ABSTRACT

HOVIS, MEREDITH ELAINE. The FloodWise Pilot Program: Leveraging Nature-Based Solutions for Flood Mitigation and Resiliency in Rural, Eastern North Carolina. (Under the direction of Dr. Frederick Cubbage).

Rising global temperatures due to anthropogenic activities have increased the frequency and severity of adverse climatic changes and events, such as extreme rainfall events, hurricanes, heat, and droughts. Nature-based solutions (NBS) are an innovative and natural technique to retain storm runoff and mitigate flooding impacts. Eastern North Carolina is prone to intensive flooding because of its flat, rural topography, susceptibility to frequent and intense hurricanes coming from the Atlantic Ocean, and the high probability of sea-level rise. NBS may help rural farm and forest lands to store runoff and reduce flooding on farms and downstream communities. "FloodWise" is a pilot project in Eastern North Carolina that proposes applying NBS to help regulate water runoff and storage during major precipitation events and provide payments for these efforts, which could supplement traditional farm incomes.

In this research, we identify the most promising NBS for the rural landscapes of North Carolina Coastal Plain. Some of the NBS are common farm practices that landowners may already incorporate but may not know the benefits for flood mitigation and storage, such as planting cover crops and using no-till farming. Other practices such as wetland restoration and creation or stream restoration may be lesser-known practices to landowners, but have been highly suggested in the literature for their ability to store stormwater runoff for an extended period of time and slow down waterflow running downstream, as well as promote other co-benefits, such as improved water quality.

In this dissertation, we also collected production and cost data from primary or secondary sources and used discounted cash flow and capital budgeting procedures at a 6% discount rate for the most promising NBS for eastern North Carolina. We estimated the payment amounts

necessary for landowners to break even to implement the NBS. These estimates could be utilized for the establishment of a potential FloodWise program for the state. Finally, we sent surveys to landowners in Eastern North Carolina to identify the determinants that may influence North Carolina landowners' participation in a future FloodWise program and their perceptions of NBS.

We identified the following most promising NBS for North Carolina's Coastal Plain: *agricultural practices* of (1) cover cropping/no-till farming, (2) hardpan breakup, (3) pine or (4) hardwood afforestation, and (5) agroforestry; establishing *wetland and stream practices* of (6) grass and sedge wetlands and earthen retention structures, (7) forest wetland banks, and (8) stream channel restoration; and establishing *structural solutions* of (9) dry dams and berms (water farming), and (10) tile drainage and water retention. From our discounted cash flows and capital budgeting analysis, we concluded that conventional cover crops had the greatest returns, and the majority of the wetland and stream practices and structural practices had negative returns at a 6% discount rate. FloodWise payments would be needed to encourage farmers to adopt NBS on their properties.

Finally, we identified the primary factors that could influence landowner willingness to accept NBS payments. Factors such as age, income, and land tract size were some of the main determinants. Other variables such as length of the program contract term, revenues lost from previous floods, knowledge of NBS, and concerns of future flooding, affected their willingness to accept NBS payments and to participate in a future cost-share program. The findings discovered in this dissertation could be used to help formulate a future flood mitigation program, such as FloodWise, as well as understand which target audience would be most likely to participate in it. The FloodWise program could fill the gaps of current hazard mitigation programs and serve as guidance for natural resources mangers, landowners, and practitioners in the discipline and who experience chronic flooding and its detrimental effects. Overall, adopting NBS could help prevent the displacement of residents, reduce infrastructure and agricultural losses, and help mitigate flooding damages to North Carolina Coastal communities.

The FloodWise Pilot Program: Leveraging Nature-Based Solutions for Flood Mitigation and Resiliency in Rural, Eastern North Carolina

by
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DEDICATION

In memory of

Dr. Erin Lindquist

Thank you for believing in me;

introducing me to my second home, Costa Rica;

and encouraging me to be a strong woman in this discipline.

BIOGRAPHY

Meredith Hovis graduated with a B.A. in Environmental Sustainability and a B.A. in Spanish from Meredith College in 2016, where she will forever be known as “Meredith that went to Meredith”. It was a dream of hers ever since she was in elementary school when her parents first took her there to visit. She loves Meredith College, where she was introduced to her second home in Costa Rica, and discovered her interest in natural resources and research.

Before graduate school, Meredith worked at Environment North Carolina (ENC), collecting petitions and comments for the “Don’t Drill NC” and “Kick Coal Ash” campaigns for the state. She worked as the Assistant Director of Canvassing, where she oversaw over thirty canvassers who went knocking on doors every day throughout the Triangle, educating the public and asking for their support. She also wrote letters-to-the-editor and led rallies in downtown Raleigh to recognize the campaign and the harmful impacts of off-shore drilling and coal ash. By working at ENC, Meredith discovered her passions for education, people, advocacy, and policy.

Meredith continued her education at NC State University in the College of Natural Resources, graduating with a M.S. in Natural Resources with a Technical Option in Policy and Administration in 2018. Inspired by her advisor and her time in graduate school, she strove to continue towards a Ph.D.

Now, in 2022, Meredith plans to graduate with a Ph.D. in Forestry and Environmental Resources Even a global pandemic could not stop her. Her research interests are in the natural resource management and policy, hazard mitigation, and disaster resilience disciplines. During her Ph.D., she taught two undergraduate courses at NC State University and one at Elon University, which unveiled her passion for teaching and mentoring students. She currently works as a Program Coordinator for the Southeast and Caribbean Disaster Resilience Partnership

(SCDRP) where she supports managing monthly membership meetings, monthly Board meetings, and assists in the coordinating the SCDRP Annual Meeting.

Meredith is excited for this next chapter in life and hopes to make the world a little bit better than how she found it.

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To my committee members, who have given me so much guidance during my Ph.D. Thank you, Dr. Megan Lupek, for inspiring me to be a strong woman in this field and guiding me as an instructor in ENV 101. Teaching this course gave me the opportunity to find my love for teaching, and financially supporting my way through graduate school. Thank you, Dr. Dave Garson, for teaching me everything I know to this day about quantitative research methods and analysis. I'm appreciate of your patience and support as I fought through many data analysis hurdles throughout this dissertation. Thank you, Dr. Ted Shear, for pushing me to be a better researcher and writer, and always uplifting me for my accomplishments. Thank you for the funding to support my work. Lastly, I thank, Dr. Gavin Smith, who was a last-minute addition to the committee, but an extremely important one. You introduced me to the natural hazards and disaster resilience disciplines, the Graduate Certificate in Disaster Resilient Design, Engineering, and Policy, and SCDRP. Because of you, I want to spend my career in this space and make a difference.

To my co-authors on the manuscripts in this dissertation, thank you for your expertise and support, and seeing our work through publication. Thank you also for helping contribute to all the grants that funded this work, such as the UNC Policy Collaboratory through the NC Sea Grant Program and the Environmental Enhancement Grant through the NC Dept. of Justice.

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INTRODUCTION

Oceans, land, and the atmosphere are increasingly warming due to anthropogenic activities and emissions, and in consequence, climatic events are abnormally and rapidly changing (IPCC, 2021). As this global climate change endures, we can expect to experience dangerous and unforeseen chronic hazards, such as hurricanes, flooding, droughts, and extreme heat, to name a few (IPCC, 2021; Scholz and Yang, 2010; US EPA, 2016). Therefore, climate change adaptation is crucial to protect against future chronic and acute hazards (Glavovic & Smith, 2014).

Glavovic and Smith (2014) suggest four types of climate adaptation strategies: (1) *protection*, (2) *accommodation*, (3) *retreat*, and (4) *avoidance*. *Protection* typically involves deploying hard- or soft-engineering approaches to protect against hazards and their impacts. *Accommodation* refers to working with a landscape to reduce risk, such as planting trees for flood storage and water in-take to reduce flooding downstream. *Retreat* indicates the relocation of human settlements or at-risk infrastructure out of hazard-prone regions, such as flood zones. Similarly, *avoidance* involves preventing human developments in hazard-prone areas in the first place (Glavovic & Smith, 2014). These climate adaptation strategies have their tradeoffs, and some arrangements incorporating each approach may need to be considered for enhanced climate adaptation.

Over time, in the U.S., flood mitigation has been dominated using hard-engineered structures, like levees and dams, or also referred to as “grey infrastructure” (White, 2000) (grey refers to the color of the rock or concrete often used in these structures). Extensive literature has criticized grey infrastructure for its adverse effects on ecological processes, and a growing body of literature is questioning whether sole reliance on these tactics for hazard mitigation is appropriate (Collentine and Futter 2018; Glavovic & Smith, 2014; Nicholson et al., 2019; Kundzewicz, Pinskwar, & Brakenridge, 2012; Scholz & Yang, 2010). These critiques have been bolstered by two 2017 US Army Corps of Engineers (USACE) Infrastructure Reports, which indicate that over 2,100 dams in the US are deficient and admitted that the condition of the nation's levees is mainly unknown. These reports also suggest that an estimated $125 billion is needed to keep current flood control infrastructure in sufficient shape over the next ten years. Thus, soft-engineered approaches and alternative approaches, such as natural infrastructure, have increasingly been brought to attention for future protection measures (Glavovic & Smith, 2014).

Natural flood risk management, using "natural infrastructure" or "nature-based solutions" (NBS), is a relatively new concept and one that is worthwhile for further consideration (Schanze, 2017). Natural flood management is defined by Nicholson et al. (2019) as the alteration, restoration, or use of landscape features to help reduce flood risk. By working with landscapes to slow and detain water runoff from heavy precipitation events, the stormflow hydrograph can be desynchronized and decrease the high flows of rivers after serious precipitation events (Mitchell et al., 2018). Some natural infrastructure practices that have been suggested are the creation or restoration of wetlands (Bullock et al., 2003), implementation of various agricultural best management practices (Antolini et al., 2020), and using soft-engineering practices to integrate flood defenses within landscapes to allow for the temporary storage of excess water (Oullette et al. 2018, Nicholson et al. 2019). In this dissertation, I use the terms "natural infrastructure" and "NBS" interchangeably as practices that work with landscapes for flood defense, storage, and reduction downstream.

The inland coastal plain of North Carolina offers rogramtive area to consider how natural infrastructure could produce landscape flood resilience. This region is particularly prone to flooding due to its flat topography rivers. Flooding issues have likely been exacerbated by land-use changes, including the removal of natural landscapes within the watersheds of the major rivers (Kim et al., 2014). The inland coastal plain is also home to towns and agricultural communities that have been devastated by fluvial floods in recent years. From Hurricane Florence in 2018 alone, NC farmers experienced approximately $1.1 billion in losses (NCDA, 2018).

This dissertation uses Eastern North Carolina as a case study and pilot project for a potential flood reduction program for the state, which we refer to as "FloodWise". The FloodWise program could help rural communities improve water quality, flood mitigation, other farm benefits, and community governance connections. So far, our network consists of researchers, students, and faculty members at the NC State University's College of Agriculture and Life Sciences, College of Design, and College of Natural Resources, as well as practitioners and employees at NC Foundation for Soil and Water Conservation Districts, Farm Bureau, and Environmental Defense Fund. We are seeking to develop subsequent farm demonstrations sites in Eastern North Carolina for best management practices for water quality and flood mitigation.

Chapter 1 of this dissertation is a systematic review of the scientific literature on various natural infrastructure practices and an iterative scoping process of the various practices with professionals, consultants, practitioners, and farmers in the discipline. We identified a list of the most promising NBS for Eastern North Carolina and ranked them based on their physical capability to store water and reduce water flow downstream. Based on our literature reviews and an iterative scoping process with professionals in the field, we came up with a list of ten top practices worth pursuing in Eastern NC for flood reduction downstream. These practices include *agricultural practices* of (1) cover cropping/no-till farming, (2) hardpan breakup, (3) pine or (4) hardwood afforestation, and (5) agroforestry; establishing *wetland and stream practices* of (6) grass and sedge wetlands and earthen retention structures, (7) forest wetland banks, and (8) stream channel restoration; and establishing new *structural solutions* of (9) dry dams and berms (water farming), and (10) tile drainage and water retention. We refer to these same practices throughout the other two chapters. We conclude in this study that NBS are promising tactics for future flood mitigation compared to traditional grey infrastructure, and we suggest a handful of practices for future research and implementation.

Chapter 2 is a study that assesses the costs and revenues of the ten practices discussed in Chapter 1. In this chapter, we used general economic-engineering and finance approaches to examine the input-output production functions, engineering processes, input costs, and output prices or benefits for each natural infrastructure practice. We gathered all data from interviews with agricultural and environmental consulting firms, extension professionals, farm and environmental agency representatives, farmers, and equipment operators, and previous literature. We also assessed potential governmental payments in order to determine average costs for the selected practices and the payments that might be required for landowners to adopt them. Payments may be needed to incentivize landowners to implement NBS, especially for the practices that results in negative Net Present Values (NPV).

Chapter 3 uses a payment card contingent valuation method to estimate the payment amount at which landowners would be willing to accept to adopt NBS on their properties. We selected a random sample of landowners in Robeson County, NC. The study utilizes various logit models to reveal the determinants that influence landowner's participation in a potential FloodWise program. We also discuss flood mitigation program options for rural communities in Eastern NC, and where a potential flood reduction program for localities may be housed. The estimates identified in this study could be used to help budget a future FloodWise program, as well as understand the type of landowner who would be willing to enroll.

The overall purpose of this work is to identify potential NBS for Eastern North Carolina (Chapter 1), assess their costs and benefits (Chapter 2), and understand landowner's perceptions of adopting them on their properties (Chapter 3).

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CHAPTER 1: NATURAL INFRASTRUCTURE PRACTICES AS POTENTIAL FLOOD STORAGE AND REDUCTION FOR FARMS AND RURAL COMMUNITIES IN THE NORTH CAROLINA COASTAL PLAIN[1]

Abstract

Increased global temperatures resulting from anthropogenically-induced climate changes have increased the frequency and severity of adverse weather events, including extreme rainfall events, floods, and droughts. In recent years, nature-based solutions (NBS) have been proposed to retain storm runoff temporarily and mitigate flood damages. These practices may help rural farm and forest lands to store runoff and reduce flooding on farms and downstream communities and could be incorporated into a conservation program to provide payments for these efforts, which would supplement traditional farm incomes. Despite their potential, there have been very few methodical assessments and detailed summaries of NBS to date. We identified and summarized potential flood reduction practices for the Coastal Plain of North Carolina. These include *agricultural practices* of (1) cover cropping/no-till farming, (2) hardpan breakup, (3) pine or (4) hardwood afforestation, and (5) agroforestry; establishing *wetland and stream practices* of (6) grass and sedge wetlands and earthen retention structures, (7) forest wetland banks, and (8) stream channel restoration; and establishing new *structural solutions* of (9) dry dams and berms (water farming), and (10) tile drainage and water retention. These practices offer

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different water holding and storage capacities and costs. A mixture of practices at the farm and landscape level can be implemented for floodwater retention and attenuation and damage reduction, as well as providing additional farm and forest ecosystem services.

4.1 Introduction

Increasing frequency and intensity of precipitation and river flooding are common indicators of global climate change, causing increased potential for soil erosion and flood damage. Large amounts of flooding caused by heavy rainfall and storms can damage farmer's crops, displace residents, contaminate the local water supply, disrupt natural ecosystems, and deteriorate infrastructure [1, 2]. Flooding is the most frequent natural disaster globally and one of the most devastating in both lives lost and economic damage [3, 4, 5]. It is expected that the frequency and duration of riverine flooding events will increase in the coming years due to changing patterns in precipitation, continued urbanization, and other changes in land use that affect natural landscapes [5, 6, 7].

Historically in the United States, flood risk mitigation has relied on engineered structures such as levees and dams, also referred to as "grey infrastructure" [8] (grey refers to the color of the rock or concrete often used in these structures). These practices have been extensively criticized for their adverse effects on aquatic wildlife and ecological processes, such as degrading natural wildlife habitats and the buildup of sediments, leading to water pollution and reduced dam capacity. In addition, dams and levees are particularly ineffective in mostly flat or lightly rolling terrain, since they would need to flood large areas of productive land in order to hold an adequate volume of water to reduce flooding and would be very expensive to build and to buyout inundated farm or urban lands.

There is also growing concern about relying solely on these structures for flood mitigation [3, 9, 10, 11]. The average age of the 90,580 dams in the United States is 56 years. The number of high-hazard potential dams (those that will cause loss of life if they fail) climbed to nearly 15,500 in 2016, of which 2,179 were considered deficient [12]. The condition of the nation's levees is largely unknown. Over the next ten years, an estimated $125 billion is needed to keep existing flood control infrastructure in satisfactory working condition. In North and South Carolina, 83 dams failed from October 2015 to November 2017 and 20 dams in North Carolina failed during Hurricane Matthew in 2016 [13, 14].

2. Nature-Based Solutions

Natural infrastructure, also known as nature-based solutions (NBS), has emerged across the U.S. to provide potential practices that can simultaneously reduce flooding, improve water quality, enhance biodiversity, and address food security [15]. Modern natural infrastructure flood management is a relatively new concept, arising in the late 1990s, and is worthy of further consideration [16]. However, while this is perceived as a new concept, it was identified presciently more than 70 years ago by conservationist Ding Darling as a better concept than massive dams in Iowa:

> "Darling had what he thought was a better idea, backed by experience, knowledge and successful demonstration projects. In a hearing conducted in 1950, in conjunction with plans to build Iowa's Red Rock Reservoir, Darling testified: 'We have ample proof on demonstration areas that runoff can be stopped before the waters reach the rivers and thereby save not only the water but the soil which is washed off with it. On such demonstration areas we have the triple benefit of

> flood control, soil conservation and restocking of our subterranean water table.'"
> [17, p. 260].

More recently, natural flood management is the alteration, restoration, or use of landscape features to reduce flood risk [9]. By working with landscapes to slow and detain water runoff from heavy precipitation events, the stormflow hydrograph can be desynchronized, decreasing the high flows of rivers after heavy precipitation events [18]. These practices also are referred to as flood attenuation approaches—slowing down the release of water after major storm events. Promising landscape alterations include the creation or restoration of wetlands, implementation of various agricultural best management practices, and earthen and vegetation "structural" practices that integrate flood defenses within landscapes to temporarily detain excess water [9, 19, 20]. As noted by Ding Darling, small microstructures were commonly used to capture rainwater before the modern intensification of agriculture. More purposeful and well planned efforts could be renewed to address such increased problems in the current era.

In 2016, the International Union for Conservation of Nature (IUCN) defined NBS as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits [15]." In addition, the U.S. National Oceanic and Atmospheric Administration (NOAA) considers natural infrastructure an "effective solution for minimizing coastal flooding, erosion, and runoff, as do man-made systems that mimic natural processes [21]." NOAA also states that natural infrastructure initiatives are profitable and cost-effective for safeguarding coastal communities. The New Climate Economy's 2018 report recommends natural infrastructure, such as forests and wetlands, for providing flood control [22]. Many countries, including Australia, New Zealand, and Indonesia, have already adopted NBS such as better management of forests and mangroves. These countries have seen positive impacts on global climate and economic benefits [23, 24]. Belgium has recently applied NBS methods by reconnecting rivers to the floodplains in order to improve the natural capacities of the floodplains and increase social co-benefits and biodiversity [25].

There are many types of NBS that restore natural landscapes. Such projects can mitigate flooding and enhance the habitats throughout the watershed. Not only is natural infrastructure an advantage for water quantity, but it is also beneficial for ecological processes and biodiversity, such as protecting downstream ecosystems and removing harmful pollutants from runoff; serving as critical habitat for wildlife; functioning as a sink for harmful greenhouse gas emissions; or generating revenues for landowners via crop or wood production [15]. These NBS practices must fit well within existing physiographic landscape features, land uses, and infrastructure in order to be successful. They must strive to modify existing agricultural and built environments to restore more natural resilience and adaptability to increasingly severe climate changes and adverse weather events.

As global climate change exacerbates flooding problems, adapting to new NBS and institutional arrangements to encourage implementation on rural lands is essential for flood mitigation and resilience. These practices refer to a subset of NBS that can be implemented on farm and forest lands to reduce runoff and downstream flooding, and could potentially receive ecosystem payments for these efforts, which will supplement traditional farm incomes, and replace the traditional infrastructure. We have initiated research in North Carolina about nature-based solutions, coupled with conservation payments to rural landowners to implement these practices, which we have termed “FloodWise”. This review of appropriate biophysical practices is one component of that line of research.

FloodWise practices may benefit farms, forests, biodiversity, individual landowners, and local downstream communities. Some are existing farming methods that are beneficial for water storage, and others are relatively new practices designed specifically for mitigating floods. In many cases, the practices are used concurrently for increased resilience. Landowners may already incorporate some of these practices, but with further education, outreach, and financial incentives, many more could adopt them to increase farm income and mitigate flooding. However, there have been almost no methodical and detailed summaries of rural natural infrastructure practices to date, which we sought to redress with this research. The following questions guided our study:

- What are the most effective natural infrastructure practices that can be used for rural lands in North Carolina?
- What the strengths and weaknesses of each of the selected natural infrastructure practices?
- Can the identified flood disaster mitigation practices be effective at the individual practice level for individual farms?
- Can the identified flood disaster mitigation practices be effective in aggregate at the downstream watershed or community level?
- What are the co-benefits of natural infrastructure flood mitigation practices for water quality protection?

3. North Carolina Coastal Plain

In North Carolina, hurricanes are one of the most frequent and devastating climate-related hazards to the state's environment and economy compared to other natural hazards.

Hurricane Matthew in 2016 and Hurricane Florence in 2018 hit the same urban and agricultural communities in eastern North Carolina. These two storms caused the loss of 85 human lives and damages of $17.6 billion for the state; from Hurricane Florence alone, NC experienced approximately $1 billion in tobacco, corn, soybean, cotton, chicken, turkey, and hog losses [26]. The areas that were hit the hardest commonly consisted of low-income and agricultural communities. The regions experienced prolonged flooding that completely inundated farmland for weeks after the hurricanes passed. The floods also caused massive pollution and adverse effects from sediment, farm sewage ponds, and chemical runoff, adversely impacting shellfish and fish habitat, human drinking water supplies, coastal waters and beaches, and more.

Our NBS assessment focused on the Coastal Plain of eastern North Carolina. It is prone to riverine flooding due to its relatively flat topography and slow-moving rivers, and the current flood mitigation infrastructure is insufficient (Figure 1.1). A recent survey in North Carolina indicates that 11% of its dams are unsatisfactory or inadequate [27]. Additionally, land-use changes have exacerbated flooding issues, including the alteration of natural landscapes within the watersheds of the major rivers due to new development towards the coastal region and agricultural expansion [6]. This region of North Carolina is representative of 75 million hectares (188 million acres) of Coastal Plain in the U.S. South’s Atlantic and Gulf coasts, extending from the Virginia coast southward through the Florida peninsula, then along the Gulf coast to Texas [28]. This entire region has relatively similar topography, vegetation, ecosystem, climatic conditions, as well as similar problems with frequent flooding of low-lying topography by hurricanes or other major storm events. Riverine flooding issues related to flatter terrain also extend more broadly across the nation, and indeed the world.

North Carolina is currently developing a comprehensive strategy for reducing its vulnerability to climate change. The strategy relies partially on nature-based solutions that conserve, restore, and manage its natural and working lands to build climate change resilience in communities and ecosystems and sequester carbon while also meeting other economic, ecological, and societal goals [29].

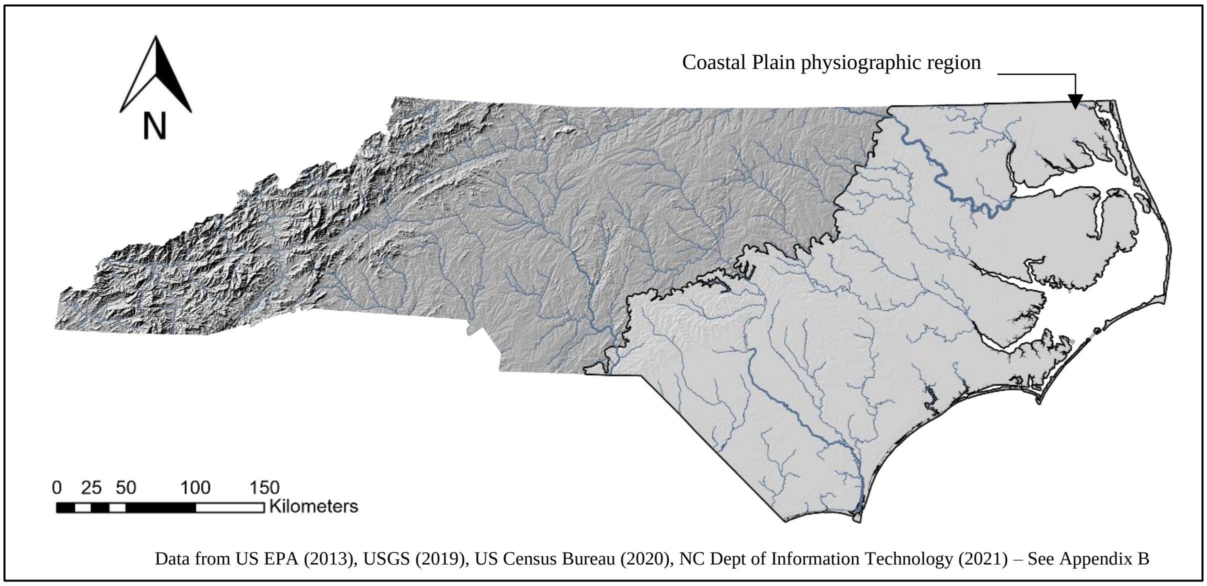

Figure 1.1 Map of North Carolina Topography and Major River Systems

4. Methods

4.1 Iterative NBS Scoping Process

The modern era of natural infrastructure and nature-based solutions is quite new, so the first research task was to determine which existing or new conservation and NBS practices were appropriate in North Carolina for flood reduction and attenuation. The 14 co-authors employed an iterative scoping process using scientific documents, refereed papers, expertise of practitioners, and practical knowledge of our research team to identify the most promising NBS practices (Figure 1.2). First, the co-authors from the NC State University (NCSU) Department of

Forestry and Environmental Resources (FER) and Department of Biological and Agricultural Engineering (BAE) identified a list of 18 possible NBS practices for flood mitigation after consultation with other experts, farm association experts, environmental engineers, and researchers. The original list of 18 practices is shown in Appendix A. Next, co-authors from FER and six NCSU Environmental Science (ES) senior project team students completed a semester-long project with an extensive literature review on the effectiveness of each of the 18 practices. They conducted interviews with environmental engineering consulting firms to obtain more information on the best practices and their costs. FER and BAE research team members and ES students compiled a list of environmental engineering firms and government conservation agencies as their organizational sample for contacts for individuals to interview about conservation practices and costs. The NC State University Institutional Review Board (IRB) reviewed and authorized the interview protocol and research. Finally, co-authors from NCSU College of Design (COD), NC Foundation for Soil and Water Conservation, scientists with the Environmental Defense Fund, and practitioners with farm associations reviewed the list of selected practices, noting their advantages and disadvantages, and helping refine the best practices and their descriptions.

Based on the literature reviews, interviews, and best professional judgment, the co-authors categorized the 18 practices as “best,” “possible,” or “not promising” for flood mitigation in eastern North Carolina (Appendix A), based on the criteria of (1) probability of flood reduction, (2) costs of practices, (3) percent of flood reduction, (4) likelihood of adoption by landowners, (5) risk of failure, and (6) the interaction of these effects.

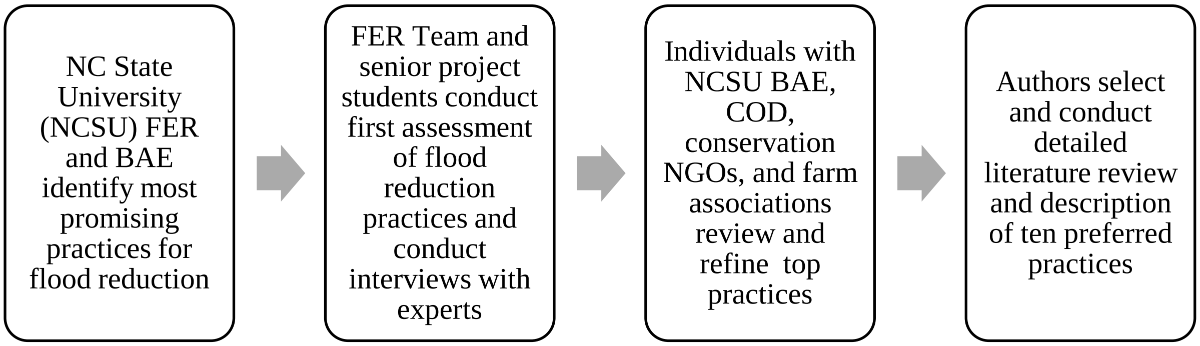

Figure 1.2 Natural Infrastructure Practice Identification and Review Process

We finalized our list and selected the ten best NBS practices for flood reduction in North Carolina (Table 1.1). These include *agricultural practices* of (1) cover cropping/no-till farming, (2) hardpan breakup, (3) pine or (4) hardwood afforestation, and (5) agroforestry; *wetland and stream practices* of (6) grass and sedge wetlands and earthen flood control structures in water retention basins, (7) forest wetland banks, and (8) stream channel restoration; and *structural solutions* of (9) dry dams and berms (water farming), and (10) land drainage and water retention with tiling.

The three broad categories range in upfront cost and the ease with which they can be adopted and installed. The agricultural practices are a distinct category of best crop and forest practices with comparatively small barriers to adoption. However, wetland and stream practices require significant earth moving to achieve the new NBS natural state and may include some water management control structures. The structural solutions must employ permanent low-rise dams or tiling, respectively. These ten practices require varying degrees of establishment and maintenance effort and costs, with wetland water retention basins and the dry dams and berms requiring the largest investments.

Our subsequent research consisted of obtaining extensive details about the ten preferred practices, including clarifying the practices required and identifying useful names and previous examples of their application. Based on the knowledge of the co-authors, the literature and interview data collected by the ES senior project team, and a detailed literature review of these ten best NBS practices, we identified their potential or drawbacks for implementation. We also conducted a review of the selected NBS practices for water quality protection.

Table 1.1 Preferred Nature-Based Solution Flood Mitigation Practices for the Coastal Plain of North Carolina

Categories	Best Practices and Descriptions
Agricultural	
Cover crops and no-till	(1) Including legume and non-legume cover crops on fields during winter
Hardpan breakup	(2) Breaking up compacted hardpan layers to allow for soil water infiltration
Forests and Tree Planting	Planting (3) bottomland hardwood or (4) pine forest species
Agroforestry	(5) Combining mixed pine trees and pasture fields
Wetland and Stream	
Wetland restoration and retention basins	Restoring natural wetlands in or along waterways with (6) the use of grasses, sedges, and water control structures in water retention basins, or (7) bottomland hardwood forest wetland banks
Natural stream channel restoration	(8) Restoring previously straightened streams to a natural configuration
Structural	
Dry dams and berms (water farming)	(9) Constructing low-level dams and berms to retain and store floodwater during storm events
Land drainage features	(10) Installing land drainage controls to manage runoff

5. Results

We provide the qualitative results of the scientific review of the ten most effective flood retention and mitigation practices in North Carolina below. This provides an extensive description and summary of the literature regarding their effectiveness and drawbacks.

5.1 Cover Crops and No-Till

Cover crops are planted on agricultural fields to protect and improve the soil and complement row crop production. A growing body of research indicates that cover crops increase landscape resilience [30, 31]. Integrating cover crops into both summer and winter crop rotations can improve water infiltration, decrease soil surface evaporation, and decrease the amount of soil water through plant use [32, 33, 34, 35, 36]. Because cover crops are planted after the primary crop is harvested, their benefits for flood control would be primarily limited to winter or early spring when fewer major flooding events occur. However, better soil infiltration conditions and less runoff, in general, may provide moderate benefits throughout the year.

Various plant species can be used effectively as a cover crop. Stormwater runoff decreased by 50% during a corn-growing season by incorporating rye cover crops in silt loam soil [37]. By including chickweed cover crops in a soybean-growing season, stormwater runoff was reduced 44% [38]. Cereal rye cover crops improved water storage when incorporated with maize-soybean crops [34]. Over a seven-year timeframe study, winter rye cover crops were found to improve soil water health and storage for a maize-soybean crop [39]. Winter rye increased soil water retention by approximately 11% [39]. Mixing cover crop species in the same plot can optimize outcomes, especially its benefits to underground water [40].

No-till farming practices increase soil pore space by adding carbon to the soil, which improves water infiltration and storage [41]. Many researchers and practitioners acknowledge the negative impacts of tillage practices on soil and water conditions by leaving no plant residue on the soil surface [42, 43]. No-till can increase rainfall infiltration and reduce water overland flow and soil erosion during rain events compared to intensive plowing. It also would reduce soil compaction and help improve (reduce) soil density.

Cover cropping and no-till can work in tandem, particularly because the proper implementation of cover crops can eliminate the need for tillage [44]. Research has shown that a combination of these practices could be effective at increasing landscape water storage. A 2007 report by the Sustainable Agriculture Research and Education (SARE) program indicated that by incorporating cover crops and no-till farming practices in North Carolina, the landscape could store an additional 91 billion liters (24 billion gallons) of water [45].

The combination of no-till and cover crops has also been shown to benefit farmers through increased production. Leon Moses, the manager of North Carolina A&T State University's 200-hectare farm in Greensboro, North Carolina, explains that adding cover crops has provided an approximately 40% return on investments [44, 45]. By incorporating cover crops, soybean and corn yields increased substantially [46, 47]. No-till farming retains soil surface residue and generates the most revenue from crop production [48]. However, there are instances where cover crops have been shown to decrease cash crop yield. Bergtold et al. [44] examined eight studies of cover crops' effect on subsequent cash crop yield; six had increases of 10-131%, two had decreases of up to 50%. They identified the termination of the cover crop as a critical factor in crop yield response. A poorly implemented or poorly timed termination will cause cash crops to compete with dying or unaffected cover crops.

Farmers generally understand the benefits of cover crops. A survey of 3,500 farmers in Iowa, Indiana, Illinois, and Minnesota revealed that 96% of farmers believed cover crops reduce soil erosion, but only 18% utilized cover crops [49]. This appeared to be due to the extra cost and labor involved. Cover cropping processes must include cutting the last crop, soil preparation, and sowing operations, all of which must be performed within a week [50]. Different tillage practices are used for various reasons, and farmers generally decide which practice to perform to enhance their profitability [51]. Tilling is conducted to prepare the seedbed and prevent and remove weeds. One of the main reasons for implementing tillage practices has been to provide the best layout for seed germination and root growth [51].

Conservation crop farming practices are already used relatively extensively in North Carolina (Table 1.2). The USDA 2017 Agricultural Census shows that the adoption of these practices in North Carolina is growing slowly [52]. Most NC farms already either use no-till or reduced till practices, with only 30% reporting in the 2017 Census that they use conventional tillage. However, only 11% of NC farmers reported using cover crops. In addition, farmers in North Carolina and the rest of the U.S. may already apply for and receive financial payments for a wide variety of programs and hundreds of individual conservation practices, either through the U.S. Farm Bill or similar state conservation programs. These types of conservation programs could be a model for ecosystem service payments that could be instituted for FloodWise nature-based solutions as well.

North Carolina farmers can help mitigate flooding and improve soil health via cover crops and no-tillage. The primary effect of these practices would be to reduce runoff during the first part of an extreme precipitation event before the soil becomes saturated. Flood modeling has shown that this can reduce the peak flow downstream; however, we are not aware of any published studies that quantify the effects of this additional water storage on downstream flooding.

Table 1.2: Area of North Carolina Cropland using Cover Crops, No-Till, or Reduced Tillage[52]

Practice	2012 Area (ha)	2017 Area (ha)	2017 Percent of Total Crop Farmland in NC
Cover Crops	159,042	195,436	11%
No Tillage	760,249	772,616	43%
Reduced Tillage	257,463	291,690	16%
Regular Tillage	754,040	541,624	30%
Total Cropland	1,771,752	1,805,415	100%
Total Pastureland	425,666	383,248	N/A

Note: 1 ha = 2.47 ac

5.2 Hardpan Breakup

Dense and compacted soil, also known as a hardpan layer, is one of the key issues in crop production [53, 54]. The hardpan layer can be found anywhere between 0.1 to 1.0 meters under the soil surface. It can be caused by plowing or tilling to the same depth every year, resulting in the underlying soil becoming very compacted. Hardpans can also be caused by heavy traffic of tractors and other machinery, especially in wet weather. Hardpans also may be caused by the use of chemicals that kill important soil microorganisms and by droughts [55].

Research conducted in the Southeastern U.S. indicates that hardpan layers constrain root growth and restrict soil water infiltration and soil aeration, limiting crop yield and increasing erosion and flooding from runoff [54, 56]. Breaking up areas where the soil is compacted and root growth is restricted increases soil moisture [54, 57]. Chisel plows are attached to tractors and rip the hardpan, allowing better water infiltration and deeper root growth.

The development of hardpans can also be prevented with no-till practices [58]. No-till farming is desirable on highly erodible land or high clay soils because it can reduce soil erosion and enhance crop establishment [59].

The effectiveness of breaking up hardpans and the subsequent runoff and flood reduction depends on the extent of the hardpan, the permeability of the soil layer above and below it, and the intensity of the precipitation. Where soils are permeable, and the hardpan is extensive, the effectiveness of the break-up can be significant. However, where soils are less permeable or have a less permeable layer relatively close to the surface, such as is found in much of the NC Coastal Plain, the effectiveness of this practice for flood mitigation is more limited.

5.3 Forestry

Forest lands are common throughout eastern North Carolina, with forests comprising about half of the land area in the U.S. southern states from East Texas to Virginia. So, establishing forests may not be considered an innovative runoff reduction practice per se. Further, forestry may already have moderate rates of return, albeit less than conventional pasture and crop farming. Thus, we do not provide an extensive review of forest practices here, which has an extensive body of literature already. Forests generally have higher water infiltration rates, less surface runoff, and erosion, and more transpiration than pastureland or crop land, helping reduce flooding [60]. Forests also provide more biodiversity and require less use of chemicals and fertilizers, enhancing natural ecosystems in situ and downstream.

Converting croplands that are frequently flooded or are on low productivity soils to planted forest stands can provide runoff retention benefits while not significantly reducing economic returns. The use of trees and pasture in frequently flooded fields in eastern North

Carolina has been shown to reduce crop losses from flooding. While forests are common, tree planting (afforestation) on marginal crop or pasture lands can reduce floods and increase net income.

As one indicator of water quality and quantity, Richter [60] reported that forest land in North Carolina had an average soil erosion rate of 0.36 metric tonnes per hectare per year, while pastureland averaged 3.8 metric tonnes per hectare year, and crop land 10.3 metric tonnes per hectare per year. Forests would have greater erosion rates in the years that they were harvested, ranging from 0.38 to 3 metric tonnes per hectare per year depending on topography, but these higher rates would decrease within one to three years as forest lands regenerated.

Hydrologic modeling of two North Carolina Coastal Plain watersheds has shown that converting crop and pastureland to forest reduces runoff and downstream flooding after sufficient tree growth has occurred. The degree to which the reduction occurs is dependent on the many factors including the amount of land conversion, the topography, and soil permeability of the land being converted to forest.

5.4 Agroforestry

Agroforestry integrates farming practices with silviculture by growing trees and crops on the same unit of land or trees and pasture animals on the same unit of land [61]. Much of the research around agroforestry systems has focused on ecosystem benefits. Various studies have provided evidence that agroforestry systems provide more benefits for carbon storage, biodiversity conservation, and water quality enhancement than standard farming practices. The carbon stored in trees and roots can offset livestock methane emissions, resulting in reduced net greenhouse gases. The shade from the trees can help provide thermal regulation for animals, increasing health and reproductive success [62, 63].

To a large extent, agroforestry practices are an extension of traditional forest land management practices, which offer more flood water retention benefits. Substantial evidence indicates that forested areas exert some control on the hydrologic cycle [64, 65, 66]. As previously noted, forests have less erosion and thus produce less runoff that reaches rivers [60], but deforestation generally increases runoff amount [67]. Multiple studies have suggested that agroforestry systems may offer some benefits for flood control and risk reduction [68, 69]. Agroforestry may alleviate flooding-through increased uptake of precipitation and facilitate more significant soil profile recharge compared to row crops and pasture. A 2019 meta-analysis of 89 papers discussing water infiltration in agricultural soils indicated that agroforestry increased water infiltration by 59.2 ± 20.9% [70].

In the southeastern U.S., microclimate differences occurred in a typical open pasture system with a young (5-8 years) longleaf pine (*Pinus palustris*) agroforestry system [71]. Soil water content was significantly higher (26%-98%) in the agroforestry system than in a normal pasture, suggesting that the agroforestry system's soil was better at holding water. However, a similar study within a mature (18-20 years) loblolly pine (*Pinus taeda*) agroforestry system found that soil water content was significantly lower (29%-77%) over a normal pasture [72]. Looking at the results of both studies, the authors concluded that mature trees' extensive root systems allow them to utilize the excess water in the system. Water extraction by deep-rooted vegetation reduces groundwater storage and decreases the amount released to streams [73]. However, the magnitude of this change on the stormflow hydrograph likely varies based on vegetation type, climate, soil types, and other factors [74].

Some studies have suggested that agroforestry practices may increase farmers' income, particularly on poor soil sites. In 2007, a 7-hectacre replicated block agroforestry and silvopasture research and demonstration project was established at the Center for Environmental Farming Systems (CEFS) in Goldsboro, North Carolina, and in 2007. Researchers tracked the performance of these systems for 13 years to date [75]. The site was a lower-lying field in a bend in the Neuse River, which has flooded frequently and is not highly productive due to poor soils and flooding. A corn/soybean annual rotation was planted between rows of planted trees in the first six years. The crops performed very poorly due to either floods or droughts, but the trees prospered [75]. Since then, warm-season grasses were planted, and by the 10th year, beef cattle have been grazed between the tree rows in rotational grazing, and both the grasses and the trees have grown very well.

There are also some significant agroforestry implementation challenges. Landowners in the Southeastern U.S. are hesitant to consider agroforestry due to lack of information or misconceptions [76], and many natural resource professionals and registered foresters (to which farmers may turn to for information) are untrained or unfamiliar with agroforestry systems [77]. Agroforestry practices usually will reduce crop or grass yield due to competition for light and nutrients, or due to the selection of tree species usable by crop pests [78]. Some studies have also pointed out that the accumulation of agroforestry waste (i.e., pinecones, seeds, leaves) increases crop pest species populations, provides fuel for wildfires, and contributes to other issues such as eutrophication in water bodies if not properly managed [79].

5.5 Wetland Restoration

Wetland restoration refers to re-establishing a degraded or prior converted wetland to its original hydrologic and vegetative conditions. In our scoping efforts, we identified two types of wetland restoration practices that could be used to retain and store floodwaters. One is the excavation of wetland retention basins in or along waterways using berms and water control structures at the downstream end, and planting with grasses, sedges, and other hydrophytic vegetation. This would require considerable earthwork and berms of one meter or more tall in order to create wetland basins with enough storage volume to substaintially reduce stormflows. This was the most extensive and expensive flood mitigation practice identified. A second less intensive but still complex system would be hardwood forest wetland restoration on drained agricultural land, which would require reformation and grading to its original wetland contours, plugging any existing agricultural drainage ditches, and maintaining wetland hydrology with flashboard risers in the ditch outflows.

The time required to restore a wetland can vary; a wetland with marsh vegetation could take three to four years, while forests may take 30 or more years. However, restoring a wetland for flood storage purposes alone is typically quicker as these functions depend primarily on the topography [80]. In a study of the Charles River in Massachusetts (U.S.), the U.S. Army Corps of Engineers (USACE) calculated that the loss of all wetlands in the watershed would result in an additional $17 million of flood damage annually [81]. Many wetlands have been degraded by draining or dredging [82, 83]. At the time of European settlement in the early 1600s, the area that would become the conterminous United States had approximately 89 million ha of wetlands. About 42 million ha remained in the mid-1980s when wetland protection began [84]. North Carolina alone is estimated to have lost almost 2.2 million about 49% of its pre-European settlement total wetland area, mainly for agriculture [84]. A growing body of research demonstrates the importance of properly maintaining existing wetlands and restoring old wetlands with appropriate, sustainable methodologies [82, 85, 86, 87].

The effect of wetlands on flooding depends on multiple factors, including the wetland location in the landscape, the surrounding topography, and management decisions [88].

However, in general, it appears that floodplain wetlands help mitigate flooding. Wetlands in floodplain regions can delay floodwaters and reduce the flow of water downstream [20], resulting in a reduction in peak flood height. In addition, restoring wetlands with herbaceous vegetation provides coarseness, causing a decrease in stream velocity and sedimentation [89].

Wetland grasses and sedges have fast-growing and dense root matrices that help capture pollutants and as a vital habitat for wildlife. Wetlands also provide many other benefits to human and ecosystem livelihoods, including sustaining biodiversity, sequestering carbon, enhancing water quality, improving downstream aquatic habitat, recharging aquifers, and providing protection from storms [82, 90, 91, 92].

However, wetland restoration is challenging. First, it has not always been met with enthusiasm by landowners. By providing an area of the property for wetland restoration, a landowner is permanently unable to use the area for non-recreational purposes. Once established, removing or filling the wetland without a permit from USACE is unlawful [93]. If constructing a forested wetland, flood mitigation's full benefits may not be realized for decades. Restored wetlands may not perform as planned due to inadequate designs, unsuitable site selection, and lack of follow-up on maintenance [94]. To avoid some of these challenges, the North Carolina Wetlands Restoration Program (NCWRP) recommends working with landowners to develop a detailed assessment of the watershed and topography for wetland decision-making and implementation [95].

Restored mature floodplain forests can be effective as wetland restoration. Forested wetlands can soak up, transpire, and evaporate a large amount of water. Additionally, in a mature forest system, trees drive a large wood cycle process. Large logs from fallen trees can alter the channel process of a river, either by protecting certain areas from erosion and thus allowing trees to reach a greater size or by directing water in a bank to cause erosion which causes more trees to fall into the channel [97]. The increased mature forest-driven complexity of the floodplain surface has been shown to increase the lag time for peak floodwaters. The logjams provided by the forest may be effective at reducing peak flood heights [98].

Establishing a typical forested wetland bank on “prior converted” agriculture lands is common for wetland mitigation banking and development offsets. This requires only a modest amount of grading and restoring a current crop field back to a flat wetland site, with some drainage controls, flashboard risers for the ditches, and tree planting to restore the prior wetland functions and values.

In addition, many forests in the Carolinas and the South have already been converted from native hardwood or pine forests, ditched, and drained in the last 70 years, which amount to about 1.3 million hectares on wetland soil types [99]. These ditching and draining practices are no longer allowed without a USACE permit, and indeed establishing new areas of converted, intensively managed planted pine stands is unlikely. However, existing stands usually already have extensive ditches and water control structures to remove excess water during wet periods of the year and retain water to promote tree growth during dry periods.

Planted pine forests on converted wetlands could easily just have their water management practices modified without much new construction or costs. The owners could draw down the ditch levels and forest water tables before anticipated major flood events; then raise the existing flashboard risers before heavy rainfall begins; and then let water out more slowly. This approach would require new research to examine the absorption capacity of drained, planted forests and the amount of extended flooding that could occur without harming trees and industrial forest production.

5.6 Stream Restoration

Most natural streams follow a sinuous pattern. In nature, straight channels are rare [100]. A meandering bend in a stream increases resistance and decreases water velocity [101]. Over hundreds of years, streams have been modified by straightening the channels to move water downstream as quickly as possible and reduce local flooding. However, the compounded effect of many straightened stream channels in a watershed can increase flood risk in downstream locations.

Restoring stream channels to their natural meandering path can reduce the high-water velocity and reduce flooding downstream. One of the most used restoration approaches is natural-channel-design~~s~~ (NCD) [101, 102, 103]. The NCD restoration approach involves reshaping the unstable stream, installing in-stream structures, and reestablishing the hydraulic connection between the stream and its floodplain. NCD also calls for planting riparian vegetation, which can stabilize the stream bank, slow down runoff, and remove pollutants [101, 102, 103]. The establishment of sequenced riffles and pools maintains the channel's slope and stability. Water flows over the riffles at low flow, removing fine sediments, and providing oxygen to the stream [101].

Not only do NCD approaches slow down water velocity and distribute floodwaters across the floodplain, which can reduce the magnitude of downstream flooding, they have also proven to provide better water quality and wildlife habitats. For example, a study found that re-meandering stream channels and adding riparian vegetation were positively correlated to habitat quality indicators [104].

However, stream NCD practices reduce flooding only modestly and are expensive. A recent stream restoration project completed by the NC State University Department of Biological and Agricultural Engineering estimated approximately $738 per meter for practice establishment. A study by the North Carolina's Department of Environment and Natural Resources from 1997 to 2006 assessed costs of stream restoration projects across the state, finding that the practice cost on average $794 per meter [105]. Also, this practice can be very time-consuming [106]. Additionally, altering a stream channel will require extensive coordination with federal and state regulatory agencies to obtain the necessary permits.

5.7 Berms and Dry Dams

One other water attenuation practice that we identified was the use of low height berms of less than a meter—raised, compacted strips of soil or other materials that act as barriers to divert water—with water control structures or flashboard risers as well. We use the term "water farming" for its potential application to temporarily catch and store waters on farms as a new land use, and the prospects of receiving FloodWise conservation payments for doing so. Farmers have employed such small water storage sites, dams, outlets, and risers for centuries to build fields to cultivate crops such as rice paddies, or even almonds in California.

Berms are commonly used in terrace systems implemented across cropland to divert runoff to a stable channel and away from the erodible land downslope. Berms are often coupled with the use of dry dams [109]. Dry dams (also referred to as detention dams) temporarily retain water during high intensity and duration precipitation events, allowing the catchment area to drain slowly until dry [110]. Holding back runoff from many catchments can desynchronize the storm flow, resulting in less flooding downstream. Dry dam and berm systems have been shown to limit the transport of sediment downstream, which, if it enters a stream channel, can exacerbate flooding.

The ability of berms and dry dams to reduce flooding is mainly dependent on how much runoff is retained and when it is released. For example, the South Florida Water Management District (SFWMD) conducted a pilot program of water storage on agricultural land in the Saint Lucie Watershed in 2013. The pilot's goal was to store an average annual volume of approximately 11,300 acre-feet of surface water and catch 100 percent of rainfall on the site [109]. From February 2014 to March 2015, both goals were met [109]. Furthermore, this program was popular with agricultural landowners who were paid on a per-acre foot basis for storing the water.

Researchers and practitioners with the SFWMD have shown that these practices are cost-effective and require minimal time to implement compared to traditional engineering structures [110]. Water quality monitoring documented that nutrient loads (e.g., Nitrogen) and downstream discharge were reduced while the retained runoff provided a supplemental source for irrigation [109, 111]. These practices and successful outcomes were conducive to Florida's flat topography; we expect similar promising results for eastern North Carolina.

Regular maintenance of dry dams, such as removing sediments and debris, would be required approximately every 10 to 20 years and generally cost five percent of the original construction price [112]. Berms are most successful when other erosion-control techniques are utilized, such as cover cropping and no-till. Otherwise, berms can rapidly acquire too much soil to function correctly [113]. Some authors recommend combining this approach with other strategies to mitigate larger floods [114].

This approach of dry dams and berms is similar to centuries-old water management practices used for a few crops such as rice. These establish low-rise water management structures—ditches and risers—across an agriculture landscape. Water is stored for part of a growing season and released at other times. We did not examine this agricultural practice explicitly, but like water management on planted pine stands in the South, this practice could be managed in reverse as well. Water on fields could be released before anticipated major storm events, dammed and collected during the storm, and released more slowly afterward.

5.8 Land Drainage and Water Retention with Tiling and Terraces

Land drainage systems also could be used for water storage as well as water drainage. There are two types of simple land drainage controls: surface drainage and subsurface drainage. Surface drainage installations remove surplus water from the soil surface. In the past, systems such as tiling and subsurface drainage have been used to drain wetlands for agricultural production, which has increased runoff and flooding. This system has been widely applied and could be useful, but would have to be carefully reverse-engineered and used to slow down and store water, not accelerate surface and subsurface runoff. Land drainage systems are well known and understood by farmers and are one of the most inexpensive and most straightforward approaches to control excessive runoff without causing erosion [115].

Excess runoff water is diverted away from erodible sloping ground and into stable waterways via a combination of small berms and channels often referred to as terraces. One type of terrace that uses underground pipes or tiles as stable conveyances to carry the runoff off the land is tile-outlet terraces [116]. Tile-outlet terraces often are designed with upslope runoff storage areas that can retain runoff to help reduce peak runoff rates and downstream flooding [117].

For subsurface drainage, excess water is removed from the soil profile by plastic perforated pipes placed underground to drain the water [115]. Subsurface drainage has proved to reduce localized flooding by enhancing infiltration. It also allows the soil to dry quicker, which increases soil aeration, nutrients, and biological activity [115]. If the subsurface water is not drained, not only can crops become damaged, but soil can become highly compacted, causing loss of porosity. The overall impact of surface and subsurface drainage, correctly applied, creates healthier soil and increased crop production [118].

However, a downfall of subsurface drainage is that it could prevent groundwater from recharging aquifers because water is not allowed to percolate fully [115]. This may exacerbate flooding in downstream areas since more water is being discharged to surface waterways than otherwise would. It also can result in soil nutrient loss [119]. It is believed that these drainage systems can be improved using simple subsurface control structures. Unlike conventional free-draining systems that remove excess soil water to the drain depth, controlled drainage increases water retention and storage within the soil profile [119].

Figure 1.3 shows how water control structures can be used in conjunction with tile drainage systems to increase water storage within the soil profile by allowing water to “back up” in the soil to a preset depth before being allowed to overflow into the next tile drainage section [120]. Research conducted in the Midwest (which has extensive tile drain systems) has shown that the use of these simple drainage control structures not only results in a reduction of total drainage volume but can also lead to an increase in crop yields, particularly in drier years [119, 121]. These structures are currently being tested and researched on the Albemarle-Pamlico Peninsula in North Carolina and have been found to reduce nitrogen runoff and improve water quality [122].

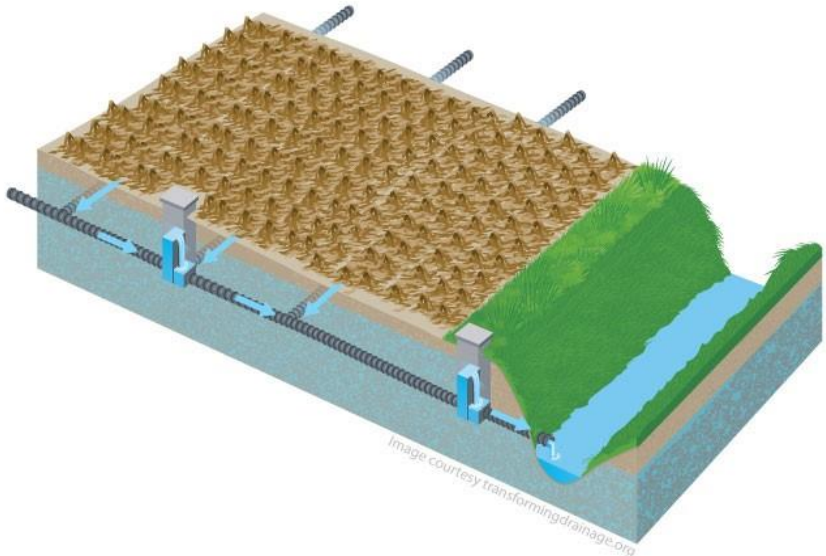

Figure 1.3 Controlled Tile Drainage [120]

A potential challenge with introducing these controls is that many free drainage systems were installed decades ago, and not all farmers have mapped them. As land has been subdivided and sold, there is also the issue that some of these systems cross current property boundaries. There have been instances of some farmers installing controls that have caused extensive flooding on their neighbors' lands. Also, these systems require continual maintenance over time by removing accumulated sediments and debris from the perforated pipes [123]. Otherwise, the pipes can become clogged and cause localized flooding on the farmland.

Many of these subsurface drain discharge into nearby ditches, which transport runoff to streams and rivers. Like the subsurface drainage features, ditch systems can reduce localized flooding while potentially increasing flooding risk downstream. Ditches can be modified with flashboard risers to temporarily slow the flow rate or back up water onto private or public property. However, care would have to be taken to avoid interference with the crops. These simple structures have been shown to reduce downstream flooding risk [124]. Flashboard risers serve both water drainage and irrigation purposes and restrict the flow of runoff and floodwaters [125]. Manale (2000) found in eight watersheds in Iowa that installing these simple water-storing controls lessened the risks of floods and increased societal welfare by reducing flood damages downstream [126].

Last, Manale [126] recommends implementing a program that requires landowners to utilize flashboard risers to plug the runoff during extensive rainfall. The researcher suggests compensating the landowners for storing water by *not* investing in an agricultural crop. Manale [126] also indicates that farmland situated in flood-prone areas undergo a contract, enabling compensation for storing water and receiving a bonus for what the landowners may have produced if they were to harvest a crop in that location. This is like the Dispersed Water Management Program of the South Florida Water Management District in theory but using a different tool. Storing water in flood-prone regions by using controls such as flashboard risers could reduce the amount of crop insurance and damage assistance elsewhere.

In summary, flood reduction from free draining underground tile and surface ditch drainage systems requires managing the structures for runoff control. The landowners need to be on board to install these features, but they will also need to know how to operate them. Alternatively, if not managed and maintained properly, flooding could increase downstream. This characteristic is the same for any of the structural practices of dry dams and berms, drained forest wetland management, or tiling.

6. Discussion

6.1 Implications for North Carolina Coastal Plain

A summary of the merits of the ten selected natural infrastructure practices examined in detail is shown in Table 1.3. These practices differ in their potential for flood reduction, the time required to establish them, their complexity, cost, compatibility with farm production practices, and co-benefits for water quality. In practice, there is not one specific solution that is best. Practice suitability will depend on their costs, the shape and form of the site and surrounding landscape microclimates and future flood events, farm or forest landowner preferences for adoption, government education and incentives, and government policies that promote or constrain land management and green infrastructure practices.

Table 1.3. Overview and Comparison of Ten Preferred Natural Infrastructure Practices

Practices	Potential for flood reduction	Time required	Complexity	Cost	Compatibility with other practices	Co-benefits
+ (minimal) + + (moderate) + + + (substantial)						
Agricultural						
Cover crops and no-till	+	+ +	+	+ +	+ + +	+ + +
Hardpan breakup	+	+	+	+	+ + +	+
Forestry – pine/hardwood	++	+	+	+	+	++
Agroforestry	+	+	+	+ +	+ + +	+ + +
Wetland and Stream						

Table 1.3 (continued)

Wetland restoration	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Forest wetland bank	++	++	++	++	+	++
Restore natural stream channels	+ +	+ + +	+ + +	+ + +	+ + +	+ + +
Structural						
Dry dams and berms	+ + +	+++	+++	+++	+ +	+ +
Simple drainage features	++	++	+ +	+ +	+ +	+ +

Structural practices include cover crops, hardpan breakup, afforestation, and agroforestry; these practices improve runoff reduction, groundwater recharge, and soil permeability. Recent studies in Northwest Europe on the effects of no-till farming and related practices have shown that when used individually and collectively, they hold vast potential for significantly reducing soil erosion from farmlands and enhancing soil porosity [127]. Cover cropping and no-till farming directly impact the structure of the soil and its ability to absorb water. Although it is difficult to determine the scale of benefits in these complex systems, understanding the biophysical functions involved in these practices can highlight their potential co-benefits; through agroforestry, the biophysical properties of tree roots improve the water uptake rate, the capacity for groundwater recharge, and evapotranspiration [128]. When implemented and managed properly, strategic combinations of afforestation, agroforestry, no-till farming, cover cropping, and hardpan breakup can provide water quality and runoff reduction benefits through improvements to soil structure. However, long-duration and intense rainfall (i.e., hurricanes) can often overwhelm these practices rendering them insufficient for preventing damage from major storms.

Wetland and stream practices include wetland restoration, flood-tolerant forest and grass species, large wetland retention basins, and natural stream channel restoration. These practices restore natural features of the landscape that facilitate ecological processes which store and filter water and can use natural meandering streams or structures such as berms, spillways, and flashboard risers to impound, store, and release floodwaters. Riverine floodplain wetlands serve as essential ecosystems that contribute to water purification, sediment and nutrient retention, pollutant reduction, and act as natural buffering systems [129]. The ecosystem services provided by wetlands and streams can offer several co-benefits beyond flood reduction, including less erosion, less pollution by farm pesticides and herbicides, less water-borne animal or human waste, better fish and shellfish habitat, and improved drinking water. Understanding the role of ecohydrology in stream and wetland management practices, which focuses on the ecological processes that occur within the water cycle, is crucial for maximizing co-benefits of these practices; adopting an ecohydrological framework in wetland and stream restoration can help reduce transportation of sediments and pollutants by flood waters [130]. The use of this framework in best management practices guides the amplification of water quality benefits.

Structural practices involve the installation of simple land drainage control systems, dry dams, and berms. Combining these structures slows down and temporarily stores floodwaters, which will reduce runoff and pollutants. These natural structures work by changing the rate of the hydrological cycle through improving soil infiltration, increasing water storage, restricting overland flow, reducing runoff, and enhancing natural hydrological processes such as evapotranspiration; the purpose of these structures is to increase water storage and retain flood waters which can provide multiple benefits to downstream communities [3]. Temporarily slowing down flood waters through structural practices such as drainage control system can considerably reduce devastating impacts caused by floods. By promoting infiltration and creating water storage, surface flood volumes and downstream flood risk are reduced [131]. Incorporating these structures and increasing the water storage potential in agricultural landscapes can help reduce runoff, protect crop yields, and reduce soil loss. Such structural flood management practices can provide multiple benefits to both agricultural landowners and downstream communities.

North Carolina already has some of the NBS practices that occur either naturally or through purposeful policy interventions. Several of these ten systems in North Carolina have data on their application to date; others are essentially new. As noted, 11% of the farmland in North Carolina used cover crops in 2017, and 59% used no-till (43%) or reduced tillage (16%) methods [52]. The extent of hardpan breakup and tiling on farmlands is not available but also is likely quite substantial. Forests comprise about 60% of the total land area in the state [132], but there are only a few purposefully managed agroforestry or silvopasture sites in the state. The proposed wetlands and water retention basins and water farming practices have not been used in the state to date. There are a large number of forest wetland banks and stream restoration sites that are used to offset losses for development. From 2008 to 2015, there was a reported 5,769 hectares of private and Division of Mitigation Service (DMS) wetland banks and 383,603 meters of stream restoration in North Carolina [133]. The key to improving the impact of NBS is to increase the total area, effectiveness, and water attenuation abilities of existing or proposed practices across broad landscapes. And indeed, the purpose of various state and federal NBS FloodWise-type programs would be to make incentive payments to increase their application to reduce expensive storm and flood damages.

Based on our extensive literature review of NBS studies and review of literature on specific practices, NBS tactics are a promising solution to mitigate harmful impacts from future natural disasters compared to traditional or complex infrastructure. Furthermore, in exceptionally flat regions such as the U.S. Southern Coastal Plain, grey infrastructure would have exorbitant costs to build long dams and levees on dozens of rivers and streams; flood vast areas of land; and destroy countless ecosystems. In brief, smaller-scale nature-based solutions widely dispersed across the landscape are a more reasonable solution to reducing existing or increasing floods from moderate to major rain events.

Each natural infrastructure practice examined here can reduce flood damages on agricultural and forest lands and in downstream communities. The degree of flood reduction, the costs of the practices, and the costs per unit of water stored need further investigation. No one practice can reduce flooding entirely on its own, and it will require widespread, landscape-scale application of different practices tailored to unique site conditions to slowly reduce flooding and protect farms and communities.

6.2 NBS Research and Practice in Other Locations

States such as Florida, Minnesota, and Iowa have already started moving away from conventional engineered systems and have begun to implement natural infrastructure practices to reduce floodwater on agricultural landscapes. These states have seen a significant reduction in water volume from storm runoff, greater water storage capacities, and improved water quality that flows from agricultural fields [34, 109].

We have identified and discussed vital practices here to capture and store rainfall in North Carolina to reduce on-farm and downstream flooding. The practices we identified and reviewed here would be broadly applicable throughout most of the Coastal Plain in the U.S. South. This concept of storing floodwaters using natural infrastructure systems is gaining interest throughout the U.S.A. Florida has had water management districts that manage water draining, withdrawals, and floods for decades. Iowa has recently started new natural infrastructure projects to reduce local and regional riverine flooding. Major new efforts have begun to use natural approaches to restore the Mississippi River Basin's capacity for more natural and less destructive flooding [134]. These ’rinciples could extend to other regions of the U.S or the world as well and indeed have begun to be applied in diverse locations.

The research and literature on the overall effectiveness of natural infrastructure solutions for flood management are quite new. However, a few articles from various places in the world support the merits of this approach. First, in a critical review on the emerging subject of NBS to flood disaster mitigation in Europe, Schanze [16] noted that little was known about the effectiveness of NBS approaches, but concluded that for flood risk management, the relatively new concept seems to be worthwhile for further consideration in both science and practice. Our FloodWise project certainly fits within this charter.

In a recent empirical field and modeling effort in England, Nicholson et al. [9] examined the introduction of catchment-wide water storage through the implementation of runoff attenuation features (RAFs). In particular, the use of offline storage areas, as a means of mitigating peak flow magnitudes in flood-causing events demonstrated local reductions in peak flow for low magnitude storm events. The authors found that peak flow could be reduced by more than 30% at downstream receptors of a high magnitude storm event [9].

Previously, Metcalfe [135] modeled another site in England to evaluate the impacts of hillslope and in-channel natural flood management interventions. This approach combined an existing semi-distributed hydrological model with a new, spatially-explicit, hydraulic channel network routing model. Based on an evaluation of the response to the addition of up to 59 features, there was a reduction of around 11% in peak discharge [133]. This could help reduce flooding from moderate but not major events. Some strategies using catchment features could increase flood attenuation by applying a nature-based approach.

Using another acronym for the approaches we examined, Collentine and Futter [3] assessed natural water retention measures (NWRM) as a multifunctional form of green infrastructure that can play an important role in catchment-scale flood risk management. However, the merits of NWRM are not yet well understood. They note that at a catchment scale, NWRM in upstream areas based on the concept of 'keeping the rain where it falls' can help reduce the risk of downstream flooding by enhancing or restoring natural hydrological processes, including interception evapotranspiration, infiltration, and ponding. However, they aptly note that "Implementing NWRM can involve trade-offs, especially in agricultural areas. Measures based on drainage management and short rotation forestry may help 'keep the rain where it falls' but can result in foregone farm income. To identify situations where the implementation of NWRM may be warranted, an improved understanding of the likely reductions in downstream urban flood risk, the required institutional structures for risk management and transfer, and mutually acceptable farm compensation schemes are all needed."

6.3 Future Research

Our extensive identification of potential Nature-Based Solutions (NBS) for flood mitigation and control is just one effort of a new area of research and practice in an important and rapidly developing subject. Large amounts of new research, literature, and outreach to landowners and professionals, by many biological and social scientists, will be needed for the application of NBS to expand successfully. This analysis and review identified most of the key practices that could be used in the North Carolina and U.S. South Coastal Plain, and probably elsewhere. The quantitative amount of water our identified practices could store, their costs for establishment and maintenance; their complexity; their compatibility with other farm practices; and their potential co-benefits all could be quantified in future research. With this detailed information, we also could use methods such as a multiple criteria decision-making (MCDM) approach to rank the relative desirability of each practice.

Policy makers also need to understand the landowner's perceptions of the NBS practices for future implementation. More extensive research is required to fully implement these practices, such as interviews with landowners, pilot test sites, and educational outreach with key stakeholders about adopting such practices on a larger scale. Our future work will look at North Carolina landowner's attitudes and perceptions of adopting these NBS practices on their properties. Our goal is to understand the factors that influence their willingness to participate in a comprehensive FloodWise program. We recommend that an integrated FloodWise program consisting of science, natural engineering and nature-based solutions, community governance, and government payments be implemented to advance these solutions in North Carolina, and indeed much more broadly.

7. Conclusion

We performed a detailed analysis of the existing and potential application of Nature-Based Solutions (NBS) in the Coastal Plain of North Carolina, which should be broadly applicable to the Coastal Plain in the southern U.S., as well as other similar topographic regions in the world. We identified ten likely best practices that could be used, including agricultural, wetland and stream, and structural applications. These vary by their level of current use and their scale of intervention: their degree of naturalness in farm, forest, and wildlands management to structural modifications; their effectiveness, water storage capacity, and costs; their co-benefits and ecological connectivity such as biodiversity, water quality, carbon storage; and their social acceptance.

Turkelboom et al. [25] in Belgium aptly concluded that successful applications of NBS would increase if there is sufficient space to retain flood water, NBS practices are socially accepted, and when economic activity and housing in the flood plain are limited. These conditions can be met in some, but certainly not all, locations in the North Carolina and Southern Coastal Plain. Drawing from Collentine & Futter [3], guidance for practitioners and landowners and payments to provide incentives for adoption of natural water retention measures can help prevent residents' displacement, reduce crop losses, and decrease economic damages to inf’astructure for both rural farm and forest landowners and downstream communities.

This review can be used as a guide of recommended practices that landowners can adopt to mitigate floodwaters on their properties. This research focused on the Coastal Plain in North Carolina, but the findings should be broadly applicable to about 75 million ha in the U.S. South, and the review is useful for assessing the merits of nature-based flood mitigation systems and associated payments for farms and forest owners throughout a much broader area. Further research could determine more about the specific volumes of floodwaters stored by the different practices; the economic and ecological implications for farms and downstream communities, by reducing flooding; the costs of installation and maintenance for these practices; on the interest of farm and forest landowners to adopt such practices; and the conservation payments or incentives that may be required to rural landowners to install such water farming practices and diversify their production of ecosystem services as well as farm and forest commodities. Many researchers and practitioners have a keen interest in natural-based solutions and landowner flood mitigation programs, and this field will continue to expand substantially in the future. This review can provide a thorough summary of these prospects in North Carolina and the U.S. South, as well as for other parts of the world.

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CHAPTER 2: DETERMINING THE COSTS, REVENUES, AND COST-SHARE PAYMENTS FOR THE "FLOODWISE" PROGRAM: NATURE-BASED SOLUTIONS TO MITIGATE FLOODING IN EASTERN, RURAL NORTH CAROLINA[2]

Abstract

FloodWise is a pilot project that proposes innovative new approaches for flood disaster resilience by applying nature-based solutions (NBS) in Eastern North Carolina to control water runoff for brief periods after major storm events. We collected production and cost data from primary or secondary sources and used discounted cash flow and capital budgeting procedures at a 6% discount rate for NBS practices to estimate the amounts of payments necessary for farmland owners to break even to adopt NBS practices. Conventional crop farming was profitable already on suitable lands and served as the business as usual (BAU) case to compare to selected NBS practices. Warm-season pasture, loblolly pine forests and agroforestry, and no-till farming exceeded the 6% hurdle rate. Other conventional farm practices of hardpan breakup, cool-season pastures and trees, and bottomland hardwoods would require total payments of up to $600/acre to break even at 6%. Modifications of existing conservation practices, such as stream buffers, cover crops, silvopasture, and tile outlet terraces and tiling, fell in the second tier of total costs of up to $1,512/acre. Major NBS projects that required substantial earthmoving and flood control structures were more expensive - $3,734/acre for water farming (i.e., retention) with berms, $13,252/acre for a forest wetland bank, and about $88,000/acre for a major flood control

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wetland - and would displace most of the existing area for farm and forest management. However, larger floodwater structure projects could store more water for more extended periods; these storage quantities and benefits need to be assessed in future research.

1. Introduction

Increased global temperatures and extensive climate changes have caused extreme and atypical weather events across the globe. While modeling the future impacts of climate change is complex, the climate models emphasize its large-scale extent [1]. Climate change is likely to increase the severity and frequency of climate patterns such as heatwaves, heavy precipitation, flooding, and droughts [2, 3]. Earth's temperatures are rising due to the increase of carbon dioxide and oth’r greenhouse gas concentrations in the atmosphere, which has been largely accelerated by human activities [2]. Atmospheric and oceanic changes are intensifying the hydrologic cycle, and such changes will result in higher precipitation rates and cause more intense tropical storms [2].

Nature-based solutions (NBS), also referred to as natural infrastructure, such as planting forests, restoring forest and herbaceous wetlands, expanding floodplains, leaving crops on the field through the year, breaking up hardpan soil layers, and restoring streams to their original configuration, can slow water flow through fields and downstream, as well as store water temporarily. Recent research indicates that water flow could be reduced by more than 30% downstream if NBS are employed [4].

The objective for our research reported here focused on estimating the installation and maintenance costs of many important NBS practices for rural landscapes in Eastern North

Carolina. The most likely NBS practices and farming or construction production methods are summarized. Data on input installation and maintenance costs were collected and economic engineering approaches using discounted cash flow analyses and capital budgeting were used to assess the amount and duration of payments needed for landowners as an incentive to incorporate these practices on their properties. The approach is similar to conservation payments for farm programs.

Although there has been some research exploring the merits of adopting natural infrastructure practices for flood risk reduction (e.g., [4, 5, 6]), very few studies have analyzed the economic costs or potential benefits of installing NBS practices. To our knowledge, the South Florida Water Management District (SFWMD) is the only organization in the U.S.A. to have monitored the costs and benefits of natural infrastructure on farmlands. SFWMD's water farming pilot project evaluated floodwater storage capacity on ’arms and conducted a basic calculation of practice implementation costs [7]. However, SFWMD only assessed the economics of two NBS— dry dams and berms designed to contain floodwaters. Our research analyzes the finances of dry dams and berms and nine other natural infrastructure practices that could be applied in North Carolina's rural landscape.

2. Site Context: Eastern North Carolina

In North Carol’na, especially in the coastal plain region due to its flat topography, flooding is the most frequent and devastating hazard that has caused damages to farmers' crops, displacement of residents, contamination of local water supplie’, disruption of natural ecosystems, and deterioration of infrastructure [5, 8, 9]. Hurricane Matthew in 2016 and Hurricane Florence in 2018 hit the same urban and agricultural communities in eastern North

Carolina, claiming 85 human lives and causing losses of $17.6 billion in the state [10]. From Hurricane Florence alone, North Carolina experienced approximately $1 billion in agricultural losses of tobacco, corn, soybeans, cotton, chickens, turkeys, and hogs [10]. In addition, the areas hit the hardest most commonly consist of low-income, traditionally marginalized, and agricultural communities. The state experienced prolonged flooding and completely inundated farmland long after the hurricanes passed.

In the past, floods have been managed using human-engineered systems made from concrete, such as levees and dams [6, 11]. However, recent literature has acknowledged the harmful impacts of such engineered structures, mainly on wildlife and ecological systems [5, 12, 13]. Many dams in the United States fail, pose financial and legal threats to their owners, and create safety hazards to local communities and many aquatic species [14]. North Carolina ranks second in the U.S. for the most defective dams [15].

Eastern North Carolina's coastal plain is a prime area to consider how natural infrastructure ’ould produce landscape flood resilience. This region is prone to riverine flooding due to its flat topography, slow drainage capability, and slow-moving rivers. Flooding has been exacerbated by land-use changes, including altering or destroying natural systems within the watersheds of major rivers [16].

We have created a pilot program, "FloodWise," to investigate NBS approaches for flood mitigation, water q“ality, and”potential landowner benefits. The fully-implemented program focuses on engaging and collaborating with local landowners and community members, and include financial incentives to encourage landowners to adopt the tactics on their properties.

As part of FloodWise, we conducted an extensive review of various NBS for reducing flooding downstream (i.e., [17]). The study identified ten most effective practices for flood resilience for rural eastern North Carolina (Table 2.1). The practices included agricultural practices of (1) cover cropping/no-till farming, (2) hardpan breakup, (3) pine or (4) hardwood afforestation, and (5) agroforestry; wetland and stream practices of (6) grass and sedge wetlands and earthen flood control structures in water retention basins, (7) forest wetland banks, and (8) stream channel restoration; and structural solutions of (9) water farming with dry dams and berms and (10) land drainage and water retention with tiling. These types of practices would be transferable to similar rural landscapes other than North Carolina that experience flooding [17].

Table 2.1: Preferred flood mitigation practices for rural, eastern North Carolina

Categories	Best Practices and Descriptions
Agricultural	
Cover Crops and No-Till	(1) Including legume and non-legume cover crops on fields during winter
Hardpan Breakup	(2) Breaking up compacted hardpan layers to allow for soil water infiltration
Afforestation	Planting (3) bottomland hardwood or (4) pine forest species
Agroforestry	(5) Combining mixed pine trees and pasture fields
Wetland and Stream	
Wetland Restoration	Restoring natural wetlands along streams or at a lower elevation with (6) flood control wetlands with grasses, sedges, and water control structures, or (7) bottomland hardwood forested wetland banks on prior converted agriculture land
Stream Restoration	(8) Restoring previously straightened streams to the original configuration
Structural	
Water Farming	(9) Creating catchment areas using dry dams and berms to store water during flooding
Land Drainage Features	(10) Installing berms and other flow controls to ditches, terraces, and drain tile systems.

3. Methods

Our research objectives were to: (1) provide detailed NBS practice summaries (production functions); (2) obtain information to estimate the costs of their establishment and maintenance; and (3) estimate the subsidy or incentive payments, if any, that would be required to attract farmland owners to install such practices on their lands. In brief, we performed these analyses by examining the installation of prospective NBS practices on existing farmland, by comparing how much it would cost to implement a NBS practice and determining the amount of the discounted cash flow payments required by landowners to maintain the practice at a given discount rate. This involved identifying, delineating, and estimating costs for a range of conventional farm and forest practices and for NBS practices that would complement those conventional practices, or perhaps supplant them, depending on the amount of land construction and water impoundment required and the duration of any floodwater storage periods. Table 2.2 summarizes the conventional farm and forest practices and the NBS scenarios analyzed to estimate costs.

Table 2.2: Selected FloodWise Scenarios Analyzed

Traditional Farm, Forestry, and NBS Scenarios Examined
Cover Crop and No-Till
Scenario A: Soybean/Winter Wheat & No-Till
Scenario B: Corn/Cool-Season Pasture & No-Till
Hardpan Breakup
Scenario A: Hardpan Breakup
Scenario A1: Scenario A + Payments
Afforestation
Scenario A: Bottomland Hardwood
Scenario A1: Scenario A + Payments
Scenario B: Loblolly Pine
Scenario B1: Scenario B + Payments

Table 2.2 (continued)

Agroforestry
Scenario A: Pine Forest Only
Scenario B: Pine Forest Only, 20% Trees
Scenario C: Cool-Season Pasture Only
Scenario D: Warm-Season Pasture Only
Scenario E: 70% Cool-Season Pasture and 20% Trees
Scenario F: 70% Warm-Season Pasture & 20% Trees
Scenario E1: Scenario E + Payments
Scenario F1: Scenario F + Payments
Wetland Restoration
Scenario A: Flood Control Wetland with Grasses & Sedges
Scenario A1: Scenario A + Payments
Scenario B: Forested Bank on Prior Converted Farmland
Scenario B1: Scenario B + Payments
Stream Restoration
Scenario A: Stream Restoration
Scenario A1: Scenario A + Payments
Water Farming
Scenario A: Dry Dams and Berms
Scenario A1: Scenario A + Payments
Land Drainage Features
Scenario A: Tiling & Tile-Outlet Terraces
Scenario A1: Scenario A + Payments

*Payments: Both Conservation/North Carolina Agricultural Cost Share Program establishment payments (Year 0 only) and FloodWise annual payment (the breakeven point at 6%) for ten years

For each of the conventional farming and ten preferred flood mitigation practices identified in Table 2, we estimated the costs to establish the practice, the costs to maintain it, and any product returns for a 20-to-60-year period (depending on the practice). The same estimates were also made for the baseline "business as usual" (BAU) scenarios of agriculture crops and forest timber production. These methods draw from finance, engineering, agriculture budgeting, and forest economics literature and methods (e.g., [18, 19, 20, 21]). The steps entailed are outlined in Figure 2.1.

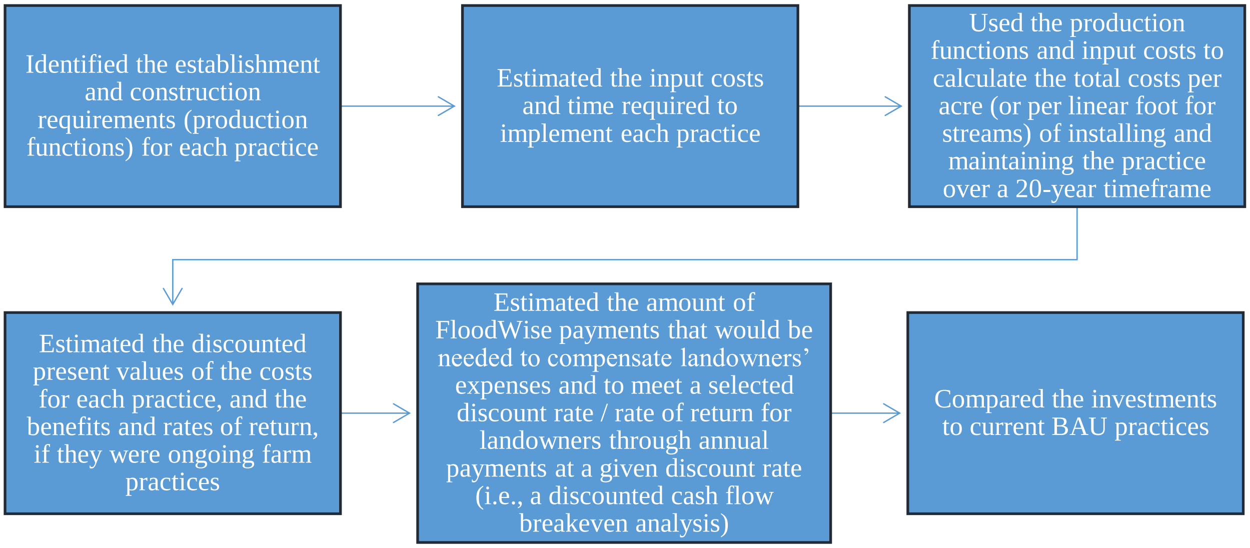

Figure 2.1: Methodological Steps

3.1 Capital Budgeting Analysis

We performed capital budgeting analyses by adapting Microsoft Excel spreadsheet templates developed by Cubbage [19, 20, 22, 23]. The spreadsheets displayed the costs, returns, net annual returns, the years in which the activities occur, and any annual costs or returns for each year. First, we conducted discounted cash flows for each NBS. Next, we identified traditional farm practices for comparison to the NBS, and determined the amount of FloodWise payments necessary for farmers to adopt the practices. Next, we identified all the primary traditional farm practices - pasture, corn, soybeans, winter wheat, and timber - which provided the–BAU base without NBS or FloodWise payments. Then, w– developed representative scenarios (shown in Table 2) to compare to traditional farm practices and NBS practices overlays.

We identified costs from the published literature for the range of possible NBS practices. Production function data were collected for each scenario between January 2020 and August 2020, which was approved as exempt under the North Carolina State University IRB administrative review (#20777). We performed interviews with agricultural and environmental consulting firms, extension professionals, farm and environmental agency representatives, farmers, and equipment operators to refine our list of possible practices and to identify every activity associated with each NBS. Then, we acquired the costs of all activities in the interviews with contractors, professionals, farmers, farm and construction supply vendors, and other experts in the field and local environmental conservation groups and government agencies such as the North Carolina Division of Mitigation Services (DMS) and published literature.

Based on the production functions, timing of activities, input costs, and any crop or timber sale income, we conducted capital budgeting to evaluate various projects and assessed the financial returns from a capital investment over its lifetime. Capital budgeting uses discounted cash flows instead of other accounting financial analyses focusing on annual profits [18, 21, 24]. Discount rates are used to calculate the present value of future income, capturing the opportunity cost of the investment funds [19, 20].

A discount rate of 6% real (not including inflation) was used to calculate how much future income earned will be worth in the present day. The best discount rate for farm and forest owners is uncertain, but 6% was chosen as reasonable based on other farm income opportunities and two supporting references. For example, business organizations state that they would like to achieve a 10% to 12% return on capital. Certificates of Deposit from banks currently earn only about 0.2% to 0.3% annual interest; government bonds are as low as 1% to 2% per year, and corporate bonds make about 3% to 6% per year. Stocks might average 8% per year in nominal returns, which would be closer to 6% real after deducting 2% for inflation.

Two references support this intuitive selection. First, Damodaran [25] tallies stocks and bond returns annually. From 2001 to 2019, average total stock returns for the S&P 500 were 7.20% per year; inflation was roughly 2% per year, so the net stock return was 5.2%. Returns have increased since then, so 6% real is a reasonable floor for a discount rate. 10-year T-bills had an average annual rate of returns of 1.97% during that time period (about 0% in real terms). Second, the World Bank [26] recommended 6% real as a social discount rate with a 3% per capita growth rate, with a range from 2% to 12%. So, 6% was considered a moderate real return rate (not including inflation) appropriate for this analysis. We used that rate as a base for all our analyses, but the spreadsheet templates allow users to modify the discount rate.

Capital budgeting measures such as Net Present Value (NPV), Land Expectation Value (LEV), Annual Equivalent Income (AEI), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR) allowed us to compare the conservation practices. NPV calculates annual revenue into a single number that can be used to compare various investments at a given discount rate [19, 20]. A positive NPV occurs when the amount of present value cash inflows exceeds the present value of cash outflows. If the discounted present value of the cash outflow is greater than the discounted present value of the cash inflow, then the NPV will be negative [24]. Capital budgeting criteria would indicate that we would accept an investment that yields a positive NPV. When comparing various projects, we would select the project with the highest positive NPV [19]. We utilized Equation 1 to calculate the NPV [27].

Equation 1:

$$NPV = \sum_{i=0}^{t} = \frac{(B - C)}{(1 + i)^t}$$

where: *B* represents annual total benefits
C equals annual total costs
i is the discount rate
t is the year of the cash flow schedule

An LEV estimates the present value of an infinite time of similar projects by utilizing costs, income, and a discount rate to measure a land-use's expected cash flow in perpetuity [23, 28]. LEVs are often used in for’stry or other projects to compare projects of unequal length (e.g., 10, 15, and 25 years) to convert them all into the same (infinite) length. Like NPV, we would accept a positive LEV project and reject the investment with a negative LEV. When comparing projects, the LEV with the greatest positive value is preferred [23]. Calculating the LEV is shown in Equation 2 [23].

Equation 2:

$$LEV = NPV + \frac{NPV}{(1 + i)^{T-1}}$$

where: *NPV* represents the net present value
i is the discount rate
T is the final year of the cash flow

Another method for analyzing capital investments is AEI. The AEI conveys NPV or LEV in annual payments distributed equally over the lifespan of the capital investment. AEI allows us to compare the long-term investments with seasonal returns from agriculture crops by representing each individual's annual payments income [20, 28]. The AEI shown in Equation 3 is equal’to the land expectation value times the discount rate [23].

Equation 3:

$$AEI = LEV * i$$

where: *LEV* represents the land expectation value
i is the discount rate

Last, another key capital budgeting measure is the IRR—the discount rate or annual internal rate of return that makes the NPV equal to zero [24]. In our farm crop and NBS practices analyses, we could not calculate an IRR because on average the annual benefits from crop farming always exceeded the costs, so there is no rate of return, just profits every year. In reality, crop returns are extremely variable, especially on poor or marginal crop lands, but that variability was not analyzed. The forestry practices did require an initial investment in Year 0 and then received payments later to calculate their IRR. We took the sum of the net annual cash flows over a 60-year timeframe to calculate the IRR, using Equation 4 [20].

Equation 4:

$$IRR = i \text{ such that} \sum_{i=0}^{t} \frac{(B)}{(1+i)^t} = \sum_{i=0}^{t} \frac{(C)}{(1+i)^t}$$

where: *B* represents annual total benefits
C equals annual total costs
i is the discount rate
t is the year of the cash flow schedule

3.2 Breakeven Analysis

Once we estimated all costs, we assessed how much payments would be required for landowners to break even at a given discount rate. This included FloodWise payments to establish the practice in full at a 100% rate and the number of annual payments for 20 years that would make the fully reimburse the maintenance costs of the practice. This analysis approximated the same process used to make farm conservation cost-share payments, such as the USDA Environmental Quality Incentives Program (EQIP). The presumption here is that we would need to pay farmers in full to get them to adopt the NBS practices.

4. Results

4.2 Costs

Based on 2020 data, we assumed the following inputs as relevant for each practice: (a) construction costs (one-time startup costs), (b) establishment costs (one-time startup costs), (c) annual management costs, and (d) periodic maintenance costs. Sources for practice materials and costs are shown in Table 2.3.

Table 2.3: Sources for Materials, Costs, and Revenues for each NBS

Practices – Materials, Costs, and Revenues	Input Data Sources*
Cover Crops and No-Till	[29, 30, 31, 32, 33]
Hardpan Breakup	[33, 34, 35, 36]
Afforestation	[23, 37, 38, 39, 40, 41, 42]
Agroforestry	[28, 39, 40, 41, 43, 44, 45]
Wetland Restoration	[37, 40, 41, 43, 46]
Stream Restoration	[31, 46, 47]
Water Farming	[7, 31, 48]
Land Drainage Features	[49, 50, 51, 52]

*Sources not listed are specific local farmers, consultants, and other experts in the field and their organization or company for reasons of confidentiality

4.2.1 Cover Crops and No-Till

Traditional crops of corn, bean, and pasture were calculated as the BAU without the NBS. We assumed two typical annual cover crop scenarios: winter wheat and soybeans, and corn and cool-season pasture/hay (Appendix C). We obtained the establishment costs, such as seeding, fertilizers, machinery, and labor costs of each crop, from various online sources and current refereed literature. These are provided in different years and formats as crop budgets from NC State University and other state Cooperative Extension Service online publications.

4.2.2 Hardpan Breakup

Breaking up hardpan layers in the soil was the least costly practice analyzed (Appendix D). After talking with local farmers, we estimated approximately $153.06/acre for establishing the practice. Machinery ($80.80/acre), labor ($22.26/acre), planning ($50/acre) such as estimating where hardpan layers exist were the only establishment costs necessary. In addition, we assumed periodic maintenance every five years to break up hardpan layers. These layers are formed when soil becomes denser from frequent farm equipment traffic and, therefore, prohibits water infiltration.

4.2.3 Afforestation

Forest establishment and maintenance costs were estimated based on typical rotations, yields, and costs drawn from prior analyses by Cubbage [23] for pines and hardwoods, Siry [37] for pines, and Siry [38] for hardwoods (Appendix E). These included average growth rates of 5 tons per acre per year, a 25-year rotation length for loblolly pine, and 2.1 tons per acre per year for a 60-year rotation for bottomland hardwoods. In addition, costs for establishment and seedlings were estimated for the Coastal Plain as reported by the North Carolina Forest Service [40, 41]. The timber prices from Timber Mart-South were obtained from reports by the North Carolina Cooperative Extension Service [43].

4.2.4 Agroforestry

The forest stand approach for silvopature as a model system was taken directly from Cubbage [23] for loblolly pine. We set up one spreadsheet tab for loblolly pine management regime for 25 years with full stocking; one tab with trees as only 20% stocking might be common in a silvopasture system; one tab with cool-season pasture; and one tab with warm-season pasture. The pasture serves as a proxy for the cattle in such a system and avoids the need to calculate a host of different cattle-raising options. Once we had the 20% pine stocking costs and returns by year, we added pasture stocking on the site's remaining 80% or so. This could be varied by users to reflect tradeof’s due to shade; we assumed a 70% net pasture cover. We did this for both cool and warm-season pasture. This mix of 20% trees and 70% grass cover for 25 years was used to estimate the silvopasture BAU (Appendix F).

4.2.5 Wetland Restoration

The construction for the flood control wetland scenario included large amounts of earthworks and flood control structures and the establishment of grasses and sedges as the primary vegetation. We estimated construction practices in Year 0 of $87,454/acre (Appendix G). Most of the establishment costs were for earth moving and hauling at $73,384/acre. Periodic maintenance costs were not included in DMS's project bids or data provided by local environmental groups and other consultants. This was the most expensive out of all the other practices.

The costs for a bottomland hardwood wetland to be established on prior converted agriculture cropland were estimated based on data from two publications [53, 54] and the forest planting costs from the previous bottomland hardwood case. Since this was a wetland bank, no timber harvest was included in the analysis, but the banking instrument specifically allowed for those could be possible. We had the costs for setting up an official wetland bank instrument as a potential opportunity. Since the wetland was to be used for water storage and retention, it might not be required to meet the designated criteria for an official wetland bank. Therefore, we did not include the costs for registration or the copayments for wetlands bank credits. However, this could be substantial as well. Appendix E shows the input costs per acre for this prior converted cropland, forested wetland bank.

4.2.6 Stream Restoration

The construction and establishment costs for a stream restoration were all calculated by linear foot. Stream restoration is the only practice with costs associated per linear foot; all remaining practices are considered per acre or hectare.

Overall, we estimated construction practices (i.e., clearing and grubbing; grading; planting and seeding; invasive species control; rock, log, and brush structures; erosion control; pumping and diversion; staging and creating haul roads; miscellaneous infrastructure; and wetland BMP) at a subtotal of $119.55/ln ft in Year 0. We estimated $166/ln ft for annual post-operation management and monitoring for seven years (Appendix H). These values were obtained from a professional ecologist and faculty member in the Department of Forestry and Environmental Resources at NC State University.

4.2.7 Water Farming

We utilized data from SFWMD's water farming pilot project for our establishment and annual management costs. SFWMD's project uses three pilot sites, which we assumed the average cost amo’g the three plots per acre. Farming project costs depend upon the volume of earth fill, haul, and berm size. We assumed approximately $3,242/acre of construction costs, which included labor, taxes, overhead, and other general administration. We also accounted for periodic maintenance for ditches and various sediment and debris removal at $200/acre every five years, as well as annual management costs of $20/acre for property taxes, overhead, and labor (Appendix I).

4.2.8 Land Drainage Features

We consulted with agricultural consultants and local landowners to acquire information on tiling construction practices, management activities, and costs. Data on tiling equipment and material costs were obtained from a large manufacturer and supplier of drainage products.

We assumed that landowners would rent larger construction equipment such as a tractor backhoe, tile plow, and trencher for installing tile. We found the tractor backhoe's cost at a daily rate of $397 ($3.68/acre). We accounted for the tile ’low rental at a $300 daily rate ($2.78/acre) and the trencher at a daily rate of $434 ($4.02/acre). We added the costs for 6-foot control boxes, perforated polyethylene pipes with a filter cloth, and animal-guard flap gates for tiling equipment. For every acre, we assumed two perforated pipes. Perforated polyethylene pipes with a filter cloth cost $2.19/ln ft. In addition, we considered one control box ($66.56/acre) for every ten acres. Lastly, we assumed $5 per acre every five years for maintaining tiles by periodically cleaning out sediments, debris, and rocks. Land drainage cost inputs are provided in Appendix J.

4.3 Revenues

Most of the NBS that we estimated are expenses that farmers must incur to catch, retain, hold, and slowly release water to reduce flooding on the farm itself or downstream on other farms or communities. The critical water retention or control practices had varying levels of costs. Some of the recommended practices identified were cover crops, buffers, or trees/forests that could generate revenue, although less than grain crops. However, the key NBS, such as berms, dry dams, flood control wetlands and banks, and tiling are the ones that are apt to hold more water. Sources for these revenues for 2020 prices are shown in Table 2.3.

Three practice scenarios generated regular farm crop income: cover crops and no-till, agroforestry, and grasses and forested wetland restoration (Table 2.4). We assumed cover crop income from soybean, winter wheat, corn, and pasture harvests; agroforestry income from pasture and timber harvests; and forest wetland restoration practices via hunting leases and timber harvests. Agroforestry yields were comprised of a blend of 20% timber area and 70% grass/hay monoculture revenues, with the 10% of foregone area/income representing the lost hay production due to shade and other competition from trees. Revenues discussed in this section do not account for cost-share or other conservation payments.

First, we estimated $338/acre crop return from soybean and $297/acre from winter wheat for cover crop scenario A. We assumed a crop return of $494/acre from corn and $283/acre from cool-season pasture/hay for cover crop scenario B. Both scenarios would generate revenue every year between Year 0 and Year 30.

Second, we assumed loblolly pine tree harvests for agroforestry scenarios, where the market value price for pulpwood was $9.63 per ton, chip-n-saw was $15.73 per ton and $22.76

per ton for saw timber. We assumed a first thinning in Year 12 of one-third of total pulpwood, a second thinning in Year 18 of half the volume of pulpwood and another half volume of chip-n-saw, and a final harvest in Year 25 of the four-fifths volume of saw timber and one-fifth volume of pulpwood. All forestry timber price data were based on Timber Mart-South [43].

Last, wetland restoration scenario A assumed $13/acre of revenue generated from hunting leases. For wetland restoration scenario B, we estimated revenue generated from bottomland hardwood harvests with a first thinning in Year 30 of approximately one-third volume of pulpwood; a second thinning in Year 45 of approximately one-third volume of pulpwood; and a final harvest in Year 60 of one-half mixed hardwood saw timber and one-half oak saw timber. Finally, in wetland restoration scenario C using loblolly pine species, we valued revenue from a first thinning in Year 12 of the approximately one-third volume of pulpwood; a second thinning in Year 18 of one-half of pulpwood and one-half of chip-n-saw; a final harvest in Year 25 of four-fifths saw timber and one-fifth of pulpwood.

The remaining four practices (i.e., hardpan breakup, stream restoration, water farming, land drainage features) only obtained income via conservation and FloodWise payments.

Table 2.4: Revenues from the Cover Crop & No-Till, Afforestation, Agroforestry, and Wetland Restoration Scenarios, 2020

Scenario	Source of Income	Revenue/acre ($/year)	Year of Revenue
Cover Crop & No-Till			
Scenario A (Soybean/Winter Wheat & No-Till)	Soybean	$338.20	Every year from Year 0 to Year 30
	Winter wheat	$296.80	Every year from Year 0 to Year 30
Scenario B (Corn/Cool-Season Pasture & No-Till)	Corn	$493.95	Every year from Year 0 to Year 30
	Pasture/hay	$282.76	Every year from Year 0 to Year 30
Afforestation			
Scenario A (Bottomland Hardwood Forest)	Pulpwood	$126.21, $583.28	Year 30, Year 45
	Oak saw timber	$2,531.66	Year 60
Scenario B (Loblolly Pine Forest)	Pulpwood	$260.00	Year 12, Year 18, Year 25
	Chip-n-saw	$399.00	Year 18
	Sawtimber	$2219.77	Year 25
Agroforestry			
Scenario A (Forest Only)	Timber harvest (pulpwood, chip-n-saw, saw timber)	$260.00, $399.00, $2,219.77	Year 12, Year 18, Year 25
Scenario B (Forest Only, 20% Trees)	Timber harvest (pulpwood, chip-n-saw, saw timber)	$52.00, $80.00, $443.95	Year 12, Year 18, Year 25
Scenario C (Cool-Season Pasture)	Grass/hay harvest	$286.20	Every year from Year 1 to Year 25
Scenario D (Warm-Season Pasture)	Grass/hay harvest	$340.00	Every year from Year 1 to Year 25
Scenario E (70% Cool-Season Pasture, 20% Trees)	Grass/hay harvest	$200.34	Every year from Year 1 to Year 25
	Timber harvest (pulpwood, chip-n-saw, saw timber)	$52.00, $80.00, $443.95	Year 12, Year 18, Year 25

Table 2.4 (continued**)**

Scenario F (70% Warm-Season Pasture, 20% Trees)	Grass/hay harvest	$267.75	Every year from Year 1 to Year 25
	Timber harvest (pulpwood, chip-n-saw, saw timber)	$52.00, $80.00, $443.95	Year 12, Year 18, Year 25
Wetland Restoration			
Scenario A (Flood Control Wetland)	Hunting leases	$13.00	Every year from Year 0 to Year 30
Scenario B (Bottomland Hardwood Forest Bank)	Hunting leases	$13.00	Every year from Year 0 to Year 30

*Values do not represent conservation or FloodWise payments

4.3 Capital Budgeting Results

Table 2.5 displays a summary of capital budgeting results for each NBS practice scenario. The results indicate that practice scenarios with a positive NPV had crop or timber revenues that exceeded the costs to establish and maintain NBS practices at the 6% discount rate. Scenarios with negative NPVs indicate that the NBS practices consisted only of costs, which were not offset by traditional farm or forestry revenues. Flood control wetland using grasses and sedges investments showed the lowest net present value (e.g., the highest costs) at a 6% discount rate (NPV = -$87,751/acre). Conversely, corn and cool-season pasture cover crop investments displayed the highest net present value out of all practices (NPV = $3,569/acre).

Table 2.5: Capital Budgeting Results for FloodWise Practices, 2020 – Net Present Value (NPV), Land Expectation Value (LEV), Annual Equivalent Income (AEI) – at 6% discount rate – and Internal Rate of Return (IRR)

Scenario	NPV ($/acre)*	LEV ($/acre)*	AEI ($/acre)*	IRR (%) (only applicable for forestry practices)
Cover Crops & No Till				
Scenario A: Soybean/Winter Wheat & No-Till	$2,799	$3,389	$203	N/A
Scenario B: Corn/Cool Season Pasture & No-Till	$3,569	$4,321	$259	N/A
Hardpan Breakup				
Scenario A: Hardpan Breakup	-$215	-$260	-$16	N/A
Afforestation				
Scenario A: Bottomland Hardwood Forest	-$749	-$772	-$46	1.87%
Scenario B: Loblolly Pine Forest	$368	$480	$29	9.66%
Agroforestry				
Scenario A: Forest Only	$368	$480	$28	9.66%
Scenario B: (Forest, 20% Trees	$71	$93	$6	9.05%
Scenario C: Cool-Season Pasture Only	$676	$881	$53	26.46%
Scenario D: Warm-Season Pasture Only	$1,364	$1,779	$107	45.56%
Scenario E: 70% Cool-Season Pasture & 20% Trees	-$350	-$456	-$27	-0.61%
Scenario F: 70% Warm-Season Pasture & 20% Trees	$512	$667	$40	16.06%
Wetland Restoration				
Scenario A: Flood Control Wetland with Grasses and Sedges	-$88,026	-$106,583	-$6,394	N/A

Table 2.5 (continued)

Scenario B: Forested Bank with Bottomland Hardwoods	-$11,738	-$63,043	-$3,783	N/A
Stream Restoration				
Scenario A: Stream Restoration*	-$1,341	-$1,624.08	-$97	N/A
Water Farming				
Scenario A: Water Farming	-$4,025	-$4,874	-$292	N/A
Land Drainage Features				
Scenario A: Land Drainage Features	-$1,508	-$1,826	-$110	N/A

*With the exception that stream restoration is $/ln ft

Both cover crop scenarios produced positive NPVs, but investment in corn and pasture cover crop rotations provided a somewhat greater return (NPV =$3,569/acre) than the soybean and winter wheat investment (NPV = $2,799/acre).

Bottomland hardwoods forests produced a negative NPV at the 6% discount rate (NPV = -$749/acre), because they had a low IRR of 1.87%. However, investments in loblolly pine forests provided a positive return (NPV = $2,799; IRR=9.66%).

Five of the six forest, pasture, and silvopasture practices proved to provide a positive NPV at the 6% discount rate, except for the agroforestry scenario for cool-season pasture and forest (NPV = -$350/acre). Warm-season pasture as a monoculture earned the greatest rate of return of the agroforestry scenarios (NPV = $1,364/acre), while monoculture cool-season pasture yielded approximately half of that (NPV = $676/acre). The cool-season pasture and tree silvopasture had lower productivity rates than warm-season silvopasture, making it less profitable as a 70% net share of a silvopasture stand.

The two wetland restoration scenarios were the most expensive of any of the NBS practices. The flood control wetland with grasses, sedges, high berms of more than four feet, and water control structures was the most expensive, with a NPV (cost) of -$88,026/acre at the 6% discount rate. A bottomland forested wetland bank created according to the program specifications from prior converted croplands cost less, since they do not require the construction of major berms and large volumes of earth moving, but still was -$11,738/acre.

Last, hardpan breakup, water farming, stream restoration, and land drainage feature investments all yielded a negative rate of returns because they had substantial expenses and no income generated. The lowest net present value of those four NBS practices was water farming (NPV = -$4,025/acre), followed by land drainage features (NPV = -$1,508/acre) due to high establishment costs and zero revenue generation.

4.4 Conservation and FloodWise Payments

When the NBS practice's establishment and maintenance costs were more than the profitable crop, pasture, or forest scenarios, we calculated how this difference between the BAU and the NBS costs and returns could be paid for by conservation payment type arrangements.

Governmental intervention through cost-share payments and conservation payments could cover the high establishment and annual or periodic management costs. In addition, payments for conservation and flood mitigation efforts can increase returns for each practice. With approximately half of the investments generating a negative net present value, we chose to assess the potential for FloodWise program payments for landowners. These could be made directly as FloodWise payments or linked to existing conservation programs such as the North Carolina Agricultural Cost-Share Program (ACSP), USDA's Farm Bill/EQIP, or FEMA's Building Resilient Infrastructure and Communities (BRIC).

Under ACSP, North Carolina farmers can receive a one-time payment for 75% of establishment costs for implementing certain conservation practices, known as best management practices (BMPs), such as incorporating cover crops and restoring the original stream channels and wetlands, and installing water control structures. However, landowners usually must pay the remaining 25% of establishment costs and annual management costs, which may deter them from participating in adopting relatively expensive NBS practices that do not increase crop or livestock production. Covering all the remaining costs for the establishment and annual management and periodic maintenance costs would make the adoption of NBS more attractive for local landowners.

To estimate the costs for effective NBS, we assumed that landowners would need to achieve a 6% discount cash flow rate of return rate, as described above. We assumed that this could be achieved by a 100% establishment cost reimbursement, coupled with a 10-year annual payment, which is quite typical for many U.S. Farm Bill and state conservation programs. With this target, we then calculated the FloodWise establishment plus the annual payment required. This was a breakeven analysis to determine what payment amount would be necessary for landowners to break even with an NPV of zero with the 6% discount rate. We used the same spreadsheets from the capital budgeting analysis to perform the breakeven analysis, which we adapted from Cubbage [19, 20, 22, 23]. We also followed similar methods to Chizmar [55] who identified breakeven payments for establishing tree plantations and agroforestry sites in Peru and the Southern US.

All NBS could incorporate a BMP that we assume would make them eligible for the North Carolina ACSP. The FloodWise payments could cover the full 100% initial payment and the 10-year annual payments. Table 5 shows the amount of the establishment payment and 10-

year annual fixed payments—which were then discounted in the cash flow analyses—that would be needed for our selected FloodWise conservation practices that would have an NPV of zero at the indicated 6% discount rate. Stated simply, the payment schedule shows what FloodWise payments are needed to earn a 6% annual rate of return (IRR). Some of the practices shown in Table 2.6 - pine forests, agroforestry with warm-season pasture, cover crops and n–-till - would be suitable for water retention and already have an IRR of more –han 6%. Thus, they would not need a FloodWise payment based on our assumptions. Nonetheless, one might have to pay more to get farmers to adopt these new practices instead of traditional row crops or open pastures.

Table 2.6: Establishment Payments and Annual Payments for Ten Years Required to Achieve a 6% Yearly Rate of Return, Equal to a Zero NPV at that Discount Rate, 2020

FloodWise Practice	Establishment Payment at 100% of Initial Costs ($/acre)	Annual Payment for 10 years Required to Achieve a 6% IRR ($/acre)	Total Payments per Practice, ($/acre)
Hardpan Breakup Scenario A	$153.06	$8.39	$236.96
Afforestation Scenario A: Bottomland Hardwoods	$595.00*	$20.86	$803.60
Agroforestry Scenario E: Cool-Season Forage and Trees	$86.00	$35.86	$444.60
Wetland Restoration Scenario A: Flood Control Wetland	$87,467.29	$77.68	$88,244.09
Wetland Scenario B: Bottomland Hardwood Forested Bank	$10,700.00	$25.52	$13,252
Stream Restoration Scenario A	$119.54**	$125.91**	$1,387.64**
Water Farming Scenario A	$3,241.82	$106.48	$4,306.62
Tiling Scenario A	$1,495.53	$1.66	$1,512.12

Table 2.6 (continued)

All Other Scenarios: Afforestation – Loblolly Pine, Agroforestry – Warm-Season Pasture, No-Till Farming, Cover Crops	N/A***	N/A***	N/A***

*This only represents 98% of total establishment costs to meet the 6% discount rate
**Units for this practice are $/linear ft
***These practices already had a positive Net Present Value at 6%, so would not need any payments to meet that criterion

5. Discussion and Conclusions

This FloodWise research was based on the premise that NBS are better than paying for or suffering from damages from floods, but more information was needed about the best types of practices and their costs. Our detailed economic engineering analyses identify promising NBS for flood mitigation and estimated the costs of establishment and maintenance. We assembled a very extensive data set of the components required for NBS flood reduction and input costs and possible revenues for analyses, and then used discounted cash flow and capital budgeting economic analyses to determine the present values of the costs for each practice. We have developed thorough and well-documented Excel spreadsheets for all of these, which can be used, adapted, or improved by landowners, technical specialists, policymakers, or other researchers.

Capital budgeting analysis has been used in various studies to assess the production systems and financial returns of specific conservation activities or natural resource management. For example, Chizmar [28] used discounted cash flows and capital budgeting to estimate the costs and returns of silvopasture systems in Amazonas, Peru. In addition, Dunn [56] utilized similar techniques to assess alley cropping practices in North Carolina. Frey [57] also used capital budgeting indicators to compare to returns of various tree plantations in Vietnam. However, we are not able to directly compare our capital budgeting values with these previous studies' estimates due to the differences in conservation practices, discount rates, term lengths, and geographic and temporal locations.

We estimated the costs and revenues, and discounted cash flow returns for traditional farm and forestry practices for crop, pasture, and timber scenarios as benchmarks, or BAU scenarios, using capital budgeting and a 6% discount rate. Then, we estimated the costs for a variety of selected NBS practices at a 6% rate, and the amount of establishment payments and 10-year annual maintenance payments that would be required for farm and forest owners to meet the 6% hurdle rate. Our discounted present value estimates fall within typical costs and returns for the BAU farm and forest practices identified, and seem reasonable for the NBS practices. Changes in the discount rates would change the present values and payments required to break even. Our spreadsheets are available upon request from the first two authors for related calculations or for modification.

This discounted cash flow method has been popular in many payments for ecosystem services (PES) research. For example, Davies [58] found the breakeven prices for various agricultural management scenarios to protect trees for carbon storage in Ghana. Similarly, Straka [59] identified the financial breakeven point for landowners restoring longleaf pine in the US South. Again, we find it difficult to directly compare the payment amount with the ones we identified in this study due to the differences in management activities, discount rates, contract term length, and geographic and temporal locations. Jayalath et al. [60] estimated landowners' willingness to accept payments for establishing grasslands in Arkansas, US. However, to our knowledge, there has not been a study that assesses the discounted cash flows and conservation payments necessary for a potential flood mitigation program that uses NBS. Therefore, we suspect the estimates in this study to act as a guideline for similar future NBS initiatives.

There are numerous studies with the consensus that market incentives are a significant factor in program participation, thus, the reasoning behind including these payments (e.g., [60, 61]. In our study, we found annual payment amounts for the FloodWise practices over a 10-year timeframe, ranging from $1.66 to $125.91 per acre (per linear foot for stream restoration) per year, depending on the type of practice. Our future research will assess landowner's willingness to accept these payments to adopt NBS on their properties.

We discovered that the conventional crops of course had the greatest returns, since they were assumed to occur on average crop land - which is more productive than pastureland and forest land. NBS, then, would need to be installed on either existing crop lands, or on pasture lands, or rarely, on forest lands. Farmers would be reluctant to give up productive, well-drained, low risk crop lands for NBS. However, such lands in eastern North Carolina are indeed rare, and floods and droughts that reduce crop and pasture yields and returns are common. So, depending on the amount of crop production and flood risk, and the variability of returns from conventional farming, FloodWise payments may be an attractive supplemental economic stream or ecosystem service payment for farmers. FloodWise payments may also help encourage farmers to store water on lands that are already commonly flooded, which may not have a very high marginal cost of reduced crop yields.

In addition, NBS are not intended to flood fields every year, or for long periods of time. Instead, they are proposed as a means to help flood water attenuation and decrease stream and river flood peaks for periods of short duration, usually of less than a week or so. For crops, extended floods would diminish or eliminate crop yields, so payments for crop flooding losses might be required. For pastures, temporary flooding to reduce floods elsewhere on a farm or in downstream communities could be tolerated with minimal effects on the pastures, as long as livestock were able to be temporarily moved to high ground.

Regardless, crop and pasturelands might well be flooded during many large storms. Savvy farmers that recognize this may be willing to develop and be paid for NBS that they could profit from when the inevitable flooding occurred. These NBS are not largely different than existing conservation practices in federal and state farm programs, and could be implemented through existing organizations, or adapted for use by farm and forest landowners. The FloodWise payments might need to be higher, but the principles are the same.

In general, the modifications of traditional agriculture practices - cover crops, no-till, hardpan breakup, forestry, and agroforestry - were the cheapest practice that we examined. However, they store less water than other NBS practices. The wetland construction and water farming practices were the most expensive but can store larger amounts of water for a more extended and controlled period. Tile systems with drainage controls and stream restoration were intermediate costs and apt to have commensurate water storage prospects. More details on total water stored and the period of such storage should be examined in future research to develop more specific unit costs for storage volume.

The practices we identified here should hold water longer on farms and help reduce downstream flooding. Our analyses estimate the number of subsidies or reimbursements that farm and forest landowners would need to be paid to achieve a 6% rate of return. The payments required may not be that large for existing farm and forest practices that already had reasonable returns. The spreadsheet templates allow for evaluating other return rates for each practice, which can be used for sensitivity analysis.

For any practice that had smaller financial returns than those generated by the best grain crops or pasture—even timber or agroforestry—farm owners still need some type of FloodWise payments to encourage them to adopt NBS rather than row crop/pastureland uses. In addition, the most effective NBS are likely to be the ones that are most expensive and most likely to flood crop and pasture lands and create production losses on those lands. Thus, sizeable FloodWise payments would be necessary to attract farmers to risk foregoing crop incomes. On the other hand, if the fields that may be best for NBS are already flood prone, they likely do not generate consistently good crop incomes. Thus, the payment levels from high-risk flood prone fields to NBS may be much less than theoretical highest crop incomes.

These average estimates of the cost of NBS are some of the first available in the disaster resilience, flood mitigation, and NBS literature. However, additional research is needed to determine what the best practices are, how costs differ in different locations, the effects of variability in costs or discount rates, and the amount of possible payments for economic viability, the willingness of farmers and rural landowners to adopt such practices, and the institutional arrangements to carry out such programs. To examine their effectiveness on a landscape scale, it also is necessary to assess NBS specific water storage ability and quantity of flood reduction and water attenuation for various watersheds and topographies.

By estimating the amount of water stored and the length of time it is stored for each practice; the amount of flood damages prevented; and the cost of such damages, benefit-cost analysis could be prepared for each practice similar to those identified in this paper. These practices could be aggregated at various watershed-level scales to develop a program benefit-cost analysis. Utilization of NBS is an important developing research subject, which many researchers and practitioners can advance in the coming years. As climate change progresses and adverse weather and flooding events increase, developing effective NBS for adapting to and reducing flood peaks will be one important response, and the detailed cost estimates provided here can contribute significantly to nascent NBS programs.

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CHAPTER 3: LANDOWNER WILLINGNESS TO ACCEPT NATURE-BASED SOLUTIONS PAYMENTS FOR FLOOD MITIGATION ("FLOODWISE") USING THE CONTINGENT VALUATION METHOD

Introduction

Natural hazards are unavoidable. Although human-induced climate changes are occurring, natural hazards such as hurricanes, floods, tornados, and earthquakes are a part of natural phenomenon, unpredictable, and largely out of human control (Sandler & Schwab, 2021). Emergency management has been extensively applied to take action to reduce the impacts from natural hazards. Throughout time, emergency management schemes are commonly implemented at the local, state, and federal government levels to help reduce hazard risk and help make communities more stable (Sandler & Schwab, 2021).

Mitigation is one of the four emergency management phases, along with *preparedness*, *response,* and *recovery*. Researchers, practitioners, and emergency managers utilize these four phases as a model for many policies and program designs. The phases are not considered separate entities, but they may overlap (Jackman and Beruvides, 2013). Historically, *response* has been at the forefront among the other phases, and less attention has been attributed to ongoing planning and mitigation activities to diminish the impacts of hazards (Birkland, 2009). However, more recently, there has been a new focus on mitigation efforts as it looks for the long-term benefits and solutions to prevent disasters and lessen harmful impacts, and is most proactive (Godschalk, 2003; Sandler & Schwab, 2021).

Hazard mitigation practices are activities that help reduce the chance of a disaster occurring or lessen the impacts from natural hazards. Drabek (1986) defines hazard mitigation as “purposive acts designed toward the elimination of, reduction in the probability of, or reduction of effects of potential disasters.” Examples of common hazard mitigation acts may include improving reconstruction, policy and regulation planning, and routinely planned vulnerability and risk assessments (VRA) (Jackman and Beruvides, 2013). Hazard mitigation solicits an interdisciplinary approach by considering environmental, social, and economic conditions, and such efforts highly depend on technical expertise and analysis to understand hazard risks and vulnerabilities (Pearce, 2000; Sandler & Schwab, 2021).

Over time, hard-engineering approaches, or grey infrastructure, have been used as primary hazard mitigation approaches (Jones et al., 2012). However, nature-based solutions (NBS) have been recognized to improve traditional grey infrastructure and serve as an innovative activity for hazard mitigation. NBS have recently grown in popularity among academic, governmental, private, and nonprofit sectors across the globe (AECOM, 2021; FEMA, 2020a; South Florida Water Management Districts, 2018; The Nature Conservancy, 2021; USACE, 2021). NBS works with and enhance natural systems to address resilience and mitigate hazardous impacts (Hobbie & Grimm, 2020; IUCN, n.d.). NBS can support adaptation by providing improved water and air quality, reducing flooding, sequestrating carbon, enhancing wildlife habitat, and providing urban cooling (Chausson & Turner et al., 2020). Although it is growing in popularity, deploying such projects have been limited on the ground (Chausson & Turner et al., 2020)

Many rural areas experience difficulties in the face of natural hazards and disaster vulnerability (Horney et al., 2016). Over time, rural communities have not been equipped to establish and implement hazard mitigation plans or prepare for disasters. This is due to rural communities’ social vulnerabilities such as limited resources, geographic isolation, higher poverty rates, or aging population base (Cutter et al., 2003; Flora and Flora, 1992; Glasgow, 2000; Saenz and Peacock, 2006). Eastern North Carolina communities largely consist of lower socioeconomic status, rural residents, high unemployment rates, and older populations (Glavovic & Smith, 2014). These social vulnerabilities increasingly influence economic losses, injuries, and fatalities from natural hazards (Cutter et al., 2003) Wealthier communities are able to recover from losses more quickly (Cutter et al., 2003; Cutter, Mitchell, & Scott, 2000), and rural residents are more vulnerable because of lower incomes and limited locally based economies (Cutter et al., 2003; Cutter, Mitchell, & Scott, 2000). The ability to decrease flood hazard vulnerability in this region is significant challenge (Glavovic & Smith, 2014).

We focus our research scope on leveraging NBS for flood mitigation in rural areas as there is a growing body of literature that concludes that NBS can reduce flooding downstream by storing water temporarily and rural regions of North Carolina have high physical and social vulnerabilities (Cutter et al., 2003; Collentine and Futter, 2018; Hovis et al., 2021; IUCN, n.d.; Nicholson et al., 2019; Turkelboom et al., 2021). Payments for ecosystem services (PES) can incentivize landowners to adopt conservation practices (Costanza et al., 1997; Fisher et al., 2010). In this study, we suggest that PES can incentivize NBS establishment and management for flood mitigation in rural areas.

There are numerous studies that assess the use of NBS for flood mitigation (e.g., Dang et al., 2021; Turkelboom et al., 2021), and many studies that assess landowner's participation in PES program. For example, some studies recognize the importance of participating in PES for carbon offsets (e.g., Soto et al., 2016), wildlife habitat (e.g., Kreye et al., 2017, 2018), water quality (e.g., Nyongesa et al., 2016), for planting forests (e.g., Kang et al., 2019) or restoring wetlands (e.g., Wei et al., 2016). However, to our knowledge there are no notable studies that examine landowners' perceptions in participating in a PES program specifically for flood control and management. This study aims to understand the landowner motives and characteristics that influence their participation in a potential flood mitigation program, using contingent valuation methods to estimate the willingness to accept the set payment price point.

Theoretical Framework

We draw on Protection Motivation Theory (PMT) to assess landowners' willingness to accept payments and participate in a potential flood mitigation program. Although originating in the health discipline (Rogers, 1983; Rogers and Prentice-Dunn, 1997), PMT has more recently appeared in environmental disaster management, natural hazards, and climate change research (Grothmann and Patt, 2005; Luu et al., 2019). PMT suggests that individuals' perceptive threat and outcome are categorized in two appraisals: risk appraisal and coping appraisal. Risk appraisal consists of two factors: perceived future threats and perceived future consequences (Bubeck et al., 2017). Thus, in the context of this study, risk appraisal estimates the perceived threat of future flooding and its impacts on one's property.

There is also a large body of research on risk communication, which could influence the perceived threat of risk. If risk information is communicated effectively among government, risk management departments, interest groups, and the public, then there will be a result of action or participation (Dai & Zeng, 2021).

Coping appraisal deals with the ability to deal with the flooding and reduce the impacts. If an individual believes flooding will impact them in the future and that they can cope with the threat, they will agree to preventative measures (Truelove et al., 2015). A coping appraisal consists of three variables: the perceived effectiveness, the perceived ability to implement, and the perceived cost associated with the measure (Bubeck et al., 2017).

Both risk and coping appraisals influence protection motivation. Therefore, we suspect that risk and coping appraisal will affect landowners' willingness to accept payments in a flood mitigation program. Hence, we adapted various PMT constructs in a landowner survey, such as landowners' concern of future flooding; their revenue losses due to flooding; water quality; knowledge of NBS; previous flood experience; and their personal responsibility to reduce flooding downstream.

Methods

Study Area

Robeson County, NC, is in the Coastal Plain of the state and reported to have a population of approximately 130,600 in 2019 (Figure 3.1) (US Census Bureau, 2019). Many of Robeson County residents consist of traditionally marginalized and low-income communities. In 2016, approximately 33% of residents were living in poverty, compared to approximately 17% within the state (US Census Bureau, 2020; Willet, 2016). According to the U.S. census, the County is home to the Lumbee Indians, the largest Tribe in NC, with the predominant ethnicity of American Indian (~42%), followed by Caucasian (~31%), African American (~24%), and Latinx (~9%). The County's primary economic driver is the agricultural sector, mainly tobacco, soybeans, cotton, vegetable, poultry, and swine commodities (Mazzocchi, 2006). It is one of the six top agriculture producing counties in the state (Jacobs, 2018).

Most recently, the County has been set back from harsh impacts from chronic storms, including Hurricane Matthew (2016), Hurricane Florence (2018), and Hurricane Dorian (2019), which caused excessive riverine flooding of the Lumber River. Residents are affected years after these storms. For example, tarps still act as some residents' roofs who do not have the means for repairs or flood insurance (Barnes, 2019). Agricultural communities have suffered substantial revenue losses from crops and livestock yields (Strickland, 2018).

Figure 3.1: Robeson County, North Carolina (US Census Bureau, 2019)

Researchers at NC State University's College of Natural Resources and College of Design, and practitioners with the NC Foundation of Soil and Water Conservation, Environmental Defense Fund, and NC Farm Bureau Federation have pioneered a proposed program in the area, which we have termed "*FloodWise.*" The proposed program would assist landowners and farmers in adopting NBS on their properties by providing educational tools, technical assistance, and financial incentives. Such a FloodWise program could be funded under a variety of Farm Bill authorized programs similar to the current North Carolina Agricultural Cost-Share Program (NCACSP) and North Carolina Agricultural Water Resources Assistance (NC AgWRAP) in the state. However, if the state does not have the funding or technical capacity to support the program, FloodWise could be a fixed or perpetually funded project supported by federal emergency programs such as the Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA), or Building Resilient Infrastructure and Communities (BRIC). A review of each of these federal and state grant programs is discussed later in this chapter. If the pilot program succeeds in North Carolina, it could be considered in other states with similar topography, geographical settings, and flooding problems.

Many farm conservation practices and some NBS, such as wetland or stream restoration, are already considered as best management practices (BMPs) under either the NCACSP or AgWRAP. These programs cover 75% of establishment costs; the remaining costs are left up to the private landowners, limiting and possibly preventing participation by those with limited funding. However, non-federal match is an on-going challenge for many small and rural communities who do not have the resources or capacity to cover the remaining costs (Glavovic & Smith, 2014).

In order to attract participation in the new and usually more expensive NBS practices, we believe that state or federal programs would need to pay the full establishment and maintenance costs. This is different than traditional farm programs, where farmers can cover part of their establishment costs through their own labor and bid the extra costs for maintenance or foregone income into their annual payments received for the term of the conservation practice. The justification here is that NBS solutions are expensive to establish, and may have exceptional maintenance costs exceeding farm conservation practices. The benefits of flood reduction from the NBS may provide direct advantages to farmers, but most benefits would accrue to downstream landowners and communities. These costs for NBS would be larger than traditional conservation programs, but theoretically they would be much cheaper than the costs of major downstream flooding.

Thus, we assumed in our survey that the FloodWise program would cover the remaining 25% of the establishment costs—more than traditional farm conservation programs—as well as give annual payments for management and periodic maintenance costs so that landowners breakeven. We stated this assumption in the questionnaire in our case descriptions.

Building on the public policy conservation incentives approach and prior literature assessing its success, this study evaluated the factors which influence landowners' willingness to accept payments to participate and install a NBS program and identify the payment price required for participation. Building on our previous work, the FloodWise program would offer the most promising NBS for reducing floodwaters in eastern North Carolina. Hovis et al. (2021) identified ten NBS practices, separated into two general categories: common farm practices and NBS structural practices. The common farm practices are cover cropping/no-till, breaking up hardpan layers, planting pine and bottomland hardwood forests, and agroforestry. The NBS structural practices include forested wetland banks, grasses and sedge wetlands with earthen flood control structures, stream channel restoration, water farming using dry dams and earthen berms, and simple land drainage features and water retention using tile outlet terraces (Hovis et al., 2021). Some of these practices are common farming approaches that many farmers are familiar with, but they may not know the benefits for flood reduction. Other practices that are more structural in nature such as wetland and stream restoration have been heavily researched and proven to slow down water from storms. These are the same practices we refer to in this study (Table 3.1).

Table 3.1: Most Promising NBS for Eastern North Carolina (Hovis et al., 2021)

Categories	Ten Best NBS and Descriptions
Common Farm Practices	
Cover Crops and No-Till	(1) Including legume and non-legume cover crops on fields throughout the year
Hardpan Breakup	(2) Breaking up compacted hardpan layers to allow for soil water infiltration
Afforestation	Planting (3) bottomland hardwood or (4) pine forest species
Agroforestry	(5) Combining mixed pine trees and pasture fields
Structural NBS Practices	
Wetland Restoration	Restoring natural wetlands along streams or at a lower elevation with (6) flood control wetlands with grasses, sedges, and water control structures, or (7) bottomland hardwood forested wetland banks on prior converted agriculture land
Stream Restoration	(8) Restoring previously straightened streams to the original configuration
Water Farming	(9) Creating catchment areas using dry dams and berms to store water during flooding
Land Drainage Features	(10) Installing berms and other flow controls to ditches, terraces, and drain tile systems.

Survey Design

The main body of the survey was separated into four sections: questions regarding (1) landowner experience with flooding, (2) knowledge of conservation practices, (3) program preferences, and (4) landowner demographics. Questions were designed based on theoretical factors found in the literature. The survey booklet is shown in Appendix K.

The first section of the survey asked questions regarding the landowner’s property and experience with flooding. The questions revealed information about landowners’ concerns towards future flooding; impacts on crop, tree, or livestock yields, and water quality; and the use of previous or current flood mitigation tactics.

The second section focused on landowners’ understanding of the various farm conservation and NBS practices, their participation in previous conservation programs, and their attitudes regarding NBS effectiveness and implementation feasibility.

The third section focused on the landowner’s willingness to accept (WTA) farm conservation and NBS payments. The CVM-PC questions were as follows: (1) “If you enrolled in a common farm conservation practices programs to reduce floods, assume you would get paid at similar rates for existing conservation programs. What is the minimum payment per acre per year you would accept to participate in the program?” and (b) “If you enrolled in a FloodWise program to reduce floods, assuming you received 100% of the establishment costs, annual payments for keeping practices for the contract terms, and payment for crop losses, what is the minimum payment amount per acre per year you would accept to participate in a FloodWise NBS program?” In addition, we asked questions regarding preferred cost-share rates for the establishment of practices and contract term lengths. In all questions, participants were given an option not to participate.

The fourth section included questions regarding participant’s socio-economic status and demographics, such as total household income, education, gender, age, ethnicity, and race. The information could be used to assess the WTA estimates (Wang et al., 2016).

The survey was first prepared by co-authors Hovis, Cubbage, and Shear, and then reviewed by the other co-authors. It also was sent for review to a larger study examining FloodWise research, including colleagues with the NC Foundation for Soil and Water Conservation, NC Association Soil and Water Conservation Districts, and NC Farm Bureau Federation, and colleagues in the NC State University Department of Biological and Agricultural Engineering. The colleagues with the farming agencies and organizations best represented the perspectives from farmers and landowners in the state. Based on input from these groups, the final versions of the survey were designed, and taken as samples by graduate students in Forestry and Environmental Resources at NC State University.

Data Collection

We followed Dillman's (1978) Total Design Method by sending a questionnaire booklet in the mail with a return paid postage envelope to Robeson County landowners. We obtained participant information from an online public GIS database with landowner mailing addresses and land acreage. We narrowed down the list to meet the following criteria: cropland or open land greater than 20 acres, excluding high-value crops and basic infrastructure (buildings + 100-ft buffer, roads + 20-ft buffer, parcels less than 4 acres). We assumed NBS practices to be most achievable on 20 acres or greater plots. These criteria reduced the list to a population of 2,822 participants. Due to limited funds, we could not survey everyone on the population list. We performed a Power Analysis One Sample T-Test in SPSS to determine the estimated sample size for a power of .8 or greater, assuming a 25% response rate. Based on these results, we selected a random sample of 1,200 in hopes of achieving this power. We did not end up attaining this sample, but still used still found the method valuable to advise us on how many surveys we needed to send out to Robeson County landowners.

We began the survey process by sending each landowner a postcard notice of the research purpose and that a survey would be sent next. The next week we sent the subsequent survey, including a small NC State University car sticker as a modest incentive for participation. Following Dillman's approach, we sent postcard reminders twice and a replacement survey. All steps were mailed to the same 1,200 mailing addresses. In order to encourage replies, the surveys were anonymous, and had no unique numbers or other means of tracking nor any phone numbers, so we could not contact landowners for follow up or non-response bias samples. To improve coverage and response, we adopted Dillman's (2011, 2014) Mixed-Method Approach by using different modes to collect more information from people in the population. We included an electronic link and QR code if participants instead preferred to complete the survey online. Overall, we received a 16% response rate. This research was approved in accordance with the NC State University Office of IRB policies (IRB #23851).

Our response rate was lower than anticipated, and we recognize that a low response rate may contribute to bias. We cannot draw complete inferences about the target population, but only the sample itself. We note that low response rate could have been due to the lengthy survey questionnaire or farmers may have been busy in the fields due to the time of year that we sent the surveys.

In the results section of this dissertation, we discuss the demographics of our survey respondents compared to the target population. In brief, we found that the demographics of our sample size was closely related to the target population. Therefore, it is possible that we can make some generalizations from the target population based on this sample's responses.

We also obtained a list of 591 Robeson County landowner email addresses from the Robeson County Cooperative Extension office and tried to reach landowners who may have not been in the GIS mailing database, although we could not determine if the Cooperative Extension landowner contacts overlapped with landowners in the mail survey. In a separate batch after the mail survey, we also sent emails using the same Total Design Method by sending an initial notice of research purpose and five follow-up reminders. We received very few responses using this method, but they were included in our overall total sample responses.

Contingent Valuation Method (CVM)

The Contingent Valuation Method (CVM) is an economic technique commonly used to measure the value of non-market environmental goods and services (Borger, 2019; Goldar & Misra, 2001). CVM uses hypothetical scenarios that resemble real market situations via a survey questionnaire. It has been widely used to set appropriate PES by assessing willingness to accept (WTA) financial incentives for participation in conservation efforts (Boyle, 2003; Chandara et al., 2019). WTA is defined as the minimum payment amount that participants will choose until some sort of change affects them, as opposed to the willingness to pay (WTP), which is the maximum compensation one would pay for a public good (Borger, 2019; Haneman, 1991; Shogren & Hayes, 1997). CVM can elicit participants to reveal either WTA or WTP for a specific public or environmental good (Borger, 2019). However, in this study, we used CVM to determine landowners' minimum WTA compensation to adopt NBS on their properties via participating in the proposed FloodWise program.

To determine landowners' minimum payment that they are WTA, we utilized the payment card approach (PC), one of several CVM approaches. The PC and dichotomous choice (DC) approaches are the most popularly used approaches in the literature (Zhao et al., 2013) and most recommended by economists (Bateman et al., 2002; Pearce & Ozdemiroglu (2002). However, many scholars suggest that the PC approach is more robust, results in more conservative amounts, increases efficiency, and reduces biases compared to the DC approach (Blaine et al., 2005; Drichoutis et al., 2016; Ghanie et al., 2020; Kerr, 2001; Ready et al., 2001; Reaves et al., 1999). The PC approach provides continuous values compared to the DC approach, which offers a single binary choice format. In a PC approach, participants are asked to choose one value that best represents their minimum WTA values (Drichoutis et al., 2016;

Venkatachalam, 2004). However, a downfall of WTA is that it tends to generate higher rates than what a participant would accept (Groothuis et al., 1998). To limit this bias, we gave participants payment card options ranging by tens from $40/acre/year to $190/acre/year, containing comparable figures to similar conservation programs and the costs of implementing NBS in the study area (Hovis et al., 2021).

We utilized the CVM-PC approach to answer the following research questions:

- RQ1: What is the average amount that participants are WTA for farm payments?
- RQ2: What is the average amount that participants are WTA for structural NBS payments?
- RQ3: What determinants influence landowner's WTA farm payments and amount?
- RQ4: What determinants influence landowner's WTA structural NBS payments and amount?

Data Analysis

We selected a binary logistic regression to determine the effect size of the independent variables on the dependent variables and rank the relative importance of the independent variables (Garson, 2016). The dependent variables (WTA_{Farm} and WTA_{NBS}) are binary variables; either the participants are WTA (1=yes) or are not WTA (0=no). We chose to perform a binary logistic regression since the dependent variables are a forced dichotomy, and the independent variable are of various types. A forced dichotomous dependent variable for the model was used in similar WTA studies, which we somewhat based our Logit models after (e.g., Jayalath et al., 2021; Soto et al., 2016; Villanueva et al., 2017). We also selected the Logit model over a Probit model since we cannot assume that our data is normally distributed for all unobserved variables (Train, 2002). We also preferred to interpret odds ratio results, the primary effect size measure for logistic regressions (Garson, 2016). We reported significant variables at both a confirmatory level ($p \leq .05$) and an exploratory level ($p \leq .10$).

Theoretically, a landowner's WTA payments for adoption farm practices (WTA_{Farm}) or NBS practices (WTA_{NBS}) could be related to their type of land and acreage, personal experiences with flooding, preferences in a potential cost-share program, income status and social demographics, and knowledge of the practices. Table 3.2 below displays the variables used in the model that we obtained from the literature and the expected relationship. One model that closely resembles the ones in this study is from Jayalath et al. (2021), which looked at WTA compensation for adopting native grasslands in the Gulf Coast.

We ran two full models (Logit Model 1A and Logit Model 1B below), each with 15 independent variables, using WTA_{Farm} as our dependent variable. Then we used two reduced models (Logit Model 2A and Logit Model 2B below) that included limited variables from the full models. The odds ratio values greater than 1.0 signify that an increase in the predictor variable is associated with an increase in the odds of WTA. An odds ratio under 1.0 indicates a negative relationship with the predictor. An odds ratio of 1.0 means that there is no effect (Garson, 2016).

Logit Model 1A (Full):

$$ln(WTA_{Farm})=\beta_0+\beta_1 Total\_Ac\_Own+\beta_2 Manage\_Land+\beta_3 Total\_Ac\_Oper+\beta_4 Flood\_Times+\beta_5 Revenue\_Loss+\beta_6 Worry\_flood+\beta_7 Worry\_Yields+\beta_8 Program+\beta_9 farm\_know\_avg+\beta_{10} Farm\_Contract\_Term+\beta_{11} Income+\beta_{12} Age+\beta_{13} Educ+\beta_{14} Gender+\beta_{15} Responsible$$

where: WTA_{Farm} is the dependent variable,
β_0 is the estimated constant, which reflects the logit of the dependent variable when the independent variables are evaluated at 0,
β_1 through β_{15} are the independent variables' coefficient and unique code (e.g., *Total_Ac_Own*) are the independent variables

Logit Model 1B (Full):

$$ln(WTA_{NBS})=\beta_0+ \beta_1 Total\_Ac\_Own+ \beta_2 Manage\_Land+ \beta_3 Total\_Ac\_Oper+ \beta_4 Flood\_Times+ \beta_5 Revenue\_Loss+\beta_6 Worry\_flood+\beta_7 Worry\_\ Yields+ \beta_8 Program+ \beta_9 NBS\_know\_avg+ \beta_{10} NBS\_Contract\_Term+ \beta_{11} Income+ \beta_{12} Age+ \beta_{13} Educ+ \beta_{14} Gender+ \beta_{15} Responsible$$

where: WTA_{NBS} is the dependent variable,
β_0 is the estimated constant, which reflects the logit of the dependent variable when the independent variables are evaluated at 0,
β_1 through β_{15} are the independent variables' coefficient and unique code (e.g., *Total_Ac_Own*) are the independent variables

We rearranged the full model using a condensed version of variables, which we call the reduced model. We eliminated any variables with a p≥.15 from the full model. A common use of a reduced model is to determine the greatest interaction effects and compare the goodness-of-fit with the full model. We derived the variables listed in Logit Model 2A and 2B equations since they showed the highest interactions in the full models.

Logit Model 2A (Reduced):

$$ln(WTA_{Farm})=\beta_0+ \beta_1 Manage\_Land+ \beta_2 Total\_Ac\_Oper+ \beta_3 Flood\_Times+ \beta_4 Worry\_flood + \beta_5 Farm\_Contract\_Term+ \beta_6 Income+ \beta_7 Age$$

where: WTA_{Farm} is the dependent variable,

β_0 is the estimated constant, which reflects the logit of the dependent variable when the independent variables are evaluated at 0,
β_1 through β_7 are the independent variables' coefficient, and unique code (e.g., *Manage_Land*) are the independent variables

Logit Model 2B (Reduced):

$$ln(WTA_{NBS})=\beta_0+ \beta_1 Manage\_Land + \beta_2 Flood\_Times + \beta_3 Revenue\_Loss + \beta_4 Worry\_flood + \beta_5 Worry\_\ Yields + \beta_6 NBS\_Contract\_Term+ \beta_7 Age$$

where: WTA_{NBS} is the dependent variable,
β_0 is the estimated constant, which reflects the logit of the dependent variable when the independent variables are evaluated at 0,
β_1 through β_7 are the independent variables' coefficient, and unique code (e.g., *Manage_Land*) are the independent variables

Next, we created a new binary dependent variable, *Combined_WTA*, which included if survey respondents were both WTA NBS payments (*WTA_NBS*) and farm payments (*WTA_farm*). If participants stated they were only WTA one type of payment and not the other, we assigned them of "0", which indicated they were not overall WTA. We chose significant indicators from both Models 2A and 2B as the Combined Logit Model independent variables.

Combined Logit Model:

$$ln(WTA_{Combined})=\beta_0+ \beta_1 Manage\_Land + \beta_2 Total\_Ac\_Oper + \beta_3 Flood\_Times + \beta_4 Revenue\_Loss + \beta_5 Worry\_flood + \beta_6 Income+ \beta_7 Age$$

where: $WTA_{Combined}$ is the dependent variable,
β_0 is the estimated constant, which reflects the logit of the dependent variable when the independent variables are evaluated at 0,
β_1 through β_7 are the independent variables' coefficient, and unique code (e.g., *Manage_Land*) are the independent variables

In addition to finding the determinants of landowner's WTA payments, we used an OLS model to determine which factors may cause an increase in the farm payment amount (OLS Model 1C) and a structural NBS payment amount (OLS Model 1D). OLS Model 1C (1C) used the dependent variable, $Payment_{\mathrm{Farm}}$, which was the minimum amount respondents would be WTA to implement common farm practices. The dependent variable, $Payment_{\mathrm{NBS}}$, used in OLS Model 1D (1D) refers to the minimum amount that participants would be WTA to implement structural NBS practices. We utilized the payment card contingent valuation method, giving options ranging by tens from $40/acre/year to $190/acre/year for each of the practice options – farm and structural NBS.

OLS Model 1C:

$$Y(Payment_{Farm}) = \beta_1 Total\_Ac\_Own + \beta_2 Crop\_Ac\_Own + \beta_3 Pasture\_Ac\_Own + \beta_4 Forest\_Ac\_Own + \beta_5 Manage\_Land + \beta_6 Total\_Ac\_Oper + \beta_7 Flood\_Times + \beta_8 Revenue\_Loss + \beta_9 Worry\_flood + \beta_{10} Worry\_Yields + \beta_{11} Program + \beta_{12} farm\_know\_avg + \beta_{13} Farm\_Contract + \beta_{14} Income + \beta_{15} Age + \beta_{16} Educ + \beta_{17} Gender + \beta_{18} Responsible + \beta_{19} Proximity\ c + e$$

where: $Y(Payment_{Farm})$ is the dependent variable,
β_1 through β_{19} are the independent variables' coefficient and unique code (e.g., *Total_Ac_Own*) are the independent variables,
c is the constant,
e is the error term reflected in the residuals

OLS Model 1D:

$$Y(Payment_{NBS}) = \beta_1 Total\_Ac\_Own + \beta_2 Crop\_Ac\_Own + \beta_3 Pasture\_Ac\_Own + \beta_4 Forest\_Ac\_Own + \beta_5 Manage\_Land + \beta_6 Total\_Ac\_Oper + \beta_7 Flood\_Times + \beta_8 Revenue\_Loss + \beta_9 Worry\_flood + \beta_{10} Worry\_Yields + \beta_{11} Program + \beta_{12} NBS\_know\_avg + \beta_{13} NBS\_Contract + \beta_{14} Income + \beta_{15} Age + \beta_{16} Educ + \beta_{17} Gender + \beta_{18} Responsible + \beta_{19} Proximity\ c + e$$

where: $Y(Payment_{NBS})$ is the dependent variable,
β_1 through β_{19} are the independent variables' coefficient and unique code (e.g., *Total_Ac_Own*) are the independent variables,
c is the constant,
e is the error term reflected in the residuals

Table 3.2: Theoretical Model Variables and Expected Relationships

Variable	Variable Type	Description	Expected Sign (+, -, ?)	Source
Dependent Variables				
Farm_WTA	Binary	Equals 1 when WTA, and 0 for not WTA	N/A	N/A
NBS_WTA	Binary	Equals 1 when WTA, and 0 for not WTA	N/A	N/A
Farm_payment	Continuous	Amount in USD	N/A	N/A
Farm_payment	Continuous	Amount in USD	N/A	N/A
Independent Variables				
Total_Ac_Own	Continuous	Total acreage of land that is owned by respondent	+	Arriagada et al., 2015 Arriagada et al., 2018 Bremer et al., 2014 Jiang et al., 2018 Pattanayak et al., 2003 Villanueva et al., 2016
Manage_Land	Binary	Equals 1 when manages land, and 0 for does not manage or leases land	+	Kang et al., 2019 Lindhjem and Mitani, 2012

Table 3.2 (continued)

Total_Ac_Oper	Continuous	Total acreage of all land that is operated or managed by the landowner?	?	Cubbage et al., 2003 Gutierrez-Castillo et al., 2022 Jiang et al., 2018 Kang et al., 2019 Ma et al., 2012 Nyongesa et al., 2016 Pattanayak et al., 2003 Rabotyagov and Lin, 2013 Wang et al., 2016
Crop_Ac_Own	Continuous	Total acreage of crop land that is owned	+	Arriagada et al., 2015 Arriagada et al., 2018 Bremer et al., 2014 Jiang et al., 2018 Pattanayak et al., 2003 Villanueva et al., 2016
Pasture_Ac_Own	Continuous	Total acreage of pasture or grass land that is owned	+	Arriagada et al., 2015 Arriagada et al., 2018 Bremer et al., 2014 Jiang et al., 2018 Pattanayak et al., 2003 Villanueva et al., 2016
Forest_Ac_Own	Continuous	Total acreage of forest land that is owned	+	Arriagada et al., 2015 Arriagada et al., 2018 Bremer et al., 2014 Jiang et al., 2018 Pattanayak et al., 2003 Villanueva et al., 2016

Table 3.2 (continued)

Flood_Times	Categorical	Equals zero when flooding has never occurred, 1 when flooding occurs every 25 years, 2 when flooding occurs every 15 years, 3 when flooding occurs every 10 years, 4 when flooding occurs every 7 years, 5 when flooding occurs every 5 years, 6 when flooding occurs every 2 years, and 7 when flooding occurs every year	+	Brouwer and Schaafsma et al. (2013) Bubeck et al., 2017 Pattanayak et al., 2003 Rambonilaza and Brahic, 2016 Rogers, 1975 Jayalath et al., 2021 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015
Revenue_Loss	Continuous	Percent of annual agriculture or forest revenue loss	+	Brouwer and Schaafsma et al., 2013 Bubeck et al., 2017 Jiang et al., 2018 Lupek, 2014 Pattanayak et al., 2003 Jayalath et al., 2021 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015

Table 3.2 (continued)

Worry_Wquality	Ordinal	*I worry that harm may harm water quality* Equals 1 when strongly disagrees with the above statement, 2 when disagrees with the above statement, 3 when has no opinion/neutral with the above statement, 4 when agrees with the above statement, 5 when strongly agrees with the above statement	+	Bubeck et al., 2017 Dyer et al., 2015 Ernst and Wallace, 2008 Kreye et al., 2016 Lupek, 2014 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015
Worry_Yields	Ordinal	*I worry that floods will harm my crop, tree, or livestock yields* Equals 1 when strongly disagrees with the above statement, 2 when disagrees with the above statement, 3 when has no opinion/neutral with the above statement, 4 when agrees with the above statement, 5 when strongly agrees with the above statement	+	Bubeck et al., 2017 Ernst and Wallace, 2008 Lupek, 2014 Ouvrard et al., 2020 Rambonilaza and Brahic, 2016 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015
Worry_flood	Ordinal	*I worry about my land flooding after a major rainfall* Equals 1 when strongly disagrees with the above statement, 2 when disagrees with the above statement, 3 when has no opinion/neutral with the above statement, 4 when agrees with the above statement, 5 when strongly agrees with the above statement	+	Brouwer and Schaafsma et al. (2013) Bubeck et al., 2017 Rambonilaza and Brahic, 2016 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015

Table 3.2 (continued)

Program	Binary	Equals 1 when participated in previous conservation cost-share program, and 0 for has not participated in previous conservation cost-share program	+	Cubbage et al., 2003 Dyer et al., 2015 Gutierrez-Castillo et al., 2022 Pattanayak et al., 2003 Jayalath et al., 2021
Farm_avg_know	Ordinal	Equals 1 when not familiar with common farm practices, 2 when slightly familiar with common farm practices, 3 when moderately familiar with common farm practices, 4 when very familiar with common farm practices, 5 when extremely familiar with common farm practices	+	Bubeck et al., 2017 Jiang et al., 2018 Lupek, 2014 Pattanayak et al., 2003 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015
Farm_Contract_Term	Categorical	Equals 1 if landowner prefers 5-year contract for a farm conservation program, 2 for a 10-year contract, 3 for a 20-year contract, 4 for a 30-year contract, 5 for a contract for more than 31 years, 6 for a permanent land easement, and 0 for landowner would not participate in a farm conservation program	?	Kabii and Horwitz, 2006 Kreye et al., 2017 Lupek, 2014
NBS_avg_know	Ordinal	Equals 1 when not familiar with structural NBS, 2 when slightly familiar with structural NBS, 3 when moderately familiar with structural NBS, 4 when very familiar with structural NBS, 5 when extremely familiar with structural NBS	+	Bubeck et al., 2017 Jiang et al., 2018 Lupek, 2014 Pattanayak et al., 2003 Rogers, 1983 Rogers and Prentice-Dunn, 1997 Truelove et al., 2015

Table 3.2 (continued)

NBS_Contract_Term	Categorical	Equals 1 if landowner prefers 5-year contract for a structural NBS program, 2 for a 10-year contract, 3 for a 20-year contract, 4 for a 30-year contract, 5 for a contract for more than 31 years, 6 for a permanent land easement, and 0 for landowner would not participate in an NBS program	?	Kabii and Horwitz, 2006 Kreye et al., 2017 Lupek 2014
Responsible	Ordinal	*It is my responsibility as a property landowner/operator to incorporate flood reduction practices* Equals 1 when strongly disagrees with the above statement, 2 when disagrees with the above statement, 3 when has no opinion/neutral with the above statement, 4 when agrees with the above statement, 5 when strongly agrees with the above statement	+	Bubeck et al., 2017 Lupek, 2014 Mishra et al., 2021 Rogers, 1983 Rogers and Prentice-Dunn, 1997
Income	Categorical	Equals 1 when annual household income is less than $2,499, 2 when annual household income is between $25,000-$49,999, 3 when annual household income is between $50,000-$74,999, 4 when annual household income is between $75,000-$99,999, 5 when annual household income is between $100,000-$149,999, and 6 when annual household income is $150,000 or more	?	Cubbage et al., 2003 Jiang et al., 2018 Joshi & Mehmood, 2011 Kreye and Adams, 2016 Pattanayak et al., 2003 Jayalath et al., 2021 Wei et al., 2016

Table 3.2 (continued)

Age	Categorical	Equals 1 when landowners' age is less than 30 years, 2 when age is between 31-45 years, 3 when age is between 46-60 years, 4 when age is between 61-75 years, and 5 when age is 76 years or more	?	Jiang et al., 2018 Kazcan et al., 2013 Kreye and Adams, 2016 Pattanayak et al., 2003 Jayalath et al., 2021
Educ	Categorical	Equals 1 when landowners' highest education completed is high school/GED, 2 for vocational/ technical certificate, 3 for associates, 4 for Bachelors, 5 for Graduate, 6 for professional, and 7 for other	+	Jiang et al., 2018 Kreye et al., 2016 Ma et al., 2012 Nygonesa et al., 2016 Pattanayak et al., 2003 Wolde et al., 2016
Gender	Binary	Equals 1 when landowner gender is male, and 0 for female	?	Kazcan et al., 2013 Kreye and Adams, 2016 Nyongesa et al., 2016 Pattanayak et al., 2003
Proximity	Categorical	Equals 1 when landowner lives on or near the land, 2 when landowner lives within 50 miles, 3 when landowner lives elsewhere in NC and outside of 50 miles, and 4 when landowner lives out of state	+	Conway et al., 2003 Gutierrez-Castillo et al., 2022 Kang et al., 2019 Kendra and Hull, 2005

Results

Descriptive Statistics

Of 1,200 mailed questionnaires, 206 were returned and 101 were fully completed. The study sample consisted of 44 women and 121 men (N=161) (Figure 3.2). The majority (n=91) reported to be between the ages of 61 and 75 years and the second highest majority (n=38) reported to be 76 years or older (N=165) (Figure 3.3). Approximately 79% of the sample were White, 18% Indigenous or Native American, and 3% African American (N=162) (Figure 3.4). The majority annual household income reported greater than $150,000 ($n$=31) and between $100,000 and $149,999 ($n$=31), annually (Figure 3.5).

This sample is a pretty close representation of the overall population, which were Robeson County landowners that owned more than 20 acres of land. Again, this sample does not reflect residents in Robeson County, but only those individuals who own land of 20 acres or greater. Our sample consisted of approximately 25% women and 75% men, which closely represents the county. The 2017 North Carolina Agriculture Census reported approximately 28% women and 72% men of the total agricultural producers in Robeson County. The Census also reported 5% under the age of 34 years old, 58% between 35 and 64, and 37% over the age of 65 years. Very similarly, our sample contained approximately 55% of landowners between the ages of 61 and 70 years, roughly 23% over the age of 71, and 4% under the age of 45 years old. Additionally, our sample consisted of similar race to the overall population, with the majority of landowners identifying as White and the second highest group identifying as Native American. The Census reported 56% White landowners, 5% African American, 36% American Indian, and 1% Asian (NC Census of Agriculture, 2017). Although, our sample did not have Asian landowner representation, as well as a slightly lower Native American representation. We recognize that this could be because we included only landowners with property equal or greater to 20 acres. It is possible that the remaining American Indian and Asian landowners in the County owned less than 20 acres.

Of the respondents (*n*=196), 99% stated they were landowners in the County. Out of those landowners, 34% manage their own land and 64% (*n*=198) reported they do not manage their own land, perhaps leasing out the land. The average number of acres the landowners owned was 292, with an average of 147 acres of cropland, 127 acres of forest land, and 12 acres of pasture or grassland (Table 3). Approximately 59% of the respondents (*n*=104) live on their property or within 5 miles of it, 20% (*n*=35) live within 50 miles, 16% (*n*=29) live outside of 50 but within the state, and some (*n*=8) are located out of the state (Figure 3.6). See Appendix L for the full variable list codebook and Appendix M for their descriptive statistics. Table 3.2 displays the selected variables for our analyses, which help answer this study's research questions.

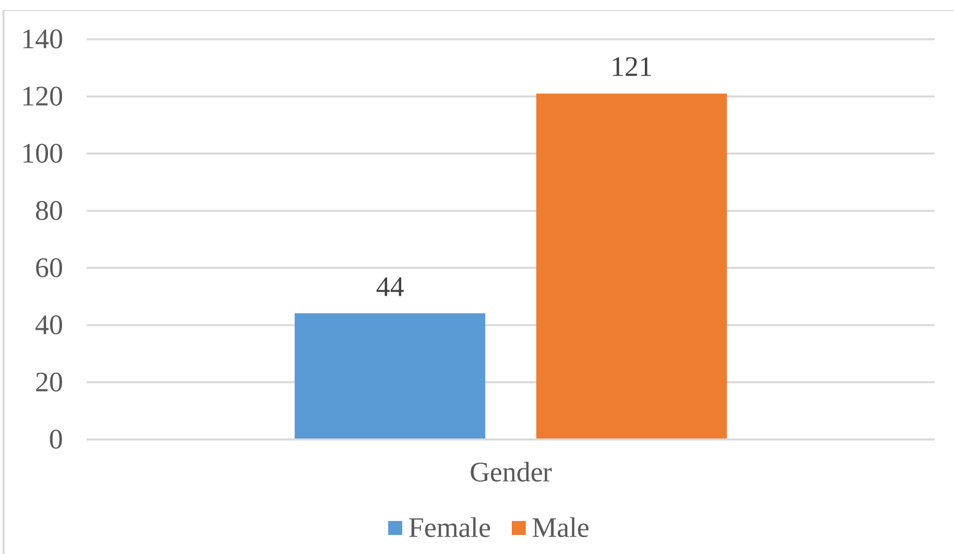

Figure 3.2: Gender of Survey Respondents, N=165

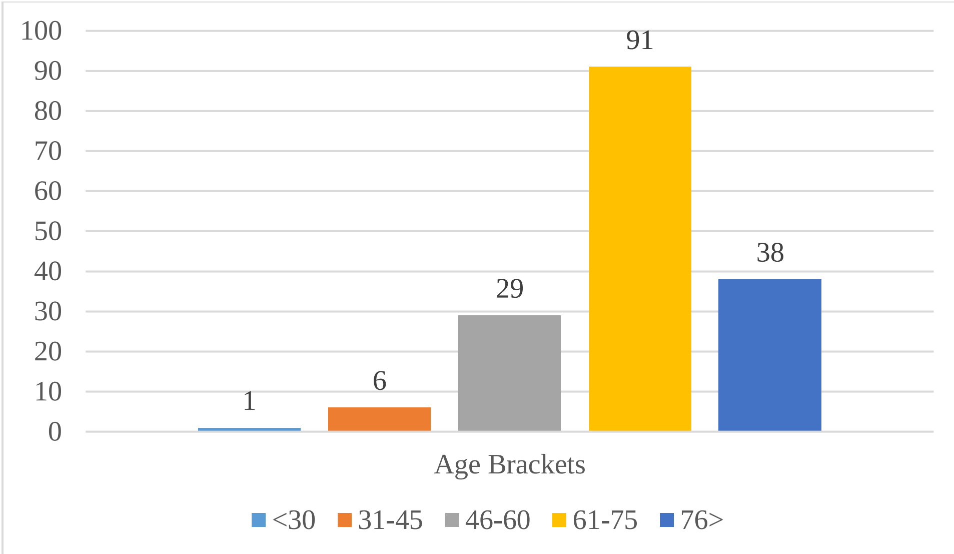

Figure 3.3: Age of Survey Respondents, N=165

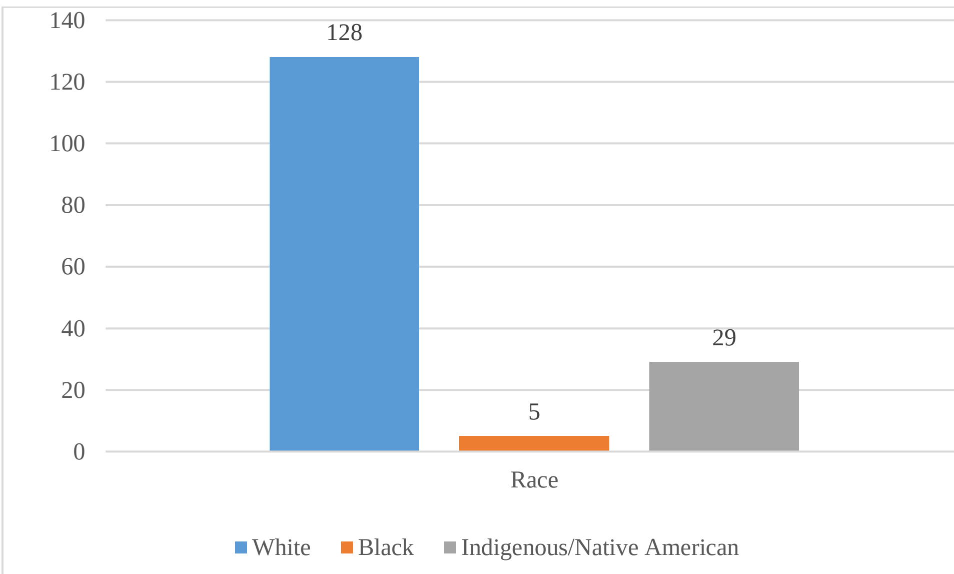

Figure 3.4: Ethnicity of Survey Respondents, N=162

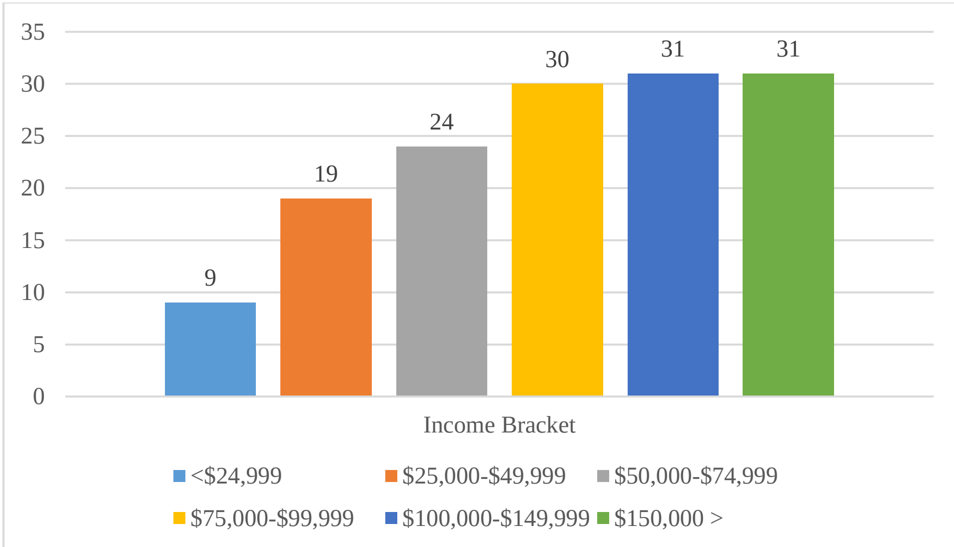

Figure 3.5: Household Income of Survey Respondents, N=144

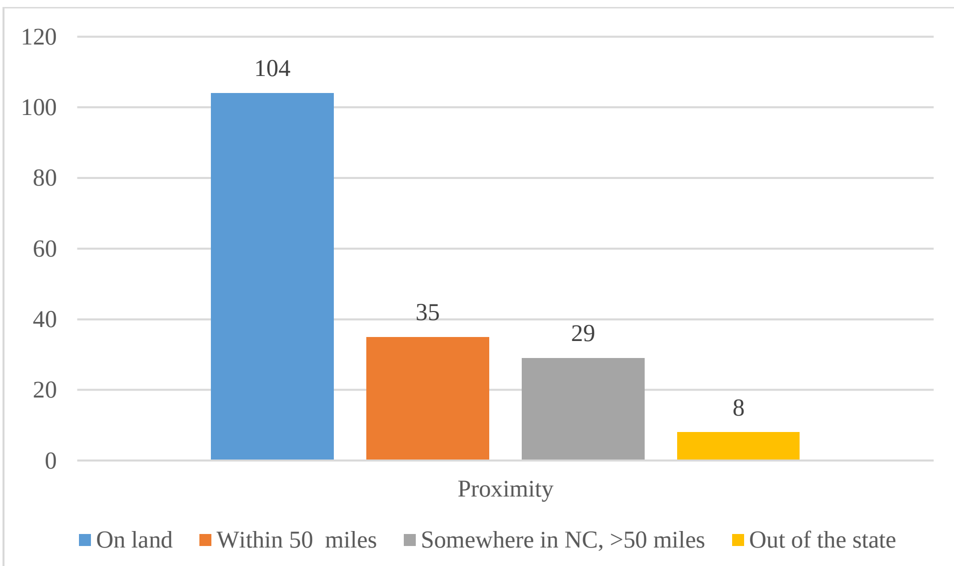

Figure 3.6: Survey Respondents' Proximity to Robeson County Land of N=176

Table 3.3: Average Acres and Type of Land Owned by Survey Respondents

Land Type	Average Acres Owned	Average Acres Operated
Total	292	174
Crop land	147	137
Forest land	127	39
Pastureland	12	5

In terms of landowners' previous flooding experience, participants reported on average that their land floods significantly about every 10 years and approximately 11% of crop, livestock, or forest revenue was lost due to extreme flooding since the major storms that occurred in 2016 and 2018. We asked several questions regarding landowners' perceptions and concerns of future flooding on their properties. We measured variables with a rising Likert scale 1 (strongly disagree) through 5 (strongly agree). Participants' concern of future flooding damaging their agriculture or forest yields was a median of 4 (agree), and their concern of flooding impacting water quality was a median of 3 (have no opinion). 58% stated they already incorporate some sort of flood reduction practice on their properties (agree and strongly agree). 50% said they believe they are responsible for reducing flooding on their properties and preventing flooding downstream (agree and strongly agree).

We asked a variety of questions regarding participants' opinions about a potential FloodWise cost-share program. Approximately 60% stated they would require payments (agree and strongly agree) to establish NBS on their properties. 63% would require technical help to develop and maintain NBS on their properties (agree and strongly agree). 18% believed NBS was too costly to implement (agree and strongly agree). 16% said NBS was too time-consuming and would take away from other farm activities (agree and strongly agree). 59% stated they would require a payment from crop or forest losses due to flooding (agree and strongly agree).

We also asked several questions about program preferences. First, we wondered what contract term length they would accept if they were to implement common farm practices. The responses range from a 5-year contract term with annual payments to more than 30 years. The average survey response was a 10-year contract with annual payments to adopt common farm practices. We asked the same question for structural NBS, including the same response choices. The average contract term for structural NBS was also a 10-year contract with annual payments.

Next, we asked what cost-share rate participants would require to establish common farm practices. The average rate was 53% for those who stated they would participate in typical farm conservation practices. We did not ask this for NBS practices, due to the assumption explained previously that they would require 100% coverage of establishment and periodic maintenance costs.

Finally, we asked what the minimum common farm and structural NBS payments landowners were WTA to participate in the FloodWise program. We gave the option "none" if participants wished not to participate. We coded 1 as "yes" if participants selected a payment amount and a "0" if they chose "None. I would not participate". The majority of participants (*n*=105) stated they would be WTA a payment to adopt common farm practices that may reduce flooding, while the remaining (*n*=41) would not be WTA farm practice payments. The average farm payment amount was approximately USD $128 per acre per year. In addition, the majority of respondents (*n*=100) would be WTA structural NBS payments, while the remaining who answered (*n*=45) would not. Slightly less than the farm payment response, the average structural NBS payment amount was USD $132 per acre per year (Table 3.4).

Table 3.4: Survey Descriptive Statistics

Variable	Obs	Mean	Median	Std. dev.	Min	Max
Total_Ac_Own	172	291.70	121.5	535.211	19.8	3900
Manage_Land	198	.35	0	.4792	0	1
Total_Ac_Oper	161	173.58	0	590.81	0	6000

Table 3.4 (continued)

Crop_Ac_Own	162	147.41	50	327.14	0	2500
Pasture_Ac_Own	165	11.73	0	38.57	0	400
Forest_Ac_Own	164	127.39	37.5	400.52	0	3480
Flood_Times	162	3.07	3	2.42	0	7
Revenue_Loss	153	11.39	5	15.58	0	80
Worry_flood	170	3.04	3	1.31	1	5
Worry_Yields	170	3.26	4	1.27	1	5
Worry_Wquality	170	3.21	3	1.25	1	5
Program	177	.23	0	.46	0	1
Farm_know_avg	165	2.74	2.67	1.09	1	5
NBS_know_avg	163	1.99	1.67	.94	1	5
Farm_Contract_Term	120	1.87	2	.99	1	6
NBS_Contract_Term	108	2.09	2	1.23	1	6
Farm_WTA	146	.72	1	.45	0	1
NBS_WTA	145	.69	1	.46	0	1
Combined_WTA	142	.67	1	.47	0	1
Farm_Payment	106	128.21	120	46.20	40	190
NBS_Payment	101	131.98	130	46.22	40	190
Income	144	4.03	4	1.53	1	6
Age	165	3.98	4	.80	1	6
Educ	165	3.53	4	1.58	1	7
Gender	165	.73	1	.44	0	1
Responsible	158	3.29	3	1.02	1	5
Proximity	177	1.69	1	.97	1	6

T-Test

We ran a paired sample t-test analysis to compare the WTA farm payment amount was statistically different from the WTA structural NBS payment amount (Table 3.5). We found that they were not significantly different (t=0.56). This indicates that typical farm program payment expectations were almost the same as for structural NBS payments, other than our stated assumptions of differences among the payments for establishment and periodic maintenance. This is encouraging for program implementation, suggesting that landowners essentially considered structural NBS practices about the same as farm conservation practices—no riskier or more problematic for farm adoption.

Table 3.5: T-Test Results

	$Payment_{Farm}$	$Payment_{NBS}$
Mean	128.21	131.98
Variance	2134.85	2136.04
Observations	106	101
Pooled Variance	2135.43	
Hypothesized Mean Difference	0	
df	205	
t Stat	-0.587	
P(T<=t) one-tail	0.279	
t Critical one-tail	1.652	
P(T<=t) two-tail	0.558	
t Critical two-tail	1.972	

Logistic Models of Willingness to Accept Payments

Table 3.6 summarizes the results for the full logistic regression models of the landowners WTA payments to perform farm conservation practices. The statistically significant independent variables are shown in bold at various significance P levels. We report odds ratios which are logistic regression's version of parameter estimates or coefficients that those used in OLS regression. Odds ratio is the natural log base, *e*, to the exponent, *b*, which is the logistic regression parameter estimate (Garson, 2016). For continuous variables, the odds ratio represents the factor by which the odds, or the WTA (either farm payments or structural NBS payments), increases or decreases one unit in the independent variable (Garson, 2016). We use odds ratios here as an effect size measure.

For example, from the output in Logit 2A Model, the odds of decreasing in managing land (i.e., landowner that does not manage their own land) are .052 the odds of a landowner who manages their own land, controlling for other variables in the model.

Flood_Times and *Age* had the greatest significance on WTA conventional farm practice payments. *Manage_Land, Flood_Times, Farm_Contract_Term,* and *Age* were significant at a confirmatory level ($p \leq .05$). *Total_Ac_Oper, Worry_flood,* and *Income* were found significant at an exploratory level ($p \leq .10$). *Total_Ac_Own, Revenue_Loss, Worry_Yields, Program, Farm_know_avg, Educ, Gender, Responsible* were not found significant (Table 3.6).

A marginal increase in total acres operated leads to the increased probability of WTA farm payments by 1.3%, controlling for other variables in the model. Younger farmers are more WTA than older farmers ($p \leq .05$). The longer the contract length term, the more likely participants are WTA farm payments ($p \leq .05$).

Table 3.6: Logit 1A Model (Full), WTA Payments for Farm Conservation Practices

					Number of obs = 90	
					Waldchi2(15) = 78.84	
Log Likelihood = -12.634877					Pseudo R2 = 0.7195	
WTA_Farm	Odds ratio	Robust std. err.	z	P>|z|	95% Confidence Interval	
Total_Ac_Own	1.000028	.00156	0.02	0.986	.9969753	1.00309
Manage_Land	.0519047	.0784736	-1.92	**0.050****	.002681	1.004894
Total_Ac_Oper	1.012764	.0075036	1.71	**0.087***	.9981638	1.027578
Flood_Times	.5281142	.1339947	-2.52	**0.012*****	.3211874	.8683547
Revenue_Loss	1.066791	.088947	0.78	0.438	.905978	1.256177
Worry_flood	2.696833	1.768215	1.51	**0.130** [a]	.7460232	9.748907
Worry_Yields	.615152	.4517387	-0.66	0.508	.1458479	2.594566
Program	.2235496	.5388991	-0.62	0.534	.0019835	25.19534
Farm_know_avg	.4739285	.2838727	-1.25	0.213	.1465082	1.533076
Farm_Contract_Term	33.05788	58.64859	1.97	**0.049****	1.021275	1070.058
Income	2.457804	1.514991	1.46	**0.145** [a]	.7342878	8.226747
Age	.1415163	.1201683	-2.30	**0.021****	.0267923	.7474855
Educ	1.026458	.6165091	0.04	0.965	.3162964	3.331103
Gender	1.764511	1.482896	0.68	0.499	.3398398	9.161672
Responsible	1.249575	.5284322	0.53	0.598	.5455044	2.862375

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

In Logit 1B Model of WTA payments for structural NBS, *Revenue_Loss* was the only predictor significant at a confirmatory level (p≤.05). *Flood_Times*, *Worry_floods*, *NBS_Contract_Term*, and *Age* were found significant at an exploratory level (p≤.10) (Table 3.7). Unlike the Logit 1A Model, *Manage_Land* and *Total_Acre_Oper* were not found significant.

The more revenue that is lost due to flooding increased the likelihood of WTA structural NBS payments (p≤.05), and the more concerned landowners are about flooding occuring on their land they are WTA structural NBS payments (p≤.10).

Similar to the Logit 1A Model, younger farmers are more WTA structural NBS payments than older farmers (p≤0.10), and the longer the contract length term, the more likely participants are WTA NBS payments (p≤0.10).

Table 3.7: Logit Model 1B (Full), WTA to Payments for Structural NBS Practices

	Number of obs = 88
	Waldchi2(15) = 45.63
Log Likelihood = -13.784897	Pseudo R2 = 0.7149

WTA_NBS	Odds ratio	Robust std. err.	z	P>|z|	95% Confidence Interval	
Total_Ac_Own	.9997651	.0013042	-0.18	0.857	.9972121	1.002325
Manage_Land	2.173602	1.215507	1.39	0.165	.726402	6.504039
Total_Ac_Oper	1.000266	.0010819	0.25	0.805	.9981482	1.002389
Flood_Times	.7420778	.1200827	-1.84	**0.065***	.5403914	1.019038
Revenue_Loss	1.067743	.0341539	2.05	**0.040****	1.002858	1.136827
Worry_flood	2.750689	1.467943	1.90	**0.058***	.9664644	7.828833
Worry_Yields	.473658	.2560175	-1.38	0.167	.1642029	1.366309
Program	1.101261	.7336201	0.14	0.885	.2984354	4.063777
NBS_know_avg	1.058277	.3790679	0.16	0.874	.5244506	2.135473
NBS_Contract_Term	31.03591	65.26644	1.63	**0.102***	.5033207	1913.746
Income	1.331905	.3597409	1.06	0.289	.784455	2.261406
Age	.3387368	.211817	-1.73	**0.083***	.0994475	1.153801
Educ	1.108721	.2771506	0.41	0.680	.6792737	1.809672

Table 3.7 (continued)

Gender	.9498579	.6400761	-0.08	0.939	.25355	3.558391
Responsible	1.221888	.4175368	0.59	0.558	.6254083	2.387258

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

We ran the reduced form of the Logit 1A Model (1A), which we've titled Logit 2A Model (2A) (Table 3.8). Compared to the full model (1A), the reduced form (2A) had a lower pseudo-r-square of .68; although we still deem this relatively strong. However, 2A had a slightly better model fit with a -2LL of -16.47 than 1A, which was -12.63. -2LL, standing for minus two times the log likelihood, is a common measure of goodness-of-fit of the overall model, and a measure of model error (Garson, 2016). A lower -2LL value indicates better model fit. -2LL measures are recommended to compare differences in model fit over pseudo-r-squared values (Garson, 2016). In addition, some of the predictor variables from 1A increased their significance when run in 2A. For example, *Total_Ac_Oper* and *Income* showed significant at the confirmatory level ($p \leq .05$).

In the reduced form, *Manage_Land* did not show significant at the confirmatory or exploratory levels, and *Flood_Times* displayed significance at $p \leq .10$, which was greater than in 1A. *Income* showed the greatest significance among the other predictors.

In the Logit 2A Reduced Model, *Total_Ac_Oper*, *Flood_Times*, *Income*, and *Age* had the greatest signficiance on the WTA farm payments ($p \leq 0.05$). The odds of WTA farm payments compared to those who are not WTA farm payment increases by a factor of 1.96 when annual household income increases, controlloing for other variables. Therefore, we can state that the more income landowners make, the more likely they are to be WTA farm payments ($p \leq 0.01$).

Also, as consistent with 1A and 1B, younger landowners are more likely to be WTA farm payments than older farmers ($p \leq 0.05$). Thus, the odds of WTA farm payments compared to those who are not WTA farm payment decreases by a factor of .38 for each year age increases, controlling for other variables.

Table 3.8: Logit 2A Model (Reduced), WTA Payments for Farm Conservation Practices

	Number of obs = 97
	Waldchi2(15) = 25.35
Log Likelihood = -16.468631	Pseudo R2 = 0.6829

WTA_Farm	Odds ratio	Robust std. err.	z	P>|z|	95% Confidence Interval	
Manage_Land	.230776	.255882	-1.32	0.186	.0262657	2.027651
Total_Ac_Oper	1.005646	.0025923	2.18	**0.029****	1.000578	1.010739
Flood_Times	.7202579	.1018641	-2.32	**0.020****	.5458897	.9503228
Worry_flood	1.492714	.385891	1.55	**0.121** [a]	.8993462	2.477571
Farm_Contract_Term	46.00385	96.75812	1.82	**0.069***	.7455815	2838.529
Income	1.961607	.5023729	2.63	**0.009*****	1.187454	3.240463
Age	.3782093	.1680469	-2.19	**0.029****	.1583157	.9035251

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

Next, we computed the reduced form of Logit 1B Model (1B), which we labeled as Logit 2B Model (2B). Previously in 1B, *Revenue_Loss* was the only predictor significant at $p \leq .05$; however, *Manage_Land* and *NBS_Contract_Term* proved to both be significant at $p \leq .05$. *Revenue_Loss* and *Age* were signfiicant at $p \leq .10$. Overall, 2B portrayed to have a slightly better model fit than 1B because of its lower -2LL at -17. Again, a lower -2LL estimate indicates better model goodness-of-fit. *Manage_Land* and *NBS_Contract_Term* showed the most significant among all other variables ($p \leq 0.05$) (Table 3.9).

Table 3.9: Logit 2B Model (Reduced), WTA Payments for Structural NBS Practices

Number of obs = 112
Waldchi2(15) = 20.43
Log Likelihood = -17.034034   Pseudo R2 = 0.7458

WTA_NBS	Odds ratio	Robust std. err.	z	P>|z|	95% Confidence Interval	
Manage_Land	2.985201	1.127256	2.90	**0.004*** **	1.424122	6.257487
Flood_Times	.8260885	.1296631	-1.22	0.224	.6073258	1.123651
Revenue_Loss	1.049049	.0265767	1.89	**0.059***	.9982317	1.102453
Worry_flood	3.20172	2.870456	1.30	0.194	.5523966	18.55734
Worry_Yields	.413439	.2945866	-1.24	0.215	.1023074	1.670767
NBS_Contract_Term	84.57859	176.4776	2.13	**0.033****	1.416396	5050.52
Age	.6833077	.1528806	-1.70	**0.089***	.4407292	1.059402

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

Combined Logit Model

We assessed the overall WTA (*WTA_Combined*), including both WTA farm and structural NBS payments. Logit results from this model are shown in Table 3.10. Five of the seven independent variables showed significant at p≤.01.

Table 3.10: Combined Logit Model, WTA Payments for Both Farm and Structural NBS Practices

Number of obs = 95
Waldchi2(7) = 28.31
Prob > chi2 = 0.0002
Log Likelihood = -32.7677918   Pseudo R2 = 0.3897

WTA_Combined	Odds ratio	Robust std. err.	z	P>|z|	95% Confidence Interval	
Manage_Land	.8777809	.5774297	-0.20	0.843	.241795	3.186626
Total_Ac_Oper	1.000659	.0014733	0.45	0.655	.9977754	1.003551
Flood_Times	.5065916	.094238	-3.66	**0.000*** **	.351815	.7294603

Table 3.10 (continued)

Revenue_Loss	1.103137	.0387661	2.79	**0.005*** **	1.029715	1.181795
Worry_flood	2.548318	.7411052	3.22	**0.001*** **	1.44114	4.506104
Income	2.074741	.5595338	2.71	**0.007*** **	1.222939	3.51842
Age	.2643132	.1205701	-2.92	**0.004*** **	.1081015	.6462581

***Significant at 1%; ** Significant at 5%; * Significant at 10%

OLS Models of Factors that Affect Payment Amounts

We used the OLS models to estimate the factors that influenced farm payment amount. In OLS 1C Model (1C), *Crop_Ac_Own, Total_Ac_Oper, Flood_Times, Farm_Contract_Term, Income*, and *Age* were all significant at p≤.05 with *Flood_Times* and *Farm_Contract_Term* portraying the highest significance at p≤.01. *Pasture_Ac_Own* was found significant at p≤.10 and *Worry_Wquality* at p≤.15. The overall goodness of fit was moderate, with a R-squared of .59. However, all other twelve variables did not have a relationship with the farm payment amount (Table 3.11).

In addition, the variable with the greatest significance was *Farm_Contract_Term* (p=.000), meaning the longer the contract term length for farm payments is associated with higher payment amounts required. Additionally, landowners who own fewer acres of crop land are associated with higher farm payment amounts (p≤.05). However, landowners who own more pasture land are associated with higher farm payment amounts (p≤.10). The more acres landowners operate and maintain are associated with greater amounts (p≤.05). The total forested acres owned (*Forest_Ac_Own*) did not have a significant relationship with *Payment_Farm* (p≥.15).

Table 3.11: OLS Model 1C of Variables that Affected WTA Farm Payment Amount

Number of obs = 87
F(20, 66) = 15.00
Prob > F = 0.0000
R-squared = 0.5949
Root MSE = 46.343

Payment_Farm	Coefficient	Robust std. err.	t	P>|t|	95% Confidence Interval	
Total_Ac_Own	.0550589	.0475891	1.16	0.251	-0.0399557	.1500735
Crop_Ac_Own	-.1156857	.0473732	-2.44	**0.017****	-.2102694	-.0211021
Pasture_Ac_Own	.2950671	.1759992	1.68	**0.098***	-.0563265	.6464607
Forest_Ac_Own	-.0427077	.0526357	-0.81	0.420	-.1477983	.0623829
Manage_Land	15.72646	14.79785	1.06	0.292	-13.81841	45.27133
Total_Ac_Oper	.0260209	.0128547	2.02	**0.047****	.0003556	.0516862
Flood_Times	-7.446659	2.692282	-2.77	**0.007*****	-12.82197	-2.071345
Revenue_Loss	.5417377	.375453	1.44	0.154	-.2078784	1.291354
Worry_flood	11.04311	7.745672	1.43	0.159	-4.421626	26.50784
Worry_WQuality	7.443969	4.883144	1.52	**0.132** [a]	-2.305544	17.19348
Worry_Yields	-2.10954	8.245628	-0.26	0.799	-18.57247	14.35339
Program	-20.44157	14.31017	-1.43	0.158	-49.01274	8.129607
Farm_know_avg	-8.088477	6.702173	-1.21	0.232	-21.4698	5.292843
Farm_Contract_Term	23.48213	6.082182	3.86	**0.000*****	11.33867	35.6256
Income	9.045509	4.475642	2.02	**0.047****	.1096024	17.98142
Age	-17.21149	7.414062	-2.32	**0.023****	-32.01414	-2.408834
Educ	2.480523	3.875589	0.64	0.524	-5.25734	10.21839
Gender	11.00363	14.25231	0.77	0.443	-17.45202	39.45927
Responsible	5.332642	5.255903	1.01	0.314	-5.161106	15.82639

Table 3.11 (continued)

Proximity	-4.16481	6.877477	-0.61	0.547	-17.89613	9.566515

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

In OLS Model 1D, *NBS_Contract_Term*, *Income*, and *Age* were significant at the p≤.05 level, with NBS Contract Term with the greatest significance (p=.001). Variables, *Crop_Ac_Own*, *Total_Ac_Oper*, *Flood_Times*, *Worry_Flood*, *Worry_WQuality*, *Program*, and *NBS_know_avg*, were significant at the p≤.15 level (Table 3.12).

Like Model 1C, landowners who own fewer acres of crop land are associated with higher farm payment amounts (p=.144); however, neither *Pasture_Ac_Own* nor *Forest_Ac_Own* did not have a significant relationship with *Payment_NBS*. Also similar to Model 1C, the total number of acres operated was significant with the dependent variable. The more operated acres, the more the NBS payment amount is desired (p≤.10).

All variables found significant in 1C were also found significant in 1D, except *Program* and knowledge (*NBS_know_avg*), which were both significant at p≤.15. Therefore, the landowners who have participated in a conservation cost-share previously are associated with accepting higher NBS payments than those who have participated in a similar program. Also, those individuals with less knowledge about structural NBS practices may require a higher structural NBS payment amount.

Table 3.12: OLS Model 1D of Variables that Affected WTA Structural NBS Payment Amount

Number of obs = 84
F(20, 66) = 9.20
Prob > F = 0.0000
R-squared = 0.5252
Root MSE = 54.387

Table 3.12 (continued)

Payment_NBS	Coefficient	Robust std. err.	t	P>|t|	95% Confidence Interval	
Total_Ac_Own	.0297416	.0608589	0.49	0.627	-.0918752	.1513584
Crop_Ac_Own	-.0859008	.0581035	-1.48	**0.144** [a]	-.2020115	.0302099
Pasture_Ac_Own	.2909824	.2055838	1.42	0.162	-.119844	.7018088
Forest_Ac_Own	-.0178318	.0656476	-0.27	0.787	-.149018	.1133544
Manage_Land	7.611208	17.59833	0.43	0.667	-27.55625	42.77867
Total_Ac_Oper	.0271511	.0139547	1.95	**0.056***	-.0007351	.0550372
Flood_Times	-5.979442	3.155521	-1.89	**0.063***	-12.28525	.3263645
Revenue_Loss	.4691153	.3983019	1.18	0.243	-.3268275	1.265058
Worry_flood	16.43702	9.851445	1.67	**0.100***	-3.249522	36.12356
Worry_WQuality	10.9032	5.88299	1.85	**0.069***	-.8530131	22.65942
Worry_Yields	-7.013587	9.515351	-0.74	0.464	-26.0285	12.00132
Program	-20.68599	14.0813	-1.47	**0.147** [a]	-48.82522	7.453239
NBS_know_avg	-14.07912	8.919625	-1.58	**0.119** [a]	-31.90357	3.745329
NBS_Contract_Term	19.35254	5.467299	3.54	**0.001*****	8.427016	30.27806
Income	10.23	5.129969	1.99	**0.050****	-.0214271	20.48142
Age	-18.87282	8.541596	-2.21	**0.031****	-35.94184	-1.803806
Educ	-.56253	4.863419	-0.12	0.908	-10.2813	9.156237
Gender	18.20336	17.24605	1.06	0.295	-16.26012	52.66685
Responsible	-.6907786	6.116017	-0.11	0.910	-12.91266	11.53111
Proximity	1.638908	7.548826	0.22	0.829	-13.44622	1672403

***Significant at 1%; ** Significant at 5%; * Significant at 10%; [a] Significant at 15%

Discussion

This research provides interesting insights about the use of nature-based solutions (NBS) to reduce flooding, ranging from the experiences and concerns of farm landowners about flooding; their participation in farm programs in the past; their willingness to extend those practices and use NBS; and the amounts of payments that they would require to participate in such programs.

Generally, research shows that landowners are accepting of conservation cost-share programs (Kabii and Horwitz, 2006; Lupek, 2014). There is an enormous body of literature regarding landowner's views of conservation cost-share programs (Chizmar et al., 2021; Cubbage et al., 2003; Pattanayak et al., 2003). Jacobson et al. (2009) discussed that landowners prefer state incentive programs when meeting conservation objectives. Royer and Moulton (1987) found that landowners are more likely to adopt conservation practices like reforestation if they have familiarity with cost-share programs. One reason that landowners may not chose to participate is their lack of trust in the hosting organization or governmental assistance (Cross et al., 2011; Lachapelle et al., 2003; Lupek, 2014). For instance, Kreye et al. (2018) found that family forest landowners in Florida were less trusting of government assistance. Another factor that may hinder landowners' views on conservation programs is lack of knowledge or experience on the program or the technical aspects of adopting the practices (Pattanayak et al., 2003).

Our survey results regarding the interest and WTA farm conservation and structural NBS payments provide many insights for the sample in Robeson County, which is a reasonable microcosm of the North Carolina Coastal Plain and flooding issues. One of the key findings was that there does not seem to be a significant difference between landowners' views of farm conservation programs and potential NBS programs. The basic comparison of the payment amount they would require for participation in these programs was not also statistically different. In addition, while the logistical and OLS regression models of variables that affected their interest had slightly different outcomes between farm conservation and NBS programs, they still were quite similar. A recap of some of these findings follows.

The majority of survey participants experienced major flooding from Hurricane Florence in 2016 (58%) and Hurricane Matthew in 2018 (60%). Excluding these two major storm events, survey respondents reported that they lose a mean of 11% of revenues due to flooding each year. Again, this revenue loss percentage only depicts flooding that occurs after “normal” heavy rain events; not including the most recent devastating storms in 2016 and 2018. Additionally, 55% of respondents conveyed they are concerned about future flooding on their properties, and 64% testified that they worry that future flooding will harm their crop, tree, or livestock yields. Most of the respondents (68%) also indicated that they are concerned that flooding may harm their local water quality. Aligning with Protection Motivation Theory (PMT), we can see that there is a consensus of perceived threats from flooding among survey participants. From these percentages alone, we can assume that this group of landowners would perceive future flooding as a risk and would potentially want to perform preventative actions (Bubeck et al., 2017; Rippetoe and Rogers, 1987; Rogers, 1975). In addition, Pattanayak et al. (2003) indicates that bio-physical factors, such as greater slope, higher chance of erosion, and higher probability of flooding, act as incentives for adopting new technologies to alleviate future impacts. Therefore, we can predict from landowner’s previous experiences with flooding and concerns of future flood events and its affects that landowners will generally be accepting of a potential FloodWise program.

Our survey results also indicated that less than half of respondents (20%) had participated in a previous farm program. We can assume that the 20% that had participated in previous programs would be receptive to the FloodWise program or similar conservation programs (Royer and Moulton, 1987). However, in this study previous program participation (*Program*) was not a significant indicator of WTA.

In addition, our survey respondents had a higher average knowledge score of common farm practices (mean=3, moderately familiar) than structural NBS practices (mean=2, slightly familiar), which was expected as some of the structural NBS practices are more complex and newer concepts than traditional farm practices. Based on previous literature (e.g., Bubeck et al., 2017; Jiang et al., 2018; Pattanayak et al., 2003; Truelove et al., 2015), we anticipated a positive relationship between knowledge and WTA. However, the knowledge of either practice genre (*farm_know_avg* and *NBS_know_avg*) showed to be significant indicators of WTA in this study.

Our results showed that contract term lengths for both types of payments (i.e., *Farm_Contract_Term* and *NBS_Contract_Term*) had a positive relationship with landowner's participation in the FloodWise program. Participants in this study were interested in a 5- to 10-year contract term, similar to Soto et al. (2016)'s, which found landowners in Florida would be WTA payments for a 5- to 10-year commitment in a carbon sequestration program. Markowski-Lindsay et al. (2011) also concluded that individuals would rather have a shorter contract term for planting forests in a carbon offset program. Similarly, Kreyes et al. (2017) and Kang et al. (2019) both discovered that 5- to 10- year contracts were most preferred when participating in a wildlife or forest conservation program.

The majority of the survey respondents (72%) said they would be WTA payments to implement common practices, such as planting cover crops, breaking up hardpan layers, agroforestry, and planting pine and bottomland hardwood trees. We found a mean WTA of USD 128 per acre per year. Like the WTA farm payments, most of our survey participants (69%) responded that they would be WTA payments to adopt structural NBS, such as water farming or flood-controlled wetland practices, per the assumption that installation and maintenance costs would be covered. The mean estimate varied slightly at USD 132 per acre per year compared to the mean WTA farm payment.

These WTA values fall within the range of similar PES studies, at the lower end. For example, Jayalath et al. (2021) found that landowners in the Gulf Coastal Plain and Ozarks would be WTA $290.10 per acre per year to maintain forests and wetlands. Also, on the higher end, Kang et al. (2019) discovered that landowners' WTA baseline payment for planting pine and bottomland hardwood forests was $164 per acre per year.

However, some researchers have found somewhat lower WTA estimates. Soto et al. (2016) indicated that individuals would prefer payments between $20 to $30 per acre per year for maintaining forestland for carbon sequestration. Similarly, Yu and Belcher (2011) found that landowners in Canada would be WTA USD $31 per acre per year for implementing wetlands.

It is important to note that these differences in estimates may be corroborated by the costs and revenues associated with various crops and forest types across different places of the world and at different points in time. The range of WTA bid estimates we offered was restricted to between $40 and $190 per acre per year, which certainly would have limited the bids to within that range, and eliminated open-ended bid approach outcomes with high end averages such as $290 per acre per year. The range we provided in our survey does align with actual averages and ranges experienced by current Farm Bill programs and by our previous calculations of breakeven costs for farmers for both farm conservation programs and for NBS practices (Hovis et al. 2021).

We think that while this eliminates speculative bids by landowners and higher WTA estimates, it still provides the best reasonable bid range based on previous known program outcomes.

Determinants of WTA Farm Payments

Two sociodemographic characteristics, *Income* and *Age*, were associated with the probability of WTA farm payments. The more income landowners make, the more likely they are WTA farm payments ($p \leq .01$). Additionally, we discovered that the younger landowners, the more likely they are to be WTA farm payments than older landowners ($p \leq .05$).

These findings are consistent with results found in similar PES studies (Cubbage et al., 2003: Jiang et al., 2018; Joshi & Mehmood, 2011; Pattanayak et al., 2003; Jayalath et al., 2021). For example, a meta-analysis study by Cubbage et al. (2003) determined that the higher landowners' income, the more likely they are to plant and manage forests. In addition, Pattanayak et al. (2003) concluded that generally, income is statistically correlated with participation in agroforestry programs, and Wei et al. (2016) noted that household income was a factor that positively influenced farmers' willingness to participate in a wetland restoration program.

As for *Age*, Jiang et al. (2018) noted that older farmers might have less time to understand the benefits of investing in a new practice and are less willing to try new practices than younger farmers. In addition, this could be because younger generations are typically more accepting of climate change and its impacts (Lawson et al., 2018; Stevenson & Peterson, 2015; Stevenson et al., 2014).

However, other sociodemographic variables like education level and gender did not significantly correlate with the probability of WTA farm payments ($p \geq .15$). These two findings are consistent with Jayalath et al. (2021). Nyongesa et al. (2016) also found gender not significant ($p \geq .15$); however, they discovered that education had a positive relationship with WTA PES. Similarly, Jiang et al. (2018), Ma et al. (2012), and Wolde et al. (2016) discovered that more educated landowners are more likely to participate in a PES program. This, however, was not the case for our survey sample.

The total of operated acres (*Total_Ac_Oper*) showed a positive relationship with WTA farm payments. A marginal increase in total acres operated leads to the increased probability of WTA farm payments by 1.3%, controlling for other variables in the model. Some of the literature suggests that the larger the land size increases the likelihood of participating in PES (e.g., Gutierrez-Castillo et al., 2022; Ma et al., 2012; Pattanayak et al., 2003; Rabotyagov and Lin, 2013; Wang et al., 2016; however, this is inconsistent across studies (e.g., Cubbage et al., 2003; Jiang et al., 2018; Kang et al., 2019; Nyongesa et al., 2016). For example, Jiang et al. (2018) found a positive relationship between land tract size and their willingness to participate in an energy crop program. Still, the willingness varied among the types of crops. Additionally, the results found by Kang et al. (2019) showed that the size of the property does not impact forest owners' willingness to participate in PES. This could be because many landowners have more than one property, and the size may not be a significant factor in their decision to participate (Kang et al., 2019).

The number of flood times (*Flood_Times*) was negatively associated with the WTA farm payments ($p \leq .05$). The results showed that an increase in the frequency of flood time events decreases the WTA farm payments. This result is not consistent with our anticipated relationship or the literature (Table 3.2). We expected that the more flooding events occurred, the more likely landowners would be WTA payments. The literature states that those who have a higher perception of risk, which can be influenced by previous flood experience, would likely leaddi to WTA farm payments (Campbell Institute, 2014; Pattanayak et al., 2003; Rogers 1975; Wildavsky & Dake, 1990). Brouwer and Schaafsma (2013) also found that landowners' perceived future risk of flooding led to their decision to purchase flood insurance.

This group of landowners may be high-risk adverse, which could be influenced by educational, political, economic, or cultural conditions (Wildavasky & Dake, 1990). Per PMT, which proposes that individuals' perceptive threat and outcome are categorized in two appraisals: risk appraisal and coping appraisal. Risk appraisal consists of two factors: perceived future threats and perceived future consequences (Bubeck et al., 2017). Thus, risk appraisal estimates the perceived threat of future flooding and its impacts on one's property. These survey respondents may not perceive flooding events to be threatening or severe (i.e., risk appraisal) or may perceive that they are able to manage with the risks on their own (i.e., coping appraisal) without receiving payments for flood mitigation practices (Rippetoe and Rogers, 1987).

The relevant survey question asked "On average, how many times have storm events caused major flooding that damaged your crops or fields in Robeson County?" This question did not specify a time period, such as over the past year or the past 10 years. Therefore, newer Robeson County landowners may have not yet experienced flooding impacts in recent memory, although many respondents said that they damage from the major floods of Florence and Matthew within five years ago. We will follow up on this question in one-on-one interviews in 2022.

Determinants of WTA Structural NBS Payments

Like the determinants of landowner's WTA payments for common farm payments, the sociodemographic variable, *Age*, had a positive relationship with the WTA structural NBS payments. Therefore, younger landowners are more likely to be WTA structural NBS payments. These consistencies with the literature have been discussed above. Also, similarly to the WTA farm payments results, *Flood_Times* had a negative relationship with the dependent variable, and we can make conclusions likewise to the determinants of WTA farm payments.

However, different from the WTA farm payments results, variables, *Manage_Land* and *Revenue_Loss*, were found significant and positively associated with the WTA structural NBS payments. An increase in managing land (i.e., landowner that manages their own land; 0=does not manage land) increased the odds ratio of WTA structural NBS payments by .95%. This is in harmony with Lindhjem and Mitani (2012) and Kang et al. (2019)'s findings that suggest landowners who are more active in management are more likely to be WTA payments than those who are absentee owners.

As expected, *Revenue_Loss* displayed a positive relationship with WTA structural NBS payments ($p \leq .10$). Therefore, the more revenue from crop, tree, or livestock production and yields loss from flooding events, the increased likelihood of WTA structural NBS payments. The perception of income gain or loss is one of the most common factors influencing WTA (Pattanayak et al., 2003; Rogers, 1975). Additionally, Brouwser and Schaafsma (2013) noted that individuals are most WTA compensation for flooding damages due to the increased risk of revenue losses. McKillop (1993) also discussed that forest owners respond to environmental regulations, such as conservation program participation, due to the loss of previous revenues from timber production (Kreye et al., 2018). In our case, we can assume that the more timber, livestock, and crop damages caused by flooding will motivate landowners to participate in the FloodWise program.

Determinants of Farm Payment Amount

We examined the factors that influenced the amount of farm payment. We discovered the variable with the greatest significance on the dependent variable, *Payment_Farm*, was *Farm_Contract_Term* ($p \leq .001$). Longer contract term lengths for farm payments are associated with higher payment amounts. If landowners want a more extended farm contract, they want higher amounts. This is consistent with Soto et al.'s (2016) findings that revealed landowners would be WTA payments in a forest carbon offset program at approximately USD 12 per acre per year for a 10-year contract and about USD 29 per acre per year for a 100-year contract. Fletcher et al. (2009) also found an increase in payment amount with an increase in contract length. For example, an average WTA for a one-year contract was approximately USD 15 per acre. A 5-year contract would prefer roughly USD 20 per acre per year and USD 28 per acre per year for a permanent conservation easement. Although these values differ among studies, the increase in payment amount with an increase in contract length is uniform and logical.

The type of land owned showed some differences in the farm payment amount. For example, landowners who own fewer acres of crop land (*Crop_Ac_Own*) are associated with higher farm payment amounts required ($p \leq .05$), and landowners who own more pasture land (*Pasture_Ac_Own*) are associated with higher prices ($p \leq .10$). However, the total forested acres owned (*Forest_Ac_Own*) did not have a significant relationship with *Payment_Farm* ($p \geq .15$). This could be because these individuals have more at stake, such as greater hay, livestock, or pasture yields compared to certain crop production, and suffer more from the impacts of flooding (del Saz-Salazar et al., 2012; Wang et al., 2016). Additionally, the more active acres an individual operated (*Total_Ac_Oper,* p≤.05) was associated with higher amounts. This is similar to Wang et al. (2016) and del Saz-Salazar et al. (2012) findings that determined landowners who had a larger farmland size expected a higher compensation.

The sociodemographic variable, *Income*, proved positively significant at p≤.05, and *Age*, displayed negatively significant p≤.05 on the outcome variable. This denotes that the more income an individual makes, the higher the payment amount they might require. In addition, the younger an individual is, the greater the required payment amount for adopting farm practices.

Last, only significant at 15%, *Worry_Wquality* indicated a positive relationship with *Payment_Farm*. Therefore, we can infer at a weak confidence level that the more people care about water quality is associated with the higher compensation rate. Aligning with PMT (Rogers, 1975), we can suggest that individuals who see a perceived threat to water quality due to flooding will take preventive measures, but at a higher price than those who do not.

Determinants of Structural NBS Payment Amount

Our OLS 1C detected similar determinants to OLS 1C with *NBS_Contract_Term, Income*, *Age*, *Crop_Ac_Own*¸ *Total_Ac_Oper*, *Flood_Times*, *Worry_Flood,* and *Worry_WQuality* were all found significant (p≤.15) with the same associations as to the *Payment_Farm* discussed above.

Although not greatly significant (p≤.15), *Program*, *Worry_flood*, and *NBS_know_avg* were indicators of a higher structural NBS payment amount, which were not indicators of higher or lower farm payment amounts. Landowners who previously participated in conservation cost-share programs are associated with higher structural NBS payments than those who have not participated in a program before. Perhaps this is because structural NBS practices are more intensive, costlier, or potentially unknown than traditional conservation program BMPs, such as cover cropping and no-till farming. A higher price may be associated with structural NBS adoption since it encompasses more complex activities and maintenance.

Also, those individuals who worry more about future flooding occurring on their properties (*Worry_flood*) are associated with wanting higher compensation. This result supports PMT that an increase in one's perceived risk of flooding influences their participation in taking preventative measures (Rogers, 1975). Still, they are most willing to participate at a higher rate of compensation.

Last, individuals' greater knowledge about the structural NBS practices (*NBS_know_avg*) is associated with accepting a higher payment rate. Some structural NBS practices are very costly to establish and maintain, such as flood-controlled wetland and water farming (Hovis et al., 2021). Therefore, we can assume that the landowners who are more familiar with the structural NBS practices understand that they require extra costs, thus, preferring a higher compensation amount. We can also turn to PMT to corroborate this finding. One factor influencing coping appraisal is self-efficacy (Rogers 1975), or one's perceived ability to perform the preventative measures. An increase in knowledge of the structural NBS practices likely influences a landowner's adaptive behavior.

Prospective FloodWise Program Elements and Implementation

An integrated FloodWise program would involve farm demonstration and educational tools for adopting NBS, which will be examined in our future research under the North Carolina Department of Justice Environmental Enhancement Grant that has funded this research.

Engaging and understanding landowners' needs and flooding experiences and involving them in NBS establishment and maintenance training can provide them with the skills to control and manage, also lending them a sense of place and community. Private landowners often consider top-down regulations uncompromising and burdensome (Niemiec et al., 2020). Establishing a sense of place for community members promotes collaboration, builds community identity, and enhances trust among users (Mikalsen & Jentoft, 2001). Pearce (2000) also suggests that sustainable hazard mitigation efforts need interdisciplinary approaches encompassing environmental, social, and economic considerations. Implementing both nature-based and a diverse community-led program can protect farmers' crops and livestock and help prevent flooding damages from occurring downstream. These two components aid in yielding sustainable hazard mitigation while enhancing the environment, the economy, and social capital.

While hazard mitigation initiatives have high start-up costs, the Multihazard Mitigation Council found that mitigation measures reduce the cost of future disasters. The council discovered that for every dollar spent on hazard mitigation, there was an average of four dollars saved (CRS, 2009; MCC, 2005). Overall, hazard mitigation is a cost-effective tool over time and can save human livelihoods. Implementing hazard mitigation practices specific for eastern North Carolina communities can aid in the sustainability and endurance of communities' overall wellness, properties, and goods and services.

Mileti (1999) emphasizes six objectives that must be met for sustainable hazard mitigation: (1) conserving and enhancing environmental quality, (2) sustaining and enhancing human livelihoods, (3) promoting local responsibility and engagement, (4) understanding that lively local economies are crucial, (5) safeguarding generational equity, and (6) incorporating local decision-making and enhancing collective action. The FloodWise program could help achieve Mileti's (1999) six objectives for flood mitigation and yield positive environmental, social, and economic outcomes for rural, eastern North Carolina, and surrounding regions.

There are some options for hazard mitigation efforts and grant programs available in North Carolina to fund these efforts; however, not all are accessible for rural landowners and communities or specific to flood mitigation. Under FEMA's Hazard Mitigation Assistance (HMA) division, there are three federally funded programs to assist with specifically hazard mitigation projects and three federally funded Farm Bill programs -- Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), and Conservation Stewardship Program (CSP)—that help establish specific BMPs (Table 3.13).

At the state level, the North Carolina Agricultural Cost Share Program (NCACSP), established under the Farm Bill and North Carolina Agricultural Water Resources Assistance Program (AgWRAP), supports communities with establishing conservation projects, which have the potential to decrease stormwater runoff, water velocity, and flooding (Table 3.13).

Table 3.13: Flood Mitigation Using NBS Cost-Share Options for North Carolina Landowners

Government Level	Programs
Federal Programs	Hazard Mitigation Grant Program (HMGP)
	Flood Mitigation Assistance (FMA)
	Building Resilience Infrastructure and Communities (BRIC)
	Conservation Reserve Program (CRP)
	Environmental Quality Incentives Program (EQIP)

Table 3.13 (continued)

State Programs	North Carolina Agricultural Cost Share Program (NCACSP)
	Agricultural Water Resources Assistance Program (AgWRAP)
	Forest Development Program (FDP)

Federal Hazard Mitigation and Recovery Programs

FEMA's Hazard Mitigation Assistance (HMA) offers grant programs that provide states and local communities with hazard mitigation funding. The programs aim to reduce or eliminate the harmful impacts on human livelihoods and land brought about by natural hazards, such as flooding. Programs under the HMA include the Hazard Mitigation Grant Program (HMGP), the Flood Mitigation Assistance Grant Program (FMA), and Building Resilient Infrastructure and Communities (BRIC). In 2019, HMA approved 1,229 grants, contributing $840 million in funding to states and local governments for various hazard mitigation projects (FEMA, 2020a).

The HMGP was established under the Robert T. Stafford Act to assist states, territories, tribes, local governments, and private nonprofit organizations once a Presidential disaster is declared. The HMGP is the main disaster risk mitigation policy in the United States to substantially reduce or completely eradicate risks to humans and land from natural hazards (FEMA, 2020a; Ji & Lee, 2019). Eligible entities can receive 75% of the cost of hazard mitigation projects; however, those entities must obtain approval of a mitigation plan, including the local community's participation. The remaining 25% of costs must be derived from non-Federal sources; typically, these costs are funded by the state or local government. The HMGP adheres to different types of hazards and does not solely focus on flood mitigation. Once a

Presidential disaster is declared, the state of North Carolina could apply for funding for specific mitigation projects.

However, there are some downfalls to this program and current gaps in the system. Eligible entities can only receive funding once a Presidential disaster declaration has been stated, and therefore, many projects are only funded based on recovery efforts after disasters have occurred (Birkland, 2009; Glavovic & Smith, 2014). Also, many small and rural communities cannot afford to provide the remaining costs, and many will decide to not participate. In addition, there is lack of flexibility when it comes to climate adaptation efforts due to federal government prescriptive rules and regulations, which also hinders community-led involvement in disaster resilience and planning (Glavovic & Smith, 2014).

In the past, HMGP has allocated funding to small- to medium-sized communities in eastern North Carolina after Hurricane Fran (1996) and Floyd in (1999); two of the largest storm events and flooding impacts the state has ever experienced (Glavovic & Smith, 2014). Post-disasters, HMGP bought out more than 5,000 homes in flood-prone areas to be relocated to higher elevation. HMGP-funded buyouts do not provide funding for maintenance of open space once the property is bought out. Thus, a FloodWise program could allocate funding for establishing and maintaining NBS on the bought-out properties. Many of the bought-out properties are left unattended and abandoned because there is no funding to support on-going maintenance (Glavovic & Smith, 2014; Zavar, 2015). NBS could easily be implemented on these properties if a FloodWise program established.

The BRIC program was established under the Disaster Recovery Reform Act in 2018, which replaced the previous Pre-Disaster Mitigation Program (PDM). In comparison to PDM, BRIC gives a more generous funding cap, allows for pre-award costs, and gives clearer project guidelines such as incorporating particular building codes (Crain, 2020, Aug 26). The purpose of BRIC is to (a) build culture preparedness, (b) better the work force and prepare the nation, and (c) reduce the complexity of FEMA (Crain, 2020, Aug 26). All 50 states, US territories, and tribal governments are eligible to receive assistance. BRIC supports the eligible entities by incentivizing public infrastructure projects, nature-based practices, and modern building codes to reach program goals.

Unlike the HMGP, BRIC will finance to 90% of projects costs for impoverished communities (Crain, 2020, Aug 26). This high-cost share value further incentivizes localities to invest in mitigation projects. BRIC is one of the first federal programs that incentivizes the implementation of nature-based mitigation practices and improves impoverished communities' financial conditions. However, the impacts and advantages of this program are still unknown due to its recent establishment, and funding is very difficult to obtain, especially among low-capacity communities (FEMA, 2020a). Similar to the problems associated to the HMGP, communities that apply for BRIC grants may experience a lag of funding or the denial of funding.

In 2020, FEMA released one of the first reports from stakeholder's experience and opinions of the BRIC program. Many stakeholders acknowledged that the 90/10 cost-share was still burdensome for many small and rural communities and dissuaded them from participating. Some individuals also stated that their community may not qualify as "small impoverished", one criteria of the grant, but still remained under resourced with limited capacity and lack of the staff and funding (FEMA, 2020b). The most frequent stakeholder need was assistance with writing the grant application and understanding FEMA regulations and processes. Many found the application process to be too complex and did not allow for enough flexibility for projects (FEMA, 2020b).

HMGP and BRIC are two federally funded grant programs to assist states and other localities in implementing hazard mitigation strategies. FMA, however, is the only federal-funded program that provides resources to states, tribes, territories, and other local communities specifically for efforts to reduce or eliminate risks of repetitive flood damages (NCDPS, 2020). FMA was established under the National Flood Insurance Program (NFIP) and is administered by FEMA. FMA was designed to help reduce the number of claims under the NFIP. The communities that participate in the NFIP are only eligible to receive assistance, which brings up an issue for those who can receive the funding.

Towns in eastern North Carolina have previously received assistance through FMA. For instance, the City of New Bern is currently working on a project to mitigate flood damages caused by Hurricane Florence in 2018. The project includes elevating residences above base flood elevation, updating to proper building codes, and demolishing damaged flood-prone structures (NC DOA, 2020). However, similar to the funding distribution of the HMGP, the aid is typically offered after a natural disaster has occurred. For instance, the City of New Bern was granted assistance after Hurricane Florence’s impacts in 2018. Additionally, towns that have severely flooded in the past or have flood-related damages on two or more occasions are the only entities qualified to obtain FMA assistance. Towns in eastern North Carolina that have been fortunate to have been missed by previous storms, but are still situated in vulnerable conditions, are not eligible for assistance under the FMA program.

Farm Bill and State Programs

Several federal and state farm and forestry inventive programs also can be used to fund and provide technical assistance to a FloodWise program. CRP and EQIP are other program designed to enhance overall environmental quality. Each of them incentivizes the use of some sort of NBS; although, the program does not emphasize their implementation for hazard mitigation purposes.

For example, the CRP provides landowners with financial incentives to remove land in agricultural production temporarily (around ten to fifteen years) to improve soil, water, and habitat quality (CRS, 2019). Retiring land could help with flood reduction or even allow for water storage; however, this program has been less popular for landowners since commodity prices and land rental rates have risen and landowners would rather keep their lands in production (CSR, 2019). Thus, since 2008, there has been a shift in participation in EQIP rather than CRP since it provides assistance to those with land in production. In addition, there are caps to how many acres can be enrolled, which may or may not be applicable to North Carolina landowners.

Additionally, EQIP gives funding and technical assistance to landowners to install "structural, vegetative, and land management practices on eligible lands to alleviate natural resource problems (CRS, 2019, pg. 6)." However, the funds are only to be used for payments related to livestock practices, wildlife habitat benefits, or air quality concerns (CRS, 2019). Although the NBS for flood reduction may overlap greatly with some of these other practices, such as afforestation or wetland restoration, there is not a specific intent stated for hazard or flood mitigation practices within the program.

State programs that assistant landowners and are more adapted to the specified geography, topography, and environmental conditions could very well be more relevant for NBS implementation. The NCACSP was created to address nonpoint source pollution issues by providing technical and financial incentives for landowners to install best management practices (BMPs) on their agricultural land. The objectives of the program include: (a) properly managing nutrients from runoff, (b) reducing sediment downstream, (c) managing farm pesticide, and (d) reducing freshwater loading in Primary Nursery Areas (NCACSP, 2020). The goal of the program is to develop strategies to address water quality issues that arise from soil erosion, animal waste, fertilizers, construction, and deforestation (NCACSP, 2020). Any landowner or renter of a North Carolina agricultural operation is eligible to participate in the NCACSP and receive benefits to implement BMPs on their lands.

There are a host of BMPs that can be implemented by participants. BMPs are separated into the following practice categories: agricultural pollution prevention, erosion and nutrient management, sediment and nutrient management, stream protection, and waste management (NCACSP, 2020). Although this program was established to resolve water quality and pollution issues, many of the BMPs can help slow down stormwater runoff, store water, and reduce floodwaters on flat agricultural lands. Eligible BMPs such as stream restoration, cover crops, and wetland restoration can help mitigate damages caused by floodwaters. Many of the eligible BMPs are nature-based solutions as opposed to traditional engineered structures such as levees or dams, which have shown to be outdated, highly hazardous, and failed to function adequately when needed the most (Nicholson et al., 2019; Collentine & Futter, 2018).

Even though some of the BMPs can help mitigate floodwaters, this is not the program's primary intention. Eastern North Carolina is a huge target for heavy rainfall, hurricanes, and, subsequently, large amounts of flooding. Also, residents across the state, and even country, rely on eastern North Carolina agricultural commodities. In 2004, North Carolina provided 75.3% of total US production (more than any other state) of tobacco (McLaughlin and Dunn, 2006). It is surprising that the state has not already established a program specific for flood mitigation on agricultural lands due to the high reliance on revenues generated by agricultural goods, as well as the reoccurrence of flood damages.

Another state program with the potential for flood management is AgWRAP, an assistance program administered by the North Carolina Soil and Water Conservation Commission. The objectives of AgWRAP are to (a) identify areas to increase water storage for agricultural purposes, (b) adopt BMPs to conserve water resources, and (c) increase water use efficiency (NCACSP, 2020). The program allocates 70% funding for approved AgWRAP BMP implementation. The remaining 30% must be spent on repairs for irrigation conversions, pond repairs, or water collection and reuse systems through a competitive grant program that requires individuals to apply.

Additionally, the FDP is a cost-share program managed by the NC Forest Service to improve reforestation and afforestation efforts (NCFS, 2021). The goals are not precisely designed for flood mitigation efforts, but it does provide assistance for forest restoration, planting, and management, which is a promising NBS for flood resiliency in the state (Hovis et al., 2021; NCFS, 2021). North Carolina landowners are eligible for up to100 acres of FDP cost-share funds, annually. The program limits the amount of reimbursement costs, which could potentially be problematic or dissuade rural eastern North Carolina landowners from participation.

However, similar to the NCACSP, the AgWRAP and FDP BMPs have the potential to reduce water flow downstream by storing water for a period of time. However, the program has not been designed for flood management or reducing the risks of landowner properties. Thus, a program designated with the outcomes specific to reducing or eliminating floods on agricultural lands is crucial for mitigating future damages in the state.

There are promising options for mitigating floodwaters and reducing flood damages in North Carolina; however, all programs have their shortcomings. Issues such as the lag of funding delivered to states and other localities, deficiencies in top-level management and governance, lack of full funding coverage, and lack of mitigation tactics specific to individual agricultural landowners leave room for mitigation improvements for the state.

Federally funded programs such as HGMP, FMA, BRIC, CRP, EQIP, and CSP can aid states and other localities with the financial and technical support of investing in mitigation projects; however, administrative, technical, and political issues may arise and may discourage communities from participating in mitigation opportunities. Other state programs such as NCACSP and AgWRAP incentivize landowners to adopt BMPs on their properties. However, the BMPs are not explicitly designed for flood management, nor do the financial incentives cover the total cost of the installation and maintenance of the practice, which could dissuade landowners from participating. The FloodWise program could be an all-in-one program that specifically addresses flood reduction and mitigation techniques using NBS, leverages localities for natural resource management and collaboration, and covers the costs of NBS establishment and maintenance.

Recommendations

We recommend that this information be transferred to other communities with similar experiences of climatic patterns and flood events. For most of the Southeastern U.S. coastal and inner-coastal physiographic provinces, flooding is prominent issue and hazard mitigation tactics must be explored. We argue that NBS are a promising solution to reducing flooding downstream, and further research on landowner's perceptions on a cost-share program for flood mitigation objectives should be explored.

However, we acknowledge several limitations in this study. We recognize that small sample size and even smaller number of observations may not accurately depict the opinions and perceptions from the overall population. Future research should further examine Robeson County landowners' perspectives, as well as broader communities in eastern North Carolina. In addition, each of the individual NBS practices require their own costs, and some practices costs more than others. For example, implementing wetland restoration activities will cost double the price of planting pine or hardwood trees (Hovis et al., 2021). A future study assessing WTA estimates for each individual NBS practice as opposed to an overall WTA payment, as we performed in this study, is recommended for more accurate WTA estimates.

The WTA estimates identified in this study can be used to help budget a future FloodWise program. This information can also be used to understand which groups of individuals to promote the future program to, such as younger landowners. Future studies can also assess why landowners may not be WTA and which factors, if any, could incentivize their participation. Our future research plans include in-depth interviews and focus groups, expanding on some of the concepts explored in this study, with landowners in Robeson County. We also plan to extend this similar study to other counties to better generalize landowner's perceptions of flooding risk and WTA within the state.

Conclusion

In this study, we utilized the Contingent Valuation Method, Payment Card, (CVM-PC) to assess Robeson County landowner's WTA payments to participate in a potential FloodWise program, which could act as a hazard mitigation program within the state. Robeson County should be reasonable typical of North Carolina Coastal plain counties in physiography, flooding, and relatively poor demographic characteristics. However, the farmers we surveyed on average had large tracts (mean=292), and were relatively affluent with higher annual incomes (mean category=$75,000-$99,000) than average Robeson County residents. These characteristics are probably favorable for farm program knowledge and enrollment, and would extend to facilitating NBS adoption. Just like farm programs, any NBS programs would need to balance the advantages and efficiencies of working with such larger farmers and the equity of trying to disburse funds and assistance to have practices with willing lower income and minority landowners.

We found that the majority of survey participants (n=105) would be WTA a payment to adopt common farm practices with an average WTA payment of approximately USD 128 per acre per year. Additionally, most survey respondents (n=100) would be WTA structural NBS payments with an average WTA payment amount of USD 132 per acre per year. There was not a significant difference between the amount of farm payment that respondents were WTA and the amount of structural NBS payments (t=0.56). We conclude that landowners who participate in common farm program conservation practices would also be willing to enroll in a flood mitigation program, using NBS, if the establishment costs were covered as assumed and the annual payments were sufficient.

We discovered the main determinants of WTA farm and structural NBS payments were landowners who were younger, wealthier, and operated larger tracts of land. Other factors, such as the length of the contract term and the revenue lost due to previous flooding events, affected the WTA payments. In addition, causes such as landowners' previous participation in a conservation cost-share program, knowledge of practices, concerns of future flooding and water quality impacts, and the type of land owned, such as crop, pasture, or forest land, impacted the amount of the payment.

In conclusion, the proposed FloodWise program could incentivize landowners in eastern North Carolina to implement NBS on their properties and alleviate landowner's financial burdens from high establishment and maintenance costs. Jurisdiction is the greatest constraining factor known for natural infrastructure (Collentine & Futter, 2018), and there have been recommendations for state-level programs that allow for more flexibility for community-led and locally driven projects (Glavovic & Smith, 2014). The FloodWise program could fill the gaps of current mitigation programs such as burdening small and rural communities with remaining establishment and maintenance cost and permit more adaptable practices for localities.

Additionally, drawing from Collentine & Futter (2018), guidance for practitioners and landowners, and payments to provide incentives for adoption of NBS can help prevent the displacement of residents, reduce crop losses, and decrease economic damages to infrastructure, for both rural farm and forest landowners and for downstream communities. As global climate change endures, adapting to new institutional arrangements that adopt NBS and leverage community management is essential for natural disaster resilience and relief.

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CONCLUSION

Communities in eastern North Carolina have been faced with increasing natural hazards like floods and hurricanes, and need new solutions, policies, programs, and technical assistance. The majority of the North Carolina Coastal Plain consists of rural, agricultural lands and these specific communities have seen reduced farm incomes from traditional crops and other land and livestock damages due to the ongoing devastating disturbances. This dissertation assesses nature-based solutions (NBS) to help achieve better disaster resilience and climate adaptation. The pilot program, FloodWise, referred to in this dissertation could help landowners prevent damages on rural lands and downstream by adopting natural flood mitigation and management tactics. Farms and forests can serve as natural buffers and water storage locations, and may offer many opportunities to store and manage stormwaters to prevent rapid runoff and reduce flooding downstream.

The success of effective flood mitigation and a potential cost-share program like FloodWise will rely on collaboration among government and non-government organizations, agricultural producers, and local community members and stakeholders. This research project is a start to that collaboration and network as our co-authors come from various disciplines and sectors. The FloodWise program is a proactive approach to mitigate the impacts from natural hazards and can be more cost-effective than traditional mitigation techniques such as grey infrastructure, which have been expensive, often not successful, and harmful to ecological systems.

In Chapter 1 of this dissertation, we analyze existing and potential NBS for the Coastal Plain of North Carolina, and identify the top most promising practices for flood reduction. The practices differ by their level of current use and familiarity among landowners, their effectiveness to slow down water from storms and store water temporarily, costs, and co-benefits such as revenue generation (i.e., crop and timber harvest) and other ecological outcomes like improved wildlife habitat and water quality. The identified NBS could be broadly applicable to other Coastal Plains in the U.S. Southeast and possibly other regions with similar topography in the world. Our review of these top practices can be used as a guide for landowners in the region who often experience flooding and to help mitigate its effects.

In Chapter 2, we conducted a detailed economic engineering analysis, which allowed us to estimate the costs of establishing and maintaining the ten NBS practices that we identified in Chapter 1. We collected an extensive dataset of all the activities required to establish and maintain each NBS, and noted every cost, including labor and property taxes, and possible revenue. Using discounted cash flow and capital budgeting analysis, we determined the net present values of the costs for each practice at a 6% discount rate. We also calculated payments to offset the costs for the practices with negative net present values, which could incentivize landowners to adopt the practices. The spreadsheets we developed for each of these scenarios can be adapted and used by landowners, technical specialists, other researchers, and decision-makers. The discounted cash flow method and breakeven analysis that we used in chapter 2 have been used in the literature to determine payments for ecosystem services (PES) (e.g., Davies et al., 2021 and Straka, 2010). However, to our knowledge, we believe this is one of the first studies determining PES specifically for flood mitigation on agricultural lands.

From our discounted cash flow and capital budgeting analyses, we concluded that conventional crops – such as soybeans and corn – have the highest rate of returns. However, it is likely that traditional farm practices like cover cropping and no-till are less effective for reducing flooding and storing water compared to more structural NBS like water farming, wetland restoration, and stream restoration. Further research is needed to explore this. The structural NBS; however, are apt to have much higher costs due to more excessive construction and establishment compared to traditional farm practices. The complexity, costs, and unfamiliarity with the structural NBS could deter landowners from adoption on their properties, and farmers may be reluctant to take conventional crops out of production in replace for structural NBS that may or may not provide financial returns. Therefore, FloodWise payments and technical assistance would be an attractive offer for landowners, and encourage their participation in a program to help with flood mitigation. FloodWise payments would be similar to existing federal and state farm programs such as those created under the Farm Bill. However, FloodWise payments may be higher to assure complete coverage of costs.

Last, in Chapter 3, we utilized the Payment Card Contingent Valuation Method to estimate the minimum payment amount that landowners would be willing to accept (WTA). We surveyed landowners in Robeson County to obtain their WTA payments for traditional farm practices and their WTA payments for structural NBS practices. The majority of survey participants would be WTA a payment to adopt common farm practices with an average payment of USD $128 per acre per year. The majority of survey respondents also stated they would be WTA structural NBS payments with an average payment of USD $132 per acre per year. We assumed most landowners were most familiar with the common farm practices, thus, we wanted to compare if the WTA farm practices differed to the WTA structural NBS. However, we did not find a statistical difference. Landowners that were WTA payments to adopt farm practices were also likely to accept payments for structural NBS, assuming that the establishment costs were covered, and the annual payments were adequate.

Our results indicated that the landowners who responded to our survey had on average a large tract size (mean of 292 acres) and had high annual incomes (mean category of $75,000-$99,000). The characteristics and factors that influenced their decision to accept payments for common farm practices includes landowners' age, income, tract operation size, previous flooding experiences, concern of future flooding, and the contract term length of the potential cost-share program if enrolled. Thus, landowners who are younger, wealthier, and operated larger tracts were more likely to accept payments for common farm practices. Some of the variables that affected landowner's choice to accept payments for structural NBS were similar to the WTA farm practice payments, such as age and contract term length. However, different from the WTA farm payments, whether the landowner managed their own land or not was a significant factor, as well as the amount of revenue previously lost from flood damages.

We also examined the determinants that affected the amount or price of the payment required. Factors such as landowners' previous participation in a conservation cost-share program, knowledge of practices, concerns of future flooding and water quality impacts, and the type of land owned, such as crop, pasture, or forest land, affected the amount of the payment.

The payment estimates identified in this study can be used to help estimate funds required for a future program such as FloodWise, and the factors that lead participants enrolled and accept payment, as well as utilized to understand which groups of individuals to promote the future program to.

Overall, flooding and changes in climatic events that disrupt human and ecological livelihoods are problems for many communities with the U.S. Southeast. Although we analyzed this program in eastern North Carolina, this information can be transferable to other communities with similar experiences with flooding on rural landscapes. Robeson County closely resembles other North Carolina Coastal Plain counties in terms of physiography, chronic flooding, and social vulnerability. NBS is promising for future flood mitigation efforts and prorams such as FloodWise could be a regional initiative to assist landowners with implementing the mitigation practices. Just like similar farm cost-share programs, a program would need to balance working with larger commercial farmers and pay special considersation to the equity of funding distribution to minority landowners.

As climate change progresses and adverse weather and flooding events become more frequent and extreme, developing effective NBS and leveraging community-based management efforts for adapting to and reducing flood peaks will be one important response. The findings in this dissertation can contribute significant to future climate adaptation decision-making and implementation for the state.

Future Work

A continuation of this research will include site assessments and demonstrations with local landowners. Local collaborative and engagement with stakeholders will be key in developing a NBS program. The demonstration sites will also allow for researchers and farmers to estimate which practices are most effective on-the-ground to reduce water levels downstream. Demonstrations could help track how long the stormwater may be stored for on an agricultural plot, and possibly the amount of water stored. This information could help develop an overall program benefit-cost analysis, which assesses the preventative damage costs and the benefits that the NBS provide.

We have planned to conduct focus groups and semi-structured interviews with landowners in eastern North Carolina to gather in-depth qualitative data to triangulate the findings in this dissertation and reveal other important policy themes to implement such a program.

Last, we recommend that future research include a review of additional NBS from the iterative scoping process discussed in Chapter 1. We recognize that these techniques will not be able to mitigation flooding completely; however, with additional NBS, not reviewed in this dissertation, we could have a greater chance of preventing damages. Utilization of NBS is an important developing research subject, and we anticipate many researchers and practitioners will use this information and expand on our work as NBS advances in the coming years for hazard mitigation purposes.

APPENDICES

Appendix A: List of Possible Floodwater Retention Practices Classified by Desirability

Priority	Practice	Description
"Best"		
1	Cover crops and no till	Keep plants on the fields in winter to help improve soil infiltration throughout the year. No till also reduces soil erosion and rapid overland flow.
1	Break Up Hardpan	Break up hardpan to allow for deeper water infiltration may slow runoff.
1	Forestry	Plant hardwood and pine trees on marginal crop or pasture lands
1	Agroforestry	Mixes of trees and pasture grasses may increase infiltration and slow runoff.
1	Wetland Restoration	Restore natural wetland areas along streams, or along low points in the landscapes. In NC, may be able to restore the unique Carolina Bays. Plant wetland plant species or trees in marginal crop or pasture lands. Create wetland basin to store water temporarily.
1	Stream Restoration	Restore and convert streams to a natural, meandering configuration.
1	Dry Dams and Berms (i.e., Water Farming)	Create catchment areas to hold excess water in times of flooding and allow water to flow freely in normal conditions.
1	Land Drainage Controls	Install tiling and tile-outlet terraces to drain excess water from agriculture land.
"Possible"		
2	Flood Tolerant and Preferable Crop and Pasture Species	Use preferred grass species such as summer grasses (e.g., bluestem, switchgrass)
2	Greentree Reservoirs	Manage restored wetlands with tree species, largely for migratory birds and hunting
2	Daylight Piped Streams	Restore natural stream channel and floodplain, a type of stream restoration
2	Pump Water from Rivers/Canals onto Private Property	Pump water from rivers onto adjacent properties for storage after heavy rains. Storage areas can be drainage ditch networks, farm ponds, or wetlands. Mostly appears to be used by citrus groves in Florida.
2	Saturated Buffer on Fields	Install French drain-like structures on the downward slope side of the field.
2	Fill Drainage Ditches	Create drainage ditches that are filled with coarse sand to slow runoff.

2	Bio-Retention Basins	Develop bio-detention areas and planting wetland vegetation around them.
2	Coastal Wetland Restoration	Restore wetland systems along the coastline, providing a buffer against storm surges.
“Not promising”		
3	Aquifer Recharge System	Inject surface waters into underground aquifers for storage.
3	Leaky Dams	Install dams made of large logs installed in tributaries and wetlands, simulating beaver dams.

Appendix B: North Carolina Topography Map and Major River Systems Geospatial Information Services (GIS) sources

Hillshade - 20ft grid cells
North Carolina Department of Information Technology (2021). Government Data Analytics Center, Center for Geographic Information and Analysis. Accessed from NC OneMap Geospatial Portal. Available at https://www.nconemap.gov.

North Carolina Boundary (Extracted from National File)
United States Census Bureau (2020). Spatial Data Collection and Products Branch, Geography Division. Accessed from TIGER/Line Shapefile Geospatial Portal. Available at https://www.census.gov/cgi-bin/geo/shapefiles/index.php

Coastal Plain Physiographic Region (Level III Ecoregions of the Conterminous United States)
United States Environmental Protection Agency (2013). National Health and Environmental Effects Research Laboratory. Accessed from EPA Ecosystems Research page. Available at https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

Major Rivers (National Hydrography Dataset Plus - High Resolution)
United States Geological Survey (2019). Accessed from The National Map Data Download Portal. Available at https://apps.nationalmap.gov/downloader/#/

Appendix C: Cost Inputs for Cover Crop & No-Till Scenarios

Cost Inputs for Cover Crops – Soybean (SB) and Winter Wheat (WW) Cover Crop & No-Till Scenario A	
Activity	**$/Acre**
Establishment	**$434.97**
Seed (SB)	$44.00
Fertilizer – Nitrogen (SB)	$18.09
Fertilizer – Potash (SB)	$22.26
Lime (SB)	$16.83
Hauling (SB)	$10.40
Machinery (SB)	$80.80
Labor (SB)	$22.26
Seed (WW)	$45.00
Fertilizer – N, Ph, Potash (WW)	$56.55
Lime (WW)	$11.41
Hauling (WW)	$14.00
Machinery (WW)	$23.13
Labor (WW)	$19.81
Planning	$50.00
Periodic Maintenance Treatments	**$63.18**
Herbicide (SB)	$31.59
Herbicide (WW)	$31.59

Cost Inputs for Cover Crops & No-Till – Corn (C) and Cool-Season Pasture (P) Cover Crop & No-Till Scenario B	
Activity	**$/Acre**
Establishment	**$518.65**
Seed (C)	$79.68
Lime (C)	$16.83
Fertilizer – Nitrogen (C)	$43.40
Fertilizer – Potash (C)	$13.80
Hauling (C)	$70.00
Machinery (C)	$80.80
Labor (C)	$22.26
Scout (C)	$12.00
Lime (P)	$56.55
Fertilizer – N, P, K (P)	$11.41
Other Soil Amendments (P)	$14.00

Seed (P)	$23.13
Herbicide (P)	$19.81
Machine, Labor, Storage, Inspection	$54.98
Periodic Maintenance Treatments	**$98.97**
Herbicide, Equipment, & Labor	$32.72
Lime	$10.50
Fertilizer – N, P, K	$50.28
Drying, Irrigation, & Energy	$5.47

Appendix D: Cost Inputs for Hardpan Breakup Scenario

Cost Inputs for Hardpan Breakup Hardpan Breakup Scenario A	
Activity	**$/Acre**
Establishment	**$153.06**
Machinery	$80.80
Labor	$22.26
Planning	$50.00
Periodic Maintenance Treatments	**$25.28**
Heavy Duty Ripper/Subsoiler	$11.50
200 HP Tractor	$10.94
Labor	$2.84

Appendix E: Cost Inputs for Afforestation Scenarios

Cost Inputs for Bottomland Hardwood Afforestation Afforestation Scenario A	
Activity	**$/Acre**
Site Preparation	**$195.00**
Chemical Release	$95.00
General Site Preparation, Plowing, Layout	$100.00
Planting	**$400.00**
Seedlings	$240.00
Planting	$160.00
Periodic Stand Treatments	**$155.00**
Herbicide and Cleaning (Per Application)	$65.00
Fertilizer (Mid-Rotation)	$90.00
Management	**$12.00**
Disease Control & Prevention, Roads, Fire Control	$12.00

Cost Inputs for Loblolly Pine Afforestation Afforestation Scenario B	
Activity	**$/Acre**
Site Preparation	**$180.00**
Mechanical Preparation, Plowing, Ripping	$100.00
Chemical & Control	$80.00
Stand Establishment	**$100.00**
Loblolly Hand Planting	$100.00
Management	**$10.00**
Disease Control & Prevention, Roads, Fire Control	$10.00

Appendix F: Cost Inputs for Agroforestry Scenarios

Cost Inputs for Loblolly Pine Forest Only Agroforestry Scenario A	
Activity	**$/Acre**
Site Preparation	**$180.00**
Mechanical Preparation, Plowing, Ripping	$100.00
Chemical & Control	$80.00
Stand Establishment	**$100.00**
Loblolly Hand Planting	$100.00
Management	**$10.00**
Disease Control & Prevention, Roads, Fire Control	$10.00

Cost Inputs for Loblolly Pine Forest, 20% Trees Agroforestry Scenario B	
Activity	**$/Acre**
Site Preparation	**$36.00**
Mechanical Preparation, Plowing, Ripping	$20.00
Chemical & Control	$16.00
Stand Establishment	**$50.00**
Loblolly Hand Planting	$50.00

Cost Inputs for Cool-Season Pasture Only Agroforestry Scenario C	
Activity	**$/Acre**
Establishment	**$198.63**
Fertilizer – N, P, K	$37.90
Other Soil Amendments	$63.00
Seed	$33.00
Herbicide	$9.75
Machine, Labor, Storage, Inspection	$54.98
Annual or Periodic Treatments	**$127.04**
Lime and Other Amendments	$10.50
Fertilizer – N, P, K	$50.28
Drying, Irrigation, & Energy	$5.47
Machine, Labor, Storage, Inspection	$60.79
Management	**$84.13**
Other	$84.13

Cost Inputs for Warm-Season Pasture Only Agroforestry Scenario D	
Activity	**$/Acre**
Establishment	**$198.63**
Fertilizer – N, P, K	$37.90
Other Soil Amendments	$63.00
Seed	$33.00
Herbicide	$9.75
Machine, Labor, Storage, Inspection	$54.98
Annual or Periodic Treatments	**$127.04**
Lime and Other Amendments	$10.50
Fertilizer – N, P, K	$50.28
Drying, Irrigation, & Energy	$5.47
Machine, Labor, Storage, Inspection	$60.79
Management	**$84.13**
Other	$84.13

Cost Inputs for 70% Cool-Season Pasture & 20% Trees Agroforestry Scenario E	
Activity	**$/Acre**
Establishment	**$198.63**
Fertilizer – N, P, K	$37.90
Other Soil Amendments	$63.00
Seed	$33.00
Herbicide	$9.75
Machine, Labor, Storage, Inspection	$54.98
Annual or Periodic Treatments	**$127.04**
Lime and Other Amendments	$10.50
Fertilizer – N, P, K	$50.28
Drying, Irrigation, & Energy	$5.47
Machine, Labor, Storage, Inspection	$60.79
Management	**$84.13**
Other	$84.13

Cost Inputs for 70% Warm-Season Pasture & 20% Trees Agroforestry Scenario F	
Activity	**$/Acre**
Establishment	**$198.63**

Fertilizer – N, P, K	$37.90
Other Soil Amendments	$63.00
Seed	$33.00
Herbicide	$9.75
Machine, Labor, Storage, Inspection	$54.98
Annual or Periodic Treatments	**$127.04**
Lime and Other Amendments	$10.50
Fertilizer – N, P, K	$50.28
Drying, Irrigation, & Energy	$5.47
Machine, Labor, Storage, Inspection	$60.79
Management	**$84.13**
Other	$84.13

Appendix G: Cost Inputs for Wetland Restoration Scenarios

Cost Inputs for Flood Control Wetland Creation Wetland Restoration Scenario A	
Activity	**$/Acre**
Establishment	**$87,454.29**
Earthwork	$73,384.62
Matting	$794.36
Silt Fence	$221.54
Check Dams	$132.78
Seeding	$132.46
Planting	$4,840.00
Rip Rap/Stone	$1,884.62
Outlet	$272.53
Pump	$527.47
Survey	$1,124.54
Mobilization	$4,139.37
Periodic Maintenance Treatments	**$200.00**
Sediment/Debris Cleaning & Ditch Maintenance	$200.00
Annual Management	**$20.00**
Property Taxes & Administration & Overhead	$20.00

Cost Inputs for Forested Wetland Bank (on Prior Converted Cropland) Wetland Restoration Scenario B	
Activity	**$/Acre**
Establishment (Years 0-2)	**$10,700.00**
Site Evaluation	$200.00
Draft Bank Instrument	$2,100.00
Final Banking Instrument	$300.00
Section 404 Permitting	$200.00
Record Restrictive Covenant	$200.00
Construction, Sire Grading, & Tree Planting	$7,500.00
Report with GPS Survey & Local Credit Schedule	$200.00
Annual Management (Years 0-10)	**$400.00**
Monitoring of Bank & Reference Sites	$400.00

Appendix H: Cost Inputs for Stream Restoartion Scenario

Cost Inputs for Stream Restoration Stream Restoration Scenario A	
Activity	**$/Linear Foot**
Establishment	**$119.54**
Clearing & Grubbing	$0.79
Grading	$39.06
Planting & Seeding	$16.68
Invasive Species Control	$0.54
Rock Structures	$10.31
Log & Brush Structures	$12.58
Erosion Control	$9.95
Pumping & Diversion	$3.99
Staging & Haul Roads	$5.42
Miscellaneous Infrastructure (E.g., culverts, fencing)	$7.34
Wetland BMP	$0.27
Mobilization	$7.15
Survey & Boundary Marking	$5.46
Annual Management (Years 0-7)	**$166.00**
Site Assessment, Monitoring, and Maintenance	$166.00

Appendix I: Cost Inputs for Water Farming Scenario

Cost Inputs for Water Farming (Dry Dams and Berms) Water Farming Scenario A	
Activity	**$/Acre**
Establishment	**$3,242.27**
Earthwork	$1,121.29
Rock Structures	$190.89
Erosion Control	$286.12
Infrastructure	$218.16
Mobilization	$98.74
Survey	$158.42
Site ID	$59.25
Property	$161.00
Design	$355.48
Contingency	$177.74
Assurances	$59.25
Markup/Profit	$355.48
Periodic Maintenance Treatments	**$200.00**
Sediment/Debris Cleaning & Ditch Maintenance	$200.00
Annual Management	**$20.00**
Property Taxes & Administration & Overhead	$20.00

Appendix J: Cost Inputs for Land Drainage Features Scenario

Cost Inputs for Land Drainage Features Land Drainage Features Scenario A	
Activity	**$/Acre**
Establishment	**$1,495.53**
Tractor Backhoe Rental	$3.68
Tile Plow Rental	$2.78
Trencher Rental	$4.02
Labor	$1.53
Control Box 6’	$66.56
Perforate Pipe (Polyethylene) with Cloth Filter	$1,366.56
Animal Guard Flap Gate	$0.40
Elevation Survey	$20.00
Design Survey	$10.00
Flagging/Stakeout	$20.00
Periodic Maintenance Treatments	**$5.00**
Remove Sediment & Debris Cleaning	$5.00

Appendix K: Survey Questionnaire

ROBESON COUNTY FLOODWISE FARM OWNER/OPERATOR SURVEY

Description

Flooding is the most frequent natural disaster globally and one of the most devastating in both lives lost and economic damage. Many of North Carolina's agricultural and urban communities have been hit hard by intense hurricanes, especially since 2015. Alternative mitigation practices that reduce flood damage should be further explored.

We are asking you to complete a brief survey on your experiences with flooding and preferences regarding flood mitigation program design. We have termed this research and outreach effort *FloodWise* to reflect the need for farmers and communities to adopt new natural flood management practices, financial incentives, and community governance methods for program delivery.

This survey is part of a project about flooding and farm conservation program development conducted by a study team at North Carolina State University, NC Farm Bureau, NC Association of Soil and Water Conservation Districts, and NC Foundation for Soil & Water Conservation.

The survey should not take more than 20 minutes of your time. Your participation is voluntary, and your responses will remain confidential. You may withdraw from participation at any time even after providing consent to participate. By filling out this survey, you consent to having a researcher include your responses in their analysis. **A separate consent form is on the back of this booklet.**

If you have any questions, please contact Meredith Hovis, graduate student, at mehovis@ncsu.edu, or Dr. Fred Cubbage at cubbage@ncsu.edu or phone at 919-515-7789.

Please fill it out only once. When you are done, please fold the survey in the return envelope provided in your packet and place it in the return envelope provided in your packet and mail it back. Or you may take the survey online:

SCAN QR CODE WITH SMARTPHONE CAMERA OR GO TO GO.NCSU.EDU/FLOODWISE2021

Section A: Landowner Experience with Flooding

1. Do you own or operate farm or forestland in **Robeson County**, N.C.? (Please check which ones apply)

	Own	Operate
Yes		
No		

If you checked no to both → you have finished the survey → **please return it**

2. How many total acres do you own or operate in Robeson County by land use? (Please fill in the blanks with your best estimate)

	Own	Operate
Total Area (acres)		
Crops (acres)		

Pasture/Fields (acres)		
Forest (acres)		
Other:		

3. How close do you live to the land you farm in Robeson County? (Circle the **best letter** estimate)

   a. On or near the land
   b. Within 50 miles
   c. Elsewhere in North Carolina
   d. Out of state

4. How many years have you (or your family) owned of farmed these tract(s) in Robeson County? (Circle the **best letter** estimate)

   a. 0 - 5 years
   b. 6 - 10 years
   c. 11 - 20 years
   d. 21 - 30 years
   e. 31 - 40 years
   f. 40+ years

5. Did any of these storms cause major flooding that damaged crops or fields on any part of your tract(s) in Robeson County? (Circle **all** that apply)

   Hurricane Florence, 2018
   Hurricane Matthew, 2016
   Hurricane Floyd, 1999
   Hurricane Fran, 1996

6. **On average**, how many times have storm events caused major flooding that damaged your crops or fields in Robeson County? (Circle **best letter** choice)

   a. Never
   b. Every 25 years
   c. Every 15 years
   d. Every 10 years
   e. Every 7 years
   f. Every 5 years
   g. Every 2 years
   h. Every year

7. Since 2015, have you ever received crop insurance payments because of flooding on your tract(s) in Robeson County?

   [ ] No. [ ] Yes. How many times?___ [ ] I don't know.

8. <u>Excluding Hurricanes Florence and Matthew</u>, because of flooding, approximately what percentage of your expected annual agricultural revenues were lost because of flooding since 2015?

   a. 5% or less
   b. 10%
   c. 20%
   d. 30%
   e. 40%
   f. 50%
   g. 60%
   h. 70%
   i. 80%
   j. 90%
   k. 100%
   l. 0% -no major flooding

9. Please circle (1 to 5) the extent to which you strongly disagree (SD), disagree (D), have no opinion (N) agree (A) or strongly agree (SA) with each statement.

Statement	SD	D	N	A	SA
I worry about my farmland flooding after a major rainfall.	1	2	3	4	5
I worry that floods may harm my crop, tree, or livestock yields.	1	2	3	4	5
I already use practices to reduce flooding on my property.	1	2	3	4	5
I worry that flooding may harm water quality.	1	2	3	4	5

10. Which of the following actions have you taken in response to a flood event?

    a. Avoided planting crops in areas prone to flooding
    b. Planted trees or other vegetation in areas prone to flooding
    c. Built or enhanced tiling
    d. Built or enhanced ditches and canals
    e. Built or enhanced other water control structures
    f. Switched to different crops in flood-affected areas
    g. Practiced no-till
    h. Planted cover crops
    i. Other (please specify): ___________________________
    j. No actions taken

Section B: Knowledge of Conservation Practices

11. In the past 5 years, have you participated in a program that paid you for land conservation?

    [ ] No – {{if "No", continue to Question 12}}
    [ ] Yes - If "Yes", which program(s)? (Circle all that apply)

    a. Conservation Reserve Program (CRP)
    b. Conservation Reserve Enhancement Program (CREP)
    c. Environmental Quality Incentive Program (EQIP)
    d. Forest Land Enhancement Program (FLEP)
    e. Partners for Fish and Wildlife Program
    f. Wetland Reserve Program (WRP)
    g. Wildlife Habitat Incentives Program (WHIP)
    h. A conservation or mitigation banking program
    i. A state agricultural cost share program for soil and water
    j. A state forestry cost share program
    k. A conservation easement with a land trust
    l. Other (please specify) ___________________________
    m. I have participated in a program, but don't know which program

NATURE-BASED SOLUTIONS

12. Before this survey, have you heard or read about the terms "Nature-Based Solutions (NBS)" or "Natural Infrastructure"?

    [ ] Yes [ ] No [ ] I don't know

We define nature-based solutions (NBS), also known as "natural infrastructure", as practices that work with nature or mimic nature to address natural hazards like flooding to benefit both human well-being and biodiversity. Specifically, NBS involve the protection, restoration, or management of natural and semi-natural ecosystems. Examples of nature-based flood control practices may include:

(a) Common or modified **farm conservation practices**, including no-till, cover crops, hardpan breakup, forest planting, agroforestry.

(b) Various land and hydrology **structural NBS water management practices** such as tiling, drainage, wetland or stream restoration, temporary water storage on fields (Figure A on page 6) or constructed wetland water catchments/basins (Figure B on page 6).

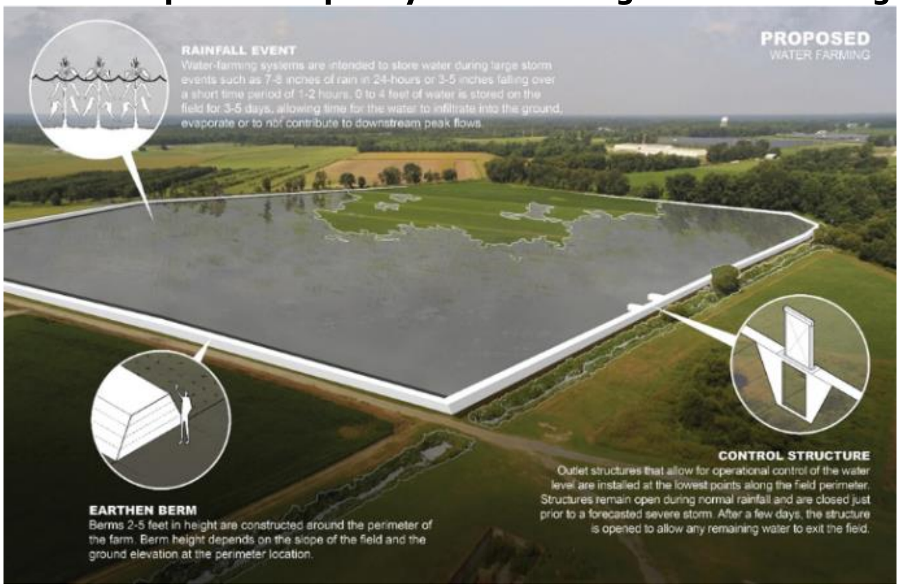
13. Have you ever used nature-based solutions on your property?

    [ ] Yes [ ] No [ ] I don't know

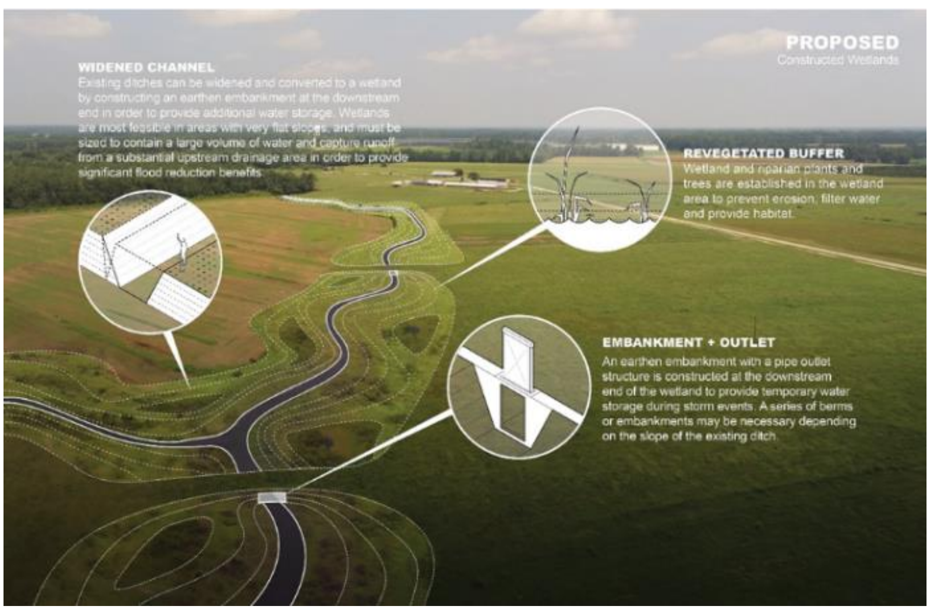
If yes, please describe the ways that you have used nature-based solutions:

____
____
____
____
____
____

A. Proposed Temporary Field Flooding – Water Farming



B. Proposed Wetland Water Catchment Basin, Dams, and Risers



14. Please circle (1 to 5) the extent to which you strongly disagree (SD), disagree (D), have no opinion (N) agree (A) or strongly agree (SA) with each statement.

Statement	**SD**	**D**	**N**	**A**	**SA**
I believe that nature-based solutions (NBS) could reduce flooding risk on my property.	1	2	3	4	5
I believe that NBS could reduce flood risk to communities downstream.	1	2	3	4	5
I feel confident that I could perform certain NBS on my property.	1	2	3	4	5
I would require payments to install and maintain NBS.	1	2	3	4	5
I would require payments to cover the costs of any crops or pastures lost during flooding caused by NBS.	1	2	3	4	5
I might participate in a NBS flood reduction program if I received help to implement and maintain them.	1	2	3	4	5
Implementing NBS flood reduction practices are too costly even with landowner or operator incentives.	1	2	3	4	5
Implementing NBS flood reduction practices would be too time consuming, reducing other farm activities.	1	2	3	4	5
It is my responsibility as a property owner/operator to incorporate flood reduction practices.	1	2	3	4	5
I would not implement nature-based flood reduction practices for reasons other than costs.	1	2	3	4	5

15. Please indicate to what extent you are familiar with the following farm conservation and nature-based solutions. Check **one** box per line.

Practice	Not familiar	Slightly familiar	Moderately familiar	Very familiar	Extremely familiar
Common Farm Conservation Practices					
Cover crops					
No-till cropping					

Hardpan Breakup					
Planting pines					
Planting hardwoods					
Agroforestry/ silvopasture					
Structural NBS Water Management Practices					
Tiling with Water Storage Berms					
Stream Restoration					
Forest Wetland Restoration/ Banks					
Field ditching/ Control/Drainage Districts					
Temporary Field Flooding (see "A" on page 6)					
Wetland Water Catch Basins (see "B" on page 6)					

Section C: Program Preferences

Assume that installing NBS practices might flood your farm fields or forests for periods of up to one week after a major storm event to prevent flooding elsewhere on the farm or downstream. Federal, state, or local programs could pay you to store this water temporarily. Assume that:

(a) You could install common agricultural **farm conservation practices** (no-till, cover crops, hardpan breakup, forest planting, agroforestry) for partial cost-share payments, like farm conservation programs, and

(b) Technical experts and full incentives will be paid to cover the costs for establishing **structural NBS water management practices** (tiling with water storage berms, stream and wetland restoration, field ditching and draining, temporary managed field flooding (Figure A on cover), wetland water catchment basins (Figure B on cover).

16. Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Circle **all letters** that apply).

a. Productive crop lands
b. Marginal crop lands
c. Productive pasture and grazing land
d. Marginal pasture and grazing land
e. Brushy and grown-up fields
f. Forest land
g. Other: ___________________
h. None of the above

17. If adequate funding were provided, which of the following farm conservation and structural nature-based practices would you consider implementing to prevent future flooding? (Circle **all letters** that apply)

    a. Cover crops
    b. No till cropping
    c. Hardpan breakup
    d. Planting pines
    e. Planting hardwoods
    f. Agroforestry
    g. Tiling with berms
    h. Stream restoration
    i. Forested wetland restoration
    j. Field ditching/drainage districts
    k. Managed field flooding/water farming
    l. Wetland water catchment basins
    m. Other:___________________
    n. None of the above

Assume there were a FloodWise program to assist with implementing **common farm conservation practices** of no-till, cover crops, hardpan breakup, forest planting, agroforestry/silvopasture on your property, circle the contract term length that you would require. (Circle **one** letter)

a. 5-year contract with annual payments
b. 10-year contract with annual payments
c. 20-year contract with annual payments
d. 30-year contract, annual payments
e. More than 30 years, annual payments
f. Permanent land easement
g. None of the above. I would not participate

18. If you enrolled in these **common farm conservation practices** programs to reduce floods for the contract duration above, assume you would get paid at similar rates for existing farm conservation programs.

    a. What cost-share rate would you require to establish the preceding farm conservation practices? (Circle the best **one** choice)

10%	40%	70%	100%
20%	50%	80%	None, I would not participate
30%	60%	90%	

    b. What is the **minimum** payment per acre per year you would accept to participate in and maintain the above farm conservation practices? (Circle the best **one** choice)

\$40	\$70	\$110	\$140	\$170
\$50	\$80	\$120	\$150	\$180
\$60	\$90	\$130	\$160	\$190

    None, I would not participate

19. Assume that due to the higher costs, a FloodWise program that would pay for the establishment and annual management costs for implementing **structural water management practices** of tiling with water storage berms, stream and wetland restoration, field ditching and draining, temporary managed field flooding (Figure A, page 2), wetland water catchment basins (Figure B, page 3), circle the contract term length that you would accept. (Circle the best **one letter** choice)

a. 5-year contract with annual payments
b. 10-year contract with annual payments
c. 20-year contract with annual payments
d. 30-year contract, annual payments
e. More than 30 years, annual payments
f. Permanent land easement
g. None of the above. I would not wish to participate.

20. If you enrolled in a FloodWise program to reduce floods for the contract duration you selected in question 20, assume that you would get paid: (1) 100% of the costs to establish the practices and compensation when crops are lost due to the practice, (2) annual payments for keeping these practices for the term of the contract, and (3) payment for any crop losses.

    What is the **minimum** payment per acre per year you would accept to participate in and maintain the **structural NBS water management practices**—e.g., let the program "lease" your land for the designated practice and time period? (Circle the best **one** choice)

$40	$70	$110	$140	$170
$50	$80	$120	$150	$180
$60	$90	$130	$160	$190

None, I would not participate

21. Please indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property. Please circle (1 to 5) the extent to which you strongly disagree (SD), disagree (D), have no opinion (N) agree (A) or strongly agree (SA) with each statement, **one** per line.

Organization	**SD**	**D**	**N**	**A**	**SA**
NC Cooperative Extension Service (County Agents)	1	2	3	4	5
NC Farm Bureau	1	2	3	4	5
NC Dept. of Agriculture Services	1	2	3	4	5
NC Soil and Water Conservation Districts	1	2	3	4	5
NC Water Drainage Districts	1	2	3	4	5
NC Wildlife Resources Commission	1	2	3	4	5
A nonprofit land conservancy or environmental organization	1	2	3	4	5

USDA Farm Services Agency	1	2	3	4	5
US Federal Emergency Management Agency (FEMA)	1	2	3	4	5
US Fish and Wildlife Service	1	2	3	4	5
USDA Natural Resource Conservation Service (NRCS)	1	2	3	4	5
Other(s) (Please specify): ______________________________	1	2	3	4	5

Section D: Demographic Questions

In order to more fully understand your responses to the previous questions, we need to know a few things about your background. Remember that your responses are *__completely confidential__*. Neither your name nor your address will be linked to your responses in any way. Please circle the best letter choices.

22. What is your gender? a. male b. female

23. What is the highest level of schooling/education you have completed?
    a. High school or GED
    b. Vocational, technical, trade school or certificate program
    c. Associates degree (2-year degree)
    d. Bachelors degree (4-year degree)
    e. Graduate degree
    f. Professional degree
    g. Other (please specify): ___________________________________

24. What is your age in years?
    a. Less than 30
    b. 31-45
    c. 46-60
    d. 61-75
    e. 76 or more

25. What is your race/ethnicity?
    a. White/Caucasian
    b. Black/African American
    d. Hispanic/Latino
    e. Asian

c. Native American/ Indigenous

f. Other (please specify): ___________________

26. What was your approximate total household income (AGI) in 2020?

a. less than $24,999
b. $25,000 - $49,999
c. $50,000 - $74,999
d. $75,000 - $99,999
e. $100,000 - $149,999
f. $150,000 or more

-end of survey-

THANK YOU for your participation! Please share any additional comments:

____
____
____
____

Consent Form

Title of Study: FloodWise: Flood Reduction for Farms and Communities in Eastern North Carolina
Principal Investigator: Dr. Fred Cubbage
Funding Source: NC Department of Justice
Point of Contact: Fred Cubbage, 919.515.7789, cubbage@ncsu.edu

- You are being asked to complete a survey about farm conservation program development. Completing this survey is voluntary. You can stop at any time and do not need to return the survey.
- You must be 18 years of age and reside in the United States to participate in this survey. There are minimal risks associated with your participation in this survey. You will not receive compensation for completing this survey.
- If you have any questions about the survey, how it is implemented, or survey compensation, please contact Dr. Fred Cubbage (see contact info above). If you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NC State University Institutional Review Board at IRB-Director@ncsu.edu or 919.515.8754 for help.

If you consent to complete this survey, please return it in the provided stamped envelope to the following address. Please do not include personal information such as your address or name. All surveys sent out and returned are anonymous.

Fred Cubbage
Department of Forestry and Environmental Resources
Box 8008, North Carolina State University, Raleigh, NC 27695-8008

Appendix L: Variable Codebook

Code_ID	**Description**	**Levels**
Own_Land	Do you own land in Robeson County?	Yes=1, No=0
Manage_Land	Do you manage land in Robeson County?	Yes=1, No=0
Total_Ac_Own	How many total acres of land do you own in Robeson County?	Continuous
Total_Ac_Oper	How many total acres of land do you operate in Robeson County	Continuous
Crop_Ac_Own	How many acres of land do you own are in crops?	Continuous
Crop_Ac_Oper	How many acres of land do you operate that are in crops?	Continuous
Pasture_Ac_Own	How many acres of land do you own that are in pastures or fields?	Continuous
Pasture_Ac_Oper	How many of these acres of land of pastures or fields do you operate?	Continuous
Forest_Ac_Own	How many acres of land do you own in forests?	Continuous
Forest_Ac_Oper	How many acres of land do you operate that are in forests?	Continuous
Proximity	How close to do you live to the land you own in Robeson County?	1= On or near the land, 2= within 50 miles, 3= elsewhere in NC, 4= out of state
Years	How many years have you (or family) owned or farmed these tracts?	1= 0-5 years, 2= 6-10 years, 3= 11-20 years, 4= 21-30 years, 5= 31-40 years, 6= 40+ years
Storm_Flor	Did any of these storms cause major flooding that damaged crops or fields on any part of tracts? (Select all that apply)	1= Hurricane Florence, 0= No
Storm__Matt	Did any of these storms cause major flooding that damaged crops or fields on any part of tracts? (Select all that apply)	1= Hurricane Matthew, 0= No
Storm_Floyd	Did any of these storms cause major flooding that damaged crops or fields on any part of tracts? (Select all that apply)	1= Hurricane Floyd, 0= No
Storm_Fran	Did any of these storms cause major flooding that damaged crops or fields on any part of tracts? (Select all that apply)	1= Hurricane Fran, 0= No
Flood_Times	On average, how many times have storm events caused major flooding that damaged crops or fields?	0= Never, 1= Every 25 years, 2= Every 15 years, 3= Every 10 years, 4= Every 7 years, 5= Every 5 years, 6- Every 2 years, 7= Every year
Crop_Insure	Since 2015, have you ever received crop insurance payments because of flooding?	Yes=1, No=0, 2=I don't know
Insure_Times	If yes to #7, how many times?	Continuous
Revenue_Loss	Excluding Hurricane Florence and Matthew, because of flooding, ~what percentage of expected annual agricultural revenues were lost in 2015?	Continuous, 0= no flooding

Worry_flood	I worry about my farmland flooding after a major rainfall	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Worry_yields	I worry that floods may harm my crop, tree, or livestock yields	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Practice_Use	I already use practices to reduce flooding on my property	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Worry_Wquality	I worry that flooding may harm water quality	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Action_avoid	Which of the following actions have you taken in response to a flood event? (Select all that apply): AVOID PLANTING CROPS IN AREAS PRONE TO FLOODING	Yes=1, No=0
Action_trees	Which of the following actions have you taken in response to a flood event? (Select all that apply): PLANTED TREES OR OTHER VEGETATION IN AREAS PRONE TO FLOODING	Yes=1, No=0
Action_tile	Which of the following actions have you taken in response to a flood event? (Select all that apply): BUILT OR ENHANCED TILING	Yes=1, No=0
Action_ditch	Which of the following actions have you taken in response to a flood event? (Select all that apply): BUILT OR ENHANCED DITCHES AND CANALS	Yes=1, No=0
Action_WCS	Which of the following actions have you taken in response to a flood event? (Select all that apply): BUILT OR ENHANCED OTHER WATER CONTROL STRUCTURES	Yes=1, No=0
Action_crops	Which of the following actions have you taken in response to a flood event? (Select all that apply): SWITCHED TO DIFFERENT CROPS IN FLOOD-AFFECTED AREAS	Yes=1, No=0
Action_notill	Which of the following actions have you taken in response to a flood event? (Select all that apply): PRACTICED NO-TILL	Yes=1, No=0
Action_cc	Which of the following actions have you taken in response to a flood event? (Select all that apply): PLANTED COVER CROPS	Yes=1, No=0
Program	Which of the following actions have you taken in response to a flood event? (Select all that apply): OTHER	Yes=1, No=0
Program_CRP	If yes to #11, which programs? (Select all that apply): CONSERVATION RESERVE PROGRAM (CRP)	Yes=1, No=0
Program_CREP	If yes to #11, which programs? (Select all that apply): CONSERVATION RESERVE ENHANCEMENT PROGRAM (CREP)	Yes=1, No=0
Program_EQIP	If yes to #11, which programs? (Select all that apply): ENVIRONMENTAL QUALITY INCENTIVE PROGRAM (EQIP)	Yes=1, No=0

Program_FLEP	If yes to #11, which programs? (Select all that apply): FOREST LAND ENHANCEMENT PROGRAM (FLEP)	Yes=1, No=0
Program_PartFW	If yes to #11, which programs? (Select all that apply): PARTNERS FOR FISH AND WILDLIFE PROGAM	Yes=1, No=0
Program_WRP	If yes to #11, which programs? (Select all that apply): WETLAND RESERVE PROGRAM (WRP)	Yes=1, No=0
Program_WHIP	If yes to #11, which programs? (Select all that apply): WILDLIFE HABITAT INCENTIVES PROGRAM (WHIP)	Yes=1, No=0
Program_MitBank	If yes to #11, which programs? (Select all that apply): A CONSERVATION OR MITIGATION BANKING PROGRAM	Yes=1, No=0
Program_stsw	If yes to #11, which programs? (Select all that apply): A STATE AGRICULTURAL COST SHARE PROGRAM FOR SOIL AND WATER	Yes=1, No=0
Program_stforest	If yes to #11, which programs? (Select all that apply): A STATE FORESTRY COST SHARE PROGRAM	Yes=1, No=0
Program_landtrust	If yes to #11, which programs? (Select all that apply): A CONSERVATION EASEEMENT WITH A LAND TRUST	Yes=1, No=0
Program_other	If yes to #11, which programs? (Select all that apply): OTHER	Yes=1, No=0
Program_unknown	If yes to #11, which programs? (Select all that apply): I'VE PARTICIPATED IN A PROGRAM BUT DON'T KNOW WHICH PROGRAM	Yes=1, No=0
NBS_know	Before this survey, have you heard or read about the terms Nature-based solutions or natural infrastructure?	Yes=1, No=0, 2=I don't know
NBS_use	Have you ever used nature-based solutions on your property?	Yes=1, No=0, 2=I don't know
NBS_reduce	I believe that nature-based solutions could reduce flooding on my property.	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
NBS_community	I believe that NBS could reduce flood risk to communities downstream	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Confidence	I feel confident that I could perform certain NBS on my property	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Require_Pay	I would require payments to install and maintain NBS	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Require_Loss_Pay	I would required payments to cover the costs of any crops or pastures lost during flooding caused by NBS	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Help	I might participate in a NBS flood reduction program if I received help to implement and maintain them	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Costly	Implementing NBS flood reduction practices are too costly even with landowner or operator incentives	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree

Time	Implementing NBS flood reduction practices would be too time consuming, reducing other farm activities	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Responsible	It is my responsibility as a property landowner/operator to incorporate flood reduction practices	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
WTA	I would not implement nature-based flood reduction practices for reasons other than costs	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
CC_know	Indicate to what extent you are familiar with the following farm conservation or NBS: COVER CROPS	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
Notill_know	Indicate to what extent you are familiar with the following farm conservation or NBS: NOTILL	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
hardpan_know	Indicate to what extent you are familiar with the following farm conservation or NBS: HARDPAN BREAKUP	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
pine_know	Indicate to what extent you are familiar with the following farm conservation or NBS: PLANTING PINE	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
wood_know	Indicate to what extent you are familiar with the following farm conservation or NBS: BOTTOMLAND HARDWOODS	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
agro_know	Indicate to what extent you are familiar with the following farm conservation or NBS: AGROFORESTRY / SILVOPASTURE	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
Farm_know_avg	Average knowledge from the above common farm practices	Continuous
tiling_know	Indicate to what extent you are familiar with the following farm conservation or NBS: TILING WITH WATER STORAGE BERMS	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
stream_know	Indicate to what extent you are familiar with the following farm conservation or NBS: STREAM RESTORATION	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
fbank_know	Indicate to what extent you are familiar with the following farm conservation or NBS: FOREST WETLAND BANK	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
ditch_know	Indicate to what extent you are familiar with the following farm conservation or NBS: FIELD DITCHING/ CONTROL/ DRAINAGE DISTRICTS	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
wf_know	Indicate to what extent you are familiar with the following farm conservation or NBS: WATER FARMING / TEMPORARY FIELD FLOODING	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar

wetland_know	Indicate to what extent you are familiar with the following farm conservation or NBS: FLOOD CONTROL WETLAND / WETLAND CATCH BASIN	1= Not Familiar, 2=Slightly Familiar, 3=Moderately Familiar, 4=Very Familiar, 5=Extremely Familiar
Land_prodcrop	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): PRODUCTIVE CROP LANDS	Yes=1, No=0
Land_margcrop	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): MARGINAL CROP LANDS	Yes=1, No=0
Land_prodpast	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): PRODUCTIVE PASTURE AND GRAZING LANDS	Yes=1, No=0
Land_margpast	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): MARGINAL PASTURE OR GRAZING LAND	Yes=1, No=0
Land_brush	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): BURSHY AND GROWNUP FIELDS	Yes=1, No=0
Land_forest	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): FOREST LAND	Yes=1, No=0
Land_other	Would you be willing to accept payments to install a farm conservation or structural NBS water management practices on any of the following type of farm fields (Select all that apply): OTHER	Yes=1, No=0
Practice_CC	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): COVER CROPS	Yes=1, No=0
Practice_Notill	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): NO TILL	Yes=1, No=0
Practice_hbreakup	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): HARDPAN BREAKUP	Yes=1, No=0

Practice_pine	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): PLANTING PINES	Yes=1, No=0
Practice_hwood	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): PLANTING HARDWOODS	Yes=1, No=0
Practice_agro	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): AGROFORESTRY	Yes=1, No=0
Practice_tile	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): TILING WITH BERMS	Yes=1, No=0
Practice_stream	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): STREAM RESTORATION	Yes=1, No=0
Practice_wetforest	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): FORESTED WETLAND BANK	Yes=1, No=0
Practice_ditch	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): FIELD DITCHING/DRAINAGE DISTRICTS	Yes=1, No=0
Practice_WF	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): MANAGED FIELD FLOODING/ WATER FARMING	Yes=1, No=0
Practice_wetland	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): FLOOD CONTROL WETLAND / WETLAND WATER CATCHMENT BASIN	Yes=1, No=0
Practice_other	If adequate funding were provided, which of the following farm conservation and structural NBS practices would you consider implementing to prevent future flooding? (Select all that apply): OTHER	Yes=1, No=0
Farm_contract	Assume there were a Floodwise program to assist with implementing common farm conservation practices of no-till, hardpan breakup, forest	1= 5-yr contract, 2= 10-year contract, 3=20-year contract,

	planting, and agroforestry on property, which contract length would you require?	4=30-year contract, 5=more than 30 years, 6=permanent land easement 0=none, would not participate
farm_cshare	If you enrolled in these common farm practice programs to reduce flooding, assume you would get paid at similar rates for existing farm conservation programs. What costshare rate would you require to establish to practices?	Continuous, 0=not participate
farm_payment	What is the minimum payment per acre per year you would accept to participate in and maintain the above farm conservation practices?	Continuous, 0=not participate
Farm_WTA	Willingness to accept farm practices	0=no, 1=yes
NBS_contract	Assume that due to higher costs, a FloodWise program that would pay for the establishment and annual management costs for implementing structural NBS practices of tiling, stream and wetland restoration, field ditching and drainage, water farming, and flood control wetland, which contract term length would you accept?	1= 5-yr contract, 2= 10-year contract, 3=20-year contract, 4=30-year contract, 5=more than 30 years, 6=permanent land easement, 0=none, would not participate
NBS_payment	What is the minimum payment per acre per year you would accept to participate in and maintain the above structural NBS practices?	Continuous, 0=not participate
NBS_WTA	Willngness to accept NBS practices	0= no, 1=yes
Org_Extension	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC COOPERATIVE EXTENSION SERVICE (COUNTY AGENTS)	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_FarmB	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC FARM BUREAU	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_Ag	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC DEPT OF AGRICULTURAL SERVICES	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_NCSWC	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC SOIL AND WATER CONSERVATION DISTRICTS	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_District	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC WATER DRAINAGE DISTRICTS	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree

Org_WRC	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: NC WILDLIFE RESOURCES COMMISSION	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_NPO	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: A NONPROFIT LAND CONSERVANCY OR ENVIRONMENTAL ORGANIZATION	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_FSA	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: USDA FARM SERVICES AGENCY	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_FEMA	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: US FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_FWS	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: US FISH AND WILDLIFE SERVICE	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_NRCS	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: USDA NATURAL RESOURCE CONSERVATION SERVICE (NRCS)	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
Org_other	Indicate the extent to which you agree that each of the following organizations would be most appropriate to oversee a flood reduction type of conservation contract on private property: OTHER	1= Strongly Disagree, 2=Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree
gender	What is your gender?	1- Male, 0-Female
Educ	What is the highest level of schooling you have completed?	1= high school/GED, 2= vocational, technical, certificate, 3= associates, 4= bachelors, 5=graduate, 6=professional, 7=other
Age	What is your age in years?	1= Less than 30 years, 2= 31-45 years, 3= 46-60 years, 4= 61-75 years, 5= 76 years or more
race	What is your race / ethnicity?	1=white, 2= black/AA, 3= native American/indigenous, 4= hispanic/latinx, 5= asian, 6=other

income	What was your approximate total household income (AGI) in 2020?	1= less than $2,499, 2= $25,000-$49,999, 3= $50,000-$74,999, 4= $75,000-$99,999, 5=$100,000-$149,999, 6= $150,000 or more

Appendix M: Descriptive Statistics for all Variables

Variable	Obs	Mean	Median	Std. dev.	Min	Max
Total_Ac_Own	172	291.70	121.5	535.211	19.8	3900
Manage_Land	198	.35	0	.4792	0	1
Total_Ac_Oper	161	173.58	0	590.81	0	6000
Crop_Ac_Own	162	147.41	50	327.14	0	2500
Pasture_Ac_Own	165	11.73	0	38.57	0	400
Forest_Ac_Own	164	127.39	37.5	400.52	0	3480
Flood_Times	162	3.07	3	2.42	0	7
Revenue_Loss	153	11.39	5	15.58	0	80
Worry_flood	170	3.04	3	1.31	1	5
Worry_Yields	170	3.26	4	1.27	1	5
Worry_Wquality	170	3.21	3	1.25	1	5
Program	177	.23	0	.46	0	1
Program_CRP	168	.12	0	.31	0	1
Program_CREP	168	.02	0	.13	0	1
Program_EQIP	168	.04	0	.20	0	1
Program_FLEP	168	.04	0	.20	0	1
Program_PartFW	168	.00	0	.07	0	1
Program_WRP	168	.00	0	.07	0	1
Program_WHIP	168	.02	0	.15	0	1
Program_MitBank	168	0	0	0	0	1
Program_stsw	168	.01	0	.11	0	1
Program_stforest	168	.07	0	.26	0	1
Program_landtrust	168	.00	0	.08	0	1
Program_other	168	.02	0	.15	0	1

Program_unknown	168	.03	0	.17	0	1
Cc_know	148	3.10	3	1.29	1	5
Notill_know	160	3.17	4	1.35	1	5
Hardpan_know	156	2.46	2	1.49	1	5
Pine_know	159	3.15	3	1.27	1	5
Wood_know	157	2.61	3	1.30	1	5
Agro_know	153	1.60	1	1.12	1	5
Farm_know_avg	165	2.74	2.67	1.09	1	5
Tiling_know	154	1.52	1	.95	1	5
Stream_know	153	1.94	2	1.11	1	5
Fbank_know	156	1.98	2	1.18	1	5
Ditch_know	159	2.86	3	1.29	1	5
WF_Know	154	1.52	1	.99	1	5
Wetland_know	153	1.64	1	1.04	1	5
NBS_know_avg	163	1.99	1.67	.94	1	5
Farm_Contract_Term	120	1.87	2	.99	1	6
NBS_Contract_Term	108	2.09	2	1.23	1	6
Farm_WTA	146	.72	1	.45	0	1
NBS_WTA	145	.69	1	.46	0	1
Combined_WTA	142	.67	1	.47	0	1
Farm_Payment	106	128.21	120	46.20	40	190
NBS_Payment	101	131.98	130	46.22	40	190
Income	144	4.03	4	1.53	1	6
Age	165	3.98	4	.80	1	6
Educ	165	3.53	4	1.58	1	7
Gender	165	.73	1	.44	0	1

Responsible	158	3.29	3	1.02	1	5
Proximity	177	1.69	1	.97	1	6
Years	163	5.49	6	1.17	1	6
Storm_Flor	167	.59	1	.49	0	1
Storm_Matt	167	.57	1	.49	0	1
Storm_Floyd	167	.30	0	.46	0	1
Storm_Fran	167	.299	0	.46	0	1
Crop_Insure	175	.42	0	.75	0	2
Insure_Times	15	2.2	2	1.32	1	5
Practice_Use	163	3.28	4	1.23	1	5
Action_Avoid	165	.21	0	.41	0	1
Action_Trees	165	.11	0	.32	0	1
Actions_Tile	165	.14	0	.35	0	1
Action_ditch	165	.53	1	.50	0	1
Action_WCS	165	.12	0	.33	0	1
Action_crops	165	.07	0	.25	0	1
Action_notill	165	.31	0	.46	0	1
Action_cc	165	.21	0	.40	0	1
NBS_know	168	.31	0	.63	0	2
NBS_use	167	.65	0	.78	0	2
NBS_reduce	157	3.43	3	1.09	1	5
NBS_community	156	3.45	4	1.08	1	5
Confidence	157	3.26	3	1.07	1	5
Require_Loss_Pay	155	3.69	4	1.10	1	5
Help	156	3.64	4	1.08	1	5
Costly	152	2.87	3	.91	1	5
Time	151	2.75	3	.83	1	5

Land_prodcrop	152	.29	0	.46	0	1
Land_margcrop	152	.33	0	.47	0	1
Land_prodpast	152	.18	0	.39	0	1
Land_margpast	152	.22	0	.42	0	1
Land_brush	152	.29	0	.45	0	1
Land_forest	152	.56	1	.49	0	1
Land_other	150	.07	0	.26	0	1
Practice_CC	155	.51	1	.50	0	1
Practice_Notill	155	.47	0	.50	0	1
Practice_hbreakup	155	.37	0	.48	0	1
Practice_pine	155	.53	1	.50	0	1
Practice_hwood	154	.43	0	.49	0	1
Practice_agro	155	.19	0	.39	0	1
Practice_tile	155	.23	0	.42	0	1
Practice_stream	155	.36	0	.48	0	1
Practice_wetforest	155	.28	0	.45	0	1
Practice_ditch	155	.64	1	.48	0	1
Practice_WF	154	.21	0	.41	0	1
Practice_wetland	155	.25	0	.43	0	1
Practice_other	144	.04	0	.20	0	1
Org_Exten	149	3.33	4	1.09	1	5
Org_FarmB	146	2.87	3	1.10	1	5
Org_Ag	145	3.54	4	.99	1	5
Org_NCSWC	150	3.71	4	1.02	1	5
Org_District	140	3.36	3	1.03	1	5
Org_WRC	145	3	3	1.09	1	5
Org_NPO	144	2.65	3	1.10	1	5

Org_FSA	146	3.38	3	1.07	1	5
Org_FEMA	146	3.66	3	1.15	1	5
Org_FWS	143	2.78	3	1.10	1	5
Org_NRCS	146	3.27	3	1.08	1	5
Org_other	11	2.91	3	1.30	1	5