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Sustainable Land Management in South Carolina: A Focus on Landowner Perceptions, Challenges, and the Implementation of Forestry and Agriculture Best Management Practices

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SUSTAINABLE LAND MANAGEMENT IN SOUTH CAROLINA: A FOCUS ON LANDOWNER PERCEPTIONS, CHALLENGES, AND THE IMPLEMENTATION OF FORESTRY AND AGRICULTURE BEST MANAGEMENT PRACTICES

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ABSTRACT

This study provides a holistic overview of a variety of different methods for land management and a framework for implementations of these methods. Many of these management practices for agriculture and forestry are labor intensive, provide long term benefits, and require significant expertise for implementation. This thesis will detail a variety of alternative and environmentally sound methods and funding streams to aid in implementation of management practices for agriculture and forestry land. Not only are these practices aimed at protecting the environment, they also contribute to increased yields for agriculture lands and provide co-benefits to the environment (i.e. increased water quality, sediment retention, carbon sequestration, and wildlife habitat and connectivity).

The first study details how forest landowners can utilize funding from the California Carbon Market to enhance carbon sequestration on their lands. Because of this, land use change can be minimized because there are incentives to keep forests as forests. Furthermore, two surveys were distributed to agriculture and forestry landowners, with the goal of eliciting their perceived benefits, challenges, and desire to implement cover crops and forestry best management practices, respectively. With this data, we hope to be able to provide better information to educators, federal agents, and Cooperative Extension agents on what educational methods work best for helping landowners implement these practices and how to work to overcome barriers that are stopping them from implementation, including funding streams.

DEDICATION

This thesis is dedicated to all of the incredible friends and colleagues that I gained here at Clemson. Thank you for your guidance, technical advice, and most of all, your friendship.

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There are many people who contributed to this project and provided significant insight on how to carry out this research, provided opportunities for presentations, and gave encouragement. Dr. Tom Williams, Sarah Wescott, Dr. Mustapha Alhassan, and Stephen Prisley provided invaluable information about forest management, the California Carbon Market, and utilizing FIA data effectively. Dr. Bhupinder Farmaha, Dr. Alejandro Plastina, Ronnie Clevenstine, and Dr. Mustapha Alhassan were helpful in creating and analyzing the cover crops survey.

I am very thankful for the opportunity to present this research at a variety of Forest Service meetings and other conferences across the country. It is my hope that presenting our research will have an impact on sustainable land management somewhere, somehow.

Dr. Rob Baldwin and Dr. Bo Song provided unwavering support and advice for the direction of my research and insight into the “big picture” of how this research will affect stakeholders.

I am indebted to my colleagues in Marzieh Motallebi’s lab for their help and support of my projects and stimulating my passion for research. Carl and Joan Ureta, Sam Cheplick, Jeremy Dertien, and Dr. Daniel Hanks have provided both technical and personal support over these last two years. Katie Perkins, a Clemson undergraduate student, provided invaluable help with data entry, analysis, and presentations.

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CHAPTER ONE

AN INTRODUCTION TO SUSTAINABLE LAND MANAGEMENT

South Carolina is dominated by agriculture and forestry lands. Much of these lands are owned by private landowners and contribute to a large portion of South Carolina's economy. In 2019, forestry was the state's largest industry, pulling in $21 billion. With the significant agriculture and forestry farming of these lands, it is crucial that the land is protected in a way that allows for the continued use and production for many years. Best management practices (BMPs) are methods for land conservation that preserve water quality, soil quality, and promote sustainable land management. BMPs are highly encouraged for foresters and farmers to increase and maintain forest, soil, and ecosystem health. However, one of the best ways to protect our working lands is to keep forests as forests and protect agriculture lands for current and future food production to reduce urbanization. The protection of these resources is crucial simply for the sustainability of the human race.

Management for carbon sequestration involves a large focus on specific sustainable management practices that maintain forest and stand structure. These types of management practices are for those landowners who are not interested in repeatedly clear cutting their forest for timber. In South Carolina, only 20% of forest landowners utilize their land for timber production, therefore forest management that results in carbon sequestration is potentially very applicable for 80% of forest landowners. Additionally, in the last 15 years, a market for forest carbon management has emerged. Through the California Carbon Market, landowners can be paid to sequester carbon on their forest lands. Chapter 1 of this thesis focuses on understanding which forest management practices can be most beneficial in sequestering carbon. These forest management practices focus on conservation management techniques that preserves forest structure, encourages carbon sequestration, and they will often result in many co-benefits for wildlife and water quality. South Carolina has a variety of forest types, from bottomland hardwood forests throughout the low country to oak-hickory forests in the upstate. Loblolly pine is the dominant forest type in South Carolina, and also is the primary forest harvested for timber. Because of the significant amount of privately-owned forest land in South Carolina, the carbon offset market could be a viable source of income for many landowners.

BMPs for forestry and agriculture operations have been implemented through a variety of different cost share and government programs across the country and in South Carolina. Cover crops are a viable best management practice to protect the soil resource from erosion on agriculture lands. Through the research presented in this paper, the implementation rates and perceived benefits and challenges of cover crops were analyzed throughout South Carolina. The same type of study was done to better understand best management practices for forest management practices, including prescribed fire. Many of these BMPs are crucial for protection of the environment and can have significant impacts on not just the landowners but also the general public. Many landowners suffer from a lack of awareness of educational opportunities and management alternatives for their land. It is difficult for landowners to implement best management practices when they do not know where to begin. It is the job of a variety of organizations, Cooperative

Extension, state and federal forest service agencies, and non-profits to reach out to these landowners to increase their awareness of BMPs. With this data, it can be better understood where there are shortfalls for implementation and where federal funding could increase implementation rates by analyzing willingness to accept rates. Long term goals are to better understand how landscape management and stewardship plans based on co-benefits can positively affect the environment and economic wellbeing of rural forest and agriculture landowners.

Through this research, I aim to promote a variety of options to landowners that help increase forest and watershed health, and provide landowners with different and more sustainable options to support their land management goals. With environmental changes happening rapidly, an increased rate of BMP implementation is crucial to protecting landscape-scale ecosystems.

CHAPTER TWO

CARBON SEQUESTRATION IN SOUTH CAROLINA FORESTS AND THE EFFECTS OF MANAGEMENT PRACTICES

Introduction

Forests are an important tool for carbon storage and provide a variety of ecosystem services, including the reduction of ambient CO_2 levels (Baral, Malla, & Ranabhat, 1970; Woodbury, Smith, & Heath, 2007). A global carbon sink sequesters a certain amount of carbon that is a result of anthropogenic activities and can result in reduced carbon levels in the atmosphere (Woodbury et al., 2007). These carbon sinks are important assets for mitigating climate change across the world. Forest type is known to have an effect on the quantity of carbon that can be sequestered (Lal, 2005; Woodbury et al., 2007). Furthermore, when management regimes change for different forest types, these changes can have an effect on the carbon storage capabilities (Fang, Chen, Peng, Zhao, & Ci, 2001; Woodbury et al., 2007). On the basis of our knowledge of how forest type and management regimes can affect carbon sequestration, these factors can play a major role for landowners who are interested in participating in the California Carbon Market or other carbon markets.

The California Carbon Market encourages landowners across the country to sell offset credits to industries in California that are required to purchase offset credits. Offset credits are project-based carbon credits, where certain forestry or other types of projects can mitigate carbon emissions (Galatowitsch, 2009; Lovell, 2010). Certain industries are required to purchase these credits to offset their emissions and adhere to carbon reduction targets (Lovell, 2010). One metric ton of CO_2 is equivalent to one carbon credit. Credits are currently sold for around $12–$15 per credit (“California Carbon Dashboard: Carbon Prices, the Latest News, and California Policy,” 2015). The use of offsets provides an opportunity for increased landscape-scale restoration through reforestation projects and implementing carbon offset projects on sites vulnerable to land use change. (Galatowitsch, 2009). Through offset sales, landowners are encouraged to reduce the chance of deforestation and maintain their forested land at least for the length of time the conservation easement is enforced. A conservation easement is a legal agreement that voluntarily protects and limits the development on a certain tract of land, and it is required to be implemented for any compliance market carbon project for 100 years. As of 2012, data indicates that 731 million forested acres in the U.S. could potentially sequester around 10% of annual CO2 emission in the U.S. (Miller, Snyder, & Kilgore, 2012). The expansion of the California Carbon Market and other carbon regulatory frameworks is expected to provide a market incentive and increase the desire for private landowners to manage forested land in a way that sequesters carbon and reduces the extraction of timber and land use change.

The Climate Action Reserve (CAR) was created by the California Climate Action Registry (CCAR) in 2008 as a registry for carbon offset credits (Lovell, 2010). This organization helps landowners understand how the carbon market works, provides protocols for certifying offset credits, and aids in project verification (“Climate Action Reserve,” 2015). Landowners who are interested in certifying offset credits from their forest land must enter into a 100-year conservation easement and must have a third party verify carbon sequestration every six years (“Climate Action Reserve,” 2015;

Narassimhan, Gallagher, Koester, & Alejo, 2018). Verification of the carbon credits requires that the carbon being measured is a change or increase in carbon from a previously verified value, otherwise known as a common practice value for aboveground carbon (“Climate Action Reserve,” 2015; Fahey et al., 2010). While this value indicates carbon stocks in a certain region (static values), carbon sequestration represents a rate of change in carbon stocks over time. Verification is crucial to determine as accurately as possible the actual rates of carbon sequestration and to reduce leakage (Marland, Bruce, & Schneider, 2001). Verification takes place every six years to determine if management practices or the amount of credits issued needs to change (“Climate Action Reserve,” 2015).

The following study outlines how various forest types and stands in South Carolina (SC) respond to a variety of management practices when using a forest growth model to predict changes over 100 years. Carbon sequestration values over 100 years gained from the forest growth model will help forest landowners have an idea if selling offset credits on their forestland would be a profitable endeavor.

This forest analysis will (1) determine if an increase in carbon stocks is predicted over 100 years in South Carolina forests, warranting a carbon project, (2) determine the effects of location within the state and forest type on carbon sequestration, and (3) determine which management practices are the most productive in terms of carbon stocks.

Methods

Software and Data

This project was carried out utilizing United States Department of Agriculture (USDA) Forest Service data from the Forest Inventory Analysis (FIA) database ("Forest Inventory and Analysis Database," 2019; Kerchner & Keeton, 2015). This database includes a variety of forest types and survey information for most forested lands in most states. All of the analyzed plots are one acre (0.4 hectares) in size. Data for specific forest types in South Carolina were extracted, then converted into files that were readable by the Forest Vegetation Simulator (FVS) (Crookston & Dixon, 2005; Hoover & Rebain, 2010). FVS was created by the USDA Forest Service with the intention of modeling forest dynamics on the basis of a variety of different management practices and disturbances. FVS is a semi-distance-independent forest growth model, where individual trees within a stand are primarily analyzed, and the spatial variability is statistically represented (Marland et al., 2001). The various parameters analyzed to determine growth and yield are based upon data specific to geographic location, i.e., there are different growth equations used for different areas of the United States (Hoover & Rebain, 2010). This model has been used since the 1970s and has extensive validation (Froese & Robinson, 2007; Hummel, Kennedy, & Ashley Steel, 2013; Rauscher, Young, Webb, & Robison, 2000; Teck, Moeur, & Eav, 1996). There are also many post processors that are available in the software suite. One of these includes the carbon report, which analyzes the carbon stocks every cycle, based upon the management or disturbances that are activated by the user. Carbon data are directly related to the biomass reports that are first derived from FIA data then manipulated in the model. Additionally, since FVS is a stand dynamics model, the carbon report is flexible every 5 or 10 years and is reflective of the management parameters selected (Hoover & Rebain, 2010).

Data Analysis

Four major forest types were analyzed. These include loblolly pine, longleaf pine, oak–hickory, and oak–sweetgum–cypress. FIA data showed that these were the most prolific forest types in South Carolina, and many landowners could have these forest types on their property. In total, 130 plots were chosen to model (Figure 1). Table 1 shows how many stands were analyzed for each forest type and the percent that forest type accounts for out of the total forested land in SC (“Climate Action Reserve,” 2015).

Table 2.1. Forest type, number of stands analyzed, and percentage of that forest land in South Carolina (SC).

Forest Type	Stands Analyzed	% of Forested Land
Loblolly pine	39	43.4
Longleaf pine	22	4.3
Oak–Hickory	24	22.1
Oak–Gum–Cypress	45	14.7

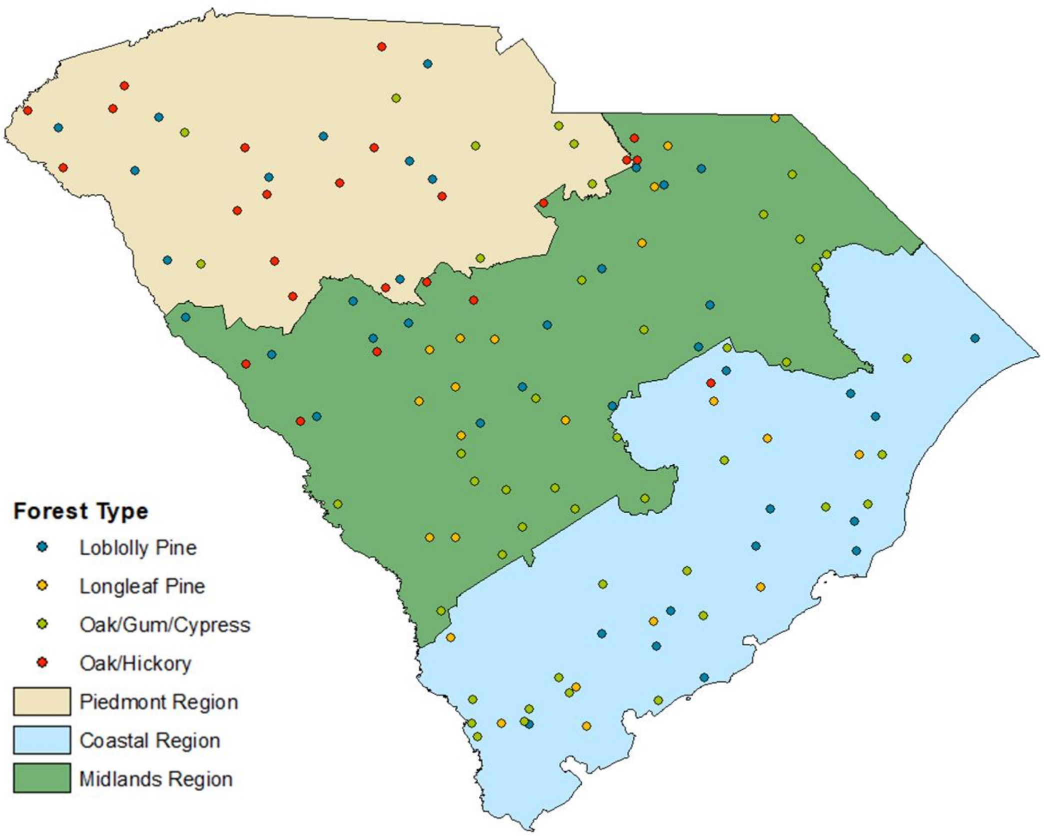

Figure 2.1. SC Forest Inventory Analysis (FIA) plot locations identified by forest type analyzed in this study.

We selected the plots by their compatibility with the FVS model. They were also selected on the basis of age and location within the state. Ideally, at least three stands within each age bracket (as determined through natural breaks based upon available stands in ArcMap) and location within the state, i.e., Piedmont, Midlands, and Coast, were chosen for the analysis. The goal was 45 stands for each forest type (3 regions × 5 age brackets × 3 stands per age bracket and stand), but due simply to the lack of availability of the necessary amount of stands that were viable for FVS, only oak–gum–cypress had the full 45 stands. For longleaf pines, there were no stands in the Piedmont area, so data will only show stands in the midlands and coastal area. For oak–hickory, there were no stands in the Coastal area, so only data from the Piedmont and Midlands are included.

Management Practices

Key features that are important in the model include tree species, density, diameter, height, crown ratio, diameter growth, and height growth (Crookston & Dixon, 2005; Leites, Robinson, & Crookston, 2009). Variables for each FIA plot analyzed included the aspect, elevation, slope, density, and site potential (Crookston & Dixon, 2005). All of these variables were consistent for each stand analyzed (data obtained from the FIA), and the only changes regarded the 10 management practices. The management practices indicated in Table 2 were implemented for all stands*. They are referred to by their number in the results. The parameters indicated in the "Notes" section of Table 2 correspond to the input requirements of the model for each management practice.

Table 2.2. Management practices used in Forest Vegetation Simulator (FVS).

Management Identifier	Step #	Management Description	Year	# of Years after 2016	Notes	
1	1	Clear cut	2036	20	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	2	Artificial Regeneration	2038	22	75% survival	Species same as forest type
	3	Clear cut	2051	35	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	4	Artificial Regeneration	2053	37	75% survival	Species same as forest type

Management Identifier	Step #	Management Description	Year	# of Years after 2016	Notes	
	5	Clear cut	2086	70	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	6	Artificial Regeneration	2088	72	75% survival	Species same as forest type
2	1	Thin from below	2031	15	Residual Density: 75% trees/acre	
	2	Clear cut	2036	20	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	3	Artificial Regeneration	2038	22	75% survival	Species same as forest type
	4	Thin from below	2046	30	RD: 50%	
	5	Clear cut	2051	35	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	6	Artificial Regeneration	2053	37	75% survival	Species same as forest type
	7	Clear cut	2086	70	5 Legacy Trees @ 15 in min.	Smallest DBH: 5 in
	8	Artificial Regeneration	2088	72	75% survival	Species same as forest type
3	1	Thin from below	2031	15	RD: 75% trees/acre	
	2	Thin from below	2046	30	RD: 50%	
	3	Thin from below	2076	60	RD: 50%	
4	1	Clear cut	2026	10	5 Legacy Trees @ 15 in min.	Smallest DBH: 10 in
	2	Artificial Regeneration	2028	12	75% survival	Species same as forest type
5	1	Thin from below every 15 years	Begin in 2026	10	Residual Density: 75% trees/acre	
6	1	Thin to Q-Factor (Thin every 20 years)	Begin in 2031	15	Minimum Basal Area: 120	Q-Factor: 1.4
7	1	Thin to Q-Factor-2 (Thin every 30 years)	Begin in 2031	15	Minimum Basal Area: 80	Q-Factor: 1.4
8	1	Prescribed Burn (Early Spring)	Every 7 years	Beginning in 2019	Wind Speed: 5 mph; Air Temp: 45 °F; 50% land burned; Fuel Designation: 3 = Dry	
9	1	Prescribed Burn (Early Spring)	Every 3 years	Beginning in 2019	Wind Speed: 5 mph; Air Temp: 45 °F; 50% land burned; Fuel Designation: 3 = Dry	
0	1	No Management				

The above management practices were applied to all stands equally, and projections were run from 2016 to 2116, with a five-year increment, which generated a carbon stock value (tons/acre) every 5 years and a carbon removed value (tons/acre) every 5 years. The carbon stock values are representative of aboveground and belowground live and standing dead carbon stocks (soil carbon is not included in the compliance protocol for offset credits in the California Carbon Market) (Kerchner & Keeton, 2015). The carbon removed values are representative of any merchantable wood removed from the forest in the model. Carbon values for each stand in each management practice were recorded.

Normalization

The baseline carbon value was determined from FIA data, and 2016 is the baseline year, so the data provided for the year 2016 were utilized as the baseline for all stands. A normalized value was determined for each stand and each management practice. This value was calculated using the below equation:

$$\text{Normalized Value} = \text{CSV}/\text{BC},$$

where CSV = average carbon stock value (averaged values from 20 outputs, i.e., five-year cycles were averaged for a 100-year carbon sequestration average) and BC = baseline carbon value (year 2016). The baseline carbon value was derived from the 2016 data for each FIA plot.

The results throughout the paper are reported as normalized values. Normalized values indicate the rate of sequestration over time in reference to the baseline, and this value is crucial to calculating carbon credits and subsequently compensating the landowners. While the baseline for carbon projects is often calculated using a more region-specific value, using a specific value in this case for each plot provides exact values for sequestration over time and a more accurate understanding of sequestration on each plot. Baseline and projected carbon stock values for all plots and information about all plots can be found in the excel tool created to read the data from this project. The link to the tool can be found here: (bit.ly/2HlkHUa). This link is beneficial for landowners looking to plan for participating in the carbon market, but landowners must know that these values are only representative of carbon sequestered on that exact plot from 2016 to 2116 and additional modeling on their own property would be required to comply with the California Carbon Market requirements. Values are reported in tons/acre.

Statistical Analysis

Statistical analysis was completed to determine: (1) the differences in carbon sequestration between management practices among all stands by forest type and (2) the difference in normalization means based on plot age among all stands by forest type. Statistical analysis was carried out using SPSS™, the ANOVA least significant difference (LSD) model for the management-based sequestration comparisons, and the non-parametric Kruskal–Wallis one-way ANOVA test for age comparisons. All values declared significant were characterized by $p < 0.05$. This statistical analysis will help landowners make more informed decisions about which of these management practices will significantly affect carbon sequestration on their land depending on forest type and age, so they can take into consideration other management actions for other goals.

Results and Discussion

Loblolly Pine Forest

Loblolly pine forests are the predominant forest type in SC. The majority of forest lands in SC are dominated by loblolly pine (“Land Cover Viewer - Map,” 2019). A variety of different management practices can provide increased carbon stocks over 100 years.

Among the three different regions of SC, Piedmont, Midlands, and Coast, 39 loblolly plots were studied. Three stands that were all under the age of two years did not have any carbon sequestration on the property for any management plan for the projected 100 years. All data hereafter do not include these three stands. Management Methods 3 and 5 (thin from below 1 and 2) and Management Method 0 (no management) provided an overall increase in carbon stocks over 100 years for all analyzed stands. Management Methods 8 and 9 (prescribed burns) provided an overall increase in carbon stocks for 33 and 29 stands, respectively. Management Methods 4, 6, and 7 (clear cut—3; thin to Q-factor; thin to Q-factor—2) provided an overall increase in carbon stocks for 27, 26, and 24 stands, respectively.

For 28 loblolly pine plots, no management (Management Method 0) generated the largest average carbon stock over 100 years. Seven stands generated the most carbon stocks using Management Method 5 (thin from below). One stand generated the most carbon using Management Method 4 (clear cut—3). If no management was not considered for maximum average carbon stocks, 34 stands would have generated the maximum average carbon stock using Management Method 5 (thin from below—2). The minimum value of carbon stocks was generated most often using Management 1 and 2 (clear cut 1 and 2).

The difference in rates of carbon sequestration can be attributed to the management performed on the property, specifically, the carbon that is removed due to thinning, burning, or uneven aged thinning/large tree removal (Powers et al., 2011). The number of stands in this study with increases in carbon sequestration is significant because of the various parameters of each plot; the more the plots that have similar carbon sequestration rates per management practice, the higher the applicability of the management practice at different locations.

Management Method 0 (no management) had the highest normalization value, indicating that the greatest amount of carbon would be sequestered with no management in these forest stands. Management 1 and 2 (clear cut) had the lowest normalization values, which were lower than 1, indicating that the values of carbon would not be greater than the baseline values. For most of the management practices, the normalization values were significantly higher in the Piedmont region and brought the average up for the entire state. This may show ($p < 0.05$) that all the management practices (except for 1 and 2) would increase carbon stocks solely depending on the location (Table 3).

Table 2.3. Normalization values (avg. carbon stock value/baseline carbon value) for loblolly pine plots.

Management Regime	Coast	Midlands	Piedmont	Overall Average
1 [a]	0.8	0.8	0.9	0.9 ± 0.1
2 [a]	0.8	0.9	1.0	0.9 ± 0.1
3 [b]	2.0	2.0	3.0	2.3 ± 0.6
4 [c]	1.5	1.5	2.3	1.8 ± 0.5
5 [b]	2.1	2.1	3.2	2.5 ± 0.6
6 [c]	1.3	1.4	2.3	1.7 ± 0.6
7 [c]	1.2	1.3	2.0	1.5 ± 0.4
8 [c]	1.6	1.7	2.4	1.9 ± 0.4
9 [c]	1.3	1.4	1.9	1.5 ± 0.3
0 [b]	2.1	2.2	3.4	2.6 ± 0.7

[a] Significantly different between all regimes except for 1 or 2, [b] significantly different between all regimes except for 3, 5, or 0, [c] significantly different between all regimes except for 4, 6, 7, 8, or 9.

Management Method 5 maintained carbon stock values closest to those of no management. This may be a more effective management regime than no management to reduce the potential for fire and pest issues. Other management practices such as Management 8 (prescribed burn—1) may provide the desired carbon stocks while reducing the threat of uncontrolled fire or disease. Furthermore, Management 6 and 7 provided smaller carbon stocks, but may provide another source of income due to the uneven-aged cutting. These benefits and tradeoffs would need to be determined by the specific landowner.

Upon analysis of the differences in carbon sequestration for all management practices based upon age, it was determined that the younger plots had a much higher sequestration rate ($p < 0.05$) than the rest of the stands (Table 4). This is likely due to the fast-growing rate of loblolly pines in the first stage of life. Additionally, loblolly pines are one the most commonly harvested tree in SC. This increases the unnatural disturbances that the land receives at a rate of every 25–35 years depending on management. These disturbances can have a significant effect on the carbon sequestration due to harvest and subsequent stand regeneration (Powers et al., 2011) ("n" in the chart is the number of plots analyzed in that age range.)

Table 2.4. Normalization (avg. carbon stock value/baseline carbon value) mean for all management practices separated by stand age for loblolly pine plots.

Age	Mean ± SD	n
1–11	2.63 ± 1.51 [a]	5
12–24	1.79 ± 1.08	9
25–36	1.52 ± 0.70	10
37–59	1.71 ± 0.90	9
60–88	1.02 ± 0.35	3

[a] Normalization values are significantly different ($p < 0.05$) from those of the rest of the samples.

Longleaf Pine Forest

Longleaf pine forests are decreasing in South Carolina, and restoration of the longleaf pine forest is paramount for many conservation organizations ("The Longleaf Alliance," n.d.). Longleaf pine forests require more intensive management, specifically, artificial regeneration and often times prescribed and managed burns. For these reasons, clear cutting is not often a viable management technique for longleaf pine forests in SC; thus, Management practices 1, 2, and 4 were not modeled.

Most management practices helped increase carbon sequestration. One stand at age 2 did not have any sequestration or foliage and will not be included hereafter.

Management Method 0 (no management) provided the most carbon sequestration for 20 out of the 21 analyzed stands (Table 5).

If Management Method 0 is not included, Management Methods 5 (thin from below every 15 years), 6 (uneven-aged thin every 20 years), and 8 (prescribed burn every 7 years) were the second more productive management practices. Management Method 5 had the highest carbon sequestration averages for 13 stands. Management Method 6 had the highest carbon sequestration average for four stands. Management Method 8 had the highest carbon sequestration average for three stands.

Management Method 9 (prescribed burn every 3 years) seemed to be the most detrimental to carbon sequestration, as only 9 stands had positive carbon sequestration averages after 100 years (above the baseline) with this management, and it had the smallest carbon sequestration value among all management practices for 14 stands. Management Method 7 (uneven-aged thinning every 30 years) had 7 stands where the average carbon sequestration after 100 years went above the baseline. This management practice had the smallest carbon normalization value among all management practices for 7 stands. While prescribed burning is extremely important for the regeneration of the species and the management of the longleaf pine forest, it may not be the best choice for carbon sequestration. Additionally, multiple types of management in a longleaf pine forest may be necessary to obtain maximum sequestration.

Table 2.5. Normalization values (avg. carbon stock value/baseline carbon value) for longleaf pine plots.

Management Regime	Coast	Midlands	Overall Average
3 [a]	2.1	1.8	2.0 ± 0.2
5 [a]	2.2	1.8	2.0 ± 0.3
6	2.3	1.6	2.0 ± 0.5
7 [b]	1.9	1.4	1.7 ± 0.4
8 [b]	1.8	1.6	1.7 ± 0.1
9 [c]	1.3	1.2	1.3 ± 0.1
0 [d]	3.0	2.2	2.6 ± 0.6

[a] Significantly different between regime 9,
[b] significantly differently between regime 0,
[c] significantly different between all regimes except for 4, 6, 7, 8, or 9,
[d] significantly different between regimes 7, 8 and 9.

Management Method 0 (no management) had the highest normalization value, indicating that the greatest amount of carbon would be sequestered with no management to these forest stands. Management 9 (prescribed burn every 3 years) had the lowest carbon sequestration for all stands, followed by Management 7. In terms of location, the average values in the state did vary slightly, with the coastal plots in the case being more productive in all categories of management.

The trends in the average carbon stocks over 100 years did show statistically significant correlations ($p < 0.05$) between stand ages, and the average normalization values for increases in carbon stocks compared to the baseline across all management practices did show a slight downward trend when comparing stand age (Table 6).

Table 2.6 Normalization (avg. carbon stock value/baseline carbon value) mean based on stand age for longleaf pine plots.

Age	Mean ± SD	n
2–11	2.32 ± 2.16 [a]	4
12–26	2.25 ± 0.88 [a]	7
27–60	1.42 ± 0.56	3
61–76	1.15 ± 0.38	3
77–90	1.43 ± 0.49	5

[a] Normalization values are significantly different ($p < 0.05$) from the rest of the samples.

Oak–Hickory Forest

Oak–hickory forest is prominent in the Piedmont (northwest) region of SC. These forest lands are the dominant forest type in western SC and would potentially be very important for carbon sequestration and contributing to the California Carbon Market. Historically, Oak–hickory forests are not a native forest type but they have become prominent as a result of fire suppression in the region over many years ("Oak-Hickory Forest," 2019). This has increased the carbon sequestration and storage of the Piedmont region, as native prairie may not have stored as much carbon (Hallgren, Desantis, & Burton, 2012). Furthermore, many of the stands are older than 66 years. This may affect their ability to increase carbon stocks, as there are already significant carbon stocks in existence.

In our model, the Oak–hickory forests were managed the same as the pine forests, and many of the results were relatively the same. Management 5 (thin from below—2), Management 0 (no management), and Management 3 (thin from below) were the most effective management practices for the oak–hickory forest. Management 0 and

Management 5 both had 11 stands that had the highest average carbon stocks. Management 3 had two stands that had the highest average carbon stocks. Management 5 continued to be the most effective as 10 additional stands for Management 5 had the highest carbon stocks, excluding Management 0. It was also notable that Management 3 (thin from below), Management 8 (prescribed burn), and Management 9 (prescribed burn 2) all had positive average carbon stocks after 100 years (Table 7).

It was very clear that clear cutting, even with regeneration, was ineffective for carbon management. We found that 22 out of the 24 stands had their lowest average carbon stocks over 100 years with Management 2 (clear cut—2). One stand had its lowest average carbon stock with Management 7 (thin to Q-factor—1), and the last stand had its lowest average carbon stock with Management 1 (clear cut). Management 1 was also highly ineffective for carbon management. Management 6 and 7 (thin to Q-factor 1 and 2) did increase carbon stock averages but not at a rate that would provide significant income for the carbon market.

Table 2.7 Normalization values (avg. carbon stock value/baseline carbon value) for oak–hickory plots.

Management Regime	Midlands	Piedmont	Overall Average
1 [a]	0.8	0.9	0.9 ± 0.1
2 [a]	0.7	0.9	0.8 ± 0.1
3 [a]	1.8	2	1.9 ± 0.1
4 [a]	1.2	1.5	1.4 ± 0.2
5 [a]	1.8	2	1.9 ± 0.1
6 [a]	1.3	1.4	1.4 ± 0.1
7 [a]	1.1	1.3	1.2 ± 0.1
8 [a]	1.5	1.7	1.6 ± 0.1
9 [a]	1.4	1.5	1.5 ± 0.1

0 [a]	1.8	2.1	2.0 ± 0.2

[a] Significantly different between all regimes except for 1 or 2,
[b] significantly different between all regimes except for 3, 5, or 0,
[c] significantly different between all regimes except for 4, 6, 7, 8, or 9,
[d] significantly different between 5, 8, and 0,
[e] significantly different between all regimes except 4 and 6,
[f] significantly different between all regimes except 9.

In terms of overall averages, Management Method 0 (no management) had the highest normalization value, indicating that the greatest amount of carbon would be sequestered with no management to these forest stands. Management 1 and 2 (clear cut 1 and 2) has the lowest carbon sequestration for all stands, followed by Management 4 and 9. Management 3 and Management 5 (thin from below and thin from below—2, respectively) were very close to Management 0. The average normalization values for the different locations were relatively close, but it is clear that the Piedmont plots had a higher average normalization value in all management categories than the Midland plots. For the Midland plots, Management 0 and 5 had the same average normalization values, whereas for the Piedmont plots, Management 0 had a slightly higher average normalization value than Management 5. These management practices are considerably different, yet they yield almost the same results.

In terms of maximization of carbon sequestration, it is known that microbial respiration has higher rates in younger stands; thus, older stands will not be as productive at sequestering carbon (Birdsey et al., 2006). These factors could potentially encourage some inclusion of thinning and uneven-aged tree removal that would increase carbon sequestration. These decisions would be made at the stand/parcel level by the landowner.

The trends in the average carbon stocks over 100 years did not show statistically significant correlations between stand age, but the average normalization values for increases in carbon stocks compared to the baseline across all management practices did show a dip for middle-aged trees (age 35–65) when comparing stand age (Table 8). Furthermore, many of the stands are older than 66 years. This may affect their ability to increase carbon stocks, as older stands often sequester less carbon than younger stands (Jin et al., 2017).

Table 2.8. Normalization (avg. carbon stock value/baseline carbon value) mean based on stand age for oak–hickory plots.

Age	Mean ± SD	n
0–34	1.48 ± 0.45	5
35–57	1.26 ± 0.48	7
58–65	1.43 ± 0.48	3
66–77	1.68 ± 0.54	5
78–91	1.49 ± 0.73	5

Oak–Gum–Cypress Forest Data Analysis

Oak–gum–cypress forests in South Carolina were important to examine because of their prominence in many lowland areas. This may mean that these areas are already providing important ecosystem services, and it is important to value these services and discourage the conversion of these lands that would ultimately reduce carbon sequestration. These services include water retention that results in flood mitigation and biodiversity hotspots that provide refuge many unique plants and animals.

There were a significant number of plots available to analyze this forest type, and we were able to obtain 45 plots. Unfortunately, all age groups and locations were not equally represented as there were not enough young plots or plots in the Piedmont region. The majority of the plots are primarily in the middle of the state but there are a few in the north, and many in the southern regions of the state. The plots in the southern regions are mostly older plots, ranging from 65 to 90 years. One plot was removed from the analysis due to the lack of vegetation and subsequent carbon sequestration.

The structure of the Oak–gum–cypress forest does not vary significantly from that of the oak–hickory forest, but the management practices that would be productive for carbon management are more variable for this forest type. This may be due to beneficial climate conditions that occur in these ecosystems, such as high amounts of moisture and nutrients. Additionally, many of these stands are well stocked, contributing to large carbon stocks (Foley, 2009). We found that 24 stands had the highest average carbon stocks after 100 years for Management 0 (no management), 13 stands had the highest average carbon stocks for Management 5 (thin from below—2), 4 stands had two management practices with identical carbon sequestration, 2 stands had identical carbon sequestration for Management 5 and Management 0, and 2 stands had identical carbon sequestration for Management 4 and Management 0. If Management 0 was not considered in the analysis, 20 more stands would have Management 5 as the highest average carbon stocks. These stocks had often only 1–2 tons/acre (2.2–4.4 tons/hectare) of carbon less than Management 0 (Table 9).

Management 1 and 2 (clear cut 1 and 2) were primarily the management practices with the lowest average carbon stocks after 100 years, as expected (Liski et al., 2001). This accounted for 31 of the 44 analyzed stands. Notably, Management 9 (prescribed burn—2) had 10 stands that had the lowest average carbon stocks. It was definitely clear that the youngest stands were most affected by prescribed fire, and this resulted in the lowest carbon stocks. This management practice was highly variable between stands. Also, Management 4 had two stands with the lowest average carbon stocks, and Management 5 had one stand.

Table 2.9. Normalization values (avg. carbon stock value/baseline carbon value) for oak–gum–cypress plots.

Management Regime	Coast	Midlands	Piedmont	Overall Average
1 [a]	1.3	1.1	0.7	1.0 ± 0.3
2 [a]	1.2	1.1	0.7	1.0 ± 0.3
3 [b]	2.7	2.6	1.6	2.3 ± 0.6
4 [c]	2.4	2.3	1.1	1.9 ± 0.7
5 [b]	2.8	2.7	1.6	2.4 ± 0.7
6 [d]	2.1	2.0	1.0	1.7 ± 0.6
7 [e]	1.9	1.7	0.9	1.5 ± 0.5
8 [e]	1.8	1.8	1.3	1.6 ± 0.3
9 [e]	1.3	1.2	1.0	1.2 ± 0.2
0 [b]	2.9	2.8	1.6	2.4 ± 0.7

[a] Significantly different between 3, 4, 5, 6 and 0, [b] significantly different between 1, 2, 7, 8, and 9, [c] significantly different between 1, 2, and 9, [d] significantly different between 1, 2, 5, and 0, [e] significantly different between 3, 5, and 0.

Management 0 (no management) had the highest normalization value, indicating that the greatest carbon would be sequestered with no management to these forest stands.

This is consistent with the results of a study by Ruddell et al. (2007). Management 1 and 2 (clear cut 1 and 2) had the lowest carbon sequestration for all stands, followed by Management 9. Management 3 and Management 5 (thin from below and thin from below—2, respectively) had carbon normalization values very close to those of Management 0. For most of the management practices, the normalization values were significantly higher in the Coastal and Midlands regions, and these areas helped bring up the average, whereas the Piedmont region was not nearly as productive. These values were among the highest for a forest types, except for the Piedmont region.

While no management provided the highest carbon sequestration values for almost all stands, this may not be the best choice, depending on the land and landowner (Fahey et al., 2010; Harmon & Marks, 2002). Consistent thinning and some prescribed burn proved to be effective for some stands, and these practices may help reduce brush that could potentially cause unwanted fires, while thinning can help reduce disease that could decimate the stand. These decisions would be made at the stand level by the landowner.

The trends in the average carbon stocks over 100 years did not show statistically significant correlations to stand age or forest type, but the average normalization values for increases in carbon stocks compared to the baseline across all management practices did show a consistent decrease, especially for the very young stands (Table 10).

Table 2.10. Normalization (avg. carbon stock value/baseline carbon value) mean based on stand age for oak–gum–cypress plots.

Age	Mean ± SD	n
0–13	4.45 ± 2.71 [a]	8
14–31	1.51 ± 0.51	9
32–43	1.40 ± 0.51	9
44–66	1.14 ± 0.44	9
67–90	1.12 ± 0.41	9

[a] Normalization values are significantly different ($p < 0.05$) from those of the rest of the samples.

Assumptions and Limitations of the Model

The FVS model is a powerful tool but may not always accurately represent what would occur in many forest stands. Each management practice does not take into account disease or unintended fire. Furthermore, it does not take into consideration the need for roads and other human-made structures that take up space in the forest, thus reducing carbon stocks. The age of the stands was also a limiting factor, as very young stands (< 3 years) would have limited data inputs compared to older stands. Three loblolly stands were removed from the analysis due to a lack of inputs. While the limitations of the FVS are known in this study, the use of the FVS model is important to replicate how landowners and carbon managers project carbon sequestration on their land. It is also worth noting that the results of this study report only the carbon stocks in forest trees and those in not removed, merchantable wood. Removed, merchantable wood could result in carbon sequestration offsite, depending on the use of those wood products. Additional research and inputs in the model are needed to take into consideration climate change-related disturbances (Anderegg et al., 2015).

Conclusions

The data provided in this document cover a range of forest types and forest plots in South Carolina. In total, 130 plots were analyzed and provided a vast amount of data regarding how different management practices affect the carbon sequestration of each stand. Overall, it was determined that for most of the plots, no management at all would increase carbon stocks the most. Next, Management 5 (thin from below every 15 years) was the second most productive management practice and could potentially provide additional income through the merchantable wood harvested. Management 3 (thin from below three times) was the third most productive management practice for all stands and may be easier on landowners, as it only requires thinning three times throughout the 100-year cycle. Overall, many of the stands increased carbon stocks over the 100 years and did not decrease carbon stocks unless clear cutting was reoccurring. This shows that there is significant potential for SC forests to sequester carbon at a rate that would be viable to sell as offset credits in the California Carbon Market. Conversely, the stands that were recently planted and very young did not show positive effects for carbon sequestration over 100 years. This may be due to the limited data available for the model that are not completely reflective of what would actually occur with that specific management initiative.

Reforestation projects and expansion of current forests can have a significant impact on the accumulation of atmospheric carbon, often sequestering more carbon than natural forests (Fang et al., 2001; Mcmahon, Parker, & Miller, 2010). Additionally, due to climate change and the rapid increase of CO2 in the atmosphere, forest disturbances may heighten the potential for increased fires, pests, and drought (Anderegg et al., 2015; Seidl et al., 2017). These types of disturbances may invalidate the FVS model over the course of the projected 100 years. The Forest Project Protocol created to manage carbon credits under the compliance system does consider the potential for increased severity of disturbances ("Climate Action Reserve," 2015). A buffer pool is required for each project in case of loss of trees due to an unexpected disturbance, and additional modeling is required over time to reevaluate carbon stocks and the current rates of sequestration ("Climate Action Reserve," 2015). Due to the potential for increased tree mortality, it is possible that buffer pools will need to be increased and requirements for carbon sequestration increased if current modeling requirements (as utilized in this study) are continued (Allen, Breshears, & McDowell, 2015). The effects of climate change on long-term modeling are still poorly understood, and additional research is needed (Anderegg et al., 2015).

The southeastern region is the largest carbon sink in the U.S. (Lu et al., 2015). Climate change mitigation is crucial to reduce sea level rise, maintain organismal biodiversity, and to maintain a sustainable food supply for the world's growing population (Mase, Gramig, & Prokopy, 2017). The California Carbon Market could provide a means for the southeast and other regions of the U.S. to increase their capacity to be a carbon sink. Additionally, as more forest land is conserved for the carbon market or otherwise, the impact of disturbances such as disease decreases (Lu et al., 2015). Land use also affects climate change significantly, as many natural forests have been converted to loblolly pine stands in the South, as does an increase in urbanization. It has been predicted that if agriculture prices can remain stable, forest lands can increase, and urbanization can be reduced (Johnsen et al., 2001). This highlights the critical nature of involving all landowners in the carbon sequestration process, whether that be avoided conversion on agriculture land or improved forest management on timber and non-industrial private forest lands.

Due to the availability of FIA data for most of the United States and the open access features of FVS, this project is repeatable for other states. Additionally, depending on the parameters of each plot and the management practices employed, this data could be used in other locations that are similar to plot locations in SC. Forest management is a crucial step to sequestering atmospheric carbon.

The Microsoft Excel tool created from this research also provides an easy-to-use database for landowners interested in how certain forest attributes and location affect carbon sequestration. This information can provide carbon stocks projection at 5-year intervals and 100-year averages for all management practices and stands (1234 different variations on 130 plots). While this information can be helpful in determining the differences in carbon sequestration between various plots and forest types, the actual values and additionality for carbon sequestration will not be representative of values required for the California Carbon Market due to the type of analysis done in this study. If landowners are interested in entering the carbon market, they may use the tool to determine a management practice utilized in the tool, then their own modeling must be done utilizing parameters from their own forest. This document can be found in the supplementary materials section.

Future research is needed to determine how income, transaction costs, and profit will relate to these different management practices and if the most productive practices determined in this study would remain the same.

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CHAPTER THREE

SURVEY OF FORESTRY BEST MANAGEMENT PRACTICES AND WILLINGNESS TO ACCEPT COST SHARE PAYMENTS FOR BMP IMPLEMENTATION

Introduction

Nonindustrial private forest landowners (NIPF) comprise about 70 percent of forest landowners in most US states (Amacher, Conway, & Sullivan, 2004). These landowners can have a significant impact on ecosystem services that forests provide. While their land is not a large source of timber production, benefits from carbon sequestration, increased water quality, and wildlife habitat are common. Additionally, more tangible ecosystem services such as shade for a home or cattle, preventing erosion, and aesthetic value for recreation and hunting are ecosystem services that are directly valued by the landowners (Bengston, Asah, & Butler, 2011). The benefits gained from NIPF lands are often contingent on management decisions and the goals of the landowner. Furthermore, timber production has been historically more valued compared to other (Tian et al., 2015).

Forestry is an important sector in South Carolina (SC), providing over 84,000 jobs, the state's number one manufacturing sector (Khanal, Straka, & Willis, 2017). Additionally, forestry represents the number one harvested crop in the state (Khanal et al., 2017). Even though forestry is a significantly part of South Carolina's economy, 80% of forest landowners are classified as NIPF landowners, among which 20% of private forest landowners manage for timber.

Previously, it was common to assess timber producing landowners across the country via survey and disregard other types of landowners. In the late twentieth century and into the twenty-first century, more surveys have been focused on the NIPF landowners and understanding their motivations for certain forest management (Bengston et al., 2011). This is partially due in part that the actions of the NIPF landowners are often unpredictable, due to the variety of objectives they have for the use of their land (Amacher et al., 2004). Additionally, the understanding of the necessity of ecosystem services has come to the forefront of both research and policy and oftentimes, NIPF landowners make a significant contribution to maintaining these ecosystems services.

It is accepted that best management practices (BMPs) on forestland could enhance the ecosystem and sustain the economic and social benefits of the forest for the future (Cristan et al., 2016; Maker, Germain, & Anderson, 2014). BMPs are defined as "a practice or usually a combination of practices that are determined by a state or a designated planning agency to be the most effective and practicable means (including technological, economic, and institutional considerations) of controlling point and nonpoint source pollution at levels compatible with environmental quality goals" (Helms, 1998; Ice, Schilling, & Vowell, 2010). Many studies have documented the effectiveness of BMPs in the southern United States. Williams et al., (1999) showed that suspended sediments in streams were lower on sites that utilized BMPs due to reduced runoff in SC. McClurkin et al. (1985) suggested that clearcutting pine plantations in Tennessee on fragile soils would not have significant impacts on the water quality of the region if BMPs were utilized effectively. Clinton (2011) found that riparian buffers that were at least 10 meters or wider would be effective in reducing sediment runoff, protecting water quality. Sawyers et al. (2012) and Wade et al. (2012) both concluded that utilizing mulch and slash on waterbars provide effective erosion control, limiting sediment runoff. Literature does show that there are positive effects on water quality by increasing the use of BMPs, especially those practices that reduce sediment loads such as access roads, in forestry operations (Cristan et al., 2016).

There is a clear link between human behavior and land cover change, where the economic and social drivers of owning land directly relate to the management practices on that land (Sorice, Kreuter, Wilcox, & Fox, 2014). Additionally, as land distribution increases, parcelization of forested plots across the country increases and land use change to urban environments is common. Between 1978 and 1994, the forest land in parcels less than 100 acres increased from 72 million to 124 million acres, or 73 percent (Sagor, 2006). Unfortunately, most best management activities are designed for larger tracts of land (Row, 1978; Sagor, 2006). Across the country, we continue to see a change in who owns the land and their goals for ownership (Sorice et al., 2014).

Objectives

Below are the three main objectives of the study:

1) To better understand the past implementation of BMPs on forested land in South Carolina. This involves surveying landowners on their use of prescribed burns, brush management, filter strips, fire breaks, stream habitat improvement techniques, stream crossings, shoreline protection, forest stand improvement, and

access roads. This survey also focused specifically on understanding prescribed fire implementation.

2) To better understand the perceived challenges and benefits of using BMPs directly from the landowners and understand their preferences for educational opportunities aimed at BMP implementation. Many landowners would be interested in many of these practices but there are barriers to their implementation.
3) Lastly, to better understand if cost share programs in South Carolina would be beneficial in encouraging landowners to adopt BMPs. Through the survey we aim to better understand their knowledge and familiarity with conservation cost share programs.

Methods

Survey

To obtain information regarding BMPs implemented on forested lands in the state, a questionnaire was mailed to 3,000 randomly selected forest landowners across the state. The contact information was obtained from the South Carolina Forestry Commission, and landowners in the database have forestland on their property. An additional 1,500 questionnaires were mailed a month later to follow up with landowners and increase the response rate. All types of forest landowners were surveyed; timber producers, NIPF landowners, and family forest landowners. In SC, there is some data for general BMP implementation on the management practices that are being used across the state on NIPF land. This data has been collected by the Southern Group of State Foresters over the last 35 years (Ice et al., 2010). The SC Natural Resources Conservation Service (NRCS) and the South Carolina Forestry Commission (SCFC) commissioned this research to provide information regarding BMPs utilized, perceptions of prescribed fire, and forest landowner's willingness to accept cost share payments through the Healthy Forests Reserve Program (HFRP) and the Environmental Quality Incentives Program (EQIP). The survey has been modeled based upon the information desired by the NRCS and SCFC with the goal of knowing better both analytically and spatially what BMPs are being utilized and use of cost share programs.

Questions

All respondents of the survey were asked the same questions regarding their demographics, forest land, and forest type. We will ask about the reasons for owning their forest land and if they implement BMPs, including prescribed fire, buffer strips, fire breaks, and stream habitat improvement. These definitions of BMPs were based on the EQIP program names and definitions. Importantly, we asked if they would implement these BMPs if cost was not a factor, our goal being to identify if cost is a barrier to implementation. They also were given a list of options to select various barriers and challenges associated with using BMPs. The survey design can be found in Appendix A.

Education

There are a variety of questions that were asked to gauge the respondent's preferences for education regarding BMPs and management of forest lands in general.

Additionally, questions regarding how extension and government agents can provide assistance to the landowners were asked. The goals following the distribution and analysis of the survey include providing education resources to landowners via the media they deem most effective for their learning, also while providing new resources that are not found in other locations.

Pretest & Distribution

The survey was pretested at the SC Forestry Commission May 2019 meeting. The survey was distributed the summer of 2019.

Results

Overview of Respondents

Response rates from this survey were not high with 280 survey responses out of 3,000 mailed surveys, a 9.3% response rate. This small response rate could be due to a variety of factors. The mailing list of forest landowners in SC has not been updated in many years, and often times there are non-resident landowners that either can't be reached or are even unaware of the management that is being implemented on their land. This also includes resident landowners who outsource their management activities to land managers and timber companies that may not be as interested in responding to the survey.

The largest group of respondents were those with 200-499 acres of land, and they made up 30% of the respondents (Figure 1). The next highest group of respondents were those with 100-199 acres of land (25%). The smallest group was the landowners with the least amount of land, 1-50 acres. In South Carolina, the average tract size for NIFP landowners is 67 acres. Additionally, across the U.S., 90% of NIPF landowners hold between 1 and 49 acres of land, with 10% holding more than 50 acres (Butler & Leatherberry, 2004). This survey seemed to capture more of the larger property landowners, presumably due to their awareness with the information solicited in the survey.

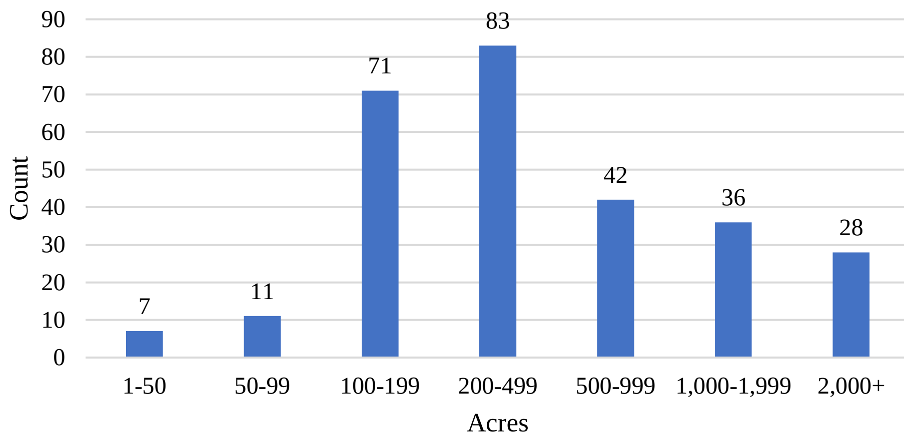

Figure 3.1 Count of respondents based on property size.

The forest types reported in the survey are a good representative of South Carolina's forests, with the most common forest type being Loblolly pine (Figure 2). Loblolly pines are commonly planted on large properties for timber production, and this was evident that 90% of the landowners with more than 1,000 acres of land had loblolly pines. Furthermore, 24% of respondents stated that Longleaf pine is the major forest type on their property. Having longleaf pine could mean implications for endangered species management for red cockaded woodpeckers (RCWs) and more rigorous forest management techniques to encourage longleaf regeneration. Longleaf also provides myriad ecosystem services include water and soil retention, habitat for many organisms, and carbon sequestration.

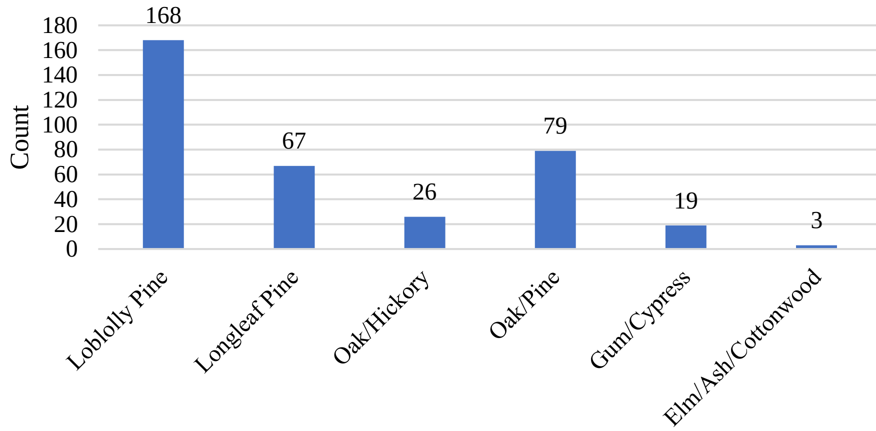

Figure 3.2. Count of landowners based on forest type.

Landowners were asked to select the importance of a variety of factors for owning their land. The options are outlined in Figure 3. For all of the questions except for "part of my home," most landowners felt that these options were very important. Many of the landowners who responded cultivate timber, but the most common response for owning their land is the protection of the land. Many landowners are interested in protection of their land for environmental quality and climate change, but also preservation for future generations and the ability to pass the land on to their family. Additionally, many times the land has been in a family for many years and they are highly interested in retaining that land. This desire by many landowners increases the conservation of forest land across the state but doesn't necessarily increase in management of the forest land. 3% of forest landowners in the south do have a written management plan for their land, but 16% of NIFP landowners have sought technical advice; these landowners own 43% of the forestland (Butler & Leatherberry, 2004). In this study, 45% of landowners reported to have a written management plan for their land. Additional literature reviews for more recent publications do not yield updated results for this statistic.

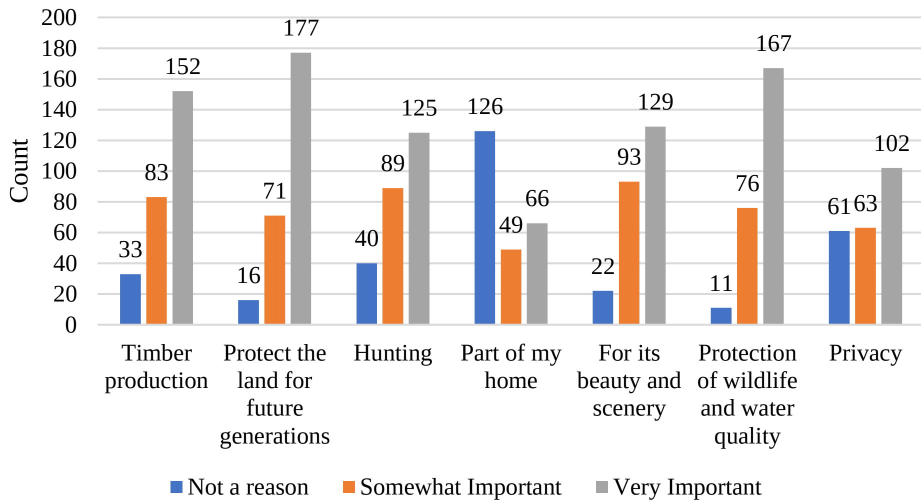

Figure 3.3. Landowners' responses to why they own their land.

Best Management Practices

Nine different BMPs were proposed in this survey. These are commonly used management practices in SC, along with management practices that directly correlate to funding through the EQIP program. The following management practices were studied:

1. Prescribed Burns
2. Brush Management
3. Filter/buffer Strips near Waterways
4. Fire Breaks
5. Stream Habitat Improvement & Management
6. Stream Crossings
7. Access Roads
8. Streambank and Shoreline Protection

9. Forest Stand Improvement

Many of these best management practices are already used by many people that responded to the survey. The most commonly used BMP was Access Roads and the least commonly used BMP was Stream Habitat Improvement & Management (Figure 4). Additionally, 45% of respondents utilize prescribed fire and 30% have used prescribed fire in the past. 58% of landowners utilize fire breaks while only 22% do not.

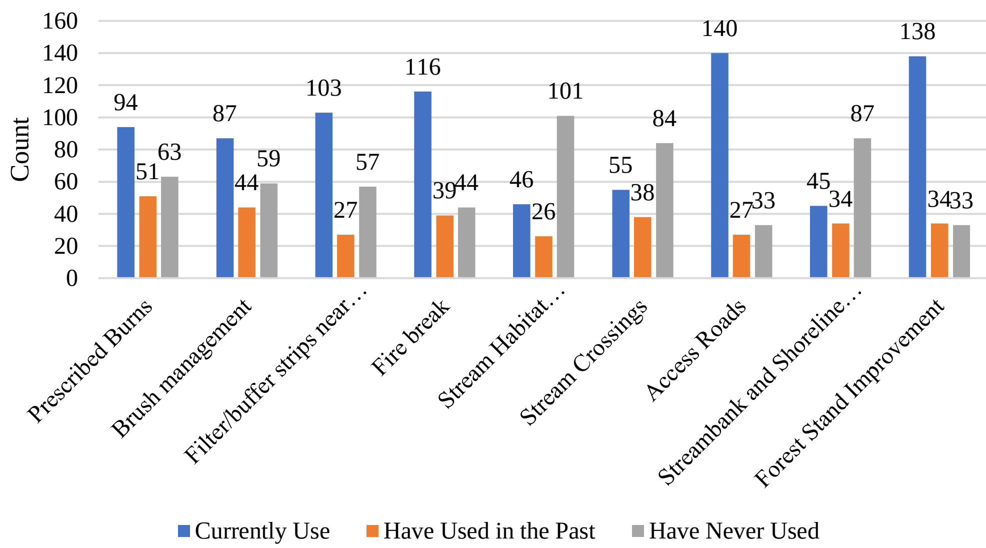

Figure 3.4. Current BMP usage by survey respondents.

Those who are not currently using the above nine management practices were asked their level of interest of implementing these management practices. While there was a fair number of people disinterested in utilizing many of these practices, there was a large number of people somewhat and very interested in utilizing some of the practices (Figure 5). When the mean was analyzed for the interest in implementation, all values were above neutral (3), and Brush Management and Forest Stand Improvement was above somewhat interested (4) (Table 1). The question was based on a scale of one to five, one being not interested at all and five being very interested.

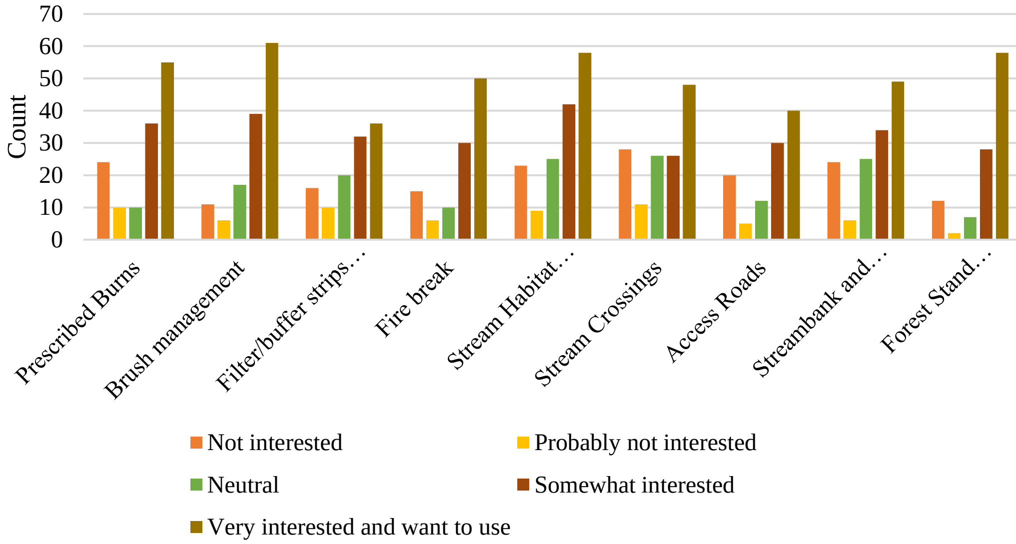

Figure 3.5. Willingness to implement BMPs for landowners' who do not use them currently.

Table 3.1. Mean Level of Interest for BMP Implementation

BMP	Mean + St. Dev	Count
Prescribed Burns	3.67 + 1.49	134
Brush Management	4.01 + 1.21	133
Filter/buffer Strips near Waterways	3.57 + 1.37	113
Fire Break	3.87 + 1.38	110
Stream Habitat Improvement & Management	3.67 + 1.39	156
Stream Crossings	3.41 + 1.51	138
Access Roads	3.63 + 1.48	106
Streambank and Shoreline Protection	3.58 + 1.44	137
Forest Stand Improvement	4.13 + 1.27	106

Analysis of Prescribed Fire

Prescribed fire is an important method for species regeneration and for mitigation of larger crown fires that could result from fuel build up on the forest floor. Longleaf and many other pine species require fire for not only for species regeneration, but for clearing the forest floor to allowing the seeds to germinate and thrive. Longleaf are a “fire sub-climax” species, meaning it requires on frequent disturbance to retain its dominance in the ecosystem, and fire is the preferred disturbance (Croker & Boyer, 1975). Frequent, low intensity fires that occur every 3-5 years are crucial are beneficial for this ecosystem and for retaining biodiversity on a large scale (Haines & Cleaves, 1999; Hiers et al., 2003). For these reasons, SC NRCS and Forestry Commission are interested in increasing the usage of prescribed fire, but there are many hazards and challenges associated with this practice, including smoke affecting surrounding neighbors, and the liability associated with fires that potentially could get out of hand. All survey respondents were surveyed to determine their understanding of prescribed fire and the benefits it provides.

Their options for selection include:

1. Reduce the possibility of extreme wildfire by reducing fuel loads
2. Thinning/reduction of woody debris for wildlife
3. Enhance soil development and fertility
4. Open up forest understory for hunting
5. Encourage regeneration of plant species
6. Manage Longleaf forest

Most landowners thought that the majority of these options were very important to occur and thus prescribed fire would be beneficial to manage these options (Figure 6). The only option that was not considered "very important" by a major of the landowners was "opening up the forest understory for hunting." Most respondents were interested in reducing fuel loads to reduce the possibility of extreme wildfire.

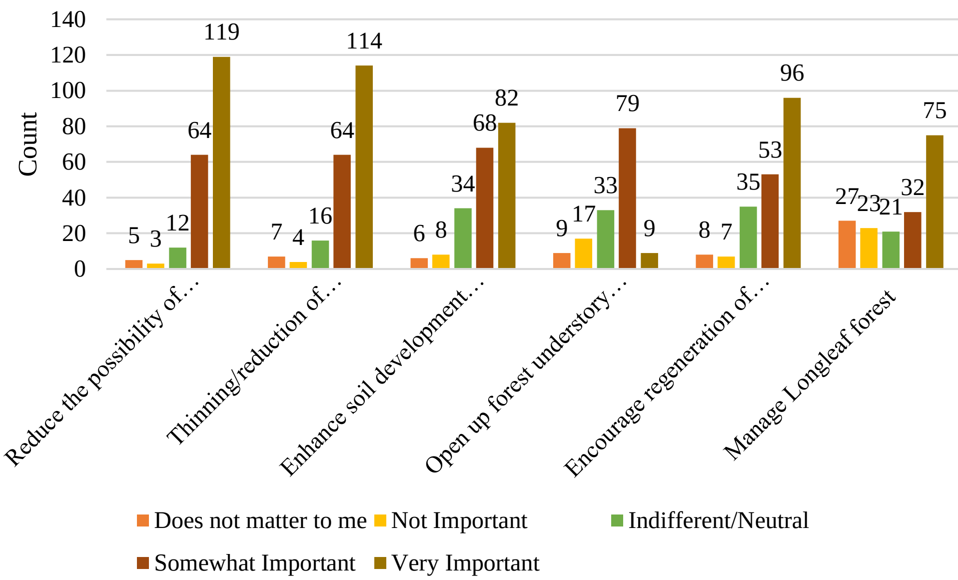

Figure 3.6. Benefits of prescribed fire to survey participants.

Educational Opportunities for BMPs

Education opportunities and mediums of education for BMPs are crucial to helping farmers effectively implement BMPs. Farmers were asked a series of questions to determine which methods of instruction were most effective for them. The options include:

1. Research by myself on the internet
2. Large, regional meeting with experts giving presentations about the latest information and research

3. Meeting with NRCS experts to talk about the purpose and implementation of BMPs
4. Local workshop where local experts and foresters who use BMPs present knowledge and share experiences
5. An on-site visit by a local conservation advisor from the SC Forestry Commission or Clemson Extension
6. Trying things out on my own and learning from successes and mistakes
7. Talking over the fence with my neighbor about their BMPs

Figure 7 shows the respondent's opinions on their preferred educational methods. For almost all options, most of the respondents chose 'sometimes effective.' When asked if on-site visits were beneficial (#5), respondents overwhelming said that they were 'Always Effective' and 'Sometimes Effective,' while only one respondent said that it was never effective.

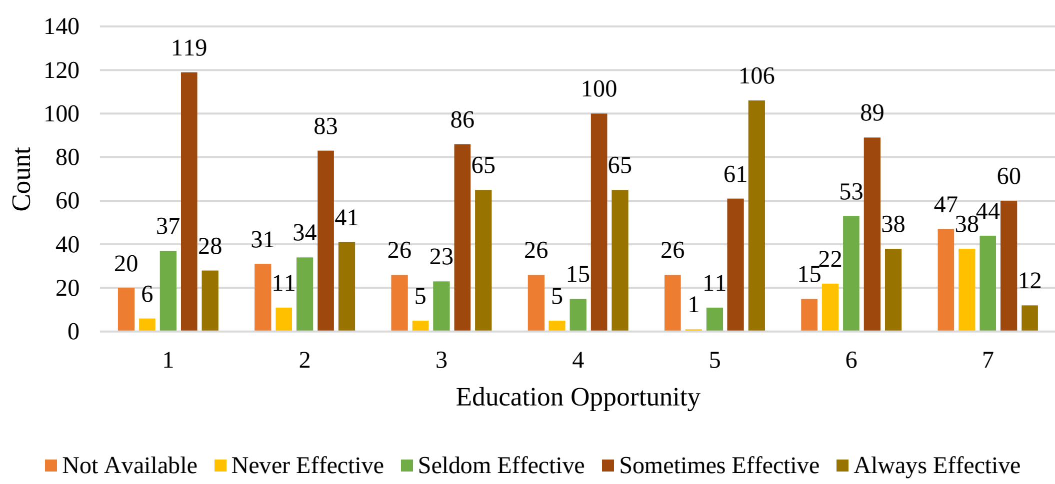

Figure 3.7. Respondent's opinions on the effectiveness of opportunities for forestry education.

Landowners were also asked what they believe the roles of NRCS foresters and Clemson Extension agents should be in helping them implement BMPs. The options included:

1. Understanding and implementing BMPs for timber harvesting
2. Help create a management plan
3. Provide advice on what BMPs are best for you; their effect on water quality
4. Provide funding for BMP implementation

Over 60% of respondents said that the first three roles were significant and should be role for these agencies. 54% agreed that providing funding (Option 4) should be a role, but 13% said it should not be a role, higher than the other options (3.6%, 4.8%, and 3.6% respectively).

Landowners were asked specifically what mediums of education would be most beneficial to learning. The options included:

1. Workshops
2. Publications
3. Internet/YouTube Videos
4. Personal Visits

The results were mostly split for all of the options, but 60% of the respondents did favor Personal Visits to their forestland for a preferred means of education (Figure 8).

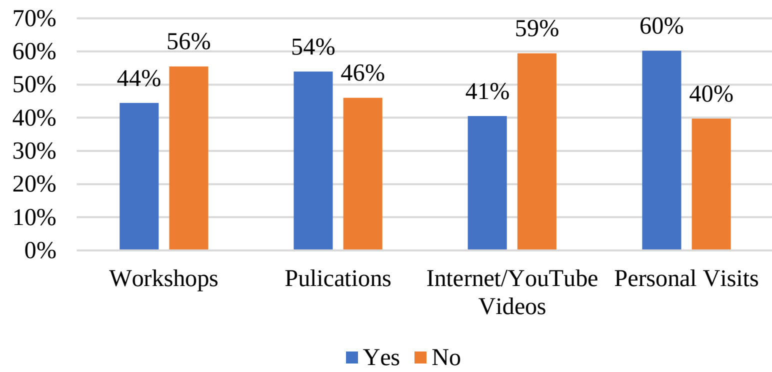

Figure 3.8. Percent of respondents that were or were not interested in certain education mediums.

Demographics and Willingness to Accept

Multiple demographic factors were collected from survey respondents. Gender, age, education, and income all can have an impact on reasons for owning forest land, and the management activities that are carried out on their land. Gender was highly skewed toward male ownership, with 83% of the respondents being male. Additionally, the results were highly skewed towards older respondents with over 60% being over the age of 65 (Figure 9).

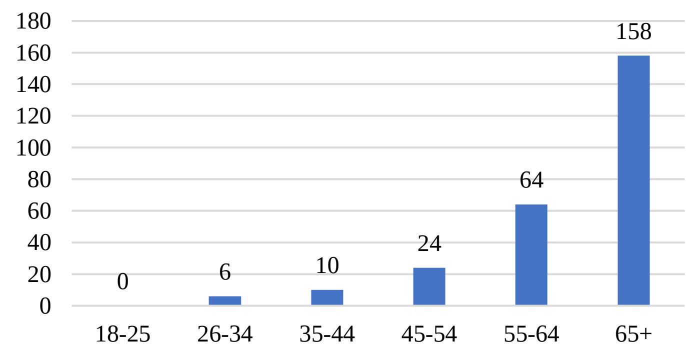

Figure 3.9. Respondent's age range.

Previous education was also highly skewed towards college degrees, with most people earning at most a Bachelor's degree and the second most people earning graduate degrees (Figure 10). The data collected from gross income yielded important results. Almost a fifth of landowners (17%) had an income higher than $500,000. All respondents reported having income for 2018. The majority of the landowners that responded (59%) made between $30,000 and $200,000. Landowners in this category that made $30,000 to $59,999 accounted for 15% of the respondents, 11% of the respondents made $60,000 to $89,999, 17% of the respondents made $90,000 to $149,999, and 15% of respondents made $150,000 to $199,999 in 2018. It is important to note that the income surveyed could be from any source, whether that is timber production or other professions.

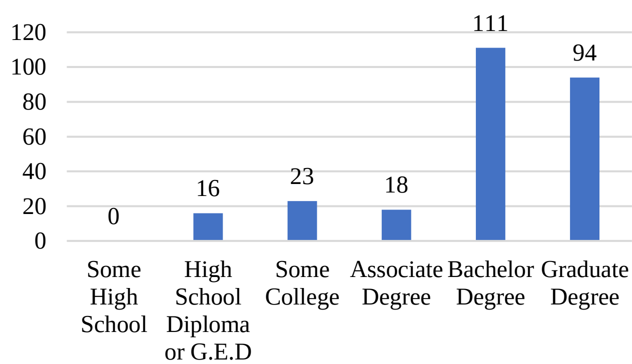

Figure 3.10. Respondents' highest levels of education.

The landowners were asked if they were willing to accept certain monetary payments for implementing these BMPs. If farmers are willing to accept, it is much more likely that the BMPs will be implemented. Cost is often a major barrier to implementation, and from the survey, it seems that most respondents would be willing to accept the proposed payment rates (Appendix A). At least 60% of respondents said they would accept payments for all of the BMP options. Just under 50% of respondents said they would accept the implementation of the Healthy Forests Reserve Program (HRFP) on their land (Figure 3.11).

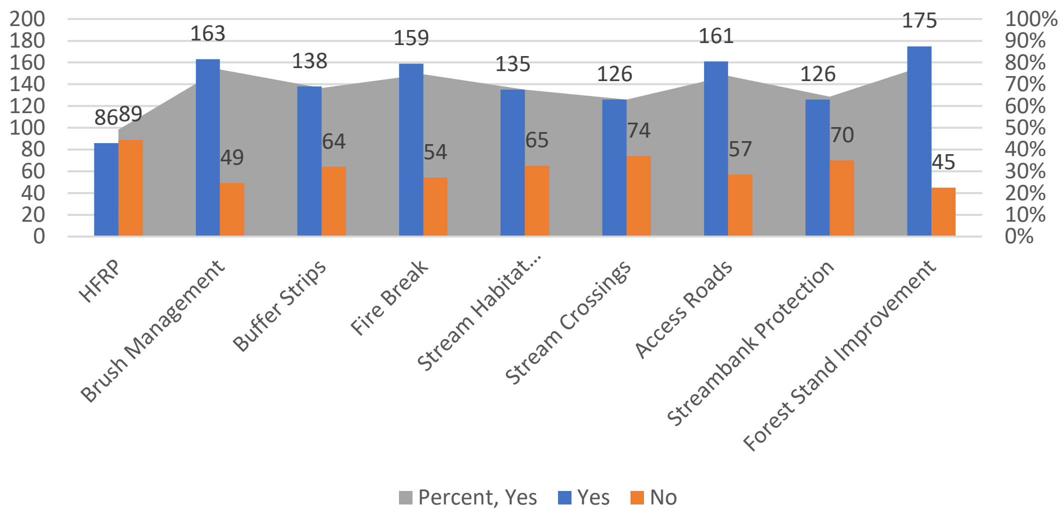

Figure 3.11. Willingness to accept cost share funds for Forestry BMPs and the HFRP (Colors are counts; Gray area is the Percent of respondents that said Yes).

Discussion

It is evident that many landowners do utilize BMPs and/or are interested in implementing BMPs. As of 2009, southern states were amongst the most active states in terms of BMP implementation, with an implementation rate of 95% in South Carolina (Ice et al., 2010). The southern United States has been relatively high with implementation of BMPs in part due to monitoring and implementation protocols produced by the Southern Group of State Foresters (Ice et al., 2010). From here, discussion will be broken down by topic and type of BMP.

Land Use Change and Retaining Forestland

Landowners have proven over the years that utility maximization for forestland is a common theme in management decisions (Tian et al., 2015). Non-pecuniary benefits such as carbon sequestration, wildlife habitat, and water quality protection are all co-benefits due to management goals discussed in Figure 3 where many landowners find the reasons for owning their land to be very important. Many landowners have a diverse set of reasons for owning their land. Because of this, for owning the land, landowners are more likely to choose management practices and funding sources that result in protection of the resource (Tian et al., 2015). The resultant effect is a protection of the ecosystem services gained from the land protection and a healthy forest for the landowner to enjoy for many years. This only underscores the continued need for resources to be provided to private landowners to encourage written management plans and the use of BMPs. Many respondents in this survey (45%) indicated they already have a written management plan. This is understandable because most of the respondents (93%) own over 100 acres of forestland. For the entire southern United States, only 3% of family forest landowners have a written management plan, but 50% of landowners with more than 100 acres do have a written management plan (Butler & Leatherberry, 2004). While it is not crucial for small tracts of land to have a written management plan, it does help landowners be aware of how their land is affecting to water quality, biodiversity, and carbon sequestration.

Education and funding are two major factors that affect the implementation and long use of BMPs. When analyzing the compliance of landowners in the northern United States, the implementation and compliance with stream crossing BMPs have shown improvement due specifically to education about the issue (Ice et al., 2010). Respondents of this survey indicate that working directly with NRCS and extension agents to understand how BMPs function are their preferred method of education. These services provide learning opportunity for landowners who have specific needs and situations while create a working relationship between the agents, landowners, and forest managers. Opportunities for Cooperative Extension and government agents to visit NIPF landowner's property can be important for understanding all of the landowner's specific goals and building trust. Factors such as mutual confidence, humbleness, and a sense of understanding about external factors (i.e. family structure, income, and history of land) by the agent are much better understood when close relationships are built.

One of the difficulties with extension/education activities are the sheer number of forest landowners compared with available agents to provide management advice. With over 3,500 forest landowners in South Carolina, it is almost impossible for all landowners to have the opportunity to meet one on one with foresters or extension agents. To improve access to professional advice, it is necessary for landowners to get educational information through workshops and publications which can help them with the necessary steps for BMPs implementation.

Prescribed Fire Implementation

Prescribed fire is gaining traction as a major management practice, but there are still many challenges associated with the practice. Over the last 20 years, prescribed fire has been utilized often to reduce fuel loads that contribute to large, destructive crown fires. Longleaf ecosystems also require fire to reduce understory debris for enhanced regeneration. These factors make prescribed fire an obvious choice to achieve these goals, but the perception that fire is a negative process is still common. Wildfires are increasingly becoming more destructive due climatic changes affecting the soil moisture and precipitation amounts. Many people that live close to forested areas understand that environmental conditions and ignition sources can drastically affect the change of wildfire (Mccaffrey, 2006). Since many people are familiar with the negative effects of wildfire, it is plausible to assume that they are fearful when it is suggested that fire will be purposefully set to the land. Education can make a significant difference in changing the perception that all fire is negative.

The research presented here shows that many forest landowners either have used prescribed fire or are interested in utilizing prescribed for woody debris reduction to reduce the chance of large wildfire and promote wildlife (Figure 6). More than half of the survey respondents have utilized prescribed fire on their land, and 90% of the respondents believed that the benefit of reducing fuel loads was either somewhat important or very important. When compared to demographic information, there was not statistically significant differences in opinion of those landowners with different educational or income levels. Also, landowners were asked the question if they belonged to any environmental organizations (i.e. The Nature Conservancy, Ducks Unlimited, a local hunting club, Tree Farm etc.). There was a significant difference ($p < 0.05$) with landowners that belonged to these groups having a greater understanding of the benefits of prescribed fire on these varying factors. This underscores the need for continued outreach regarding the benefits of prescribed fire through non-profits and land conservation organizations.

Constraints on prescribed fire can greatly affect the ability to implement prescribed fire. A survey of government agencies that utilize prescribed fire indicated that narrow burn windows, regulations, and lack of adequate personnel were the major impediments with implementing prescribed fire (Quinn-Davidson & Varner, 2012; Ryan, Knapp, & Varner, 2013). In South Carolina, there are a variety of protections for landowners that utilize prescribed fire. Landowners are required to file a burn plan with smoke management guidelines with the state to limit the liabilities landowners may face (Haines & Cleaves, 1999). Additional precautions are required, including plowing fire lanes if natural breaks do not exist. It is possible that landowners who allow fire to escape from the prescribed area could be held criminally liable for damages. Most times, this would only happen if reasonable care was not taken to contain the fire (Haines & Cleaves, 1999). There are many policies that do help landowners have the opportunity to utilize prescribed fire on their land and reduce their liability for damages. Continued education of both landowners and those who may live near prescribed fire will help overall acceptance of prescribed fire to increase. Additional dialogue between forest landowners, agencies, and those affected by prescribed fire can foster increased tolerance and trust among all parties (Mccaffrey, 2006).

Demographics of Landowners

It is commonly known that agriculture and forest landowners are aging. Just over 60% of the respondents in this survey are over the age of 65. Additionally, there were no respondents between the ages of 18 and 25. Because ownership of land is beheld significantly to the older generation, management decisions are affected directly by an older generation that has experience seeing changes in the land use and markets over time. Education must be tailored to different learning styles that come with different age groups. When it comes to education, the types of educational methods including ‘research by myself,’ ‘large regional meetings etc.,’ and ‘doing it myself’ all proved significantly different in terms of their effectiveness among different age groups ($p < 0.05$). Those options that were not significantly different were the onsite and one-on-one visits with Extension and NRCS agents. Additional analysis shows that there was not a significant difference for desire to implement BMPs among those respondents with varying education levels or levels of income.

Conclusion

Private landowners in South Carolina account for a significant portion of the forested land and their management directly affects the quality of the soil, water, and air in South Carolina and elsewhere. It is imperative that environmental policy and education for landowners reflect that constant need for landowner engagement and professional development. South Carolina and other southern states have been implementing best management practices for almost 20 years, developing a framework to increase accountability and monitoring of the implementation rates (Ice et al., 2010). To elicit more recent information, we distributed a survey to understand better the interest level of BMP implementation and the BMPs currently being used. It was evident that many of the respondents in this survey were either implementing or interested in using BMPs. Results show that continued support from both state agencies and Clemson Cooperative Extension is beneficial in continuing the education on implementation of these BMPs. Through education and outreach, landowners can be more effectively informed about all of their options for the future of their land. Organizations such as the American Forest Foundation use tools such as the Tool for Engaging Landowners Effectively with the goal of furthering landowner competency in forest management.

Climate change is a happening at a rapid pace and maintaining forest cover is hugely important for carbon sequestration and retaining a quality water source. Climate change is only increasing the potential for destructive wildfire and storms that can significantly damage our forests (Anderegg et al., 2015; Clay, Motallebi, & Song, 2019). Best management practices, including prescribed fire, provide landowners with an opportunity to help mitigate the effects of climate change by reducing fuel loads in forests that could ignite much larger, more destructive fires. While it has been thought that prescribed fire is a high controversial management practice, it seems that its acceptance is increasing, and the regulations in place in South Carolina allow for limited liability on landowners given they abide by necessary fire prevention methods. With increased education to both landowners and those that live near the implementation of BMPs, these practices will only increase in their acceptance and ultimately their effectiveness at restoring and protecting the environment.

Continued communication aiming to build strong relationships among landowners, agencies, technicians, and scientists will help utilize and increase BMPs implementation in South Carolina and promote landscape level conservation.

CHAPTER 4

SURVEY OF AGRICULTURE BEST MANAGEMENT PRACTICES (BMPS) AND WILLINGNESS TO ACCEPT COST SHARE PAYMENTS FOR BMP IMPLEMENTATION

Introduction

Cover crops are known to researchers to be an effective form of environmental management in agriculture systems. They are effective in reducing soil and nutrient losses, a mechanism for increasing soil health, and occasionally another form of income (Arbuckle & Roesch-McNally, 2015; Dunn et al., 2016). Although there is much consensus among the academic community regarding the benefits of cover crops, only a few studies have indicated that farmers are implementing cover crops into their crop rotations for these reasons. In 2012, less than 5% of farmers in the United States utilized cover crops (Dunn et al., 2016). Understanding the perceptions towards and challenges of planting cover crops can help agencies and Cooperative Extension provide better information to those farmers who have the potential to include cover crops in their crop rotation.

The farming benefits gained from cover crops are numerous and well documented. Soil erosion is a major issue in the agriculture sector of the United States, and was determined to be a serious crisis in the 1970s and after (Trimble & Crosson, 2000). It has been documented that soil erosion due to conventional till agriculture is increased by as much as 1-2 orders of magnitude (Montgomery, 2007). Furthermore, this lost sediment is not benefitting society due to its loss to waterways. With the implementation of cover crops, soils are no longer left bare at any point during the year, and the soil loss is limited (Dabney, Delgado, & Reeves, 2001). Additional documented benefits of cover crops include: ease of adoption and implementation of red clover and legumes into cereal crop rotation (Gallandt et al., 1998; Mutch & Martin, 1998), reduction in fumigation requirements (Creamer et al., 1996), and the increase in soil water holding capacity (Mutch & Martin, 1998). The goal of a continuous use of cover crops is to retain the soil organic matter, thus retaining water, nutrients, and providing aeration, all of which would be significantly reduced during a period of bare soil (Snapp et al., 2005). Moreover, the ideas of conservation agriculture are also encouraged when implementing cover crops, such as no-till fields, reduced use of fertilizers, and more efficient irrigation systems (Hobbs, 2007).

Additionally, the impact of agriculture on water quality is a major concern among scientists and the public (Arbuckle & Roesch-McNally, 2015). Sediments are the most prolific water pollutant from agriculture, limiting fish growth and making water treatment more difficult (Dabney et al., 2001). The use of cover crops is one of the primary nature-based methods to retain soil and nutrients within the cropping system, benefitting both the farm yield and the water quality that affects those external to the farm (Snapp et al., 2005).

Despite many benefits of implementing cover crops, farmers are sometimes hesitant of including them in their crop rotation. One of the major challenges for farmers implementing cover crops is the lack of perceived financial benefits. It is understandably difficult for farmers to justify the use of new conservation farming methods such as cover crops when it is already difficult year after year to profit. Some additional challenges in a variety of different cover crops include: disease problems (Mutch & Martin, 1998), lack of available species that are shade and cold tolerant (Vyn, Janovicek, Miller, & Beauchamp, 1999), and high costs with limited returns (Abawi & Widmer, 2000). Furthermore, the implementation of cover crops and other conservation measures are often viewed as a long term commitment and result in limited or nonexistent short term gains. The possibility of no short term gains is undesirable for many farmers and reduces implementation of conservation actions (Dunn et al., 2016).

In many locations, US federal and state government agencies have been using cost share programs to encourage implementation of conservation farming practices. Otherwise, conservation practices are implemented on a voluntary basis (Reimer & Prokopy, 2014). In 2011, the United States Department of Agriculture (USDA) spent over $5 billion on cost share programs as defined in the Farm Bill (USDA (U.S. Department of Agriculture), 2012). Specifically, the Environmental Quality Incentives Program (EQIP) is one of the most comprehensive conservation cost share programs funded by the federal government. This program is comprehensive in the sense that it provides over 200 options for conservation projects with cost share funding, and farmers have the opportunity to create an individualized program ("EQIP (Environmental Quality Incentives Program), NRCS," 2018).

South Carolina Natural Resources Conservation Services (SC NRCS) suggested that we investigate the perceptions and challenges towards implementing cover crops among South Carolina farmers. Therefore, our main objective for this chapter is to study opportunities and barriers of planting cover crops for farmers in SC and their information about cost share programs provided by the SC NRCS. To achieve this goal, a survey and the same follow up survey was sent to 3,000 row crop farmers between Mid-Jan and Mid-March 2019.

This survey has three major parts; the first and second part of the survey was designed to study cover crop users' and non-users' perceptions towards and challenges for implementing cover crops. The third part was designed to determine farmer's willingness to accept (WTA) monetary payments for implementing cover crops through government cost share programs. Information obtained through this survey is crucial for policy makers and outreach/extension personnel to understand where and how to encourage farmers to implement cover crops and other conservation practices.

Objectives

Below are three main objectives that we focus on in this chapter:

1) to understand who is growing cover crops and their perceptions and challenges;

2) to understand who is not growing cover crops and the perceived challenges associated with not implementing cover crops; and

3) to evaluate farmer's willingness to accept monetary payments for implementing cover crops through government cost share programs.

Methods

Survey

To obtain data on the farming community in South Carolina, a mail survey and its follow up was sent out to 3,000 row crop farmers between Jan and March 2019. These farmers were randomly selected from an NRCS database of South Carolina farmers. Additionally, the survey was designed and distributed through the online distribution software Qualtrics. Farmers that work directly with the NRCS Conservation Districts would have been able to obtain the link to complete the survey. This survey was created using a variety of resources, particularly a study completed by Plastina et al. (Plastina, Liu, Miguez, & Carlson, 2018). The survey was broken into two parts 1) The part for cover crop users and 2) the part for cover crop non-users. The cover crop users were required to answer more questions than the non-users for us to understand their motivations for utilizing cover crops. Both parties were required to answer questions regarding Education, their WTA cost share payments, and Demographics.

Questions

We designed our questionnaire for both cover crop users and non-users. The cover crop users were asked questions relating to what cover crops they used, when they used them, and how long they have been using them. Also, they were asked about the yield of both the cover crops and the cash crops. Lastly, they were asked about their application of the cover crops and their goals for using cover crops. Both the non-user and the users were then asked identical questions where they would rank a variety of perceived benefits and challenges about implementing cover crops. This information will be crucial to understanding any differences in perceived challenges and benefits.

Education

In the education section of the survey, we are attempting to determine what the best methods for communicating the research and benefits of cover crops and other conservation practices. Questions including sampling what the most effective methods for educational opportunities, what the roles are of NRCS (Natural Resources Conservation Service) and government employees, and asking them their preferred method(s) of learning about cover crops. With the information gained from these questions, ideally resources will be redistributed to educate farmers and landowners in their preferred education methods.

Pretest

The survey was pretested in a cover crops educational event hosted by the Richland County Soil and Water Conservation district in October 2018. The survey was distributed to 26 farmers that attended the event, and 14 surveys were returned to us for analysis. Respondents provided beneficial feedback regarding the ease of the survey and the questions that should be changed or modified.

Statistical Analysis

Statistical analysis was completed to determine the relationships between a variety of demographic data and the implementation of cover crops. Statistical analysis was carried out using SPSS™, the ANOVA least significant difference (LSD) model for demographic comparisons. The significance of the perceptions and challenges between users and non-users of cover crops was analyzed using a paired t-test in SPSS™. All values declared significant were characterized by $p < 0.05$ (or 0.1 for the t-test analysis). This statistical analysis will help decision makers have a better understanding on the variables that are different between users and non-users and which demographic variables affect implementation.

Results

Overview

We received 308 survey responses from across the state. This is a response rate of 10.3%. Figure 1 details where respondents were asked whether they used cover crops or not. The results were almost even among respondents with 143 respondents utilizing cover crops at some point and 148 not ever utilizing cover crops.

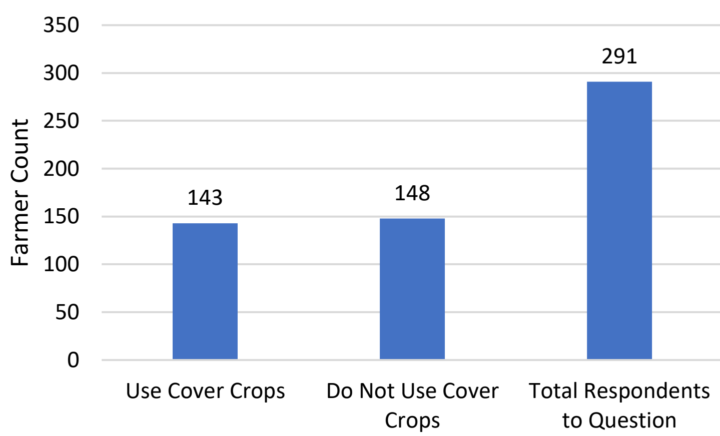

Figure 4.1. Count of Farmers Who Use and Do Not Use Cover Crops

The respondent's answer to farm size shows that most farms are between 200 and 499 acres in size (Figure 2). Additionally, when comparing those who use and do not use cover crops, those with larger properties seem to be more likely to utilize cover crops than those with smaller farms. Figure 2 shows how the implementation of cover crops changes based on farm size. Trends in the data indicate that those who have larger farmers are more likely to implement cover crops ($p < 0.05$).

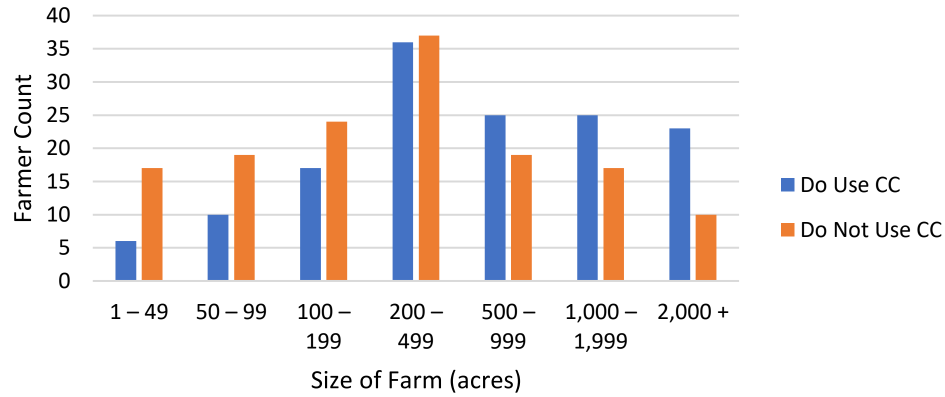

Figure 4.2. Farms sizes compared to those who implement cover crops (p < 0.05).

Out of all the survey respondents in SC, the majority of row crop farmers are planting corn, soybeans, and raising poultry and livestock (Figure 3). There are still a significant amount of farmers across the state that are planting other crops, including cotton, wheat, and peanuts. In Figure 3, these crops are not exclusive for each farmer; farmers most likely plant more than one type of crop on a cycle.

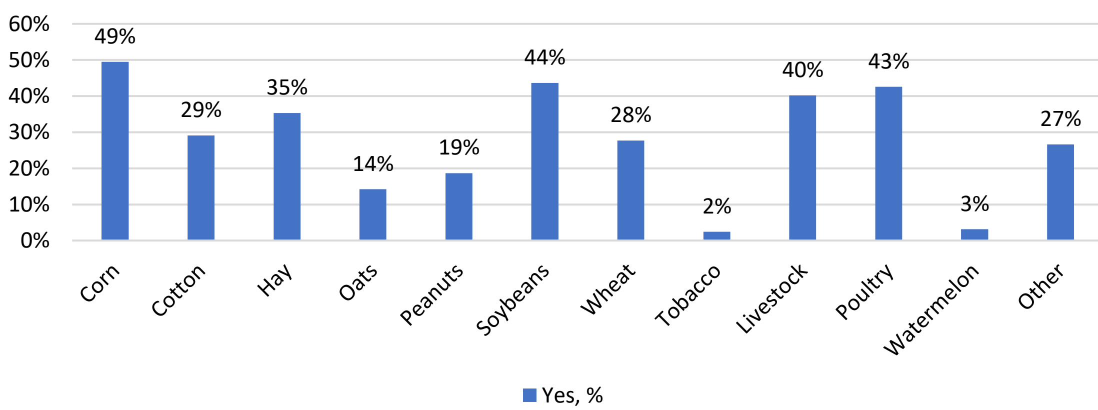

Figure 4.3. Percent of respondents who plant each cash crop on their land at any time.

Cover Crop Usage

Respondents that have implemented cover crops in the past were asked to describe which cover crops they use and how long they have been using them. Figure 4 describes which cover crops have been used and shows the trends over time for implementation of each cover crop. The bar graph shows that almost all of the cover crops have had an increase in usage between 1995 and 2017. It must also be taken into consideration that many farmers use a mix of cover crop seed.

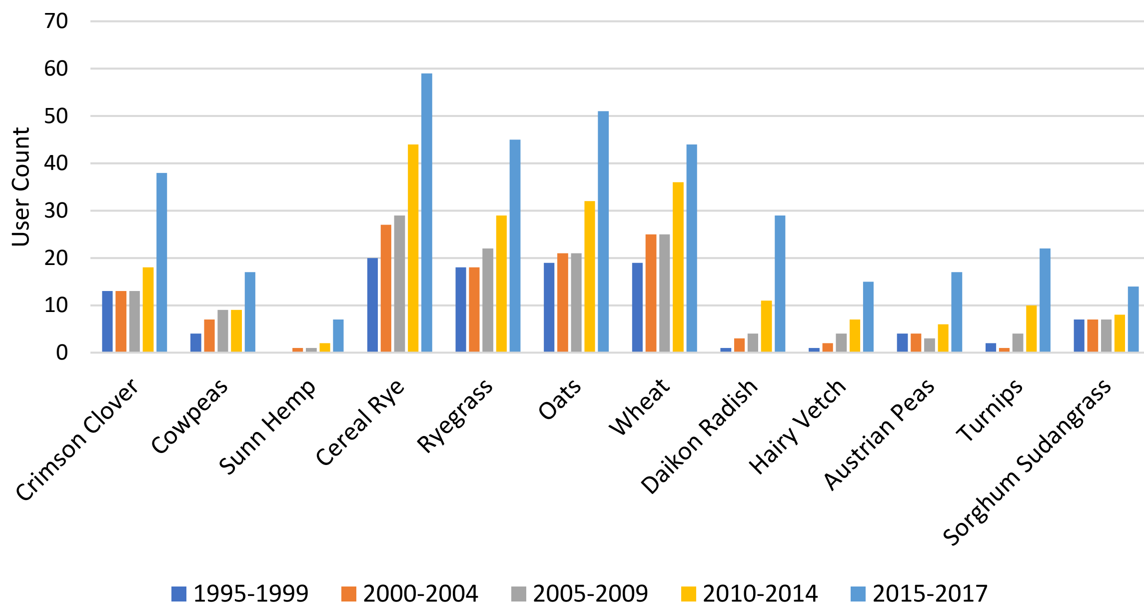

Figure 4.4. User Count for each specific cover crop based on year range.

Respondents were asked a series of questions regarding their perceptions of the challenges and benefits of cover crops. The questions regarding challenges (Table 1) were answered through a ranking scale with the following response options:

1 – Not a Problem I Considered

2 – Not a Challenge

3 – Neutral

4 – Somewhat of a Challenge

5 – A Difficult Challenge

Table 1 details the mean number selected on the ranking scale and is compared between those who have used cover crops and those who have never used cover crops. A t-test was also carried out to compared the means and determine significance between the selections of CC non-users and CC users. The highest values for both categories, otherwise considered the most challenging, were the cover crop seed costs for both users and non-users. The cost of planting and managing cover crops for non-users was the most challenging option, and was also significantly challenging for users. Cover crops sometimes use too much moisture was the least challenging option for both users and non-users. The second least challenging option was yield reduction in the following cash crop for CC users and nitrogen converting to organic forms for CC non-users.

Table 4.1. Selected challenges associated with planting cover crops; means compared between cover crop users and non-users. * Means significantly different at $p < 0.1$, ** Significant at $p < 0.05$.

	Count – CC Users						**Count – CC Non-Users**						
	1	2	3	4	5	Mean ± St. Dev CC Users	1	2	3	4	5	Mean ± St. Dev CC Non-Users	
Cover crops sometimes use too much moisture	58	32	22	6	2	1.79 ± 1.02	41	14	39	11	0	2.24 ± 1.09	**
Not knowing most effective seeding rate	33	41	17	27	1	2.45 ± 1.18	27	21	30	23	4	2.65 ± 1.21	
Selecting the right cover for my operation	27	36	22	30	5	2.55 ± 1.19	21	18	31	28	8	2.86 ± 1.21	*
No measurable economic return	24	25	39	15	13	2.76 ± 1.28	19	12	41	21	12	3.00 ± 1.20	
Cover crop becomes a weed the following year	40	50	18	9	1	1.98 ± 0.91	30	17	32	16	10	2.66 ± 1.32	
Nitrogen conversion to organic forms	21	36	56	4	3	2.44 ± 0.91	30	18	46	10	1	2.42 ± 1.04	

Yield reduction in the following cash crop	30	43	34	6	5	2.25 ± 1.05	29	13	47	8	7	2.60 ± 1.19	*
Increased insect potential	32	35	35	11	4	2.33 ± 1.09	27	11	46	16	4	2.68 ± 1.15	
Time/labor required for planting and increased management	18	29	16	47	10	2.99 ± 1.26	16	8	28	31	25	3.44 ± 1.31	**
Cover crop seed cost	16	13	31	48	14	3.23 ± 1.17	15	6	37	27	20	3.33 ± 1.26	
Cover crop seed availability	19	30	32	29	6	2.76 ± 1.14	19	9	46	24	8	2.99 ± 1.17	
Increased disease potential	34	37	39	7	1	2.21 ± 0.97	28	16	46	10	5	2.63 ± 1.16	**
Increases overall crop production risk	31	41	38	8	2	2.26 ± 0.97	22	13	51	12	5	2.72 ± 1.10	**
Cost of planting and managing cover crops	19	15	30	49	8	3.12 ± 1.18	13	7	30	32	25	3.82 ± 1.10	

The benefits of cover crops are numerous and a selected list is outlined in Table 2. Respondents were asked gauge the importance of these benefits from cover crops. The questions regarding benefits (Table 2) were answered through a ranking scale with the following response options:

1 – Does not matter to me

2 – Not Important

3 – Indifferent/Neutral

4 – Somewhat Important

5 – Very Important

All means are in the range of 3 to 4, indicating that all farmers, regardless of their cover usage, do believe that these general factors regarding soil health, the importance of nutrients, and environmental quality. Both CC users and non-users indicated that increasing soil organic matter and soil health was the most important benefit of cover crops. The next most important benefit of cover crops was the same for both groups as well, to reduce soil erosion. The least important benefit for both CC users and non-users is that the cover crop would winter kill easily.

Table 4.2. Selected benefits associated with planting cover crops; means compared between cover crop users and non-users. * Means significantly different at $p < 0.1$, ** Means significantly different at $p < 0.05$

	Count – CC Users						Count – CC Non-Users						
	1	2	3	4	5	Mean $\pm$ St. Dev	1	2	3	4	5	Mean $\pm$ St. Dev	
Reduces soil erosion	4	5	5	28	83	4.41 $\pm$ 0.98	8	4	16	29	54	4.01 $\pm$ 1.23	**
Controls weeds	3	3	13	36	68	4.34 $\pm$ 0.91	5	4	27	32	41	3.86 $\pm$ 1.12	**
Provides nitrogen scavenging	5	6	25	31	54	3.97 $\pm$ 1.11	6	6	33	31	33	3.70 $\pm$ 1.11	*
Increases yields in following cash crop	7	6	27	21	63	4.09 $\pm$ 1.15	6	6	41	23	32	3.62 $\pm$ 1.15	**
Economic return	4	5	24	26	63	4.19 $\pm$ 1.03	5	5	35	25	41	3.77 $\pm$ 1.12	**
Deep tap roots	6	10	27	39	38	3.79 $\pm$ 1.12	8	5	49	26	22	3.41 $\pm$ 1.06	**
Attracts pollinators to my farm	5	12	38	25	39	3.69 $\pm$ 1.13	8	6	37	30	28	3.54 $\pm$ 1.14	
Reduces nutrient/pesticide runoff	5	8	15	33	56	4.12 $\pm$ 1.09	8	4	31	29	35	3.66 $\pm$ 1.22	**
Winter kills easily	8	26	49	16	18	3.04 $\pm$ 1.05	8	9	44	33	16	3.32 $\pm$ 1.06	*
Winter hardiness/survival	7	12	34	27	37	3.71 $\pm$ 1.10	9	4	45	28	23	3.40 $\pm$ 1.12	*
Controls insects	7	10	51	22	25	3.41 $\pm$ 1.10	10	4	38	28	29	3.60 $\pm$ 1.19	
Reduces diseases	8	10	40	28	30	3.56 $\pm$ 1.15	9	7	28	33	33	3.72 $\pm$ 1.20	
Increases soil organic matter and soil health	2	3	6	29	83	4.54 $\pm$ 0.78	7	3	14	32	55	4.14 $\pm$ 1.14	**
Reduces soil compaction	4	3	11	31	71	4.39 $\pm$ 0.96	8	2	23	33	44	3.91 $\pm$ 1.17	**
Provides a nitrogen source	5	6	22	34	54	4.04 $\pm$ 1.12	7	2	24	32	45	3.92 $\pm$ 1.13	
Fibrous root system	7	6	29	35	40	3.82 $\pm$ 1.12	8	2	32	31	36	3.79 $\pm$ 1.09	
Decreases the cost of producing the following cash crops	5	7	37	26	44	3.87 $\pm$ 1.09	9	2	36	30	33	3.61 $\pm$ 1.16	*
Environmental Benefits to protect waterways	5	4	19	28	62	4.23 $\pm$ 1.03	8	2	24	32	44	3.88 $\pm$ 1.13	

Education is an important factor in helping farmers better understand how cover crops can be helpful in their operation, while also providing access to resources to ease the implementation and logistics required to add this additional process into their rotation. Figure 5. shows the general preference of farmers in regards to their desired learning medium. They had the option to choose all or none of the options. Results are reported as a percent of those respondents that choose "yes" to each learning method. All farmers that completed the survey are included (n = 245).

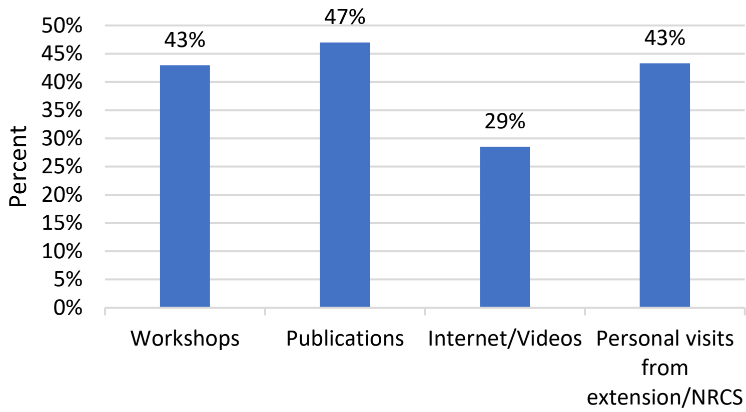

Figure 4.5. Percent of respondents that were interested in learning about cover crops in each teaching method.

Additional education questions were asked to determine what types of in person education respondents would be interesting. This type is information is important to help cooperative extension advisors, federal and state agencies, and private wholesale providers of cover crop materials to determine the best ways to get information across to farmers. In Table 3, farmers where asked, "If you had the following cover crop education opportunities available to you, please rate their effectiveness." There were five options for answers, and their corresponding numbers are listed below.

1 – Not Available

2 – Never Effective

3 – Seldom Effective

4 – Sometimes Effective

5 – Always Effective

All of the educational opportunities had a mean range of 3.38 to 3.94. The potentially least effective method is research by themselves on the internet (3.38 $\pm$ 1.32). The most effective method is trying things out on their own and learning from successes and mistakes (3.94 $\pm$ 1.19).

Table 4.3. Education opportunities and corresponding means to determine effectiveness.

	N	1	2	3	4	5	Mean + St dev.
Research by myself on the internet	208	40	3	36	97	31	3.38 $\pm$ 1.32
Large, regional meeting with experts giving presentations about the latest information and research on cover crops and how they fit into conservation systems	215	38	9	27	98	43	3.46 $\pm$ 1.34
Meeting with my seed dealer, local retailer or agronomist on my farm to discuss cover crops	219	33	4	35	85	62	3.63 $\pm$ 1.32
Local cover crops workshop where local experts and farmers who use cover crops present knowledge and share experiences	206	35	5	19	84	63	3.66 $\pm$ 1.38
An on-farm visit by a local conservation advisor	218	36	8	22	90	62	3.61 $\pm$ 1.37
Trying things out on my own and learning from successes and mistakes	223	19	7	28	83	86	3.94 $\pm$ 1.19
Talking over the fence with my neighbor about their cover crops	216	31	10	40	103	32	3.44 $\pm$ 1.23

An additional education question was asked to determine what exactly farmers think the role of cooperative extension and NRCS/other government agents should be when providing assistance and service for cover crop implementation. The question asked was, "What should the roles be for extension and NRCS (or other government) agents in providing assistance and services supporting cover crops?" The question had an option to answer three different ways.

1 – Should not be a role

2 – Should be somewhat of a role

3 – Should be a significant role

Results indicate that most people believe that these service agencies should be involved in all of the options indicated in Table 4. Helping assess and understand soil changes was the most important service they could provide and providing cover crop seeding services is the least important service they could provide.

Table 4.4. How Extension and Government helps with Cover Crops.

	N	**1**	**2**	**3**	**Mean ± St dev.**
Helping assess and understand soil changes resulting from cover crop use	224	6	77	141	2.60 ± 0.54
Helping to adjust nutrient management plans to account for cover crops	219	11	92	116	2.48 ± 0.59
Providing cover crop termination advice and service	219	15	112	92	2.35 ± 0.61
Providing cover crop seeding services	221	45	91	85	2.18 ± 0.75
Advising farmers on cover crop seed to purchase	221	11	101	109	2.44 ± 0.59

Environmental Considerations

Farmers were asked four questions yes or no questions that attempted to gauge their understanding of environmental issues that occur from nutrient runoff from agriculture operations. The questions are as follows:

1. South Carolina farmers should do more to reduce nutrient runoff into waterways.
2. Nutrients from farms contribute to algae blooms and red tide in the ocean.
3. I am concerned about agriculture's impact on water quality.
4. I would be willing to have someone evaluate how my farm is doing to reduce runoff into waterways.

The responses are shown in Figure 6, with the numbers corresponding to each above question.

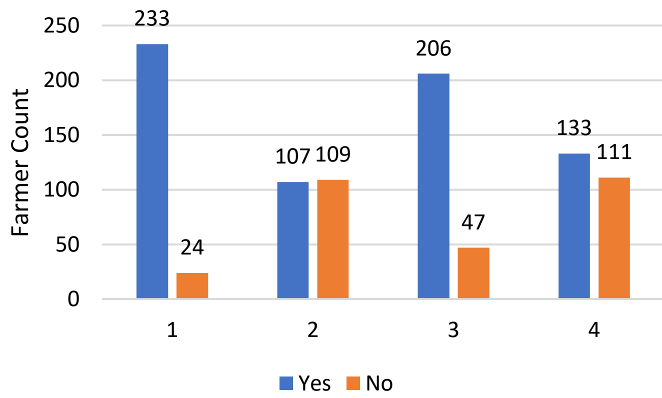

Figure 4.6. Respondent's answers to environmental questions (Yes or No).

Demographics

All respondents were asked a series of demographic questions to gauge where they were from and their background. These questions were most frequently responded to when compared to other cover crop questions. Figure 7 shows the distribution of respondents across zip codes in South Carolina. Based on the zip code analysis from the surveys, there was a distribution of respondents all over the state. Many zip codes only had one respondent, but eight different zip codes had five or more respondents. There were no trends that were extrapolated from the data regarding implementation of cover crops based on region.

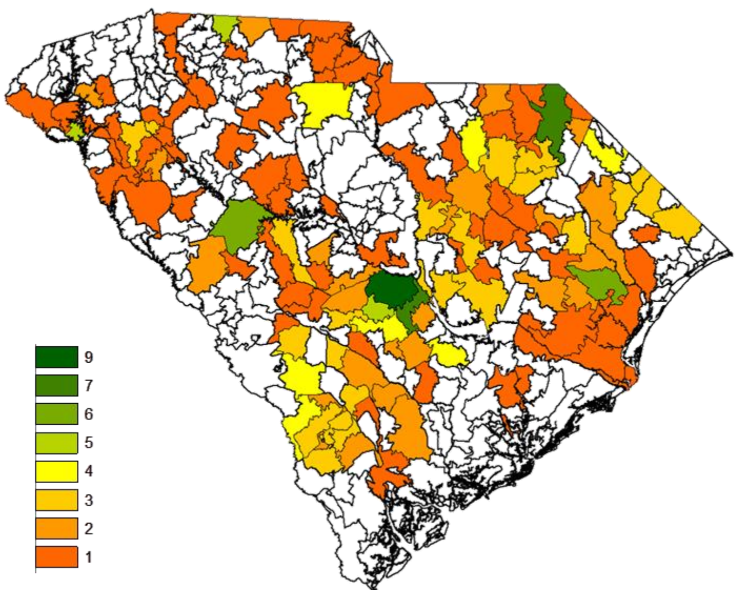

Figure 4.7. Distribution of respondents from each zip code in SC, count indicated by color.

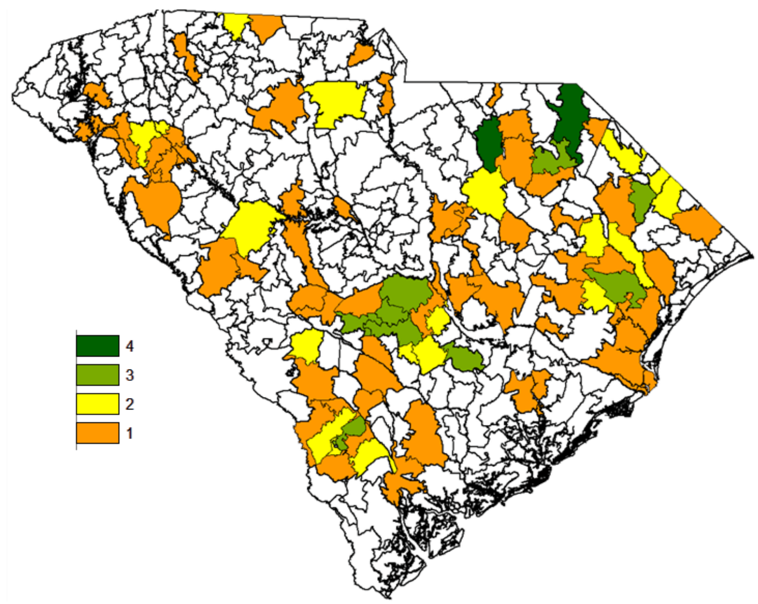

Figure 4.8. Distribution of Cover Crop user respondents across SC, count indicated by color.

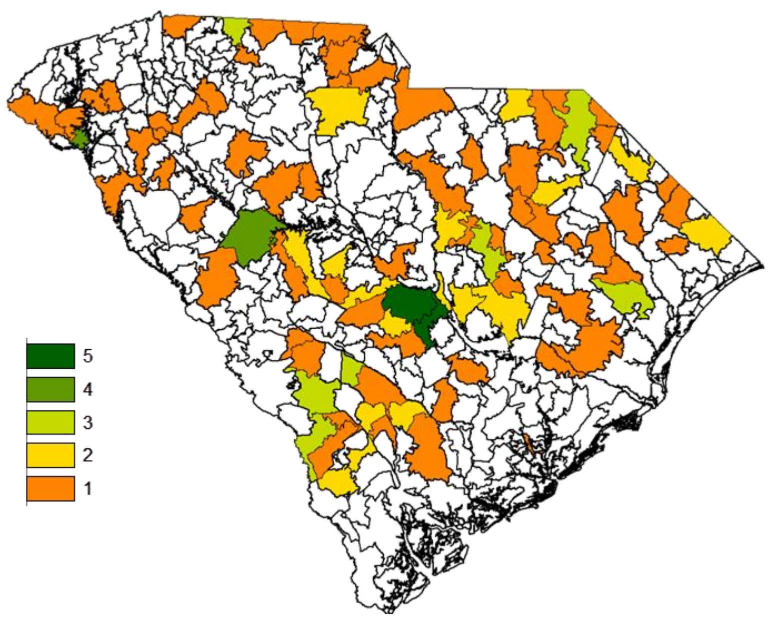

Figure 4.9. Distribution of Cover Crop Non-User respondents across SC, count indicated by color.

Age is also another important factor in the agricultural sector. It is evident in this study and across the country that many farmers are older. Figure 10 shows the distribution of respondents by age and whether or not they have implemented cover crops. Statistical analysis shows that age is significant when determining whether farmers implement cover crops or not ($p < 0.05$). Farmers that are older are less likely to implement cover crops than those who are younger. Those farmers age 65+ were the largest group of respondents, with 144 (46% of respondents). There were no respondents that were between the ages of 18 and 25.

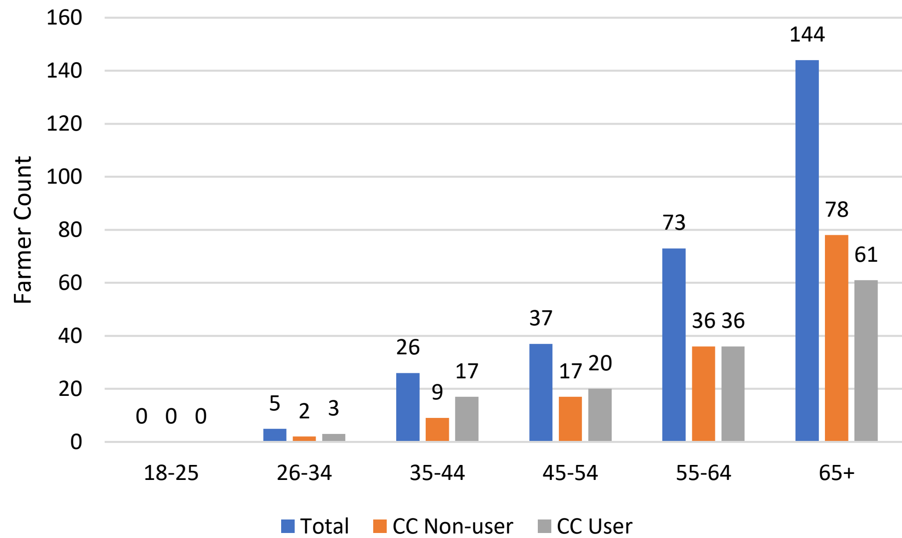

Figure 4.10. The distribution of respondents based on age ($p < 0.05$).

Farmers were also asked to indicate their highest level of education attained. 283 out of 308 survey respondents answered this question, and the largest group of respondents were ones with bachelor's degrees (86). Some high school had the smallest group of respondents (11). Figure 11 shows the education distribution. There was no statistical significance between education attained and implementation of cover crops.

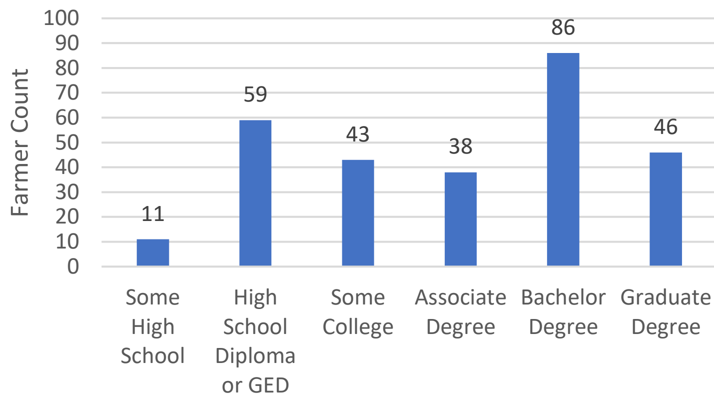

Figure 4.11. Education Level of Survey Respondents.

Gross Income was also asked of all the respondents. Response options were broken down into twelve different categories. Figure 12 shows the distribution of income for respondents based on whether they have used cover crops or not. Statistical analysis showed income is significant when considering whether farmers will implement cover crops or not ($p < 0.05$). The analysis indicates that those with a higher income are more likely to implement cover crops.

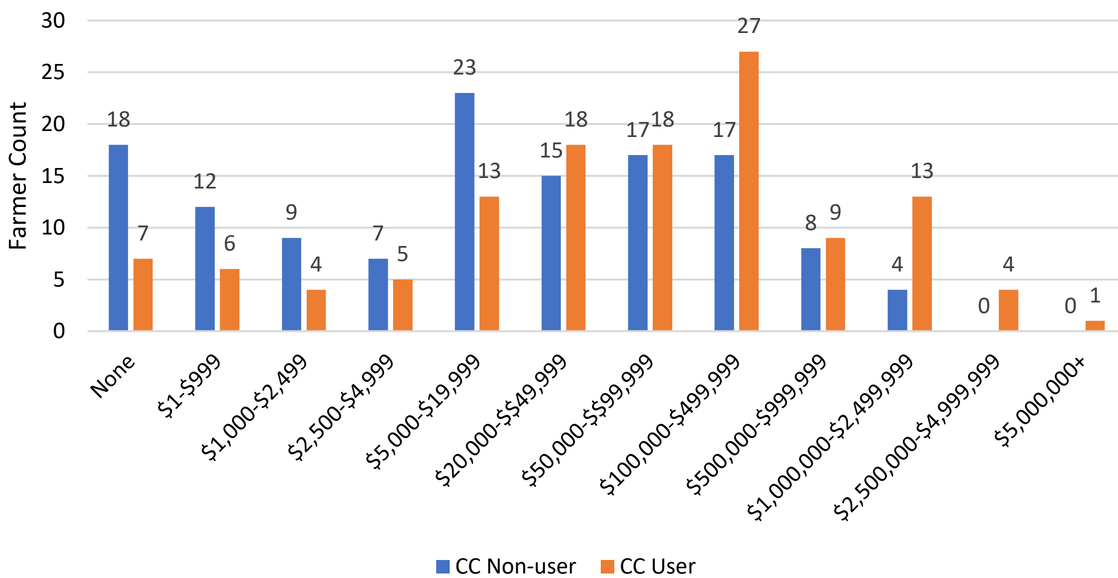

Figure 4.12. Income distribution of cover crop users and non-users ($p < 0.05$).

Discussion

Overview

308 surveys were received from the originally distributed 3,000 (10.3% response rate). There was significant representation of farmers that plant the following cash crops: Corn, Cotton, Hay, Oats, Peanuts, Soybeans, and Wheat. There were also significant responses from those who have livestock and poultry. 49.1% of these farmers indicated that they currently use or have used cover crops on their farmland. This number is indicative of an increase of cover crop users, since just as recently as 2012, only an average of 5% of farmers were utilizing cover crops across the United States (Dunn et al., 2016). This drastic increase does call into question the farmers that responded to the survey and the method of distribution. Even with a random distribution, it is plausible that farmers who have an increased interest in cover crops or even utilize cover crops are the ones that completed the survey. It is possible that those who do not have any interest in cover crops or even disagree with the science behind cover crops will not complete the survey, creating a non-response bias (Martin, Raish, & Kent, 2010). Follow up mail surveys were used in this survey to attempt to mitigate this problem.

Cover Crop Usage

A variety of cover crops were found to be utilized in SC. While it was difficult to capture when a cover crop mix was used, the data showed that cereal rye, ryegrass, oats, and wheat were dominantly used. Crimson clover and sorghum sudangrass is increasing in usage and all cover crops had significant increases in their usage between 1995 and

2017. This data indicates that farmers are branching out to other cover crops and cover crops in general are becoming more prevalent. This may also show that seed is becoming more available for the specific practice of cover cropping. Seed availability has been a challenge for many mid to small operation producers.

Challenges and Benefits

The challenges and benefits of cover crops questions were insightful to see how users and non-users think differently. For almost all questions, it was apparent that the challenges farmers face to implement cover crops are not as challenging to those using cover crops as the non-users report them to be. The same goes for the benefits of cover crops. Those who are implementing cover crops report larger perceived benefits than those who do not utilize cover crops.

Challenges that exist for South Carolina farmers are mostly those related to cost of cover crop seed, availability of the seed, and the time and labor required to plant and manage the cover crop. These challenges may result in non-implementation, but there are many challenges that do not have statistically significant means between non-users and users. Challenges such as no measureable economic return, cover crop seed cost and availability, and cost of planting and management all are significant challenges for both non-users and users, so it may be true that other factors on top of these challenges affect implementation. Case by case scenarios that consider minor factors such as accessibility to seed/resources, size of farm, income, and weather can be important factors discounting those farmers from using cover crops. Some farmers indicated in the comments section of the survey that they would like to learn about the economic benefits of cover crops, not simply to implement cover crops because a subsidy is available to help them.

In regards to benefits of cover crops, both users and non-users seem to have an understanding that cover crops provide a variety of benefits. While many of the non-user and user results are significantly different, non-users still had a mean of 4.14 (Somewhat Important) for cover crops increasing soil organic matter. This may be indicative of farmers learning and understanding the benefits of cover crops but not having the resources and time to actually carry out a cover crop operation (Roesch-Mcnally et al., 2018).

Education

Oftentimes, education can be more effective in reducing the misconceptions about a best management practice rather than enacting a change to implement that certain best management practice (Sheriff, 2005). The results show that there is no significant difference in the benefit previous education has provided to farmers that use cover crops compared to those who do not use cover crops.

Farmers educating themselves through various methods averaged to be “seldom effective” for understanding how to utilize cover crops. Most farmers are in favor of trying things on their own land. This is often a very useful method, as farmers are the ones that know and understand their land. Also, most farmers are interested in local workshops that could provide information on cover crops. These types of workshops are prevalent in SC, where Clemson Cooperative Extension and SC NRCS work together to give presentations and demonstrations on the benefits of cover crops. Expanding these programs may possibly be the best method to grow cover crop understanding, reduce misconceptions, and foster a desire to implement cover crops. Unfortunately, one of the major prevailing opinions is that new methods will not work; farmers would rather stick with processes they are most familiar with. The basis for these decisions is often rooted in risk-aversion, especially if a farmer's income is steady or increasing (Sherriff, 2005). Additionally, when changing practices or adding new crops, crop insurance companies must be consulted. This adds an additional layer of approval or may potentially result in a loss of crop insurance (Plastina et al., 2018, n.d.).

Most farmers were in favor of Extension agents helping provide information to make accurate decisions about soil health and implementing cover crops. Results show that Extension and NRCS agents could be beneficial in all aspects of the cover crop implementation process, from knowledge about cover crops to providing advice on seed mixes, dealers, and application. More discussion with government agencies on the resources available would be necessary to determine the plausibility of this endeavor, but this research suggests that trust is high among farmers in terms of information received from Extension and NRCS agents.

Environmental Considerations

The response to environmental considerations relating to how farms affect water quality was indicative of farmers already having some or extensive education on this topic. 90% of farmers agreed that they should do more to reduce nutrient runoff into waterways. Likewise, 81% of farmers are concerned about the impact of agriculture on water quality. One of the major barriers that remains is the general uncertainty associated with agriculture production (Sheriff, 2005). Growing conditions, weather, and location can have a significant effect on how farmers choose to apply fertilizers and herbicides. The over-application of fertilizers to offset the potential losses due to adverse conditions can negative affect soil and water quality.

On the contrary, when asked if nutrients from farms are contributing to algae blooms and red tide in the ocean, only 49% believe that this is actually occurring. It is possible that farmers in general understand the direct impacts of the nutrient runoff but not the long term or long distance impacts of the transfer of nutrients through river systems. Additionally, increased publicity in mainstream media of the effects of nutrient runoff and hypoxia in the Gulf of Mexico and around Florida may contribute to farmers denying that they contribute to this problem. Furthermore, as media coverages aims to identify the source of the problem, farmers are quick to deny that they are the source, even if science does indicate that this is occurring (Paolisso & Chambers, 2001).

55% of farmers would be interested in an analysis of how their farm is doing to reduce runoff into waterways. These types of mitigation efforts would benefit farmers in multiple ways; they would be protecting the environment from nutrient runoff and they would be saving top soil and nutrients and less of these nutrients could be applied to the soil.

Conclusions

Our results indicated that farmers in South Carolina are increasing their usage of cover crops. The environmental benefits of this increase in cover crops is well documented, and the understanding of the economic benefits from cover crops are increasing. Cover crops have been shown to provide economic benefit when fertilizers inputs are reduced, they are sold as feed, or foraged (Gabriel, Garrido, & Quemada, 2013). Many farmers seem to be aware of these benefits and subsequently that have made it a priority to implement cover crops. Challenges do still exist for many farmers, though, due to time, labor, and funds required to change the crop rotations to include cover crops.

It is evident in the study that farmers are understanding of the localized effects of nutrient and soil runoff on the environment. Education efforts in the state through Cooperative Extension, SC NRCS, and the Richland County Soil and Water District provide resources to help farmers understand the connections between soil runoff, environmental degradation and ultimately crop yield. It is imperative that these education efforts continue to provide sound science that will help farmers understand these connections and show why cover crops and other best management practice such as no-till are viable methods to both protect the environment and increase crop yields. Challenges in the realms of seed cost and labor requirements can and should also be addressed at educational session so farmers can be better informed of their options to make budgeting for cover crops easier. Outreach to more farmers will also be crucial to implementing conservation practices.

Additional research will explore farmer's Willingness to Accept cost share payments for implementing cover crops utilizing data from this study. These types of funds can help spur a farmer's cover crop operation to the point where it is more sustainable economically.

CHAPTER FIVE

THE BROADER IMPACTS OF SUSTAINABLE LAND MANAGEMENT

Climatic changes poses a huge risk to business as usual for humans. In the very near future, seas will rise to a point where the current coastline is unlivable. Storms are becoming stronger and causing even greater damage to human-made infrastructure. Pollution is affecting our health in large cities, causing disease to increase. Water resources are being drastically redistributed across the globe during to the warming climate, affecting drinking water resources, agriculture production, and underground aquifer regeneration. Many of these consequences from a changing climate are already happening. Mitigation is our only option in many situations. When it comes to forest and agriculture production, there are many factors that affect the sustainability of the industry. Whether or not climate change was occurring, best management practices are crucial for maintaining soil health for both crop and timber production. In the face of climate change, decisions to manage land sustainably are even more important to feed a growing number of people that are displaced and significantly affected. The result of all of these best management practices (i.e. carbon, forestry BMPs, and cover crops) are co-benefits. Co-benefits are simply additional benefits gained from implementing a certain practice. All of these different projects highlight a goal to help landowners or increase yield for commodities. While these are worthy goals, ultimately, the co-benefits obtained by implementation of these best management practices will significantly benefit humanity if implemented on a large scale.

The co-benefits gained from best management practices for carbon sequestration have a significant impact on the surrounding ecosystem. Carbon projects inherently help reduce land use change to agriculture or urban areas. Because of this, soil and water can be retained instead of increased sediment deposition to rivers, affecting water quality. Additionally, wildlife habitat is retained or increased, helping to curb biodiversity loss. The chance of wildfire is also decreased due to active management required for carbon projects. All of these benefits are gained through management by the landowner and result in profits for the landowner, but they also provide myriad benefits to surrounding landowners and wildlife.

Each landowner has a story to tell about their land and the future of their land. It is important for land managers to understand the demographics, history, and goals of landowners. Conversely, it is important to listen to the stories of the landowners. Landowners know the most about their land because they have spent their life there. As land managers, it is our job to listen and then to provide assistance based upon their goals. When we provide land owners with knowledge, they can be confident in their land management decisions. Across the country, most forest and agricultural landowners want to do what is best for protecting the environment at a landscape level. With increased education and ultimately knowledge, landowners can write their own story that includes a holistic understanding of environmental protection, ecosystem services, and sustainable commodity production.

REFERENCES

Abawi, G. S., & Widmer, T. L. (2000). *Impact of soil health management practices on soilborne pathogens, nematodes and root diseases of vegetable crops*. *Applied Soil Ecology* (Vol. 15). Retrieved from https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=934&content=PDF

Allen, C. D., Breshears, D. D., & McDowell, N. G. (2015). On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere*, *6*(8), 1–55. https://doi.org/http://dx.doi.org/10.1890/ES15-00203.1

Amacher, G. S., Conway, M. C., & Sullivan, J. (2004). *Nonindustrial Forest Landowner Research: A Synthesis and New Directions*. Retrieved from https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs075/gtr_srs075-amacher001.pdf

Anderegg, W. R. L., Schwalm, C., Biondi, F., Camarero, J. J., Koch, G., Litvak, M., … Pacala, S. (2015). Pervasive drought legacies in forest ecosystems and their implications for carbon cycle models. *Science* , *349*(6247), 528–532. https://doi.org/10.1126/science.aab1833

Arbuckle, J. G., & Roesch-McNally, G. (2015). Cover crop adoption in Iowa: The role of perceived practice characteristics. *Journal of Soil and Water Conservation*, *70*(6), 418–429. https://doi.org/10.1016/j.forsciint.2012.03.015

Baral, S., Malla, R., & Ranabhat, S. (1970). Above-ground carbon stock assessment in different forest types of Nepal. *Banko Janakari*, *19*(2), 10–14. https://doi.org/10.3126/banko.v19i2.2979

Bengston, D. N., Asah, S. T., & Butler, B. J. (2011). The Diverse Values and Motivations of Family Forest Owners in the United States: An Analysis of an Open-ended Question in the National Woodland Owner Survey. *Small-Scale Forestry*, *10*(3), 339–355. https://doi.org/10.1007/s11842-010-9152-9

Birdsey, R., Pregitzer, K., & Lucier, A. (2006). Forest Carbon Management in the United States: 1600-2100. *Journal of Environmental Quality*, *35*, 1461–1469. https://doi.org/10.2134/jeq2005.0162

Butler, B. J., & Leatherberry, E. C. (2004). America's Family Forest Owners. *Journal of Forestry*. Retrieved from https://academic.oup.com/jof/article-abstract/102/7/4/4613202

California Carbon Dashboard: Carbon Prices, the Latest News, and California Policy. (2015). Retrieved January 14, 2019, from http://calcarbondash.org/

Clay, L., Motallebi, M., & Song, B. (2019). An Analysis of Common Forest Management Practices for Carbon Sequestration in South Carolina. *Forests*, *10*(949), 1–15.

Climate Action Reserve. (2015). Retrieved January 14, 2019, from http://www.climateactionreserve.org/

Clinton, B. D. (2011). Stream water responses to timber harvest: Riparian buffer width effectiveness. *Forest Ecology and Management*, *261*(6), 979–988. https://doi.org/10.1016/J.FORECO.2010.12.012

Creamer, N. G., Bennett, M. A., Stinner, B. R., Cardina, J., & Regnier, E. E. (1996). Mechanisms of Weed Suppression in Cover Crop-based Production Systems. *HORTSCIENCE, 31*(3), 410–413. Retrieved from http://hortsci.ashspublications.org/content/31/3/410.full.pdf

Cristan, R., Aust, W. M., Bolding, M. C., Barrett, S. M., Munsell, J. F., & Schilling, E. (2016). Effectiveness of forestry best management practices in the United States: Literature review. *Forest Ecology and Management*, *360*, 133–151. https://doi.org/10.1016/J.FORECO.2015.10.025

Croker, T. C., & Boyer, W. D. (1975). Regenerating longleaf pine naturally. *Res. Pap. SO-105. New Orleans, LA: US Department of Agriculture, Forest Service, Southern Forest Experiment Station. 26 P.*, *105*.

Crookston, N. L., & Dixon, G. E. (2005). The forest vegetation simulator: A review of its structure, content, and applications. *Computers and Electronics in Agriculture*, *49*(1), 60–80. https://doi.org/10.1016/J.COMPAG.2005.02.003

Dabney, S. M., Delgado, J. A., & Reeves, D. W. (2001). Using winter cover crops to improve soil and water quality. *Communications in Soil Science and Plant Analysis*, *32*(7–8), 1221–1250. https://doi.org/10.1081/CSS-100104110

Dunn, M., Ulrich-Schad, J. D., Prokopy, L. S., Myers, R. L., Watts, C. R., & Scanlon, K. (2016). Perceptions and use of cover crops among early adopters: Findings from a national survey. *Journal of Soil and Water Conservation*. https://doi.org/10.2489/jswc.71.1.29

EQIP (Environmental Quality Incentives Program), NRCS. (2018). Retrieved January 24, 2019, from https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Fahey, T. J., Woodbury, P. B., Battles, J. J., Goodale, C. L., Hamburg, S. P., Ollinger, S.

V, & Woodall, C. W. (2010). Forest carbon storage: ecology, management, and policy. *Frontiers in Ecology and the Environment*, *8*(5), 245–252. https://doi.org/10.1890/080169

Fang, J., Chen, A., Peng, C., Zhao, S., & Ci, L. (2001). *Changes in Forest Biomass Carbon Storage in China Between 1949 and 1998*. *Science* (Vol. 292). Retrieved from http://science.sciencemag.org/

Foley, T. (2009). *Extending Forest Rotation Age for Carbon Sequestration: A Cross-Protocol Comparison of Carbon Offsets of North American Forests*. Retrieved from https://pdfs.semanticscholar.org/9ed9/05099eb4098c12a1aa837c6244904e7179b5.pdf

Forest Inventory and Analysis Database. (2019). St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. Retrieved from https://apps.fs.usda.gov/fia/datamart/datamart.html

Froese, R. E., & Robinson, A. P. (2007). A validation and evaluation of the Prognosis individual-tree basal area increment model. *Canadian Journal of Forest Research*, *37*(8), 1438–1449. https://doi.org/10.1139/X07-002

Gabriel, J. L., Garrido, A., & Quemada, M. (2013). Cover crops effect on farm benefits and nitrate leaching: Linking economic and environmental analysis. *Agricultural Systems*, *121*, 23–32. https://doi.org/10.1016/J.AGSY.2013.06.004

Galatowitsch, S. M. (2009). Carbon Offsets as Ecological Restorations. *Restoration Ecology*, *17*(5), 563–570. https://doi.org/10.1111/j.1526-100X.2009.00587.x

Gallandt, E. R., Liebman, M., Corson, S., Porter, G. A., & Ullrich, S. D. (1998). Effects of Pest and Soil Management Systems on Weed Dynamics in Potato. *Weed Science, 46*(2), 238–248. Retrieved from http://www.jstor.org/stable/4045943

Haines, T. K., & Cleaves, D. A. (1999). The Legal Environment for Forestry Prescribed Burning in the South: Regulatory Programs and Voluntary Guidelines. *Southern Journal of Applied Forestry*, *23*(3), 170–174. https://doi.org/10.1093/sjaf/23.3.170

Hallgren, S. W., Desantis, R. D., & Burton, J. A. (2012). *Fire and Vegetation Dynamics in the Cross Timber Forests of South-Central North America*. Retrieved from https://www.nrs.fs.fed.us/pubs/gtr/gtr-nrs-p-102papers/04hallgren-p-102.pdf

Harmon, M. E., & Marks, B. (2002). Effects of silvicultural practices on carbon stores in Douglas-fir – western hemlock forests in the Pacific Northwest, U.S.A.: results from a simulation model. *Canadian Journal of Forest Research*, *32*(5), 863–877. https://doi.org/10.1139/x01-216

Helms, J. A. (ed. . (1998). The dictionary of forestry. Wallingford (United Kingdom) CABI Publishing/Society of American Foresters.

Hiers, J. K., Laine, S. C., Bachant, J. J., Furman, J. H., Greene, W. W., & Compton, V. (2003, December). Simple Spatial Modeling Tool for Prioritizing Prescribed Burning Activities at the Landscape Scale. *Conservation Biology*. https://doi.org/10.1111/j.1523-1739.2003.00381.x

Hobbs, P. R. (2007). Conservation Agriculture: What is it and why is it important for future sustainable food production. *Journal of Agriculture Science*, *145*(2), 127–137. https://doi.org/10.1017/S0021859607006892

Hoover, C. M., & Rebain, S. A. (2010). *Forest Carbon estimation Using the Forest*

Vegetation simulator: Seven things you need to Know. Retrieved from http://www.fs.fed.us/fmsc/fvs/

Hummel, S., Kennedy, M., & Ashley Steel, E. (2013). Assessing forest vegetation and fire simulation model performance after the Cold Springs wildfire, Washington USA. *Forest Ecology and Management*, *287,* 40–52. https://doi.org/10.1016/J.FORECO.2012.08.031

Ice, G. G., Schilling, E., & Vowell, J. (2010). Trends for Forestry Best Management Practices Implementation. *Journal of Forestry*. Retrieved from https://academic.oup.com/jof/article-abstract/108/6/267/4599413

Jin, W., He, H. S., Thompson, F. R., Wang, W. J., Fraser, J. S., Shifley, S. R., … Dijak, W. D. (2017). Future forest aboveground carbon dynamics in the central United States: the importance of forest demographic processes. *Scientific Reports*, *7*(1), 1–9. https://doi.org/10.1038/srep41821

Johnsen, K. H., Wear, D., Oren, R., Teskey, R. O., Sanchez, F., Will, R., … Dougherty, P. M. (2001). Meeting Global Policy Commitments: Carbon Sequestration and Southern Pine Forests. *Journal of Forestry*, *99*(4), 14–21. https://doi.org/10.1093/jof/99.4.14

Kerchner, C. D., & Keeton, W. S. (2015). California's regulatory forest carbon market: Viability for northeast landowners. *Forest Policy and Economics*, *50*, 70–81. https://doi.org/10.1016/j.forpol.2014.09.005

Khanal, P. N., Straka, T. J., & Willis, D. B. (2017). *Economic Contribution Analysis of South Carolina's Forestry Sector, 2017*. Retrieved from http://www.state.sc.us/forest/economicimpactstudy2017.pdf

Lal, R. (2005). Forest soils and carbon sequestration. *Forest Ecology and Management*, *220*, 242–258. https://doi.org/10.1016/j.foreco.2005.08.015

Land Cover Viewer - Map. (2019). Retrieved January 21, 2019, from https://gis1.usgs.gov/csas/gap/viewer/land_cover/Map.aspx

Leites, L. P., Robinson, A. P., & Crookston, N. L. (2009). Accuracy and equivalence testing of crown ratio models and assessment of their impact on diameter growth and basal area increment predictions of two variants of the Forest Vegetation Simulator. *Canadian Journal of Forest Research*, *39*(3), 655–665. https://doi.org/10.1139/X08-205

Liski, J., Pussinen, A., Pingoud, K., Mäkipää, R., & Karjalainen, T. (2001). Which rotation length is favourable to carbon sequestration? *Canadian Journal of Forest Research*, *31*(11), 2004–2013. https://doi.org/10.1139/x01-140

Lovell, H. C. (2010). Governing the carbon offset market. *WIREs Climate Change*, *1*, 353–362. https://doi.org/10.1002/wcc.43

Lu, X., Kicklighter, D. W., Melillo, J. M., Reilly, J. M., & Xu, L. (2015). Land carbon sequestration within the conterminous United States: Regional- and state-level analyses. *Journal of Geophysical Research: Biogeosciences*, *120*(2), 379–398. https://doi.org/10.1002/2014JG002818

Maker, N. F., Germain, R. H., & Anderson, N. M. (2014). Working Woods: A Case Study of Sustainable Forest Management on Vermont Family Forests. https://doi.org/10.5849/jof.13-003

Marland, G., Bruce, M. A., & Schneider, U. (2001). Soil Carbon: Policy and Economics. *Climate Change*, *51*, 101–117. Retrieved from https://link.springer.com/content/pdf/10.1023/A:1017575018866.pdf

Martin, W. E. P., Raish, C. P., Kent, B. P., Raish, C. P., & Kent, B. P. (2010). Understanding Public Perspectives of Wild re Risk . . . . Sarah McCaff rey, 25–36. https://doi.org/10.4324/9781936331611-7

Mase, A. S., Gramig, B. M., & Prokopy, L. S. (2017). Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. *Climate Risk Management*, *15*, 8–17. https://doi.org/10.1016/J.CRM.2016.11.004

Mc Clurkin, D. C., Duffy, P. D., Ursic, S. J., & Nelson, N. S. (1985). Water Quality Effects of Clearcutting Upper Coastal Plain Loblolly Pine Plantations. *Journal of Environment Quality*, *14*(3), 329. https://doi.org/10.2134/jeq1985.00472425001400030005x

Mccaffrey, S. M. (2006). *Prescribed fire: What influences Public aPProval?*

Mcmahon, S. M., Parker, G. G., & Miller, D. R. (2010). Evidence for a recent increase in forest growth. *PNAS*, *107*(8), 3611–3615. https://doi.org/10.1073/pnas.0912376107

Miller, K. A., Snyder, S. A., & Kilgore, M. A. (2012). An assessment of forest landowner interest in selling forest carbon credits in the Lake States, USA. *Forest Policy and Economics*, *25*, 113–122. https://doi.org/10.1016/J.FORPOL.2012.09.009

Montgomery, D. (2007). Soil erosion and agricultural sustainability. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(33), 13268–13272. https://doi.org/https://doi.org/10.1073/pnas.0611508104

Mutch, D. R., & Martin, T. E. (1998). Cover crops, 44–53. Retrieved from http://msue.anr.msu.edu/uploads/234/78911/covercrop.pdf

Narassimhan, E., Gallagher, K. S., Koester, S., & Alejo, J. R. (2018). Carbon pricing in practice: a review of existing emissions trading systems. *Climate Policy*, *18*(8), 967–991. https://doi.org/10.1080/14693062.2018.1467827

Nunery, J. S., & Keeton, W. S. (2010). Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. *Forest Ecology and Management*, *259*(8), 1363–1375. https://doi.org/10.1016/J.FORECO.2009.12.029

Oak-Hickory Forest. (2019). Retrieved January 21, 2019, from https://www.clemson.edu/public/scbg/natural-heritage-garden/oak-hickory-forest.html

Paolisso, M., & Chambers, E. (2001). Culture, Politics, and Toxic Dinoflagellate Blooms: The Anthropology of Pfiesteria. *Human Organization*, *60*(1), 1–12. https://doi.org/10.17730/humo.60.1.7dxhxmbl87fm34q9

Plastina, A., Liu, F., Miguez, F., & Carlson, S. (2018). Cover crops use in Midwestern US agriculture: perceived benefits and net returns. *Renewable Agriculture and Food Systems*, 1–11. https://doi.org/10.1017/S1742170518000194

Plastina, A., Liu, F., Sawadgo, W., Miguez, F. E., Carlson, S., Plastina, A. ;, … Marcillo, G. (n.d.). Annual Net Returns to Cover Crops in Iowa. *Journal of Applied Farm Economics*, *2*(2). Retrieved from https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1030&context=jafe

Powers, M., Kolka, R., Palik, B., McDonald, R., & Jurgensen, M. (2011). Long-term management impacts on carbon storage in Lake States forests. *Forest Ecology and Management*, *262*(3), 424–431. https://doi.org/10.1016/J.FORECO.2011.04.008

Quinn-Davidson, L. N., & Varner, J. M. (2012). Impediments to prescribed fire across agency, landscape and manager: an example from northern California. *International Journal of Wildland Fire*, *21*(3), 210. https://doi.org/10.1071/WF11017

Rauscher, H. M., Young, M. J., Webb, C. D., & Robison, D. J. (2000). Testing the Accuracy of Growth and Yield Models for Southern Hardwood Forests. *Southern Journal of Applied Forestry*, *24*(3), 176–185. https://doi.org/10.1093/sjaf/24.3.176

Reimer, A. P., & Prokopy, L. S. (2014). Farmer Participation in U.S. Farm Bill Conservation Programs. *Environmental Management*, *53*(2), 318–332. https://doi.org/10.1007/s00267-013-0184-8

Roesch-Mcnally, G. E., Basche, A. D., Arbuckle, J. G., Tyndall, J. C., Miguez, F. E., Bowman, T., & Clay, R. (2018). The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. *Renewable Agriculture and Food Systems*, *33*(4). https://doi.org/10.1017/S1742170517000096

Row, C. (1978). Economies of Tract Size in Timber Growing. *Journal of Forestry*, *76*(9), 576–582. https://doi.org/10.1093/jof/76.9.576

Ruddell, S., Sampson, R., Smith, M., Giffen, R., Cathcart, J., Hagan, J., … Simpson, R. (2007). The Role for Sustainably Managed Forests in Climate Change Mitigation. *Journal of Forestry*, *105*(6), 314–319. https://doi.org/10.1093/jof/105.6.314

Russell-Roy, E. T., Keeton, W. S., Pontius, J. A., & Kerchner, C. D. (2014).

Rehabilitation forestry and carbon market access onhigh-graded northern hardwood forests. *Canadian Journal of Forest Research*, *44*(6), 614–627. https://doi.org/10.1139/cjfr-2013-0437

Ryan, K. C., Knapp, E. E., & Varner, J. M. (2013). Prescribed fire in North American forests and woodlands: history, current practice, and challenges. *Frontiers in Ecology and the Environment*, *11*(s1), e15–e24. https://doi.org/10.1890/120329

Sagor, E. (2006). Nonindustrial Private Forest Landowners and Sources of Assistance. In *Forestry Cooperatives: What Today's Resource Professionals Need To Know* (pp. 1–11). Retrieved from https://www.nrs.fs.fed.us/pubs/gtr/gtr_nc266/gtr_nc266_003.pdf

Sawyers, B. C., Bolding, M. C., Aust, W. M., & Lakel, W. A. (2012). Effectiveness and implementation costs of overland skid trail closure techniques in the Virginia Piedmont. *Journal of Soil and Water Conservation*, *67*(4), 300–310. https://doi.org/10.2489/jswc.67.4.300

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., … Reyer, C. P. O. (2017). Forest disturbances under climate change. *Nature Climate Change*, *7*, 395–402. https://doi.org/10.1038/nclimate3303

Sheriff, G. (2005). Efficient Waste? Why Farmers Over-Apply Nutrients and the Implications for Policy Design. *Review of Agricultural Economics*, *27*(4), 542–557. https://doi.org/10.1111/j.1467-9353.2005.00263.x

Snapp, S., Labarta, S., Mutch, R., Black, D., Leep, R., Nyiraneza, J., & O'Neil, K. (2005). Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agronomy Journal*, *97*(January), 322–332. https://doi.org/10.2134/agronj2005.0322

Sorice, M. G., Kreuter, U. P., Wilcox, B. P., & Fox, W. E. (2014). Changing landowners, changing ecosystem? Land-ownership motivations as drivers of land management practices. *Journal of Environmental Management*, *133*, 144–152. https://doi.org/10.1016/J.JENVMAN.2013.11.029

Teck, R., Moeur, M., & Eav, B. (1996). Forecasting Ecosystems with the Forest Vegetation Simulator. *Journal of Forestry*, *94*(12), 7–10. https://doi.org/10.1093/jof/94.12.7

The Longleaf Alliance. (n.d.). Retrieved February 27, 2020, from https://www.longleafalliance.org/

Tian, N., Poudyal, N. C., Hodges, D. G., Young, T. M., & Hoyt, K. P. (2015). Understanding the Factors Influencing Nonindustrial Private Forest Landowner Interest in Supplying Ecosystem Services in Cumberland Plateau, Tennessee, *6*, 3985–4000. https://doi.org/10.3390/f6113985

Trimble, S. W., & Crosson, P. (2000). U.S. Soil Erosion Rates--Myth and Reality. *Science*, *289*(5477), 248–250. https://doi.org/10.1126/science.278.5342.1442

USDA (U.S. Department of Agriculture). (2012). *FY 2012 Budget Summary and Annual Performance Plan*. Retrieved from https://www.obpa.usda.gov/budsum/FY12budsum.pdf

Vyn, T. J., Janovicek, K. J., Miller, M. H., & Beauchamp, E. G. (1999). Soil nitrate accumulation and corn response to preceding small-grain fertilization and cover crops. *Agronomy Journal*, *91*(1), 17–24.

Wade, C. R., Bolding, M. C., Aust, W. M., & Iii, W. A. L. (2012). Comparison of Five Erosion Control Techniques for Bladed Skid Trails in Virginia. https://doi.org/10.5849/sjaf.11-014

Williams, T. M., Hook, D. D., Lipscomb, D. J., Zeng, X., & Albiston, J. W. (1999). Effectiveness of best management practices to protect water quality in the South Carolina Piedmont. In *Proceedings Tenth Biennial Southern Silvicultural Research Conference*.

Woodbury, P. B., Smith, J. E., & Heath, L. S. (2007). Carbon sequestration in the U.S. forest sector from 1990 to 2010. *Forest Ecology and Management*, *241*(1–3), 14–27. https://doi.org/10.1016/j.foreco.2006.12.008