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Quantifying the Impact of a Flood and Hurricane Event on Tree Farms in South Carolina: A Survey

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Abstract: Natural disturbances in forested landscapes are increasing in frequency. Hurricanes and flooding events can cause extreme damages to forested ecosystems and the forest products industry. The state of South Carolina experienced four major hurricanes and flooding events between 2015 and 2018. A survey was sent out to the members of the American Tree Farm System (ATFS) in South Carolina in 2017 to better understand the impact of two of these events—the historical flood of October 2015 and hurricane Matthew in October 2016—on family forest operations. Forty-eight percent of surveys were returned. Surveys were received from all counties except one. Average losses of $6.21/acre and $6.48/acre for flood and hurricane damage, respectively, were reported across all of the respondents. Major damage from the flood was reported to be on forest roads, while uprooted and broken trees were the most reported damage from the hurricane. Extrapolating damages to the state level indicated total estimated damages that were in excess of $80 million for each event. The responses also showed that only one-third of respondents were aware of disaster relief programs and less than 2% actually received financial aid. The results from this survey provide forest managers, policy makers, and extension personnel with information regarding the damages that were associated with the 2015 flood and the 2016 hurricane. Events such as these are bound to happen again in the future and information from this survey may allow foresters, policy makers, and forestry associations to refine the ways that financial aid information is distributed to increase the awareness of these programs.

Keywords: natural disaster; forest management; American Tree Farm System; family forest; financial aid; disaster relief

1. Introduction

Forested ecosystems are shaped and influenced by natural (e.g., wind, flood, fire) and anthropogenic (e.g., timber harvesting) disturbances. Natural disturbances often times cause economic losses, as anthropogenic disturbances in the form of commercial thinning and final harvests generally return economic benefits.

The natural forest disturbance regimes in many forest types have intensified in the past few decades [1,2]. Between 1900 and 1998, an average of 7.1 hurricanes hit the East Coast of the United States of America (USA), with every other hurricane being a category 3 (Saffir-Simpson scale) or higher [3]. Smith [3] reported that the frequency of hurricanes hitting the East Coast of the USA increased in the 1990's. Landowners and forest managers have to be prepared for more frequent, more damaging, and costlier hurricane and flooding events, as hurricanes are often associated with flooding.

On the global level, the warming of oceanic surface waters as a result of climate change is an important factor in explaining increases in hurricane intensities [4]. An analysis of hurricane intensity between 1970 and 2004 showed that the number of category 4 and 5 (Saffir-Simpson scale)

hurricanes doubled [5]. An increase in Atlantic tropical cyclone intensity has been noted between 1981 and 2006, a development that can be attributed to climate change [6]. A simulation of the economic impact of global warming on hurricane damage in the United States has shown a clear increase in economic damages in three out of four global climate models [7].

North Carolina, South Carolina, and Georgia were subject to 44 hurricanes that made landfall in these states between 1900 and 1998 [3]. Fourteen of these hurricanes made landfall in South Carolina. In 1989, hurricane Hugo made landfall in South Carolina as a Category 4 storm on the Saffir-Simpson scale [8]. Hurricane Hugo damaged approximately 1.8 million ha of forest land [8] and it caused damage to timber in excess of $1 billion [9]. In South Carolina, the softwood and hardwood growing stock declined by more than 1.3 billion cubic feet as a result of the hurricane [10]. Hugo also caused severe damage in the Santee Experimental Forest in South Carolina. Approximately 40% to 60% of softwood and hardwood stems in the experimental forest were broken and between 30% and 40% were uprooted [8]. Reports from hurricane Andrew in 1992 in Florida showed that approximately 1/3 of the mature pine trees in a stand were broken, with most breaks occurring slightly above ground level [11].

The forests of South Carolina were subject to four major disturbances on a landscape-level, impacting the majority of the state between 2015 and 2018. In October 2015, historical flooding occurred in South Carolina with some areas experiencing over 20 inches of rainfall over a five-day period [12]. The forest products industry experienced an estimated loss of $100 million as a result of the flooding [13]. This estimate includes the damages to timber, but also the value of lost time and production to loggers and mills due to unfavorable ground and weather conditions. On October 8th, 2016, hurricane Matthew made landfall in South Carolina [14], which caused severe wind damage to the forests in the state. On September 11th, 2017, hurricane Irma [15] caused severe damage on South Carolina's forests. Hurricane Florence made landfall in North Carolina on September 14, 2018, causing severe storm damage and excessive rain events in North Carolina [16]. The heavy rain subsequently caused extreme flooding downriver in many of the coastal areas of South Carolina.

The impact of these disturbances on the forest products industry is in the millions of dollars; however, little is known regarding the impact of these disturbances on family forest owners in South Carolina. With 62% of the non-industrial private forests in South Carolina being owned by individuals [17], these stakeholders represent a major part of the wood supply chain. We set out to contribute to the literature on the impacts to family forests with a case study of members of the American Tree Farm System (ATFS) in South Carolina. The objectives of our study were to: 1) determine the respondents' property characteristics, 2) quantify the type and intensity of damage to forest and road infrastructure from the 2015 flood and the 2016 hurricane, and 3) evaluate ATFS member's awareness of disaster relief programs.

2. Materials and Methods

We conducted a study of ATFS members in all 46 counties of South Carolina to better understand the impact of the 2015 flood and the 2016 hurricane events on family forests. Approximately 75% of the acreage enrolled in ATFS is certified (personal communication with Guy Sabin, January 2019), showing the owner's commitment to sustainable forest management practices. Forests that are certified by ATFS also play a vital role in the wood supply chain to such an extent that some companies (e.g., Weyerhaeuser) preferentially procure wood from ATFS certified forests [18].

The Forestry Association of South Carolina (FASC), as the acting ATFS agency in South Carolina, provided us with a list of all ATFS members in the state (n = 655), which we used as our sample frame. We used a mail survey study format to access our sample frame. Each ATFS member received a pre-notification letter, followed by a questionnaire packet (an envelope containing: a return-ready questionnaire booklet with pre-paid postage and stickers to seal the booklet for return). Subsequent mailings included a reminder postcard and a second questionnaire packet. We removed respondents from the mailings once we received their returned questionnaire to prevent unnecessary mailings. All of the mailings were sent out between June 13, 2017 and August 18, 2017.

We asked several questions regarding the characteristics of all of the respondent's property (ies): whether they own or lease their forestry property (ies), the acreage of the owned or leased property (ies), acreage of forested portion of the property (ies), the number of years owned/leased property (ies), and the county the property (ies) is in. We also asked whether each property had sustained damage in the 2015 flood event and during hurricane Matthew in 2016.

We then asked respondents to focus on the individual property that sustained the most damage in the 2015 flood event and, separately, the one that sustained the most damage in hurricane Matthew (if the respondent owned or leased only one property, they focused on it). We asked additional questions regarding the property with the most damage from the flood and hurricane, respectively. We also asked the approximate mileage of unpaved forest roads on the forested portion of the property (open-ended) and the distance to the nearest permanent water source (answer options: on the property, and less than one mile, 1–5 miles, 6–10 miles, and more than 10 miles from property).

We asked about specific damage sustained in each of the events (flood and hurricane) for the damage portions of our questionnaire. We asked respondents to indicate the extent of damage to trees, surface material, culverts and roads (9 pt Likert scale, where 1 = no damage, 5 = some damage, and 9 = severe damage). We asked for damage in the form of leaning trees smaller and greater than 30 degrees based on results from Brewer and Linnartz [19]. Trees with a lean of less than 30 degrees seem to have a greater chance of returning to a straight form. We asked respondents to indicate if the event delayed, sped up, or had no impact on the activities to assess how much the events impacted harvest activities; if delayed or sped up, we asked them to indicate the impact in weeks (open-ended). We asked about the change in stumpage rates, trucking distance, and trucking costs due to the flood and hurricane damage to roads and bridges outside their property (9 pt Likert scale where 1 = decreased, 5 = no change, and 9 = increased). Finally, we asked the respondents to estimate the overall cost of damage to the track of land, including repairs started or completed, planned, or repairs to damage from the events that would not be made.

We promoted design validity through an expert review of our questionnaire by Mr. Guy Sabin, Vice President of the Forestry Association of South Carolina, and Dr. Thomas Straka, Professor in the Department of Forestry and Environmental Conservation at Clemson University. The Clemson University Institutional Review Board approved our study prior to initiating the research (IRB 2016-304).

2.1. Data Analysis

All of the responses were recorded in a Microsoft Excel file and the data was analyzed using the statistical software package R [20] and the 'likert' library [21]. The responses were grouped in four regions: Upstate, Midlands, Pee Dee, and Low Country (Figure 1). Maps were created while using ArcMap 10.6 (ESRI). County-level Geographic Information System (GIS) data were provided by the South Carolina Department of Natural Resources [22], the National Hurricane Center in the form of the HURDAT2 database provided the hurricane Matthew data points [23], and stream data was provided by ESRI as part of a layer package within the ArcMap platform [24].

2.2. Non-Response Bias

We used the wave analysis method [25] by comparing answers from 10 questions from the first 40 responses and the last 40 responses to test for non-response bias. Welch two-sample t-tests and Pearson's Chi-square tests were used to compare the responses. The questions used to test for non-response bias covered multiple aspects of the survey and included the use of a consulting forester, site inspection frequency, forested acres, distribution of represented counties, flood damage, hurricane damage, gender distribution of respondents, urban background, education levels, and income.

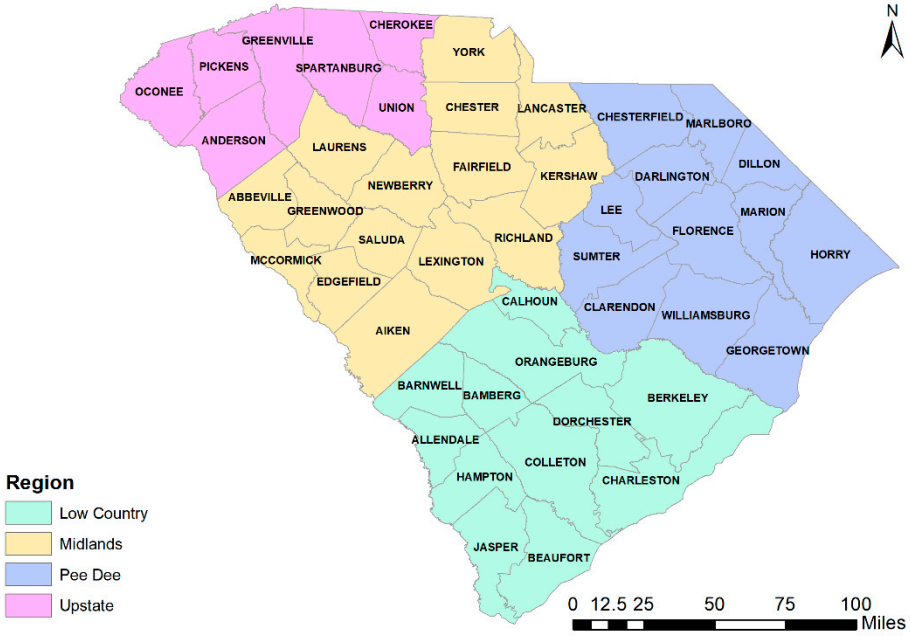

Figure 1. Responses were grouped into four regions based on the county in which their largest affected property was.

3. Results

A total of 317 surveys were returned, corresponding to a response rate of 48%. Of the returned surveys, 300 were from self-described non-industrial private forest owners (family forest owners). The responses were received from all of the 46 counties in South Carolina, except Clarendon County. The number of responses per county ranged from 1 to 19, with a median response of 5 returned surveys per county. The test for non-response bias indicated that there were no differences between early and late submissions of the surveys.

3.1. Property Characteristics

The majority of respondents (69%) indicated that they do not have a primary residence on the property that sustained the most damage in the two events. Thirty-one percent of respondents indicated that the reported property is the place of their primary residence. The median property ownership length was 28 years and the median forested and non-forested acreages were 200 and 15 acres, respectively (Table 1). The average size of forested area was 481 acres. The median length of forest roads (e.g. unpaved road) reported was three miles (Table 1). The vast majority of properties have a permanent water source (pond, lake, river, creek, etc.) on it, with the remaining properties having a water source less than 10 miles away (Figure 2).

Nineteen percent (n = 58) of respondents reported that their property sustained flood damage during the October 2015 historic flood and 33% (n = 99) reported damage from hurricane Matthew in 2016. Seventy-six percent of properties that sustained flood damage also sustained hurricane damage.

Table 1. Median, mean, standard deviation, and range of key property demographics of the property that sustained the most damage in the 2015 flood event and/or the 2016 hurricane. From a sample of Tree Farmers in 45 counties in South Carolina (June–August 2017 data collection).

	Median	Mean	Standard Deviation	Minimum	Maximum
Length of Ownership (years)	28	30	19	2	95
Forested Area (acres)	200	481	891	5	8000
Non-forested Area (acres)	15	124	583	0	8000
Length of Forest Roads (miles)	3	7	12	0	90

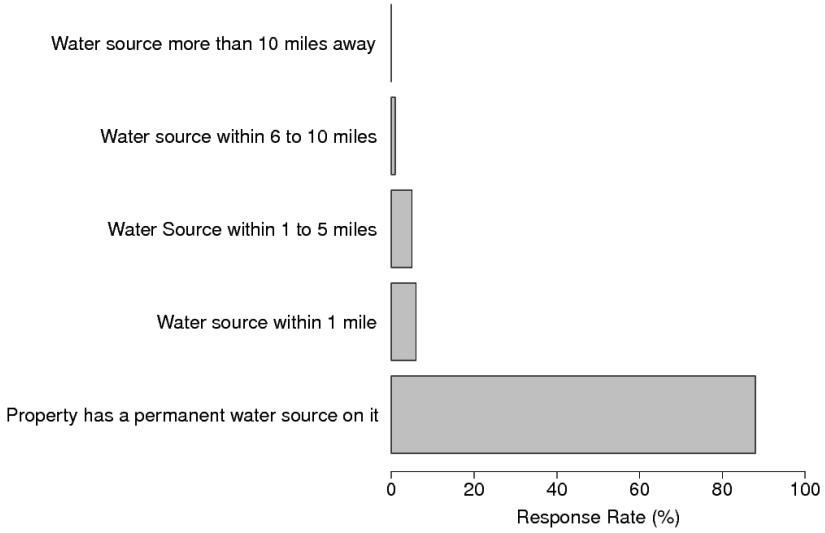

Figure 2. Percent responses of proximity to permanent water source of the property that sustained the most damage in the 2015 flood event and/or the 2016 hurricane among South Carolina Tree Farmers in 45 counties (June–August 2017 data collection).

3.2. 2015 Flood Damage

Flood damage occurred in the Pee Dee, Low Country, and Midlands region of the state (Figure 3). No flood damage was reported in the Upstate of South Carolina. The majority of flood damage was close in proximity to areas with first or second order streams, as can be expected.

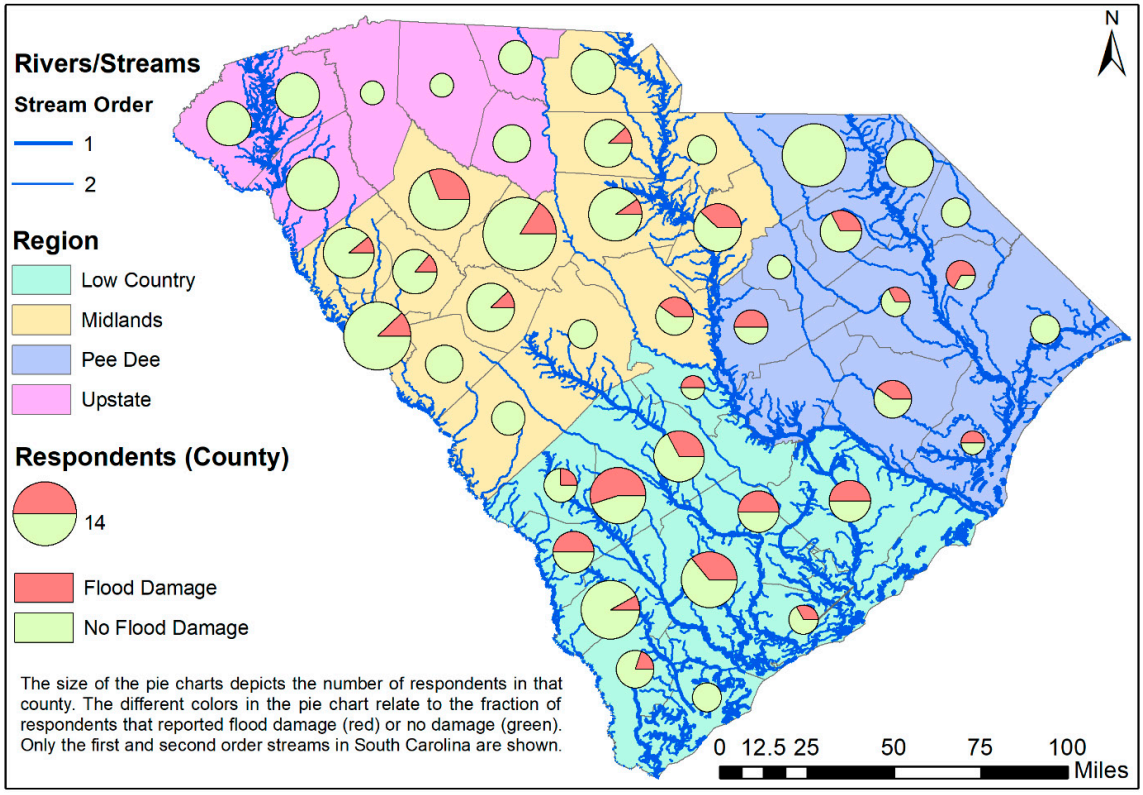

Figure 3. Frequency of reported damage from the 2015 flood event by county among South Carolina Tree Farmers in 45 counties (June–August 2017 data collection).

The majority of landowners that experienced flooding reported minor damage, as indicated by a high percentage of respondents reporting little damage (Likert-scale values 1 to 4) to their infrastructure and forest in Figure 4 (left column of percent values). Road systems were reported to have sustained the most damage of the infrastructure we asked about, with 40% of respondents reporting more than "some damage" (Likert-scale values 6 to 9) due to washed out roads. Thirty-three percent of respondents were reporting damage due to washed out culverts and another 33% reporting damage to roads from surface material loss (Figure 4; right column of percent values). The respondents reported damage from uprooted and broken trees, to a lesser degree.

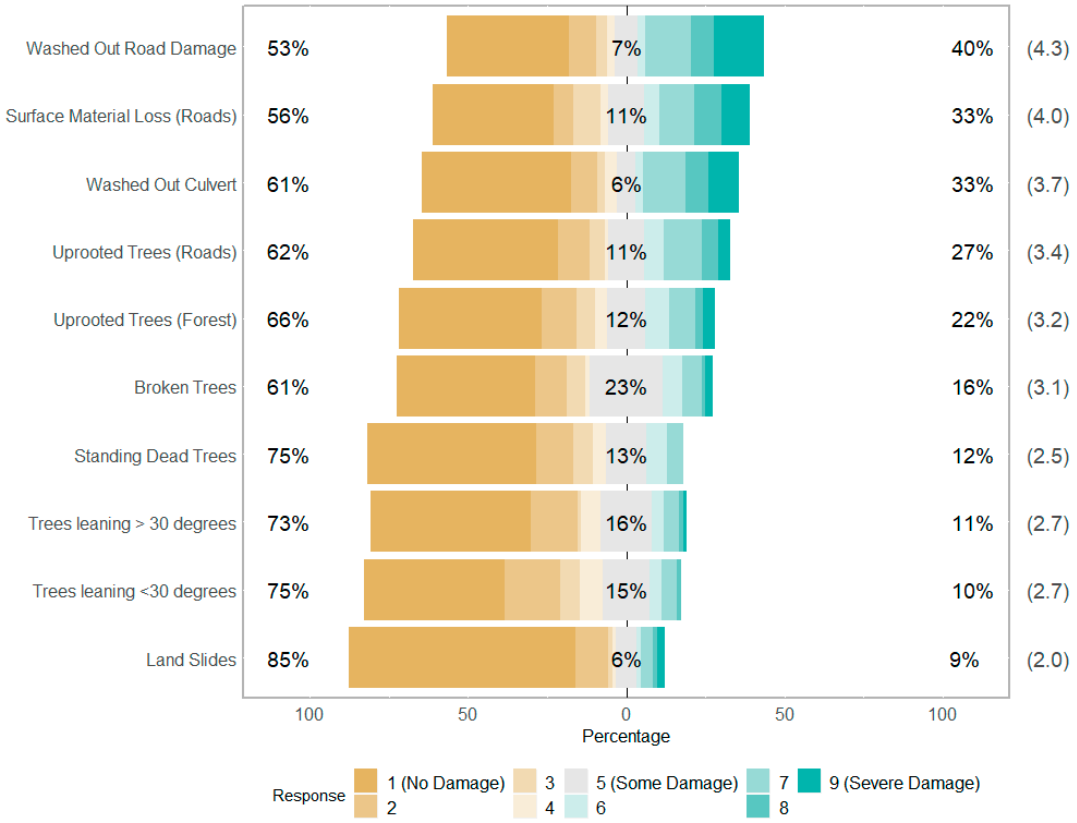

Figure 4. Percent of South Carolina Tree Farmers in 45 counties indicating damage (9-point Likert scale where 1 = no damage, 5 = some damage and 9 = severe damage) on the property that sustained the most damage from the 2015 flood (June–August 2017 data collection). Values in parentheses represent mean response values. Percent values to the left show the fraction of respondents that reported low damage (values 1 to 4) for the particular damage item, the percent values in the center show the fraction of respondents that reported some damage (value 5), and the percent values to the right show the fraction of respondents reporting high damage (values 6 to 9).

The impact of the flood on timber harvesting operations varied within the state. The average delay in timber harvesting operations ranged from 23 weeks in the Pee Dee region to 49 weeks in the Midlands region and 32% (n = 6) and 14% (n = 4) of the respondents in the regions reported it, respectively. In the Pee Dee region, 68% (n = 13) reported no change in their timber harvesting schedule and 86% (n = 24) reported the same in the Midlands region. Likewise, 72% (n = 23) of respondents in the Low Country reported no change in their timber harvesting schedule, however 28% (n = 9) of Low Country respondents indicated an average delay of 30 weeks. No delays were reported from the Upstate region of the state. When asked whether their stumpage rate changed, 71% (n = 40) of respondents that experienced flood damage reported that the stumpage rate they received decreased. Twelve percent (n = 7) reported an increase in the stumpage rate and 16% (n = 9) reported no change in stumpage rate. The answers may be interpreted as the perceived impact of the event on stumpage

rates forest owners believe the market should have provided, since most family forest owners do not harvest timber on a regular basis. However, the average forested acreage of respondents answering these questions was 865 acres, thus indicating that these forest owners may have enough exposure to timber harvests to have a good working knowledge of stumpage rates.

The cost of repairs due to damage from the flood ranged from $0 to $155,000 (Table 2). The actual damage amount varied by region, with the Midlands region showing the highest average damage per landowner. The average repairs per acre on the affected properties ranged from $5.41 in the Pee Dee region to $30.34 in the Midlands region, with an average across all the regions and affected properties of $18.82/acre (Table 2). The average per acre damage caused by the flood across the ATFS members in our sample was $6.21 based on the reported damages and both the damaged and non-damaged acreages from all regions. South Carolina has approximately 398,460 acres enrolled in the ATFS (personal communication with Guy Sabin, January 2019) and thus the extrapolated total flood damage on ATFS Tree Farms in South Carolina is estimated to be $2,474,437. The damage to family forests is estimated to be $44,412,430 when scaling this to approximately 7,151,760 acres of family forests in the state. Extrapolating these values to the state level (12.9 million acres of forest land [17]), which had a mix of affected and non-affected areas, the monetary impact in damages to forest land is estimated to be $80,109,000. That is approximately 0.4% of the annual 21-billion-dollar impact of the forest industry to the economy in South Carolina.

Table 2. Costs of repairs by region on the property that sustained the most damage from the 2015 flood (June–August 2017 data collection). All values are in $USD.

	Finished Repairs	Planned Repairs	Other Repairs	Total Repairs	Total Repairs per Acre
Midlands (*n* = 19)					
Median	$500	$500	$0	$0	$6.88
Mean	$11,338	$1853	$1182	$2031	$30.34
SD	$27,810	$2783	$3060	$11,444	-
Min	$0	$0	$0	$0	-
Max	$120,000	$10,000	$10,000	$120,000	-
Pee Dee (*n* = 13)					
Median	$1500	$0	$0	$0	$11.07
Mean	$3000	$800	$2222	$1249	$5.41
SD	$5327	$1400	$3632	$3943	-
Min	$0	$0	$0	$0	-
Max	$20,000	$4000	$10,000	$20,000	-
Low Country (*n* = 27)					
Median	5000	3500	0	0	$33.33
Mean	9656	7250	13,400	7592	$21.45
SD	14,614	8819	28,520	22,200	-
Min	0	0	0	0	-
Max	60,000	25,000	10,000	155,000	-
All Affected Properties (*n* = 59)					
Median	$5000	$2750	$4000	$5500	$16.42
Mean	$12,178	$6104	$12,444	$15,657	$18.82

Note: SD = Standard Deviation; *Other Repairs* refers to damages that are present but are not planned to be repaired.

3.3. 2016 Hurricane Matthew Damage

Hurricane damage mostly occurred in the Pee Dee and Low Country region of the state, however some respondents from the Midlands region also reported damage (Figure 5). No damage was reported in the Upstate region. Due to the trajectory of the hurricane along the coastline of South Carolina,

the majority of damage was close in proximity to the coastal areas where wind speeds reached up to 119 km/h over extended periods of time.

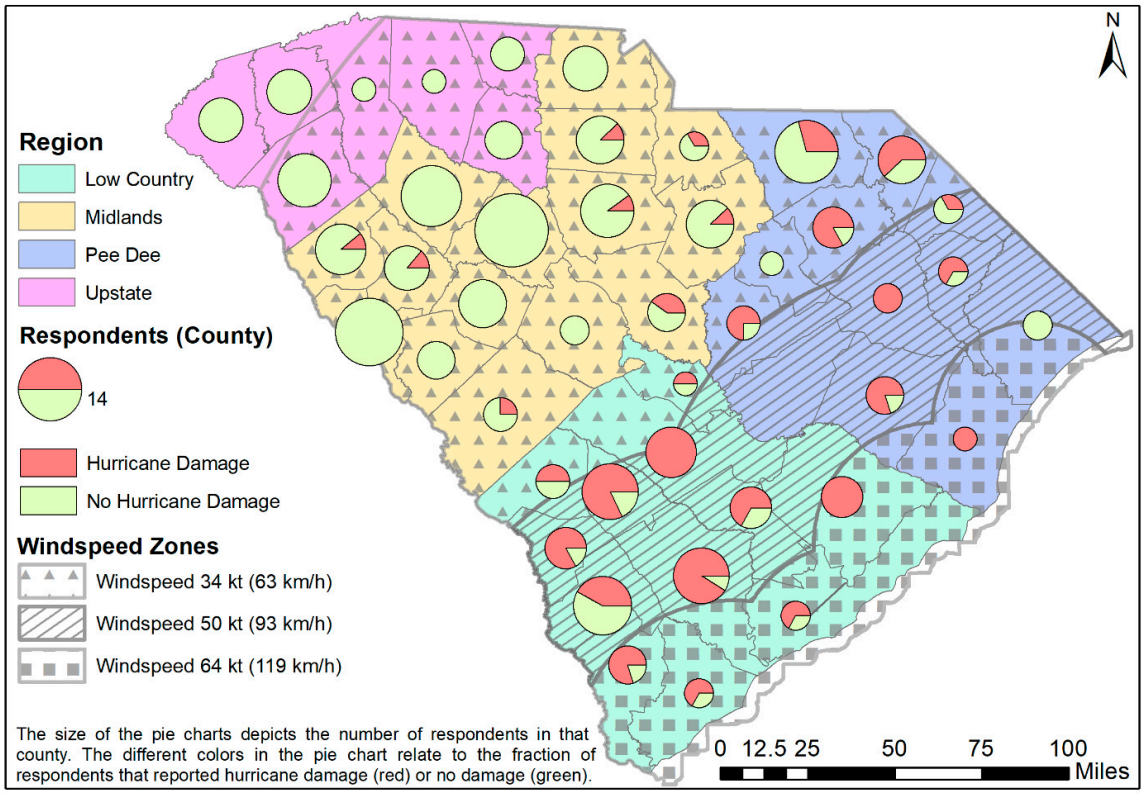

Figure 5. Frequency of reported damage from hurricane Matthew (2016) by county among South Carolina Tree Farmers in 45 counties (June–August 2017 data collection). Three different wind speed zones ranging from 63 km/h to 119 km/h are shown based on six-hourly data from the National Hurricane Center [23].

The majority of landowners that experienced damage from the hurricane reported minor damage, as indicated by a high percentage of respondents reporting little damage (Likert-scale values 1 to 4) to their infrastructure and forest in Figure 6 (left column of percent values). The most severe damage that was reported was uprooted trees in the forest and over roads (42% and 39% of respondents reported more than "some damage" (Likert-scale values 6 to 9), respectively). Dead, broken, and leaning trees were often times reported to have caused more than "some damage" (Figure 6; center and right column of percent values). The road systems experienced some damage, however, the majority of respondents reported minor damage.

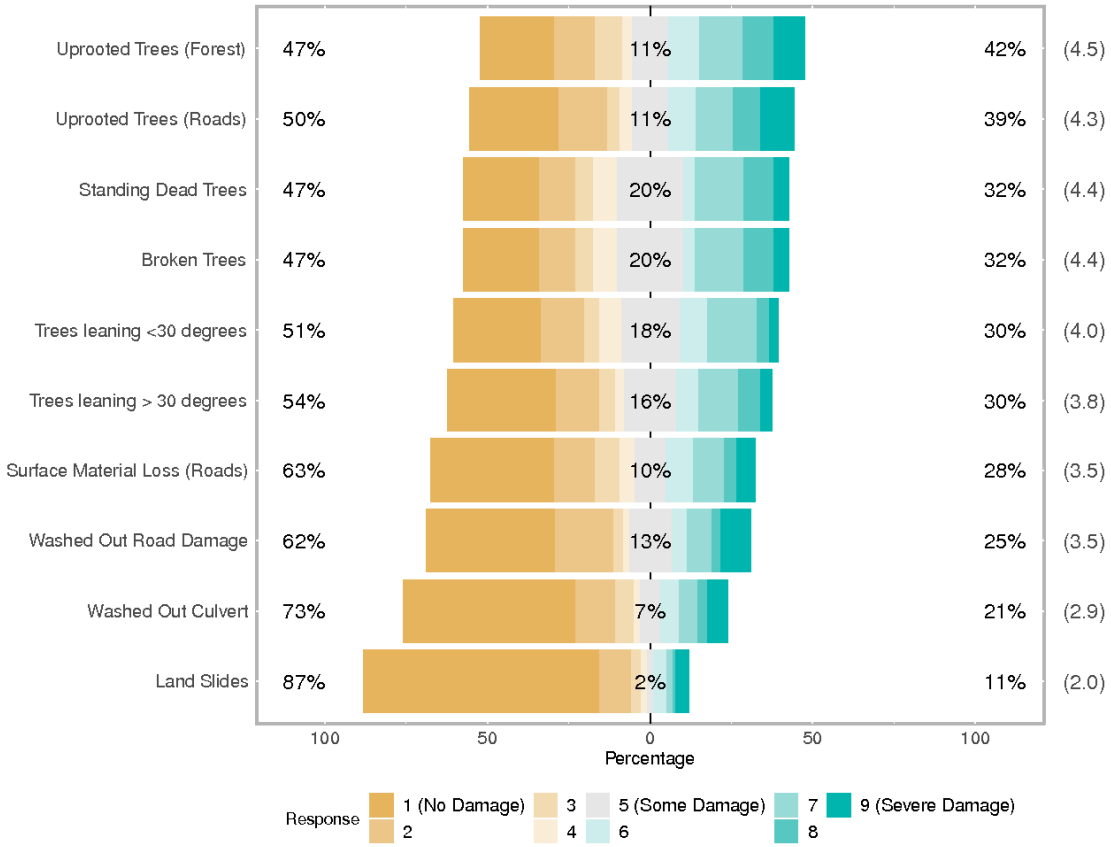

Figure 6. Percent of South Carolina Tree Farmers in 45 counties indicating damage (9-point Likert scale where 1 = no damage, 5 = some damage and 9 = severe damage) on the property that sustained the most damage from hurricane Matthew in 2016 (June–August 2017 data collection). Values in parentheses represent mean response values. Percent values to the left show the fraction of respondents that reported low damage (values 1 to 4) for the particular damage item, the percent values in the center show the fraction of respondents that reported some damage (value 5), and the percent values to the right show the fraction of respondents reporting high damage (values 6 to 9).

The impact of the hurricane on timber harvesting operations varied by region. Sixty-four percent (n = 28) of respondents reported no delay in the Low Country region, while 18% (n = 8) reported an average delay of 35 weeks, and another 18% (n = 8) reported that the hurricane sped up their timber harvest by an average of 46 weeks. Eighty-one percent (n = 22) of the respondents in the Pee Dee region reported no impact on their harvesting schedule, while 15% (n = 4) reported an average delay of 13 weeks, and 4% (n = 1) reported that they moved their harvesting schedule forward by an average of 14 weeks. Eighty-five percent (n = 23) of respondents reported no impact on their harvesting schedule in the Midlands region, while 11% (n = 3) reported an average delay of 41 weeks, and 4% (n = 1) reported that the hurricane sped up their timber harvesting operation by an average of 52 weeks. No impact was reported for the Upstate region. When asked whether their stumpage rate changed, 62% (n = 41) of all the respondents that experienced hurricane damage reported that the stumpage rate that they received decreased, however 19% (n = 11) reported a high to moderate increase in stumpage rate. No change in stumpage rate was reported by 19% (n = 11) of respondents that experienced damage.

The cost of repairs due to damage from the hurricane ranged from \$0 to \$250,000 (Table 3). The actual damage amount varied by region, with the Low Country region showing the highest average damage per landowner. The average repairs per acre on affected properties ranged from \$2.87 in the Pee Dee and Midlands region to \$17.23 in the Low Country region (Table 3). The average per acre damage on ATFS forests across the state caused by the hurricane was \$6.48/acre based on the reported damages and both the damaged and undamaged acreages reported. South Carolina has approximately

398,460 acres that were enrolled in the American Tree Farm System and thus the extrapolated total damage on Tree Farms in South Carolina is estimated to be $2,582,021. The damage to family forests is estimated to be $46,343,405 when scaling this to approximately 7,151,760 acres of family forests in the state. Extrapolating these values to the state level, which had a mix of affected and non-affected areas, the monetary impact in damages to forest land is estimated to be $83,592,000. That is approximately 0.4% of the annual 21-billion-dollar impact of the forest industry to the economy in South Carolina.

Table 3. Costs of repairs by region on the property that sustained the most damage from hurricane Matthew (June–August 2017 data collection).

	Finished Repairs	Planned Repairs	Other Repairs	Total Repairs	Total Repairs per Acre
Midlands (*n* = 18)					
Median	$0	$0	$0	$0	$0.00
Mean	$531	$176	$319	$138	$2.87
SD	$1882	$529	$1249	$1331	-
Min	$0	$0	$0	$0	-
Max	$8000	$2000	$5000	$15,000	-
Pee Dee (*n* = 17)					
Median	$2500	$0	$0	$0	$1.59
Mean	$4609	$1000	$833	$1780	$2.87
SD	$6515	$1534	$2041	$4810	-
Min	$0	$0	$0	$0	-
Max	$25000	$5000	$5000	$30,000	-
Low Country (*n* = 31)					
Median	$5000	$2000	$2000	$0	$1.67
Mean	$6610	$18,368	$13,190	$10,653	$17.23
SD	$8462	$56,634	$21,985	$31,914	-
Min	$0	$0	$0	$0	-
Max	$40,000	$250,000	$75,000	$250,000	-
All Affected Properties (*n* = 66)					
Median	$4000	$1000	$0	$500	$1.67
Mean	$5727	$12,069	$10,615	$9423	$11.32

Note: SD = Standard Deviation; *Other Repairs* refers to damages that are present but are not planned to be repaired.

3.4. Financial Aid Programs

Financial aid is often available following natural disasters from a variety of state and government agencies. Less than one-third of respondents reported that they were aware of selected financial aid programs, and generally 2% or less received financial aid for either of the two disasters (Table 4).

Table 4. Percent of respondents aware of financial aid programs, received aid and aggregate amount received (June–August 2017 data collection). No amounts of aid received following the hurricane were disclosed.

Program	% Aware of Program	% of All Respondents that Received Aid (Flood)	% of Respondents that Were Aware of Program that Received Aid (Flood)	Total Amount of Aid Received ($USD)	% of Respondents that Received Aid (Hurricane)	% of Respondents that Were Aware of Program that Received Aid (Hurricane)
Farm Service Agency Emergency Conservation Program	30%	1.6%	2.6%	$14,700	0.5%	1.3%
Tree Assistance Program	34%	1.2%	3.3%	$10,000	0%	0%
Small Business Administration Natural Resources Assistance Program	18%	0.4%	2.1%	N/A	0.5%	2.1%
Small Business Economic Injury Disaster Loan	17%	0.8%	4.3%	$3000	0.5%	2.2%
USDA Emergency Forest Restoration Program	30%	0.3%	1.2%	$6000	0%	0%

Note: N/A = amount was not disclosed.

3.5. Demographic Information

Of the respondents, 17% reported to be female and 83% male. Eighty-three percent of the respondents were over the age of 55, while the oldest respondent was 97 years of age. Only 6% of the respondents were younger than 45 years, while 11% were between 45 and 55 years of age. The youngest respondent was 31 years of age. When asked about their race/ethnicity, 91% self-identified as white, 3% black, and 1% of Asian, Hispanic, or native American/Hawaiian descent. Five percent of respondents did not report their ethnicity.

Respondents' employment status varied, with 76% of respondents being either retired or full-time/self- employed. The majority of respondents also reported that they grew up on a farm (34%) or small town (<10,000 people; 31%) for the first 12 years of their life. The remaining respondents grew up in a rural non-farm setting (9%), a suburb (9%), a city of up to 100,000 people (10%), or a major city of over 100,000 people (7%).

The completed levels of schooling and education varied among the respondents. Seventy-six percent of respondents indicated having at least a Bachelor's degree. All of the respondents had an education above the elementary and middle school levels. Household income in 2016 greatly varied, with 22% earning more than $200,000, 29% earning between $100,000 and $199,999, and 36% earning less than $100,000. Thirteen percent of the respondents did not report their household income.

4. Discussion

4.1. Flood Damage

The South Carolina Forestry Commission estimated initial damages of the flood to the forest products industry (damage to forests and economic losses to processing facilities) in the amount of $65 million [26], but later updated their estimate to $100 million [13]. However, little is reported regarding the extent of damage to family forest owners. Our results indicate that the overall statewide damage to forestland alone may have been as high as $80 million. Floods can have significant impacts on tree growth and survival and, depending on the length of flooding, can damage root systems or aid in wind throw of trees [27,28]. Our respondents reported some severe cases of uprooted or dead trees, but the most severe damage was caused on forest roads and culverts. Forest roads and skid trails are a major source of sediment runoff and erosion during normal weather conditions, so it is only understandable that erosion will increase during flooding events [29–31]. It is important to highlight the impact of floods on the timber harvesting schedule of the family forest owners. Our respondents reported an average delay of their timber harvest of 23 to 49 weeks. In addition, the stumpage that the family forest owner will receive most likely decreases. The reasons for this decrease in stumpage are unknown, but they may include increased trucking distances due to closed bridges, and increased harvest costs due to additional best management practices implementation. The small proportion of respondents that reported an increase in stumpage may be attributed to the demand for wood from the wood processing facilities in the state, and the forest land being on dry sites that could easily be operated on. However, no information regarding site conditions was requested in the survey.

No flood damage was reported in the Upstate of South Carolina. The reason for this may be the limited number of first and second order streams in the region and the fact that most of the streams on the western side of the region flow into multiple dammed reservoirs, and thus do not easily flood. Secondly, the Upstate region is higher in elevation than most of the other regions and includes parts of the Blue Ridge Escarpment with a more mountainous characteristic.

4.2. Hurricane Damage

The majority of damage that was reported due to hurricane Matthew occurred in the coastal areas along the path of the hurricane. Damage was reported more frequently within the 50 knot (93 km/h) and 65 knot (119 km/h) sustained wind speed zones. However, additional damage was reported further inland, especially along two of the major rivers in the state (Pee Dee and Santee Rivers). This can be

expected due to the heavy rainfalls that occurred in the eastern part of the state [14]. High damage was reported for the uprooted and broken trees, followed by leaning trees and surface material loss on forest roads. Some of the respondents reported that they cut their timber earlier than expected, even though the majority of our respondents reported no impact on their harvesting schedule due to the hurricane. This earlier harvest time may be due to the time sensitivity to salvage fallen trees, either to recover some economic value or to reduce the risk of insect outbreaks [32]. However, access to logging crews and markets can be difficult during major hurricane events, such as Hugo in 1989 [9].

4.3. Financial Aid Programs

Our results showed that only a small portion of the respondents were aware of financial aid programs. This is surprising, as the South Carolina Forestry Commission provides financial aid information on their website, including links to official U.S. Department of Agriculture communications. Additionally, all the ATFS members with an email address received information regarding financial aid programs on 10/12/2016 and 10/27/2016, and they were directed to the SCFC website for more details (personal communication with Guy Sabin, March 2019). It is important to understand why ATFS members are claiming to be unaware of financial aid programs, even though outreach efforts were made to inform affected ATFS members, given that the number of hurricanes on the East Coast of the USA is approximately one per year [3]. Additional information needs to be collected to understand why only a small percentage of respondents received aid. We suspect that the respondents did not apply for the aid or did not meet disaster relief requirements. The respondents may possibly be intimidated by the application process or may be concerned with providing information to government agencies.

4.4. Demographics

Our respondents cover a wide range of income levels, education, and forest sizes. However, white males dominated the respondents over the age of 55. Thirteen responses (4%) were from minority respondents. The National Woodland Owner Survey (NWOS) in 2002/2003 showed that family forest owners are, on average, 60 years of age and generally have attended college [33]. Our results are similar to the national results and, thus, indicate that we sampled across a representative group of family forest owners. ATFS does not collect demographic information on members (personal communication with Guy Sabin, March 2019), so we provide an initial estimate of the minority component of the ATFS members in South Carolina.

4.5. Limitations

During data analysis we became aware of an error in the formatting of two Likert scales that are associated with the questions of the impact of the flood/hurricane on stumpage rate, trucking distance, and trucking cost. Instead of showing a value of 1 as “Decreased”, it was shown as “No Damage”, and a value of 9 was shown as “Severe Damage” instead of “Increased”. However, the correct values were reported in the text of the questions. Given this error, the reported results to these questions may not be an accurate representation of the sample. The responses received for these questions seem to be in-line with the general trends at the time, as per the experience of the authors and discussions with foresters at the time of the two events.

Another limitation to this survey is the reported value of damages. Most of the reported damages can be classified as perceived damages and they may not represent actual damages. This is especially true with damages that were not repaired or that yet have to be repaired. Thus, the stated damages on a per acre, family forest, and state-wide level have to be carefully used in any decision making processes.

5. Conclusions

Natural disasters, such as a flood or hurricane, can create significant damage to individual family forest owners. Both the flood in 2015 and hurricane Matthew in 2016 potentially caused damages to the forest land in South Carolina of over $80 million, respectively. The estimate of a loss of over $100 million

to the forest products industry due to the 2015 flood that was released by the South Carolina Forestry Commission [13] includes additional considerations to the loss of production, whereas our estimate only focuses on forest land damages. Less than 50% of respondents reported high to severe damage in the respective damage categories, even though damage was reported across the state. The lack of awareness of disaster relief programs following the flood and hurricane is surprising and efforts should be made to increase the awareness and application rate of family forest owners in the state. However, the overall damage is less than 1% of the annual impact of the forest products industry to the South Carolina economy, and thus may not be as impactful to the industry, as it is to the individual family forest owner. It is important to grow and manage diverse and resilient forests to withstand future natural disasters and to minimize the economic losses to individuals.

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