementing the approaches of riparian areas, precision agriculture, forest intercropping, and pastureland management into the future of Chatham County's Land management approaches.

CONCLUSIONS

Our goal was to determine the amount of carbon sequestered based on the projected land change data results and provide recommendations in increasing carbon sequestration and decrease emissions from agricultural activities. As of now, Chatham County is projected to see a net loss in the land that traditionally sequesters carbon. One solution would be to set aside more forestland, and to create plans to increase the forested land area for the future. If this is the solution, plans to conserve forestland need to be put into place immediately.

However, with the rapidly growing economy in Chatham County, solutions to increase sequestration in the current agricultural land may be more practical. For this reason, we've also included research backed recommendations for policy and management strategies. Precision agriculture involves increased resolution when determining crop management plans, and will allow a more nuanced ability to sequester as much carbon as possible (Balafoutis A. et al, 2017). Tree based intercropping systems can be implemented in order to increase carbon sequestration in forests, especially planting poplar trees and maintaining forest diversity (Peichl, M et al, 2006). Using native grasses in pasture land will also sequester more carbon (Cotant et al, 2001). Additionally, implementing riparian buffers and creating policy to protect them will also sequester more carbon from agricultural sites and will protect the landscape from any nutrient additions (Harvey C. et al, 2008).

The total agricultural and forested land area in Chatham County will likely decrease in the coming decade, but the carbon sequestration can be increased through the responsible agricultural practices outlined in this report. The principal takeaways of this report are that agricultural and forested land should be preserved as much as possible and landowners should be conscious of the practices they are using in relation to their carbon sequestration potential. Agriculture and forestland provide irreplaceable carbon sinks and preserving this existing undeveloped land is crucial. Sustainable practices can be implemented through incentives, policies, and educational initiatives to make sure we have this land in the near future. The findings of this report show that carbon neutrality in the Chatham County's agriculture and forestry sector is possible. Though it will take time and effort like all attempts to mitigate climate change, the long-term payoff will benefit generations to come.

Bibliography

1. "Chatham County, NC." *Mental Health | Chatham County, NC*, 1 June 2017, www.chathamnc.org/government/appointed-boards-and-committees/climate-change-advisory-committee.
2. Chatham County, NC. (n.d.). Retrieved from http://www.chathamnc.org/government/appointed-boards-and-committees/climate-change-advisory-committee
3. "ArcGIS ." *Arcgis.com*, www.arcgis.com/home/search.html?q=chatham%2Bcounty%2Bland%2Bcover&start=1&sortOrder=true&sortField=relevance
4. "A Brief History of Climate Change." *BBC News*, BBC, 20 Sept. 2013, www.bbc.com/news/science-environment-15874560
5. Zhao, H., Sun, B., Lu, F., Wang, X., Zhuang, T., Zhang, G., & Ouyang, Z. (2017). Roles of nitrogen, phosphorus, and potassium fertilizers in carbon sequestration in a Chinese agricultural ecosystem. *Climatic Change,142*(3-4), 587-596. doi:10.1007/s10584-017-1976-2
6. Garrastazú, M. C. et al (2015). Carbon sequestration and riparian zones: Assessing the impacts of changing regulatory practices in Southern Brazil. *Land Use Policy, 42,* 329-339 Retrieved from https://doi.org/10.1016/j.landusepol.2014.08.003

7. Peichl, M., Thevathasan, N.V., Gordon, A.M. et al. (2006). Carbon Sequestration Potentials in Temperate Tree-Based Intercropping Systems, Southern Ontario, Canada. *Agroforest Syst* 66: 243.
8. Gonzalez-de-Soto, M., Gonzalez-de-Santos, P., Emmi, L., Benavides, C., Garcia, I. (2016) *Reducing air pollution with hybrid-powered robotic tractors for precision agriculture* https://www.sciencedirect.com/science/article/pii/S153751101530177X?via%3Dihub
9. De Pinto, Alessandro, et al. "Low emission development strategies in agriculture. An agriculture, forestry, and other land uses (AFOLU) perspective." World Development 87 (2016): 180-203.
10. Ronald F. Follett, Debbie A. Reed, Soil Carbon Sequestration in Grazing Lands: Societal Benefits and Policy Implications," Rangeland Ecology and Management 63(1) (1 January 2010)
11. USDA, “Riparian Areas Environmental Uniqueness, Functions, and Values.,” Natural Resources Conservation Service,” RCA Issue Brief. (11 August 1996 Web: www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014199
12. Harvey, C. and Komar, O, Integrating Agricultural Landscapes with Biodiversity Conservation in the Mesoamerican Hotspot. Conservation Biology 22(1). 2008. https://doi.org/10.2111/08-225.1

13. Rheinhardt RD, Brinson MM, Meyer GF, Miller KH. Carbon storage of headwater riparian zones in an agricultural landscape. *Carbon Balance Manag*. 2012;7:4. Published 2012 Feb 14. doi:10.1186/1750-0680-7-4
14. Chatham County, North Carolina. Watershee Protection, Riparian Buffer Requirements. Retrieved from https://www.chathamnc.org/government/departments-programs/watershed-protection/riparian-buffers/riparian-buffer-requirements
15. Balafoutis A. et al. (2017 July 31). *Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics.* Retrieved from https://www.mdpi.com/2071-1050/9/8/1339/htm
16. Working Lands for Wildlife. 2018. Economic and Production Performance of Grazing Native Grasses in the Fescue Belt. 4spp.nrcs.usda.gov/wildlife.
17. Franzluebbers, A.J., “Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA”. *Soil & Tillage Research* 83 (2005). doi:10.1016/j.still.2005.02.012