Assessing the environmental and educational value of an agricultural watershed restoration project in Mississippi

By

Audrey K. McCrary

Approved by:

Leslie M. Burger (Major Professor)
Beth Baker (Co-Major Professor)
Laura H. Downey
Kevin M. Hunt (Graduate Coordinator)
George M. Hopper (Dean, College of Forest Resources)

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Wildlife, Fisheries, and Aquaculture
in the Department of Wildlife, Fisheries, and Aquaculture

Mississippi State, Mississippi

May 2020
With a majority of land in the United States being utilized for agricultural production, water resource conservation has become a significant topic of interest for natural resource agencies. In partnership with the Mississippi Department of Environmental Quality and Natural Resources Conservation Service, Mississippi State University conducted a stream restoration project within its agricultural research properties in Oktibbeha County, Mississippi. Water sampling during storm-runoff events was conducted to assess changes in microbial, nutrient, and sediment concentrations and loads pre- and post-restoration. In addition to these water monitoring activities, a regional survey of Cooperative Extension Service agents with agriculture and natural resource responsibilities was conducted to assess the need for in-service training on water resource conservation topics. Water quality monitoring and agent survey data were used to evaluate the restoration project’s environmental impact and potential as a demonstration site for future agent training initiatives for water resource conservation.

Key words: water resources, conservation practices, needs assessment
DEDICATION

This work is dedicated to my grandad, John Manyhouse McCrary. I can’t help but feel called to follow in your footsteps as a practical problem-solver, believer in the benefits of dessert before dinner, fan of the masterpieces of Larson and Watterson, and admirer of all of God’s handiwork in nature.
ACKNOWLEDGEMENTS

I would like to sincerely thank my committee, Dr. Leslie Burger, Dr. Beth Baker, and Dr. Laura Downey, for their guidance and unwavering support throughout this project. Thank you to Water Quality Lab members past and present: Steven Byrd – who endured with me the frustration and triumph involved in learning to wire water sampling systems from scratch, Beau Badon – who commiserated in the struggle of leading storm-water collection studies in a state that gets over 60 inches of rain a year, Mark Hill – for the endless supply of high-fives and technical support, and Lexi Firth – for always helping me find my way to the silver lining in a project full of cloudy days. I would also like to thank my fellow graduate students, specifically Nicky Faucheux, Miranda Huang, Ira Parsons, Spencer Vanderbloemen, and Ryo Ogawa, for their friendship and humor that made every day feel like a great day to be in the office or field. Their love and support were instrumental in crossing the finish line. Thank you to past wildlife family – Kenneth Erwin and Cassie Cook – for encouraging my pursuit of grad school and making me feel at home in this field. Finally, and most importantly, I would like to thank my parents for their love, prayers, and understanding. They are responsible for fostering the grit, patience, endurance, and humor I have developed throughout my life and come to deeply appreciate as I grow older. And these are perhaps the most valuable skills of all.
TABLE OF CONTENTS

DEDICATION............................................................................................................. ii

ACKNOWLEDGEMENTS............................................................................................ iii

LIST OF TABLES ...................................................................................................... vi

LIST OF FIGURES ................................................................................................... viii

CHAPTER

I. INTRODUCTION ........................................................................................................... 1
   1.1 Background ............................................................................................................. 1
   1.2 References ............................................................................................................. 4

II. ASSESSMENT OF CONSERVATION PRACTICES TO IMPROVE WATER
    QUALITY IN AN IMPAIRED WATERSHED ............................................................. 6

   2.1 Introduction ............................................................................................................. 6
   2.2 Methods .................................................................................................................. 10
      2.2.1 Study Area ....................................................................................................... 10
      2.2.2 Study Design and Sampling ............................................................................. 11
   2.3 Results ..................................................................................................................... 15
      2.3.1 General Pollutant Concentrations, Loading, and Recommended Criteria ..... 15
      2.3.2 Reference vs. Treatment Concentrations ......................................................... 16
      2.3.3 Pre- vs. Post-Implementation Concentrations and Loading ......................... 16
   2.4 Discussion .............................................................................................................. 18
   2.5 Tables and Figures ................................................................................................. 25
   2.6 References ............................................................................................................. 49

III. COMPETENCIES AND TRAINING NEEDS IN WATER RESOURCE CONSERVATION
    FOR SOUTHEASTERN EXTENSION AGENTS ......................................................... 54

   3.1 Introduction ............................................................................................................. 54
   3.2 Methods .................................................................................................................. 57
      3.2.1 Target Population ............................................................................................. 57
      3.2.2 Survey Instrument ............................................................................................ 58
      3.2.3 Data Analysis ................................................................................................... 59
   3.4 Discussion .............................................................................................................. 63
APPENDIX

A. WATER RESOURCE CONSERVATION NEEDS ASSESSMENT SURVEY ........78
LIST OF TABLES

Table 2.1  Descriptions of planned conservation practices (treatments) for Phase 1 of the Catalpa Creek restoration project that are evaluated by water quality monitoring at downstream treatment sites...........................................25

Table 2.2  Descriptions of storm-event Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) concentrations at Catalpa Creek tributary sites over the complete study period...........................................................................26

Table 2.3  Descriptions of storm-event Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) loads at Catalpa Creek tributary sites over the complete study period.........................................................26

Table 2.4  Descriptions of E. coli and enterococci colony-forming units (geometric means) counts at Catalpa Creek tributary sites over the complete study period.................27

Table 2.5  Descriptions of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) concentrations at Catalpa Creek tributary sites pre- and post-implementation of planned practices..................................................................................27

Table 2.6  Descriptions of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) estimated loads (load = event concentration times total event discharge) at Catalpa Creek tributary sites pre- and post-implementation of planned practices.28

Table 2.7  Descriptions of E. coli and enterococci colony-forming unit counts (geometric means) at Catalpa Creek tributary sites pre- and post-implementation of planned practices. ...........................................................................................................29

Table 3.1  Land management topics used to assess competency in an online survey of southeastern Extension agents with agricultural and natural resources responsibilities.................................................................68

Table 3.2  Demographic characteristics of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities...............................69

Table 3.3  Mean importance, ability, and landowner expressed need scores of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities..................................................................................70
Table 3.4  Mean weighted discrepancy scores by state of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities. The top three ranking (four if tie present) MWDS scores are presented in bold. ......71

<table>
<thead>
<tr>
<th>State</th>
<th>MWDS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2.1 Map of Red Bud – Catalpa Creek watershed and study site drainage areas, located within the Tibbee Creek Sub-Basin (HUC #03160104) and Tombigbee River Basin (HUC #031601) in northeast Mississippi. .......................................................... 30

Figure 2.2 Land use in context within the South Farm and Dairy Farm study sites in the Red Bud – Catalpa Creek Watershed (National Land Cover Database (NLCD) data courtesy of U.S. Geological Survey). ................................................................. 31

Figure 2.3 Pie charts of land use distribution within site drainage areas (NLCD and drainage delineation data courtesy of U.S. Geological Survey). ................................................................. 32

Figure 2.4 Boxplots of general Total Nitrogen (TN) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period. The blue dashed line (0.850 mg/L) indicates MDEQ draft numeric criteria TN concentration for pollutant/stressor response threshold (macroinvertebrate indicators), while the red line (0.618 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TN concentrations (MDEQ, 2016; USEPA, 2000). ................................................................. 33

Figure 2.5 Boxplots of general Total Phosphorus (TP) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period. The blue dashed line (0.060 mg/L) indicates MDEQ draft numeric criteria TP concentration for pollutant/stressor response threshold (macroinvertebrate indicators), while the red line (0.0225 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TP concentrations (MDEQ, 2016; USEPA, 2000). ................................................................. 34

Figure 2.6 Boxplots of general Total Suspended Solids (TSS) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period. ................................................................. 35

Figure 2.7 Boxplots of general Total Nitrogen (TN) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period. ................................................................. 36

Figure 2.8 Boxplots of general Total Phosphorus (TP) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period. ................................................................. 37

Figure 2.9 Boxplots of general Total Suspended Solids (TSS) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line indicates the adopted MDEQ TMDL limit for TSS within the Tibbee Creek Sub-basin (MDEQ, 2007). ................................................................. 38
Figure 2.10 Boxplots of general E. coli colony counts from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2016).

Figure 2.11 Boxplots of general enterococci colony counts from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2016).

Figure 2.12 Simple linear regression analysis of Total Nitrogen (TN) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.

Figure 2.13 Simple linear regression analysis of Total Phosphorus (TP) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.

Figure 2.14 Simple linear regression analysis of Total Suspended Solids (TSS) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.

Figure 2.15 Boxplots of general Total Nitrogen (TN) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The blue dashed line (0.850 mg/L) indicates MDEQ draft numeric criteria TN concentration for pollutant/stressor response threshold (macroinvertebrate indicators), the red line (0.618 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TN concentrations (MDEQ, 2016; USEPA, 2000).

Figure 2.16 Boxplots of general Total Phosphorus (TP) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The blue dashed line (0.060 mg/L) indicates MDEQ draft numeric criteria TP concentration for pollutant/stressor response threshold (macroinvertebrate indicators), the red line (0.0225 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TP concentrations (MDEQ, 2016; USEPA, 2000).

Figure 2.17 Boxplots of general Total Suspended Sediment (TSS) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices.
Figure 2.18 Boxplots of *E. coli* colony counts from collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2007).

Figure 2.19 Boxplots of enterococci colony counts from collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2007).

Figure 3.1 Distribution of the highest degree earned by Extension agent survey respondents by state of employment.

Figure 3.2 Distribution of the experience level of Extension agent survey respondents by state of employment.
CHAPTER I
INTRODUCTION

1.1 Background

Increased agricultural production to support a growing human population is expected to lead to escalated environmental impacts on water resources (Wezel et al., 2014). The environmental effects of agriculture and associated impairment of water quality in surface water streams and rivers in the southeastern United States (U.S.) are particularly concerning to regional natural resource agencies [U.S. Environmental Protection Agency (USEPA), 2019b]. Land management techniques that balance profitable agricultural outputs with stewardship of natural resources are necessary for long-term sustainability, but face significant barriers to widespread adoption (Foley et al., 2011).

Agriculture and natural resources have been foundational to the American economic and cultural landscape since the nation’s inception. In 1862, the U.S. government implemented the Morrill Land Grant College Act, to advance agricultural research and education through the establishment of land-grant universities (LGUs). Half a century later, the Smith-Lever Act (1914) was passed to establish the Extension Service, an organizational partnership between the LGUs and the federal government to bring applied research to stakeholders outside of the academic arena (Cash, 2001). The Extension Service operates with a unique blend of county, state, and federal inputs to promote the applied agricultural and environmental research conducted at LGUs.
A persistent agricultural and environmental issue challenging university researchers and Extension personnel has been the degradation of water resources. In 1972, the federal government adopted the Clean Water Act (CWA) which enabled the Environmental Protection Agency (EPA) to implement pollution control standards and set water quality criteria for surface waterways (USEPA, 2019a). Since then, additional numerous amendments, initiatives, and assistance programs have been created to address impairment of water resources.

The most significant threat to water resources in the U.S. is nonpoint source pollution (USEPA, 2002). Nonpoint source (NPS) pollution is defined as pollution by “diffuse sources that are not regulated as point sources and normally are associated with agriculture, silvicultural, and urban runoff…” (USEPA, 1987, p. 3). To address NPS pollution, the CWA was amended in 1987 with Section 319, the “Nonpoint Source Management Program,” which charged states with the duties of statewide assessments, NPS program development, and implementation of an EPA-approved program (USEPA, 2002). This initiative allows state and federal agencies to work cooperatively to address watershed and water resource conservation issues, which are a priority to both levels of government. A trending increase in state initiatives with NPS Section 319 programs reflects a growth in concern and funding of NPS-focused watershed conservation at the federal level (Hardy & Koontz, 2008).

In the continued effort to reduce decades of NPS pollution and water quality impairment, conservation practices have been developed through research at LGUs and the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS). Perhaps the most conspicuous example of water resource conservation, practices are research-based techniques, usually changes in behaviors or structures, that are implemented on a landscape to address natural resource issues (Meals et al., 2010). Many studies have verified the ecological, financial, and practical benefits of
various conservation practices (Clary et al., 2016; Dabney et al., 2001; Kaye & Quemada, 2017; Shipitalo & Edwards, 1998; Snapp et al., 2005).

Insufficient landowner participation, improper use and placement of practices, and lack of education on water pollution sources have been identified as barriers to conservation practice implementation (Meals et al., 2010). These barriers exemplify broader obstacles to NPS management, which can be mitigated by educating and training a variety of agricultural stakeholders. Landowner education in conservation practice adoption is an important factor and may be dependent upon the educational competencies of Extension agents (Baumgart-Getz et al., 2012). Integration of federal and state water conservation initiatives with the local influence of Extension Service personnel could help address barriers to conservation practice adoption. The organization’s structure, resources, expertise, and credibility with landowners give it an inherent advantage in filling this niche. This approach leverages strengths from the policy, agencies, mechanisms, and goals in both the agriculture and natural resources fields to solve a complex social and ecological problem (Cote & Nightingale, 2012).

Knowledge of Extension agent competencies can help direct training efforts to increase Extension agents’ abilities to educate landowners on water resource issues and conservation practices. This research investigated the environmental and educational value of watershed restoration efforts in Mississippi, and the interdisciplinary linkage between water resource conservation efforts implemented by a land-grant university and southeastern Extension agents’ needs in water resource conservation training.
1.2 References


CHAPTER II

ASSESSMENT OF CONSERVATION PRACTICES TO IMPROVE WATER QUALITY IN AN IMPAIRED WATERSHED

2.1 Introduction

The majority of land use in the U.S. is dedicated to agricultural production; grazing and forestlands account for nearly 60%, and cropland comprises another 17% (Bigelow & Borchers, 2017). Land use for agricultural production is also a main contributor to water quality impairment in surface water and streams in the form of nonpoint source pollution (Evans et al., 2019). Nearly 53% of assessed rivers and streams in the U.S. have been listed as impaired in function, with NPS pollution affecting nearly three-quarters of all U.S. impaired waterbodies (USEPA, 2011; USEPA, 2019b).

The Clean Water Act (Section 303d) defines impaired waterbodies as those which are prevented from fulfilling their intended purpose for aquatic life, water supply, or recreational activities (USEPA, 2011). While it is difficult to assign exact thresholds for when impairment occurs, governing agencies have strived to set environmental budgets for surface water pollution in the form of Total Maximum Daily Loads (TMDLs). These pollutant loads are set to appropriately distribute the contributions of pollution from different sources and the effect of regulatory measures on all sources within a water body, including nonpoint sources. However, NPS pollution is challenging to accurately measure and regulate because of its broad environmental origination and variation (Bennett et al., 2001).
A variety of contaminants can impair stream function, but the three leading pollutants of concern in U.S. rivers and streams are sediment, nutrients, and pathogens (USEPA, 2019b). These pollutants are common products of agricultural activities that disturb natural conditions on the landscape and find their way into surface waters through NPS runoff. Excessive pollutants degrade ecosystem health and can threaten the health of both human and wildlife populations (Hooda et al., 2000; Jordan et al., 2016). Cattle use of riparian areas is a major contributor to soil erosion in pastures, instigating stream degradation through landscape runoff and stream bank erosion (Clary et al., 2016; Zaimes et al., 2009). Excess sediment loading causes increased turbidity levels in water bodies, which can impair aquatic life and lead to unwanted sediment build-up. Additionally, nitrogen and phosphorus runoff from agricultural sources has been established as a public health and environmental risk, and pathogens in surface water can become a problem for drinking water supplies and recreational use areas (Hooda et al., 2000).

Addressing such a widespread issue requires action at the local level and collaboration at larger scales. Funding from Section 319 (CWA) is strongly advantageous for collaborative watershed restoration efforts through state’s technical assistance for landowners, but is disadvantaged by limitations in financial flexibility and duration of funding (Hardy & Koontz, 2008). Watershed partnerships, rather than policies and regulations, have greater potential to increase landowner participation in conservation initiatives (Morton, 2009). Though improvements in water quality in the southeastern U.S. have been documented after implementation of stricter policy regarding bans on phosphate-detergents and improved wastewater treatment standards, these policies were directed solely at point source pollution (USGS, 2010). The primary mechanism for remediation of agricultural NPS pollution remains voluntary conservation practice implementation.
Implementation of conservation practices on agricultural landscapes requires consideration of a variety of benefits and barriers to adoption. D’Arcy and Frost (2001) outlined three key elements that influence adoption of practices: availability of formal guidance on management options, well-defined and specific practices, and verification of practice effectiveness through research and experience. Practices should also be financially feasible, practical to implement and maintain, effective in reducing environmental degradation, and should not impede agricultural production (Kroger et al., 2015).

Conservation practices are developed to address various natural resource concerns, including pollution of waterbodies. Sediment and nutrient pollution have been shown to be largely driven by water velocity, moreover water flow or overall discharge (Baker et al., 2016; Kroger et al., 2008; Ward et al., 2018). Improved grazing management strategies or the incorporation of vegetated buffer strips and riparian zones can slow water velocity and help reduce sediment and nutrient loads in surface runoff (Clary et al., 2016; Zaimes et al., 2009; Osborne & Kovacic, 1993). These and other conservation practices in use today are supported by research and recommended in technical consultations by U.S. government agencies, such as the Natural Resources Conservation Service (NRCS).

Reduction of key contaminants such as sediment, nutrients, and pathogens requires a network of stakeholders willing to adopt conservation practices (Yates et al., 2007). Streams may require multiple, concentrated practices to overcome an ecosystem threshold (Baker, et al., 2018; Kroger et al., 2015; Osborne & Kovacic, 1993). This threshold becomes more difficult to reach in systems where the stream itself has become a source of pollution, such as when channel morphology has been altered from natural processes into straightened agricultural ditches (Dabney et al., 2012; Shields et al., 2007). To add complexity, waterbodies have been found to be highly
influenced by the quality and volume of water discharged from upstream low-order sources (Alexander et al., 2007; Dodds & Oakes, 2008). Addressing natural resource concerns both upstream where large proportions of NPS pollution and discharge are sourced and downstream where systems suffer from anthropogenic alteration is a complex issue, requiring small-scale, intensive implementation of conservation practices and coordination of conservation or restoration efforts at larger watershed scales.

Monitoring water quality can help identify pollutants and impairment in streams to develop Total Maximum Daily Loads (TMDLs), guide implementation planning, and assess the effectiveness of conservation practices (Spooner et al., 2011). However, post-implementation monitoring often has specific challenges. Water quality exhibits a lag time in response to environmental changes, especially at the watershed level (Meals et al., 2010). However, funding for Section 319 NPS projects is short-term in nature, which makes monitoring long-term effectiveness of conservation practice adoption more difficult (Prokopy et al., 2009). Monitoring efforts on smaller watersheds near primary pollution sources and selecting appropriate monitoring sites and pollutant indicators can help reduce lag time and mitigate some data collection challenges (Harmel et al., 2006; Meals et al., 2010).

With nearly 53% of assessed rivers and streams in the U.S. listed as impaired in function, Mississippi ranks above average with an impairment rate of 66.8% (USEPA, 2018b). Therefore, watershed restoration and reducing NPS pollution is a main priority to ensure the integrity of public waters in Mississippi. This prioritization of reducing NPS pollution is critically needed alongside continued implementation of conservation practices and monitoring efforts to assess practice effectiveness. This study addresses the aforementioned watershed protection needs through a scientific case study of restoration efforts in an impaired watershed in MS, USA. To assess the
pollutant concentrations in the watershed and monitor environmental effects of a restoration project, water quality monitoring was conducted before and after conservation practice implementation (Herdon et al., 2016). The research objectives of this study were:

1. Describe nutrient, sediment, and pathogen concentrations in watershed tributaries.
2. Identify contributions of agricultural pasture land to nutrient, sediment, and pathogen concentrations in tributaries.
3. Determine the effect of conservation practice implementation in the watershed.

2.2 Methods

2.2.1 Study Area

This study was conducted in the Catalpa Creek watershed (45.2 mi$^2$) in Oktibbeha County, MS, located within the Red Bud-Catalpa Creek subwatershed (HUC 12 #031601040601) and larger Tombigbee River Basin (HUC 6 #031601) (Figure 2.1). Soils within the watershed are characteristic of the Blackland Prairie ecoregion (US EPA Level IV Ecoregion 65a), primarily consisting of clay with mixed sand, silt, and clay streambeds (USEPA, 2000). Precipitation averages 55 inches annually, with the highest monthly rainfall occurring November – April and lower monthly averages from May – October (Herdon et al., 2016). Land use within the subwatershed is dominated by hay/pasture production (44%), followed by forests/herbaceous cover (28%), cultivated crop production (10%), urban/developed land (9%), and wetland/surface water holdings (8%) (Herdon et al., 2016) (see Figure 2.2).

This watershed was determined to be impaired by the Mississippi Department of Environmental Quality (MDEQ) through the Mississippi-Benthic Index of Stream Quality (Herdon et al., 2016; MDEQ, 2007; Stribling et al., 2016; USEPA, 2012). Catalpa Creek flows into Tibbee Creek, which has excessive sediment loads (MDEQ, 2007; Herdon et al., 2016).
Nutrients and pathogens, while not the primary stressor in the watershed, are also elevated (Herdon et al., 2016).

To address these resource concerns, tributaries of Catalpa Creek that reside within Mississippi State University’s (MSU) H.H. Leveck Animal Research Center (South Farm) and the Bearden Dairy Research Unit (Dairy Farm) were selected for restoration by MSU and MDEQ. Critical management areas and conservation practice planning were determined by NRCS (Herdon et al., 2016). Examples of conservation practices implemented within the study area include heavy use pads, check dams, fencing, and establishment of vegetative buffers. Specific practice locations and general purposes are further described in Table 2.1.

2.2.2 Study Design and Sampling

Five sites were monitored along three unnamed tributaries of Catalpa Creek, consisting of two reference sites and three treatment sites. Reference sites were upstream at the boundaries of the South Farm and Dairy Farm. Treatment sites were downstream of critical management areas where conservation practices were implemented (see Table 2.1 and Herdon et al., 2016). Two treatment sites monitored were paired to upstream reference sites along the same tributary: Reference 1 (R1) with Treatment 1 (T1) and Reference 2 (R2) with Treatment 2 (T2). The site Treatment 3 (T3) was in the headwaters of a pasture and therefore placing a reference site above to assess upstream contributions to water quality was not necessary. Water quality measured at T3 was assumed to be influenced only by rainfall and direct field runoff. The paired site design allowed for the determination of upstream impacts to the treatment sites throughout the length of the project, in the event that external water quality conditions impact results. Drainage area size for sites varied: R1 with 0.57 mi$^2$, T1 with 0.87 mi$^2$, R2 with 0.56 mi$^2$, and T2 with 0.75 mi$^2$, and
T3 with .021 mi² (USGS, 2020). Distribution of site-specific land use classifications within drainage areas are illustrated in Figure 2.3.

Water quality was monitored at all five sites for one year prior to conservation implementation to track baseline water quality conditions with standard land management techniques in the drainage areas and for approximately one year post-implementation to quantify conservation practice effects on water quality. The pre-post design allows for comparison at each treatment site to determine practice effects on pollutant transport. This study was conducted in its entirety between January 2018 and December 2019.

Sampling procedures followed the EPA’s Surface Water Sampling operating procedure (Decker & Simmons, 2013). Samples were collected on a storm-event basis to quantify nutrient loading from the surrounding landscapes. Automated composite samplers (Sigma SD900, American Sigma, Inc., Loveland, CO) were deployed at all sites and programmed to collect samples at flow-based intervals of 600 meters/second, collecting a 200 mL grab sample per interval during a precipitation event to create a composite sample. Discharge was measured using ultrasonic Doppler instruments (Starflow 6526J-21, Unidata Pty Ltd., Perth, AU), which relayed signals to the automated samplers at the specific intervals for sample collection. Due to heavy storm flows and inclement weather conditions, automated equipment failures were experienced often. When this occurred, grab samples during the falling limb of storm event hydrographs with depth readings were collected. The concentration values from all sampled events were utilized in the analysis to create a median concentration for each site. Average discharge over the study period was used to calculate pollutant loads for each location to determine relative land use contributions to the watershed during storm events.
Composite samples collected in 10-liter (L) containers were split into three separate sterilized containers for analysis. Two samples were placed in duplicate 1 L containers, one preserved immediately with 0.5 milliliters (mL) of 49% sulfuric acid solution. These duplicate samples were transported from field sites to the MSU Water Quality Laboratory, refrigerated to maintain a temperature of 4°C, and shipped within 48 hours of sample collection to the MDEQ Office of Pollution Control Laboratory in Pearl, MS, for nutrient and sediment analysis. The third sample was placed into a 250 mL container and delivered within 24 hours of sample collection to the USDA-ARS Genetics and Sustainable Agriculture Research Unit in Mississippi State, MS, for pathogen analysis.

Nutrient indicators were measured by MDEQ using a Lachat Flow Injection Analyzer (Lachat Instruments, Loveland, CO, USA). Pollutant analysis was conducted using a combination of standard EPA methods: total Kjeldahl nitrogen (Standard Methods 4500-N orgD), ammonia (Standard Methods 4500-NH3G) and nitrate-nitrite (Standard Methods 4500-NO3I) were combined to calculate total nitrogen (TN); total phosphorus (TP) was calculated using LaChat Quik Chem Method 10-115-01-1-C; total suspended solids (TSS) values were calculated using Clesceri et al. (1998) standard methods procedure 2540D (Stamps, 2019). Nutrient and sediment pollutants utilized in the statistical analysis included TN, TP, and TSS. Pollutant analytes had the following minimum detection limits: 0.10 mg/L for total Kjeldahl nitrogen, 0.04 mg/L for ammonia, 0.02 mg/L for nitrate-nitrite, 0.02 mg/L for TP, and 0.10 mg/L for TSS (Stamps, 2019).

Pathogen pollutants of interest included fecal indicator bacteria *Escherichia coli* (*E. coli*) and enterococci. Water samples were filtered through a 0.45 µm membrane, placed on mTEC (*E. coli*) and mEnterococcus (enterococci) and incubated at 35-37°C (Santiago-Rodriguez et al., 2016; USEPA, 2010). After incubation, media were analyzed for enumeration of microbial indicators,
and results recorded as the number of colony forming units (CFU) per 100 ml (Rhodehamel & Harmon, 2001; Santiago-Rodriguez et al., 2016; USEPA, 2010).

Exploratory data analysis and summary statistics were used to ensure data quality before further statistical analysis was undertaken. After confirmation of data integrity, pollutant counts were tested for normality assumptions using the Shapiro-Wilk test and evaluation of QQ plots. All pollutant variables of interest were determined to have non-normal distributions. Nutrient and sediment variables were not transformed, therefore non-parametric Mann-Whitney Signed Rank Test was utilized to test for statistical significance of differences in medians between paired sites. Preliminary analysis of visual trends in concentrations of TN, TP, and TSS over the study period were conducted with linear regression models. A post-hoc Mann-Whitney U-Test was conducted on significant trends identified in the models to test differences in medians between pre- and post-implementation periods. Pathogen counts were log-transformed for descriptive analysis and comparison of geometric means within both paired sample dependent and two-sample independent t-tests. Pathogen counts were further divided into seasonal groups for analysis, due to variation in microbial activity and water quality standards between summer and winter months. Samples collected from May to October were classified within the summer season, and samples collected from November to April classified within the winter season. For the purposes of this study, significance thresholds of alpha = .05 were utilized to determines statistical significance, though moderate statistical differences with p-values of .05 to .10 are also discussed.
2.3 Results

2.3.1 General Pollutant Concentrations, Loading, and Recommended Criteria

Within the study period, the study sites received approximately 70 inches of rain in 2018 and 80 inches of rain in 2019, above the average annual rainfall of 55 inches (NOAA, 2020). Nutrient and sediment concentrations from samples over the complete study period (2018 and 2019) are described in Table 2.2. Median TN concentrations ranged from 1.0 to 3.065 mg/L and are compared with MDEQ draft numeric criteria (0.850 mg/L) and EPA Ecoregion 65a suggested numeric criteria (0.618 mg/L) in Figure 2.4 (MDEQ, 2016; USEPA, 2000). Median TP concentrations ranged from 0.23 to 1.54 mg/L and are compared with MDEQ draft numeric criteria (.060 mg/L) and EPA Ecoregion 65a suggested numeric criteria (0.0225 mg/L) in Figure 2.5 (MDEQ, 2016; USEPA, 2000). Median concentrations of TSS ranged from 30.5 to 104.0 mg/L (Figure 2.6); there were no MDEQ or regional numeric criteria available to evaluate TSS concentrations.

Nutrient and sediment loads for each site are described in Table 2.3. The TN loads for storm events within the study period ranged from 0.00001 to 0.00011 tons per acre (Figure 2.7). The TP loads ranged from 0.000003 to 0.000097 tons per acre (Figure 2.8). There were no established nutrient loads for streams within the study site. Overall TSS loads at sites were compared with the MDEQ TMDL sediment requirement for Tibbee Creek Sub-basin, which is 0.0004 to 0.0018 tons per acre per day (MDEQ, 2007). The TSS loads for storm events within the study period ranged from 0.0008 to 0.0047 tons per acre (Figure 2.9).

Overall pathogen concentrations are presented by season in Table 2.4. Mean counts of *E. coli* ranged from 10,813 to 55,542 CFU/100 mL in the summer season and 2,853 to 24,987 CFU/100 mL in winter months. Mean counts of enterococci varied from 9,203 to 54,910 CFU/100
mL in summer months and 2,464 to 7,171 CFU/100 mL during the winter season. Distribution of pathogen counts over the entire study period are shown for *E. coli* in Figure 2.10 and enterococci in Figure 2.11.

### 2.3.2 Reference vs. Treatment Concentrations

Overall, upstream and downstream concentrations within both sets of paired sites (R1/T1 and R2/T2) had statistically significant differences in TN and TP concentrations. The R1 site was more likely to have lower TN ($U = 104, \ p = .004$) and TP ($U = 65, \ p < .001$) concentrations than T1, and R2 more likely to have lower TN ($U = 104, \ p = .004$) and TP ($U = 65, \ p < .001$) concentrations than T2 over the entire study period. There was no statistical difference in TSS concentrations in samples between paired sites.

Moderate differences in mean *E. coli* counts were detected between R1 (and T1 during the same rain events, with T1 having slightly higher counts than R1 ($t(25), \ p = .094$). Enterococci levels at T1 were not significantly different from levels at R1. Both *E. coli* and enterococci were found to be significantly higher during rain events at T2 when compared to paired samples from R2 ($t(25), \ p = .003; t(25), \ p < .001$).

### 2.3.3 Pre- vs. Post-Implementation Concentrations and Loading

All median values of concentrations pre- and post-implementation are detailed in Table 2.5. Trends over time described by simple linear regression models are illustrated in Figures 2.12, 2.13, and 2.14. Sample concentrations for TN, TP, and TSS in both pre- and post-implementation periods are represented in Figures 2.15, 2.16, and 2.17, respectively. Linear regression analysis indicated apparent visual downward trends in TN concentrations at R2 and T3 ($R^2 = 0.25, F(1, 26) = 8.718, p = .007; R^2 = 0.3, F(1, 26) = 0.99, p = .327$). Post-hoc analyses with Mann-Whitney U
tests also indicated significant differences in TN concentrations between pre- and post-implementation periods at R2 and T3 ($U = 123, p = .034; U = 126, p = .01$), with pre-implementation concentrations being more likely to be higher than post-implementation concentrations. The general visual trend in TSS concentrations at R1 also appeared to suggest lower concentrations post-implementation ($R^2 = 0.089, F(1, 32) = 0.37, p = .547$). Post-hoc tests confirmed statistically significant differences in median TSS concentrations at R1, with the post-implementation period more likely to have lower TSS concentrations ($U = 183.5, p = .019$).

Alternatively, trends in TP at T2 suggested an increase during the post-implementation period ($R^2 = 0.13, F(1, 28) = 4.221, p = .049$). Post-hoc tests confirmed significant difference in TP ($U = 58.5, p = .035$) and TSS ($U = 38.5, p = .004$) concentrations between periods, with concentrations after conservation implementation more likely to be higher than pre-implementation concentrations. No significant trends or statistical differences were found between pre- and post-implementation TN concentrations at R1, T1, and T2, TP concentrations at R1, T1, T3, and R2, and TSS concentrations at T1, T3, and R2.

Estimated pre- and post-implementation loads are described in Table 2.6. Pre-implementation TN loads ranged from 0.000052 to 0.000339 tons/acre, while post-implementation loads were 0.000037 to 0.000159 tons/acre. Loads of TP varied between 0.000015 and 0.000128 tons/acre pre-implementation and between 0.000012 and 0.000152 tons/acre post-implementation. Finally, TSS loads pre-implementation were between 0.002036 and 0.006833 tons/acre, while post-implementation loads ranged from 0.001685 to 0.017569 tons/acre.

Differences in pathogen levels between implementation periods varied, as shown in Figure 2.18 and Figure 2.19. At T1 in winter seasons, post-implementation levels of *E. coli* (78765 CFU/100 mL) exceeded pre-implementation levels ($M = 9146$ CFU/100 mL; $t(12.03), p < .001$).
Enterococci levels at T1 in summer seasons were also moderately greater after the conservation practice implementation period \( (M_B = 8561 \text{ CFU/100 mL}, M_A = 17845 \text{ 100 CFU/100 mL}; t(7.05), p = .09) \). Summer measurements of enterococci at T3 were also significantly lower before implementation \( (M = 14842 \text{ CFU/100 mL}) \) than measurements after implementation \( (M = 96194 \text{ CFU/100 mL}; t(4.4205), p = .024) \). Both \( E. \ coli \) \( (M_{ECA} = 143541 \text{ CFU/100 mL}) \) and enterococci \( (M_{ENA} = 14131 \text{ CFU/100 mL}) \) were greater after conservation practice implementation than before during the winter season at T2 \( (M_{ECA} = 7352 \text{ CFU/100 mL}, M_{ENB} = 3843 \text{ CFU/100 mL}; E. \ coli: t(3.51), p = .003; \text{Ent.}: t(5.10), p = .02) \). Measurements of summer post-implementation \( E. \ coli \) \( (M_{ECA} = 96989 \text{ CFU/100 mL}) \) and enterococci \( (M_{ENA} = 71191 \text{ CFU/100 mL}) \) at T2 also had moderately greater levels than summer pre-implementation measurements \( (M_{ECA} = 18214 \text{ CFU/100 mL}, M_{ENB} = 17093 \text{ CFU/100 mL}; E. \ coli: t(9.71), p = .067; \text{Ent.}: t(9.65), p = .069) \).

Geometric means of all seasons and periods for \( E. \ coli \) and enterococci levels are outlined in Table 2.7. Cautious interpretation of pathogen counts between implementation periods is encouraged because of low sample numbers due to the splitting of samples between seasonal and period factors.

### 2.4 Discussion

All five sites within the study were found to have measures of central tendency of storm-event pollutant concentrations above MDEQ draft numeric criteria and EPA recommended guidelines for Level IV Ecoregion 65a for TN and TP, some sites with loads above TSS loads above the MDEQ TMDL, and pathogen counts above recommended levels (MDEQ, 2016; USEPA, 2000). Additionally, a complementary study during this time period found base-flow concentrations of the same pollutants to also be above draft numeric criteria (Ramirez-Avila, 2020). The overall failure of pollutant concentrations to meet numeric water quality criteria
indicates that tributaries within the study are impaired. Overabundance of these pollutants may pose an environmental threat to fish and wildlife populations using the tributaries and ultimately be contributing to both acute and chronic water quality issues downstream.

Downstream treatment sites generally had higher pollutant concentrations than upstream reference sites. Nutrient pollutant levels and loss of sediment via gully expansion in pastures has been attributed to both cattle presence and use patterns (Buck et al., 2004; Zaimes et al. 2009). Proximity of livestock in pastures at the Dairy Farm (R2/T2) to the tributary may have been a contributing factor in the development of greater pollutant concentrations (TN, TP, and pathogens) downstream. Exclusion fencing, a key component to reducing livestock proximity to the stream, was not fully installed around Catalpa Creek on Dairy Farm during the study. As a result, an entire riparian buffer within the fencing, consisting of planted grasses, trees, and natural vegetation, was also not implemented. Exclusion fencing for livestock have been studied and suggested as methods for effective, immediate reduction of cattle nutrient input and soil degradation via loafing within small riparian areas, allowing vegetation to recover and protect soil and water quality (Clary et al., 2016; Meals et al., 2010; Peterson et al., 2001). These planned vegetative conservation practices were a critical part of the implementation plan to reduce pollutant loads and their incomplete implementation may have prevented noticeable reduction of pollutant concentrations and loads.

The differences in mean concentrations of pathogen levels between reference and treatment sites was greatest at the Dairy Farm, which was characterized as having heavy livestock presence near the creek. Presence of both E. coli and enterococci was significantly greater below the grazing pastures. This hypothesized relationship is supported by previous studies, which indicate livestock presence and use of riparian streams can be a substantial source of fecal indicator bacteria (Weidhaas et al., 2018). However, other studies postulate sediment transport in runoff to streams
to be a significant source of pathogen indicators due to the transport of sediment-bound bacteria (Ferguson et al., 1996; Fraser et al., 1998). The lack of significant differences between upstream and downstream TSS concentrations at the Dairy Farm, however, suggests increases in pathogen concentrations may be more likely sourced from livestock rather than sediment transport in this situation.

Lower TN concentration post-implementation at site R1 may be attributed to changes in activity within the developing suburban area upstream of the monitoring site. This reduction would theoretically aid in accounting for upstream influence of TN reductions at T1, however, the downstream treatment site did not see any change in TN concentrations post-implementation. Meals et al. (2010) reported practice implementation may take decades to effectively influence phosphorus and sediment water quality measurements in watersheds. However, levels of nitrogen are reported to be the most responsive nutrient with detectable effects within months to years in surface runoff, depending on the size of the watershed and intensity of conservation practice implementation (Meals et al., 2010). Differences in pollutant concentrations with the implementation of practices may not be possible to detect for the larger stream order sites and certain variables within the short (1-year post-implementation) time period of this study.

The highest values for pollutants generally occurred at T3, which contains a first order stream within a small pasture-dominated watershed, downhill of a high-traffic beef cattle pasture area. Previous studies by Lowrance et al. (1997) and Buck et al. (2004) established that local land use around first order streams, particularly the abundance and movement of livestock, is highly correlated with first order stream water quality because of the immediate spatial interaction of runoff with pollutants. Site T3 may have had higher concentrations of pollutants because of its more direct interaction with land in the small drainage area, a consequence of its first order status.
With only partial implementation at other sites, T3 was the only site to receive the full complement of planned conservation practices, including multiple check dams, a drop-riser pipe with protective concrete buffer, and heavy use pads. Additionally, grass buffers were allowed to persist along and within the drainage channel. The factors of practice implementation density and placement along low order streams has been proposed by several studies to be the most effective strategy for achieving meaningful reductions in water quality parameters (Baker, et al., 2018; Kroger et al., 2015; Osborne & Kovacic, 1993). Riparian cover of first order streams have also been hypothesized to be influential in the concentrations of downstream water quality parameters, specifically for TN and TP concentrations (Alexander et al., 2007; Dodds & Oakes, 2008; Osborne & Kovacic, 1993; Peterson et al., 2001). Furthermore, the type, age, and width of riparian cover was found to influence uptake of nitrogen within buffers, with woody, younger, or wider footprints having greater percentages of nitrogen uptake than herbaceous, older, or narrower buffers (Mayer et al., 2007; Valkama et al., 2018). These studies support the observation that the presence of a new and adequately wide herbaceous buffer at T3 likely helped with nitrogen uptake in the pre-implementation period. With support from previous findings in low-order stream systems, the observed high density of practice implementation within the T3 drainage area, and direct interaction of T3 with the landscape as a first order stream, these implementation factors are interpreted to be at least somewhat responsible for the reduction of TN concentrations post-implementation of conservation practices.

Reciprocal to the discussed advantages of conservation implementation and monitoring along small order streams, determining conservation practice effectiveness in larger streams with highly incised streambanks poses challenges. Channel morphology of an incised stream (such as the tributary along sites R1/T1) exacerbates pollutant loading because of the positive feedback
loop between increased stormflow capacity, sediment loading, and streambank failure (Dabney et al., 2012; Simon, 1989). Incoming discharge from upstream sources and processes within these altered streams have more influence on in-stream water quality than the immediate surrounding landscape, which makes addressing degradation in these channels difficult (Shields et al., 2007). To fully address conservation needs in systems with modified agricultural streams, in-stream structures or intensive alteration of channel morphology to natural characteristics – such as gradual sloping banks to reduce erosion potential, meandering channel paths courses that slow water velocity, and establishment of riparian buffers to stabilize soil – would be needed (Shields et al., 2007). However, this type of full channel restoration may be difficult to fully implement given the limited financial and technical assistance of most NPS conservation projects available to landowners.

The development of water quality criteria and study of conservation effectiveness is crucial to the ongoing efforts to address broad-scale pollutant impacts, such as those in the Gulf of Mexico Hypoxia Zone. Though it may be tempting to determine sources of water quality issues within larger watershed contexts, true effectiveness of practices and conservation efforts are realized when planned at much smaller, local scales (Alexander et al., 2007; Buck et al., 2004; Lowrance et al., 2007; Meals et al., 2010). These smaller catchment areas, especially those of first order streams, interact directly with landscape sources of pollutants. The sheer number of first order streams, foundational in the natural dendritic distribution of streams and rivers, makes them integral in the pollutant transport process and exacerbation of pollutant effects downstream (Alexander et al., 2007). Thus, reductions in TN concentrations at sites such as T3 are promising in the context of potential widespread conservation implementation efforts directed at first order stream sites.
Though further studies of water quality in the context of upstream versus downstream and conservation practice implementation studies will and should be undertaken, some considerations should be given to working in the natural environment. The status of water monitoring equipment has advanced greatly, but with that comes potential variability in data due to equipment malfunction and loss, in addition to the normal human-introduced bias and error. In the duration of this study, water monitoring equipment at sites with exposure to greater instream flow, higher discharge volumes, and natural debris suffered frequent damage and required intensive maintenance efforts. In contrast, the only site at a first order stream (T3) required less maintenance and no replacement due to physical damage. With the forecasted increase in intensity and frequency of precipitation and flood events, extreme and equipment-threatening weather events may be potentially increasing in frequency within the region in the future (Kunkel et al., 2013). This could negatively impact storm-event water quality monitoring efforts by exposing sensitive equipment to severe damage and losing the input of significant flood events in data, which have been reported to be substantial sources of downstream pollutant loads (Buck et al., 2004). The extent of equipment upkeep is sometimes not fully considered or written off as inevitable in placement of study sites, but should be thoroughly considered before undertaking such intensive sampling regimes as those required for storm-event water quality monitoring. In the scenario of implementing conservation practices and assessing their effectiveness in reducing water pollutant concentrations, it is mutually beneficial for both environmental systems, regulatory agencies, and researchers to place practices within first order streams that can respond quickly to changes in resource management and be monitored without substantial risk to equipment or personnel.

The complexity of conservation practice adoption and evaluation creates several challenges for researchers and stakeholders interested in efficiently and effectively implementing
conservation practices. Private stakeholders may not have the resources (time, spatial, financial) to participate in conservation efforts at the required density and over the necessary time frame needed to overcome ecological thresholds. Additionally, confounding environmental variables, such as high rainfall events, may thwart efforts to implement and effectively establish even the best-intentioned conservation plans. When placed within context of the number of impaired watersheds and conservation practices potentially needed to remediate these impairments around the U.S., these challenges are daunting.

Several possible solutions could be pursued to reduce this complexity and increase conservation efforts. Further research into quantifying practice thresholds and the prioritization of practice selection and placement (such as precision agriculture applications) would help determine the most effective and efficient implementation plans for farm-level conservation. This in turn may increase ease of adoption by reducing the complexity of planning and implementation for individual landowners. To create a larger impact with the adoption of field and farm-level conservation plans, a network of collaboration at the watershed level between government agencies, communities, and individual landowners is also encouraged. Additionally, funding and environmental policy could be adjusted or leveraged in conservation initiatives that provide the short-term results necessary for determining conservation practice effectiveness, as there is currently an apparent discrepancy between the length of funding for projects and ecosystem response necessary to determine conservation practice effectiveness. Ultimately, a strong framework exists for meaningful conservation practice implementation and improvement in water resources. These conservation efforts simply need to be more accurately aligned with the intrinsic behavior of ecosystems and landowners.
### 2.5 Tables and Figures

Table 2.1  
Descriptions of planned conservation practices (treatments) for Phase 1 of the Catalpa Creek restoration project that are evaluated by water quality monitoring at downstream treatment sites.

<table>
<thead>
<tr>
<th>NRCS Code</th>
<th>Practice</th>
<th>Purpose</th>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>342</td>
<td>Reshaping/Grading/Planting</td>
<td>Establish vegetation; reduce soil erosion; protect water quality</td>
<td>T1, T2</td>
<td>FE</td>
</tr>
<tr>
<td>382</td>
<td>Fencing</td>
<td>Livestock exclusion from riparian areas; reduce soil erosion and establish vegetation</td>
<td>T1</td>
<td>FE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T2</td>
<td>PE</td>
</tr>
<tr>
<td>391</td>
<td>Riparian Buffer</td>
<td>Reduce soil erosion of streambanks; protect stream structure</td>
<td>T2</td>
<td>PE</td>
</tr>
<tr>
<td>410</td>
<td>Grade Stabilization</td>
<td>Control head-cutting and soil erosion</td>
<td>T1, T3</td>
<td>FE</td>
</tr>
<tr>
<td>512</td>
<td>Biomass Planting (Buffer)</td>
<td>Establish native vegetation buffer; reduce soil erosion along tributaries</td>
<td>T1</td>
<td>FE</td>
</tr>
<tr>
<td>578</td>
<td>Stream Crossing</td>
<td>Provide livestock access to land areas; reduce pollutant loading of stream</td>
<td>T2</td>
<td>FE</td>
</tr>
<tr>
<td>587</td>
<td>Check Dam</td>
<td>Reduce water velocity, head cutting, and soil erosion</td>
<td>T2, T3</td>
<td>FE</td>
</tr>
<tr>
<td>N/A</td>
<td>Streambank Stabilization</td>
<td>Correct streambank erosion</td>
<td>T1</td>
<td>FE</td>
</tr>
</tbody>
</table>

PE = Partially Established; FE = Fully Established
Table 2.2  Descriptions of storm-event Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) concentrations at Catalpa Creek tributary sites over the complete study period.

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>IQR</td>
<td>Median</td>
</tr>
<tr>
<td>R1</td>
<td>34</td>
<td>1.000</td>
<td>0.655</td>
<td>0.345</td>
</tr>
<tr>
<td>T1</td>
<td>30</td>
<td>1.385</td>
<td>0.688</td>
<td>0.510</td>
</tr>
<tr>
<td>R2</td>
<td>28</td>
<td>1.045</td>
<td>0.490</td>
<td>0.230</td>
</tr>
<tr>
<td>T2</td>
<td>30</td>
<td>1.375</td>
<td>0.730</td>
<td>0.295</td>
</tr>
<tr>
<td>T3</td>
<td>28</td>
<td>3.065</td>
<td>2.570</td>
<td>1.540</td>
</tr>
</tbody>
</table>

N = number of complete samples collected at site within indicated practice implementation period; IQR = inter-quartile range

Table 2.3  Descriptions of storm-event Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) loads at Catalpa Creek tributary sites over the complete study period.

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>TN (tons/acre)</th>
<th>TP (tons/acre)</th>
<th>TSS (tons/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>IQR</td>
<td>Median</td>
</tr>
<tr>
<td>R1</td>
<td>18</td>
<td>0.00004</td>
<td>0.00006</td>
<td>0.00015</td>
</tr>
<tr>
<td>T1</td>
<td>12</td>
<td>0.00003</td>
<td>0.00006</td>
<td>0.00011</td>
</tr>
<tr>
<td>R2</td>
<td>9</td>
<td>0.00004</td>
<td>0.00005</td>
<td>0.00007</td>
</tr>
<tr>
<td>T2</td>
<td>8</td>
<td>0.00001</td>
<td>0.00001</td>
<td>0.00003</td>
</tr>
<tr>
<td>T3</td>
<td>17</td>
<td>0.00011</td>
<td>0.00025</td>
<td>0.00097</td>
</tr>
</tbody>
</table>

N = number of complete samples collected at site within indicated practice implementation period; IQR = inter-quartile range
Table 2.4  Descriptions of *E. coli* and enterococci colony-forming units (geometric means) counts at Catalpa Creek tributary sites over the complete study period.

<table>
<thead>
<tr>
<th>Site</th>
<th>Summer</th>
<th></th>
<th>Winter</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td><em>E. coli</em> (CFU/100 mL)</td>
<td>Enterococci (CFU/100 mL)</td>
<td>N</td>
</tr>
<tr>
<td>R1</td>
<td>14</td>
<td>12136</td>
<td>10726</td>
<td>20</td>
</tr>
<tr>
<td>T1</td>
<td>11</td>
<td>13675</td>
<td>13662</td>
<td>19</td>
</tr>
<tr>
<td>R2</td>
<td>10</td>
<td>10813</td>
<td>9203</td>
<td>18</td>
</tr>
<tr>
<td>T2</td>
<td>12</td>
<td>55542</td>
<td>44248</td>
<td>18</td>
</tr>
<tr>
<td>T3</td>
<td>10</td>
<td>35324</td>
<td>54910</td>
<td>18</td>
</tr>
</tbody>
</table>

**N** = number of complete samples collected at site within indicated season (CFU/100 mL)

Table 2.5  Descriptions of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) concentrations at Catalpa Creek tributary sites pre- and post-implementation of planned practices.

<table>
<thead>
<tr>
<th>Site</th>
<th>Period</th>
<th>N</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>IQR</td>
<td>Median</td>
<td>IQR</td>
</tr>
<tr>
<td>R1</td>
<td>Pre</td>
<td>23</td>
<td>1.27</td>
<td>0.87</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>11</td>
<td>0.9</td>
<td>0.13</td>
<td>0.51</td>
</tr>
<tr>
<td>T1</td>
<td>Pre</td>
<td>21</td>
<td>1.46</td>
<td>0.79</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>9</td>
<td>1.11</td>
<td>0.51</td>
<td>0.24</td>
</tr>
<tr>
<td>R2</td>
<td>Pre</td>
<td>20</td>
<td>1.16</td>
<td>0.3675</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>8</td>
<td>0.76</td>
<td>0.305</td>
<td>1.71</td>
</tr>
<tr>
<td>T2</td>
<td>Pre</td>
<td>20</td>
<td>1.375</td>
<td>0.505</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>10</td>
<td>1.315</td>
<td>1.58</td>
<td>0.415</td>
</tr>
<tr>
<td>T3</td>
<td>Pre</td>
<td>19</td>
<td>3.82</td>
<td>2.355</td>
<td>0.275</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>9</td>
<td>1.79</td>
<td>2.43</td>
<td>0.29</td>
</tr>
</tbody>
</table>

**N** = number of complete samples collected at site within indicated practice implementation period; **IQR** = inter-quartile range
Table 2.6  Descriptions of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) estimated loads (load = event concentration times total event discharge) at Catalpa Creek tributary sites pre- and post-implementation of planned practices.

<table>
<thead>
<tr>
<th>Site</th>
<th>Discharge</th>
<th>TN</th>
<th></th>
<th></th>
<th>TP</th>
<th></th>
<th></th>
<th>TSS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (liters)</td>
<td>Area (ac)</td>
<td>Pre C (mg/L)</td>
<td>L (ton/ac)</td>
<td>Post C (mg/L)</td>
<td>L (ton/ac)</td>
<td>Pre C (mg/L)</td>
<td>L (ton/ac)</td>
<td>Post C (mg/L)</td>
</tr>
<tr>
<td>R1</td>
<td>13602890</td>
<td>364.8</td>
<td>1.27</td>
<td>0.000052</td>
<td>0.9</td>
<td>0.000037</td>
<td>0.37</td>
<td>0.000015</td>
<td>0.29</td>
</tr>
<tr>
<td>T1</td>
<td>26256335</td>
<td>556.8</td>
<td>1.46</td>
<td>0.000076</td>
<td>1.11</td>
<td>0.000058</td>
<td>0.51</td>
<td>0.000027</td>
<td>0.54</td>
</tr>
<tr>
<td>R2</td>
<td>22064421</td>
<td>358.4</td>
<td>1.16</td>
<td>0.000079</td>
<td>0.76</td>
<td>0.000052</td>
<td>0.24</td>
<td>0.000016</td>
<td>0.21</td>
</tr>
<tr>
<td>T2</td>
<td>35832818</td>
<td>480</td>
<td>1.375</td>
<td>0.000113</td>
<td>1.315</td>
<td>0.000108</td>
<td>0.275</td>
<td>0.000023</td>
<td>0.415</td>
</tr>
<tr>
<td>T3</td>
<td>1087071</td>
<td>13.504</td>
<td>3.82</td>
<td>0.000339</td>
<td>1.79</td>
<td>0.000159</td>
<td>1.44</td>
<td>0.000128</td>
<td>1.71</td>
</tr>
</tbody>
</table>

C = median concentration for indicated period; L = estimated load using average discharge over study period
Table 2.7  Descriptions of *E. coli* and enterococci colony-forming unit counts (geometric means) at Catalpa Creek tributary sites pre- and post-implementation of planned practices.

<table>
<thead>
<tr>
<th>Site</th>
<th>Per.</th>
<th>N</th>
<th><em>E. coli</em> (CFU/100 mL)</th>
<th>Enterococci (CFU/100 mL)</th>
<th>N</th>
<th><em>E. coli</em> (CFU/100 mL)</th>
<th>Enterococci (CFU/100 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td></td>
<td>5</td>
<td>14301</td>
<td>8238</td>
<td>18</td>
<td>11959</td>
<td>6001</td>
</tr>
<tr>
<td>R1</td>
<td>Post</td>
<td>9</td>
<td>10953</td>
<td>12650</td>
<td>2</td>
<td>8062</td>
<td>4035</td>
</tr>
<tr>
<td>T1</td>
<td></td>
<td>4</td>
<td>9693</td>
<td>8561</td>
<td>17</td>
<td>9146</td>
<td>4481</td>
</tr>
<tr>
<td>T1</td>
<td>Post</td>
<td>7</td>
<td>16647</td>
<td>17845</td>
<td>2</td>
<td>78765</td>
<td>13799</td>
</tr>
<tr>
<td>R2</td>
<td></td>
<td>4</td>
<td>12539</td>
<td>9242</td>
<td>16</td>
<td>2607</td>
<td>2201</td>
</tr>
<tr>
<td>R2</td>
<td>Post</td>
<td>6</td>
<td>9796</td>
<td>9176</td>
<td>2</td>
<td>5360</td>
<td>5426</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td>4</td>
<td>18214</td>
<td>17093</td>
<td>16</td>
<td>7352</td>
<td>3843</td>
</tr>
<tr>
<td>T2</td>
<td>Post</td>
<td>8</td>
<td>96989</td>
<td>71191</td>
<td>2</td>
<td>143541</td>
<td>14131</td>
</tr>
<tr>
<td>T3</td>
<td></td>
<td>3</td>
<td>24018</td>
<td>14842</td>
<td>16</td>
<td>20508</td>
<td>8016</td>
</tr>
<tr>
<td>T3</td>
<td>Post</td>
<td>7</td>
<td>41675</td>
<td>96194</td>
<td>2</td>
<td>99599</td>
<td>3286</td>
</tr>
</tbody>
</table>

N = number of complete samples collected at site within indicated practice implementation period and season
Figure 2.1  Map of Red Bud – Catalpa Creek watershed and study site drainage areas, located within the Tibbee Creek Sub-Basin (HUC #03160104) and Tombigbee River Basin (HUC #031601) in northeast Mississippi.
Figure 2.2  Land use in context within the South Farm and Dairy Farm study sites in the Red Bud – Catalpa Creek Watershed (National Land Cover Database (NLCD) data courtesy of U.S. Geological Survey).
Figure 2.3   Pie charts of land use distribution within site drainage areas (NLCD and drainage delineation data courtesy of U.S. Geological Survey).
Figure 2.4  Boxplots of general Total Nitrogen (TN) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period. The blue dashed line (0.850 mg/L) indicates MDEQ draft numeric criteria TN concentration for pollutant/stressor response threshold (macroinvertebrate indicators), while the red line (0.618 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TN concentrations (MDEQ, 2016; USEPA, 2000).
Figure 2.5  Boxplots of general Total Phosphorus (TP) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period. The blue dashed line (0.060 mg/L) indicates MDEQ draft numeric criteria TP concentration for pollutant/stressor response threshold (macroinvertebrate indicators), while the red line (0.0225 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TP concentrations (MDEQ, 2016; USEPA, 2000).
Figure 2.6   Boxplots of general Total Suspended Solids (TSS) concentrations from all storm-event samples collected within Catalpa Creek tributaries during the study period.
Figure 2.7  Boxplots of general Total Nitrogen (TN) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period.
Figure 2.8  Boxplots of general Total Phosphorus (TP) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period.
Figure 2.9  Boxplots of general Total Suspended Solids (TSS) loads from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line indicates the adopted MDEQ TMDL limit for TSS within the Tibbee Creek Sub-basin (MDEQ, 2007).
Figure 2.10  Boxplots of general *E. coli* colony counts from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2016).
Figure 2.11  Boxplots of general enterococci colony counts from all storm-event samples collected within Catalpa Creek tributaries during the study period. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2016).
Figure 2.12  Simple linear regression analysis of Total Nitrogen (TN) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.
Figure 2.13  Simple linear regression analysis of Total Phosphorus (TP) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.
Figure 2.14  Simple linear regression analysis of Total Suspended Solids (TSS) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red block indicates the planned conservation implementation period.
Figure 2.15  Boxplots of general Total Nitrogen (TN) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The blue dashed line (0.850 mg/L) indicates MDEQ draft numeric criteria TN concentration for pollutant/stressor response threshold (macroinvertebrate indicators), the red line (0.618 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TN concentrations (MDEQ, 2016; USEPA, 2000).
Figure 2.16  Boxplots of general Total Phosphorus (TP) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The blue dashed line (0.060 mg/L) indicates MDEQ draft numeric criteria TP concentration for pollutant/stressor response threshold (macroinvertebrate indicators), the red line (0.0225 mg/L) indicates suggested EPA Ecoregion 65a numeric criteria for TP concentrations (MDEQ, 2016; USEPA, 2000). Place all detailed caption, notes, reference, legend information, etc here.
Figure 2.17  Boxplots of general Total Suspended Sediment (TSS) concentrations collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices.
Figure 2.18  Boxplots of E. coli colony counts from collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2007).
Figure 2.19  Boxplots of enterococci colony counts from collected within Catalpa Creek tributaries pre- and post-implementation of conservation practices. The red dashed line (200 CFUs/100 mL) indicates MDEQ numeric criteria for fecal coliform indicators during summer months, while the blue line (2000 CFUs/100 mL) indicates suggested MDEQ numeric criteria for winter months (MDEQ, 2007).
### 2.6 References


Mississippi Department of Environmental Quality [MDEQ]. (2007). *Total Maximum Daily Load Tombigbee River Basin Designated Streams in HUC 03160104 (Tibbee Creek) for Impairment Due to Sediment*. Jackson, MS: Department of Environmental Quality.


Ramirez-Avila, J. J. (February 12, 2020). Personal interview.


Stamps, V. (March 15, 2019). Personal interview.


CHAPTER III
COMPETENCIES AND TRAINING NEEDS IN WATER RESOURCE CONSERVATION
FOR SOUTHEASTERN EXTENSION AGENTS

3.1 Introduction

Water quality impairment in surface water streams and rivers in the southeastern United States is a major concern for federal and state natural resource agencies (U.S. Environmental Protection Agency [USEPA], 2019a; USGS, 2010). Compared to the national average of 53%, nearly 55% of assessed surface water streams and rivers in the southeastern U.S. (defined in this study as Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee) are impaired in function (USEPA, 2019b; USGS, 2010). A variety of contaminants can impair stream function, but the three leading pollutants of concern in U.S. rivers and streams are sediment, nutrients, and pathogens (USEPA, 2018b). Excessive pollutants degrade ecosystem resources and threaten the health of both human and wildlife populations (Hooda et al., 2000; Jordan et al., 2016). These pollutants are common products of agricultural activities on the landscape that find their way into surface waters through NPS runoff.

Broad scale awareness of water quality issues and implementation of water conservation practices are needed to effectively address regional water quality impairments caused by agricultural activities. Baumgart-Getz et al. (2012) found that awareness and knowledge of conservation practices and programs, rather than general environmental effects of agriculture, are significant factors in determining conservation practice adoption by farmers. Some studies have
recommended that the Extension Service increase efforts to provide accurate and relevant research-based information to ANR agents, to both increase the service capacity of the organization and impact water conservation (Baumgart-Getz et al., 2012; Harder et al., 2010; Prokopy et al., 2015; Scheer et al., 2011; Smith et al., 2011).

The Extension Service, associated with U.S. LGUs is one of several organizations charged with educating landowners about agricultural practices and natural resources conservation. Extension education is considered a valuable and trustworthy source of agricultural information to farmers (Prokopy et al., 2015; Samy et al., 2003). An essential link in the flow of information and adoption of these conservation practices is outreach by county Extension agents to private-land stakeholders (Cash, 2001). They have responsibilities for delivering up-to-date and relevant information to their local agricultural stakeholders and can promote the adoption of conservation practices advocated by researchers and conservation agencies. However, landowners report using the Extension Service infrequently, which suggests a gap may exist in perceived and actual information needs of stakeholders (Prokopy et al., 2015; Wright & Shindler, 2001).

To close this gap, Extension agents with agriculture and natural resources (ANR) responsibilities must develop competency in relevant ANR subject areas, such as water conservation, and have access to up-to-date information from Extension specialists, subject matter experts tasked with producing research-based educational materials and programs (Prokopy et al., 2015). Competency is generally defined as individual or organizational capability developed by increasing awareness, knowledge, and skills, and thereby leading to greater performance (Athey & Orth, 1999; Harder, 2015; Harder et al., 2010). Previous studies have proposed prioritized lists of core competencies for a variety of state Extension Service units (Benge et al., 2011; Harder, 2015; Layfield & Dobbins, 2002; Scheer et al., 2011). However, agent competencies can vary with
cliente demand and regional ANR priorities, thus fueling the need for continuing education and professional development of Extension personnel to develop and strengthen competency levels.

Training needs for specific competency topics can be determined by conducting needs assessments, which inventory an organization’s or population’s current status in knowledge, skills, and abilities (i.e., competency), and comparing inventory outcomes to desired goals (Kettner et al., 2017). Needs assessments can be an effective method for prioritizing training opportunities and maintaining the Extension Service’s efficiency and relevance (Harder & Wingenbach, 2008; McClure et al., 2012).

The Borich needs assessment model reveals competency levels and training needs by identifying gaps between an individual’s perception of a topic’s importance, or relevance within their training needs, and their perceived ability to communicate the concept in an educational setting (Borich, 1980). This method of needs assessment is completed in four steps: (1) list competency statements, which are brief phrases indicating individual topics of interest for the needs assessment, (2) ask subjects to rate perceived importance and ability regarding each competency statement, (3) calculate and rank competency discrepancy scores, and (4) evaluate competencies in the context of current or planned programs (Borich, 1980). Competency statements with the greatest gaps between perceived importance and perceived ability represent areas of greatest training need, thus informing decision-makers where to focus organizational resources and efforts.

Determining the training needs of ANR agents is a critical step in understanding existing gaps in conservation outreach programs. The Borich model has been utilized previously to identify professional development needs for Extension agents and agricultural educators (Harder & Wingenbach, 2008; Layfield & Dobbins, 2002; Waters & Haskell, 1989). For example, McClure
et al. (2012) used this approach to compare competency levels and training needs of 4-H and ANR Extension agents in Georgia. Using the Borich model to understand training needs of personnel with specialized backgrounds, such as ANR agents, could be an effective way to improve training efficiency, increase awareness of conservation issues, improve services offered to agricultural stakeholders, and increase implementation of conservation practices on private lands through Extension programs.

This study aimed to advance this effort by prioritizing training needs in water resource conservation through a Borich model needs assessment of southeastern ANR Extension agents. The topics presented in the survey of agents were focused on land management issues affecting water resources. The objectives of this study were to:

1. Assess self-reported competencies of southeastern ANR Extension agents in topics related to water resource conservation.
2. Determine training needs of southeastern ANR Extension agents based upon competencies in water resource conservation.
3. Determine the influence of educational background and experience levels on ANR agents’ competency levels in water resource conservation.

3.2 Methods

3.2.1 Target Population

The target population of this study was all county Extension agents with ANR responsibilities in southeastern U.S. states, with region boundaries defined by the member states Association of Southern Region Extension Directors (ASRED). The thirteen states of interest in this study were: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. These states were selected
for their regional continuity, similarity in water resource concerns, and the potential for survey distribution through ASRED.

3.2.2 Survey Instrument

A 14-item web-based survey was designed to assess ANR agents’ water resources conservation competencies and training needs (Appendix A). Feasible guidelines set forth in the Tailored Design Methods were followed, which included the use of incentives to increase survey response rates and survey distribution via authoritative figures (Dillman, Smith, & Christian, 2014). An incentive of a random drawing for a gift card was incorporated in an attempt to increase survey response rates, and Extension directors were recruited to distribute the survey to their ANR agents.

Eleven land management competency topics were chosen based on their relevance to water resource conservation in the southeastern United States (Table 3.1). The majority were selected from Alibaygi and Zarafshani (2008) who used Borich’s model to determine in-service training needs of Iranian Extension agents in topics of agriculture-related sustainability. Additional water-related topics of management concerns to USDA Natural Resource Conservation Service were also included (NRCS, 2019). The list of land management competency topics was reviewed and approved by two water resources specialists to establish face validity.

The survey instrument included a brief introduction to the survey and a consent request, as well as the explanation that there would be an opportunity for respondents to enter into a random drawing for a $25 gift card. Questions on agents’ areas of responsibility were used to remove respondents without substantive ANR assignments and determine their geographic scope of influence. Several Likert-type questions were designed to determine landowner expressed needs for agent competencies and to contribute to the agent competency assessment via the Borich needs
assessment model framework. Because agents’ educational background and experience could influence competency, questions to assess their formal education and major fields of study were included. Optional questions about agent age and gender were also included.

Approval from the Mississippi State University (MSU) Institutional Review Board (IRB) for the questionnaire was obtained (Approval #IRB-19-229). A pilot study was implemented with current MSU Extension agents with ANR responsibilities (n = 10). After receiving feedback from MSU Extension ANR agents (n = 10) in a pilot study, the survey was revised for distribution to the target population. Agents who completed the pilot survey were asked to abstain from participating in the final project survey, which was distributed online through Qualtrics® (Qualtrics International, Inc., Provo, UT, USA).

The survey was distributed to southeastern Extension agents via email and an anonymous link by state Extension directors and administration. These administrators were recruited at an annual meeting of ASRED and requested to send the survey link with a scripted request within the first week of September 2019. Data collection closed after four weeks at the beginning of October 2019. To not be a burden to the Extension administrators who sent out the request to their personnel, a survey reminder was not pursued.

### 3.2.3 Data Analysis

The software program SPSS® 26.0 (IBM Corp., Armonk, NY, USA) was used to determine survey reliability, summarize respondent demographic data, and analyze educational backgrounds of agents. Program R (R Core Team, 2019) was used to summarize landowners’ expressed needs and determine mean importance, ability, and weighted discrepancy scores for in-service training needs.
Cronbach’s alpha coefficients were calculated to determine reliability, or internal consistency of questions, for Borich’s model questions pertaining to land management topic importance and agent ability to address landowner needs in these topics (Alibaygi & Zarafshani, 2008; Harder & Wingenbach, 2008).

Descriptive statistics were used to determine mean topic importance and agent ability ratings for each land management topic. The Borich (1980) formula for mean weighted discrepancy scores (MWDS) shown below (Equation 3.1) was used to calculate and subsequently rank training needs to determine priority training needs in water resource conservation (Alibaygi & Zarafshani, 2008; Borich, 1980; Harder & Wingenbach, 2008).

\[
MWDS = \frac{\sum [(\text{Perceived Importance} - \text{Perceived Ability}) \times \text{Mean Importance}]}{\text{Number of Observations}}
\]

Descriptive statistics were used to summarize education and experience levels of respondents. One-way Analysis of Variance (ANOVA) was used to detect main effects of education and experience level on land management importance, agent ability, and discrepancy scores. Tukey’s Honest Significant Difference (HSD) post-hoc test was used for multiple pairwise comparisons of means. An alpha level of \(p < 0.05\) was chosen \textit{a priori}.

3.3 Results

Seven states participated in the survey (Alabama, Arkansas, Kentucky, Mississippi, Oklahoma, South Carolina, and Virginia) for a total of 246 responses (see Table 3.2 for responses by state). Two responses were removed for not meeting ANR agent criteria (>10% ANR related responsibilities), bringing the total number of valid responses to 244. State Extension
administrations who distributed the surveys did not disclose the number of agents given access to the survey; therefore, a survey response rate cannot be determined. The Cronbach’s alpha scores for topic importance and ability questions were .87 and .88, respectively. Scores closer to 1 indicate strong reliability (Taber, 2018). Therefore, the alpha scores obtained for this survey instrument were interpreted to indicate satisfactory reliability and delineation of subtopics.

Most respondents were male (68.4%), with more than 10 years of Extension Service experience (51.4%), and had a master’s degree as their highest formal education level (66%) (Table 3.2). The highest education level reported by a majority of respondents was a master’s degree (66%), followed by a bachelor’s degree (14.3%), some graduate education (11.5%), and doctoral degree (6.1%). Age of respondents was nearly evenly distributed among the categories of 25-34 years (22.6%), 35-44 years (26.5%), 45-54 years (27.4%), and 55-64 years (18.3%) old. Most respondents described themselves as responsible for Extension activities at the county level (76.6%). Demographic profiles for individual states are in Table 3.2. Education and experience levels are also illustrated by state in Figure 3.1 and Figure 3.2, respectively.

Mean land management topic importance and agent ability scores are presented in Table 3.3, as well as landowner expressed needs (LEN). Topics rated as most important to agents were “fertilizer application” ($M = 4.28$, $SD = 0.67$), “nutrient management” ($M = 4.15$, $SD = 0.68$), “water quality in streams or ponds” ($M = 4.07$, $SD = 0.87$), “water conservation” ($M = 4.07$, $SD = 0.87$), and “soil erosion” ($M = 4.06$, $SD = 0.78$). The land management topic “reducing the use of fertilizer” was given the lowest importance rating. Agents rated their abilities highest for explaining “fertilizer application” ($M = 3.78$, $SD = 0.97$) and “nutrient management” ($M = 3.49$, $SD = 0.90$). The lowest ability ratings were given to “pathogen pollution in waterways” ($M = 2.54$, $SD = 0.97$).
“water quality in streams or ponds” \( (M = 3.02, SD = 1.06) \), and “soil loss in agricultural fields” \( (M = 3.09, SD = 1.04) \).

Landowner expressed needs are presented in Table 3.3 for comparison with competency importance and ability scores. The LEN is the mean value given by agents for their perception of how often landowners ask for information about each competency topic. Agents report that landowners seek information most often about “fertilizer application” \( (LEN = 4.03) \) and “nutrient management” \( (LEN = 3.63) \), and least often about “reducing the use of agricultural chemicals” \( (LEN = 2.17) \).

The three highest MWDS values overall were for “water quality in streams or ponds” \( (MWDS = 4.23) \), “pathogen pollution in waterways” \( (MWDS = 3.59) \), and “water conservation” \( (MWDS = 3.51) \) (Table 3.4). The lowest MWDS value was for “reducing use of fertilizer” \( (MWDS = 0.68) \). All states reported the topic of “Water quality in streams or ponds” in their top three MWDS values (Table 3.4). Alabama, Arkansas, and Mississippi shared the same top training needs as indicated by MWDS values: “water quality in streams or ponds” \( (AL = 5.98, AR = 3.76, MS = 4.83) \), “pathogen pollution in waterways” \( (AL = 5.98, AR = 3.07, MS = 4.37) \), and “water conservation” \( (AL = 5.31, AR = 3.76, MS = 4.59) \). Kentucky and Oklahoma reported “soil erosion” as a major training need, while “nutrient management” was reported as the second highest MWDS value in South Carolina. Virginia reported MWDS values of zero for the topics of “reducing use of fertilizer”, “soil erosion”, and “reducing the use of agricultural chemicals”, as well as a negative MWDS value for “soil loss in agricultural fields”, indicating no need for training in these topics.

Respondents with doctoral degrees had significantly different mean ability ratings \( (M_{\text{Doctoral}} = 3.33) \) and mean discrepancy scores \( (M_{\text{Doctoral}} = 0.13) \) compared to those with different levels of formal education (ability: \( M_{\text{Master’s}} = 2.53; M_{\text{Bachelor’s}} = 2.4 \); discrepancy scores: \( M_{\text{Master’s}} = 1.02; M_{\text{Bachelor’s}} = 2.0 \)
$M_{Bachelor’s} = 1.11$) for the topic “pathogen pollution” (ability: $F(3, 235) = 3.357, p = .02$; discrepancy scores: $F(3, 235) = 2.833, p = .04$). For the topic “water quality in streams or ponds”, there was a difference in mean ability ratings between doctoral ($M = 3.73$) and some graduate education group ($M = 2.79$) ($F(3, 235) = 2.814, p = .026$) and doctoral and master’s degree group ($M = 2.99$) ($F(3, 235) = 2.814, p = .047$), as well as a difference in mean discrepancy scores between doctoral ($M = 0.27$) and bachelor’s degree ($M = 1.23$) groups ($F(3, 235) = 2.753, p = .031$).

Mean importance rating for “water conservation” was significantly different between respondents with five to six-years of experience ($M_{5-6} = 4.36$) and those with less than one year of experience ($M_{<1} = 3.5, F(6, 236) = 2.459, p = .004$). Mean ability ratings for “reducing use of fertilizer” were significantly different between agents with more than ten years of experience ($M_{>10} = 3.52$) and those with less than one year of experience ($M_{0} = 2.5, F(6, 236) = 2.681, p = .007$). Discrepancy scores were also significantly different between agents with more than ten years of experience ($M_{>10} = 0.072$) and those with three to four years of experience in the topic of “cover crops” ($M_{3-4} = 0.811, F(6, 236) = 3.285, p = .013$), and those with one to two years of experience in the topic of “Water quality in streams or ponds” ($M_{1-2} = 1.667, F(6, 236) = 3.285, p = .048$).

### 3.4 Discussion

Overall, respondents rated the importance of land management topics greater than their perceived ability to educate landowners in these topic areas, which signals a need for further professional development in these topics and water resource conservation. A higher MWDS value indicates greater training needs, while negative values would suggest no further training is necessary. The highest MWDS values were given to land management topics related to sediment,
nutrient, and pathogen pollution. These topics are of great importance in water resource protection efforts because of their potential to harm environmental and human health (Clary et al., 2016; Hooda et al., 2000; USEPA, 2019b; Zaimes et al., 2009). Though all competency topics are concepts in water resource conservation, the contributing sources of conservation issues such as soil loss, pathogen pollution, nutrient management, and water conservation are of high training priority according to surveyed agents.

Land management topics related to sediment input in water resources were split between source issues and conservation practices. Agricultural watersheds contribute significantly to water quality impairment issues, such as sediment pollution (Evans et al., 2019). Practices such as conservation tillage and cover crops have been shown in previous studies to reduce erosion and runoff from fields (Kaye & Quemada, 2017; Shipitalo & Edwards, 1998). Source issues, referenced in the survey as soil loss in agricultural fields and soil erosion, were given higher training priority than conservation practices, referenced in the survey as no-till or reduced tillage and cover crops. Landowners reportedly expressed nearly even interest in all four sediment input topics. Numerous studies have also found other benefits of these practices, such as fuel cost savings, reduced fertilizer input, and improved soil structure (Dabney et al., 2001; Snapp et al., 2005). It is unclear whether these other conservation benefits are driving competency of agents in sediment-focused conservation practices, rather than sediment pollution concerns and landowner interest.

Fertilizer application, nutrient management, and fertilizer reduction are important components in managing nutrient pollution (Carpenter et al., 1998; USEPA, 2020). However, Extension agents in this survey did not appear to recognize the importance of reducing fertilizer use and their ability ratings were lower in this topic than the land management topics of fertilizer
application and nutrient management. This suggests there may be a disconnect in their understanding of the inter-relationship of these three land use practices and water resource conservation. These topics together describe common sources of nutrient pollution in watersheds, therefore having agents trained in each of these topics more equally would be beneficial for outreach regarding nutrient reduction strategies.

Pathogen pollution, a more prevalent issue in watersheds with animal agriculture, is also a considerable pollutant concern because of its potential health risk to humans, wildlife, and livestock. It is associated with nutrient pollution from animal waste and can be exacerbated by sediment losses in pastures (Ferguson et al., 1996; Fraser et al., 1998; Weidhaas et al., 2018). Pathogen pollution was a high priority training need as indicated by overall MWDS scores, second only to overall water quality in streams and ponds. The complementary relationship between pathogen, nutrient, and sediment pollution requires integrated pollution management strategies. Prioritizing training efforts on pathogen pollution should not happen in isolation, but rather in conjunction with other high priority nutrient and sediment pollution topics, such as nutrient management, soil loss in agricultural fields, and soil erosion.

Bailey et al. (2014) found agents perceive client questions as a main motivation for seeking information on a topic. Topics of fertilizer application and nutrient management both received high ratings of importance and above average ability by agents. When paired with the expressed landowner need, which was also high for these topics, competency ratings by agents may be explained by higher preparedness because of frequently answering landowner questions on these topics. In contrast, importance and ability ratings for nutrient reduction strategies were low while landowners’ expressed need was high. This inverse relationship indicates a gap between agent
perceptions, possibly influenced by subjective preferences, and objective evaluations of the needs of landowners.

Results suggest that although a doctoral degree and greater experience increase competency, the advantage appears limited and not discernable as a larger pattern among the respondent population. Other studies have found differences in competency performance for experience groups of agents, but only for broader, formally defined responsibilities such as developing surveys and interpreting results in program evaluation (McClure et al., 2012). This suggests that targeted training to address gaps in capabilities may be as efficacious as pursuing advanced degrees that may not be centered on topics of relevance to landowner or conservation needs.

Training needs must be prioritized to maintain the Extension Service’s capacity in the face of systematic challenges. Studies have reported time, budgetary limitations, administrative demands, and educational demands as major challenges to Extension agent performance (Bailey et al., 2014; Brian et al., 2009; Harder & Wingenbach, 2008; McCann, 2007; McClure et al., 2012). Needs assessments such as the one conducted in this study provide a framework for prioritizing training needs so that limited resources are used effectively. The findings presented here suggest a path forward for training development within several different states to address water resource conservation issues effectively and efficiently. This training development is an important step increasing exposure of traditional Extension audiences on the topic of water resources (Boellstorff et al., 2013; Harder, 2015).

This study is different from other Borich model needs assessments of Extension agents in the United States because it addresses a natural resource concern, rather than administratively defined competency topics and duties of Extension agents. An advantage of using the Borich
model is that it allows agents to objectively measure their own competency levels, rather than subjective measurements by administrative personnel (Borich, 1980). However, it is only one piece of the organizational puzzle. Further studies in landowner perceptions on conservation practice adoption, administrative viewpoints on training priorities, and testing of agents in actual landowner guidance scenarios could improve the interpretation of results from this study by providing context within the greater Extension system. Though this study addressed agents’ perceptions of landowner expressed needs, there is potential for these observations to have biased reporting. Landowners may seek water resource conservation information from other sources because they perceive Extension to be relevant in most but not all topics (Prokopy et al., 2015). Additionally, development of competency benchmarks for ANR agents by state Extension administrations would give training efforts more legitimacy within the context of reaching a measurable goal. These competency benchmarks would be advantageous for addressing water conservation specifically or other integrated natural resource concerns, including pollinator habitat, wildlife habitat management, protection of endangered species, and control of invasive species. In the event that these initiatives are overwhelming for an already overburdened Extension Service, encouragement and training could also be provided to agents on leveraging relationships with other agencies working to address these topics. For example, if a landowner has a question about soil erosion that an agent does not have the capacity or resources to directly answer, the agent could simply direct the landowner to contact the district NRCS office, which would provide further technical assistance to the landowner without demanding more of the agent’s limited resources. Working relationships like these may become critical and would effectively use the current framework of the Extension Service to further the agency’s capacity without significantly increasing the workload on already over-stretched agents.
### 3.5 Tables and Figures

Table 3.1  Land management topics used to assess competency in an online survey of southeastern Extension agents with agricultural and natural resources responsibilities.

<table>
<thead>
<tr>
<th>Land Management Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss in agricultural fields</td>
</tr>
<tr>
<td>No-till or reduced tillage</td>
</tr>
<tr>
<td>Cover crops</td>
</tr>
<tr>
<td>Fertilizer application (including rate, type, placement, or timing)</td>
</tr>
<tr>
<td>Reducing use of fertilizer</td>
</tr>
<tr>
<td>Soil erosion</td>
</tr>
<tr>
<td>Nutrient management</td>
</tr>
<tr>
<td>Pathogen pollution (disease/bacteria) in waterways</td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals</td>
</tr>
<tr>
<td>Water quality in streams or ponds</td>
</tr>
</tbody>
</table>
Table 3.2  Demographic characteristics of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities.

<table>
<thead>
<tr>
<th></th>
<th>AL N (%)</th>
<th>AL %</th>
<th>AR N (%)</th>
<th>AR %</th>
<th>MS N (%)</th>
<th>MS %</th>
<th>SC N (%)</th>
<th>SC %</th>
<th>KY N (%)</th>
<th>KY %</th>
<th>OK N (%)</th>
<th>OK %</th>
<th>VA N (%)</th>
<th>VA %</th>
<th>TOTAL N (%)</th>
<th>TOTAL %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respondents</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Of Total</td>
<td>23 (9.4)</td>
<td></td>
<td>75 (30.7)</td>
<td></td>
<td>29 (11.9)</td>
<td></td>
<td>43 (17.6)</td>
<td></td>
<td>38 (15.6)</td>
<td></td>
<td>27 (11.1)</td>
<td></td>
<td>9 (3.7)</td>
<td></td>
<td>244 (100)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>14 (60.9)</td>
<td></td>
<td>58 (77.3)</td>
<td></td>
<td>20 (69)</td>
<td></td>
<td>27 (62.8)</td>
<td></td>
<td>24 (63.2)</td>
<td></td>
<td>19 (70.4)</td>
<td></td>
<td>5 (55.6)</td>
<td></td>
<td>167 (68.4)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8 (34.8)</td>
<td></td>
<td>13 (17.3)</td>
<td></td>
<td>6 (20.7)</td>
<td></td>
<td>15 (34.9)</td>
<td></td>
<td>11 (28.9)</td>
<td></td>
<td>7 (25.9)</td>
<td></td>
<td>4 (44.4)</td>
<td></td>
<td>64 (26.2)</td>
<td></td>
</tr>
<tr>
<td>No Answer</td>
<td>1 (4.3)</td>
<td></td>
<td>4 (5.3)</td>
<td></td>
<td>3 (10.3)</td>
<td></td>
<td>1 (2.3)</td>
<td></td>
<td>3 (7.9)</td>
<td></td>
<td>1 (3.7)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>13 (5.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25 Years</td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>2 (8.3)</td>
<td></td>
<td>2 (4.8)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>4 (1.7)</td>
<td></td>
</tr>
<tr>
<td>25-34 Years</td>
<td>3 (15)</td>
<td></td>
<td>16 (21.6)</td>
<td></td>
<td>2 (8.3)</td>
<td></td>
<td>14 (33.3)</td>
<td></td>
<td>10 (28.6)</td>
<td></td>
<td>5 (19.2)</td>
<td></td>
<td>2 (22.2)</td>
<td></td>
<td>52 (22.6)</td>
<td></td>
</tr>
<tr>
<td>35-44 Years</td>
<td>6 (30)</td>
<td></td>
<td>18 (24.3)</td>
<td></td>
<td>11 (45.8)</td>
<td></td>
<td>12 (28.6)</td>
<td></td>
<td>7 (20)</td>
<td></td>
<td>4 (15.4)</td>
<td></td>
<td>3 (33.3)</td>
<td></td>
<td>61 (26.5)</td>
<td></td>
</tr>
<tr>
<td>45-54 Years</td>
<td>5 (25)</td>
<td></td>
<td>24 (32.4)</td>
<td></td>
<td>6 (25)</td>
<td></td>
<td>7 (16.7)</td>
<td></td>
<td>9 (25.7)</td>
<td></td>
<td>8 (30.8)</td>
<td></td>
<td>4 (44.4)</td>
<td></td>
<td>63 (27.4)</td>
<td></td>
</tr>
<tr>
<td>55-64 Years</td>
<td>5 (25)</td>
<td></td>
<td>14 (18.9)</td>
<td></td>
<td>3 (12.5)</td>
<td></td>
<td>5 (11.9)</td>
<td></td>
<td>8 (22.9)</td>
<td></td>
<td>7 (26.9)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>42 (18.3)</td>
<td></td>
</tr>
<tr>
<td>≥65 Years</td>
<td>1 (5)</td>
<td></td>
<td>2 (2.7)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>2 (4.8)</td>
<td></td>
<td>1 (2.9)</td>
<td></td>
<td>2 (7.7)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>8 (3.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Length of Service</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 Year</td>
<td>0 (0)</td>
<td></td>
<td>6 (8)</td>
<td></td>
<td>1 (3.6)</td>
<td></td>
<td>5 (11.6)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>2 (7.4)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>14 (5.8)</td>
<td></td>
</tr>
<tr>
<td>1-2 Years</td>
<td>1 (4.3)</td>
<td></td>
<td>7 (9.3)</td>
<td></td>
<td>1 (3.6)</td>
<td></td>
<td>4 (9.3)</td>
<td></td>
<td>2 (5.3)</td>
<td></td>
<td>3 (11.1)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>18 (7.4)</td>
<td></td>
</tr>
<tr>
<td>3-4 Years</td>
<td>6 (26.1)</td>
<td></td>
<td>13 (17.3)</td>
<td></td>
<td>2 (7.1)</td>
<td></td>
<td>7 (16.3)</td>
<td></td>
<td>4 (10.5)</td>
<td></td>
<td>3 (11.1)</td>
<td></td>
<td>2 (22.2)</td>
<td></td>
<td>37 (15.2)</td>
<td></td>
</tr>
<tr>
<td>5-6 Years</td>
<td>4 (17.4)</td>
<td></td>
<td>3 (4)</td>
<td></td>
<td>5 (17.9)</td>
<td></td>
<td>4 (9.3)</td>
<td></td>
<td>7 (18.4)</td>
<td></td>
<td>4 (14.8)</td>
<td></td>
<td>1 (11.2)</td>
<td></td>
<td>28 (11.5)</td>
<td></td>
</tr>
<tr>
<td>7-8 Years</td>
<td>0 (0)</td>
<td></td>
<td>4 (5.3)</td>
<td></td>
<td>1 (3.6)</td>
<td></td>
<td>5 (11.6)</td>
<td></td>
<td>2 (5.3)</td>
<td></td>
<td>1 (3.7)</td>
<td></td>
<td>2 (22.2)</td>
<td></td>
<td>15 (6.2)</td>
<td></td>
</tr>
<tr>
<td>9-10 Years</td>
<td>1 (4.3)</td>
<td></td>
<td>2 (2.7)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>1 (2.3)</td>
<td></td>
<td>2 (5.3)</td>
<td></td>
<td>1 (3.7)</td>
<td></td>
<td>2 (22.2)</td>
<td></td>
<td>6 (2.5)</td>
<td></td>
</tr>
<tr>
<td>&gt;10 Years</td>
<td>11 (47.8)</td>
<td></td>
<td>40 (53.3)</td>
<td></td>
<td>18 (64.3)</td>
<td></td>
<td>17 (39.5)</td>
<td></td>
<td>21 (55.3)</td>
<td></td>
<td>14 (51.9)</td>
<td></td>
<td>4 (44.4)</td>
<td></td>
<td>125 (51.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Highest Degree</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor’s</td>
<td>0 (0)</td>
<td></td>
<td>11 (14.7)</td>
<td></td>
<td>1 (3.4)</td>
<td></td>
<td>13 (30.2)</td>
<td></td>
<td>4 (10.5)</td>
<td></td>
<td>6 (22.2)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>35 (14.3)</td>
<td></td>
</tr>
<tr>
<td>Some Grad</td>
<td>1 (4.3)</td>
<td></td>
<td>12 (16)</td>
<td></td>
<td>4 (13.8)</td>
<td></td>
<td>2 (4.7)</td>
<td></td>
<td>5 (13.2)</td>
<td></td>
<td>3 (11.1)</td>
<td></td>
<td>1 (11.1)</td>
<td></td>
<td>28 (11.5)</td>
<td></td>
</tr>
<tr>
<td>Master’s</td>
<td>15 (65.2)</td>
<td></td>
<td>50 (66.7)</td>
<td></td>
<td>18 (62.1)</td>
<td></td>
<td>24 (55.8)</td>
<td></td>
<td>28 (73.7)</td>
<td></td>
<td>18 (66.7)</td>
<td></td>
<td>8 (88.9)</td>
<td></td>
<td>161 (66)</td>
<td></td>
</tr>
<tr>
<td>Doctoral</td>
<td>5 (21.7)</td>
<td></td>
<td>1 (1.3)</td>
<td></td>
<td>5 (17.2)</td>
<td></td>
<td>4 (9.3)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>15 (6.1)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2 (8.7)</td>
<td></td>
<td>1 (1.3)</td>
<td></td>
<td>1 (3.4)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>1 (2.6)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>5 (2)</td>
<td></td>
</tr>
<tr>
<td><strong>Geographic Scope of Responsibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County</td>
<td>6 (26.1)</td>
<td></td>
<td>72 (96)</td>
<td></td>
<td>28 (96.6)</td>
<td></td>
<td>17 (39.5)</td>
<td></td>
<td>38 (100)</td>
<td></td>
<td>20 (74.1)</td>
<td></td>
<td>6 (66.7)</td>
<td></td>
<td>187 (76.6)</td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>12 (52.2)</td>
<td></td>
<td>1 (1.3)</td>
<td></td>
<td>1 (3.4)</td>
<td></td>
<td>16 (37.2)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>7 (25.9)</td>
<td></td>
<td>3 (33.3)</td>
<td></td>
<td>40 (16.4)</td>
<td></td>
</tr>
<tr>
<td>Statewide</td>
<td>5 (21.7)</td>
<td></td>
<td>2 (2.7)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>10 (23.3)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>0 (0)</td>
<td></td>
<td>17 (7)</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.3  Mean importance, ability, and landowner expressed need scores of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities.

<table>
<thead>
<tr>
<th>Land Management Topic</th>
<th>M₁ (SD₁)</th>
<th>M₂ (SD₂)</th>
<th>LEN (SD₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss in agricultural fields</td>
<td>3.87 (0.79)</td>
<td>3.09 (1.04)</td>
<td>2.50 (1.06)</td>
</tr>
<tr>
<td>No-till or reduced tillage</td>
<td>3.71 (0.79)</td>
<td>3.23 (1.08)</td>
<td>2.87 (1.03)</td>
</tr>
<tr>
<td>Cover crops</td>
<td>3.61 (0.89)</td>
<td>3.29 (1.04)</td>
<td>3.04 (0.98)</td>
</tr>
<tr>
<td>Fertilizer application</td>
<td>4.28 (0.67)</td>
<td>3.78 (0.97)</td>
<td>4.03 (0.95)</td>
</tr>
<tr>
<td>Reducing use of fertilizer</td>
<td>3.53 (0.99)</td>
<td>3.34 (1.02)</td>
<td>3.02 (0.99)</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>4.06 (0.78)</td>
<td>3.37 (0.94)</td>
<td>2.93 (0.88)</td>
</tr>
<tr>
<td>Nutrient management</td>
<td>4.15 (0.68)</td>
<td>3.49 (0.90)</td>
<td>3.63 (1.08)</td>
</tr>
<tr>
<td>Pathogen pollution in waterways</td>
<td>3.55 (1.00)</td>
<td>2.54 (1.08)</td>
<td>2.84 (0.96)</td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals</td>
<td>3.57 (0.94)</td>
<td>3.17 (1.01)</td>
<td>2.17 (1.01)</td>
</tr>
<tr>
<td>Water quality in streams or ponds</td>
<td>4.07 (0.87)</td>
<td>3.02 (1.06)</td>
<td>2.89 (1.10)</td>
</tr>
<tr>
<td>Water conservation</td>
<td>4.07 (0.87)</td>
<td>3.21 (0.99)</td>
<td>3.05 (1.02)</td>
</tr>
</tbody>
</table>

M₁ (SD₁) = Mean (standard deviation) perceived importance of land management topic; Scale: 1 = Not at all important, 5 = Extremely important.

M₂ (SD₂) = Mean (standard deviation) agent ability to educate landowners in land management topic; Scale: 1 = Below average, 5 = Above average.

LEN = Landowner’s expressed needs.
Table 3.4  Mean weighted discrepancy scores by state of participants in a survey of southeastern Extension agents with agriculture and natural resources responsibilities. The top three ranking (four if tie present) MWDS scores are presented in bold.

<table>
<thead>
<tr>
<th>Land Management Topic</th>
<th>AL</th>
<th>AR</th>
<th>KY</th>
<th>MS</th>
<th>OK</th>
<th>SC</th>
<th>VA</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss in agricultural fields</td>
<td>4.17</td>
<td>2.81</td>
<td>2.64</td>
<td>2.39</td>
<td>2.26</td>
<td>4.89</td>
<td>-0.37</td>
<td>3.02</td>
</tr>
<tr>
<td>No-till or reduced tillage</td>
<td>2.19</td>
<td>0.91</td>
<td>2.27</td>
<td>1.56</td>
<td>1.32</td>
<td>3.50</td>
<td>1.19</td>
<td>1.81</td>
</tr>
<tr>
<td>Cover crops</td>
<td>2.69</td>
<td>0.68</td>
<td>0.81</td>
<td>1.24</td>
<td>-0.78</td>
<td>3.14</td>
<td>0.79</td>
<td>1.15</td>
</tr>
<tr>
<td>Fertilizer application</td>
<td>3.31</td>
<td>1.13</td>
<td>1.94</td>
<td>2.78</td>
<td>1.77</td>
<td>3.50</td>
<td>1.30</td>
<td>2.14</td>
</tr>
<tr>
<td>Reducing use of fertilizer</td>
<td>1.55</td>
<td>0.09</td>
<td>0.72</td>
<td>0.92</td>
<td>-0.23</td>
<td>2.03</td>
<td>0.00</td>
<td>0.68</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>3.30</td>
<td>2.49</td>
<td>2.92</td>
<td>3.68</td>
<td>2.91</td>
<td>2.97</td>
<td>0.00</td>
<td>2.80</td>
</tr>
<tr>
<td>Nutrient management</td>
<td>3.12</td>
<td>1.95</td>
<td>2.68</td>
<td>2.97</td>
<td>3.50</td>
<td>3.27</td>
<td>2.74</td>
<td>2.72</td>
</tr>
<tr>
<td>Pathogen pollution in waterways</td>
<td>5.98</td>
<td>3.07</td>
<td>3.82</td>
<td>4.37</td>
<td>2.02</td>
<td>4.30</td>
<td>1.19</td>
<td>3.59</td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals</td>
<td>2.41</td>
<td>0.95</td>
<td>1.39</td>
<td>2.02</td>
<td>0.35</td>
<td>2.50</td>
<td>0.00</td>
<td>1.42</td>
</tr>
<tr>
<td>Water quality in streams or ponds</td>
<td>6.55</td>
<td>3.76</td>
<td>3.74</td>
<td>4.83</td>
<td>2.91</td>
<td>5.06</td>
<td>3.28</td>
<td>4.23</td>
</tr>
<tr>
<td>Water conservation</td>
<td>5.31</td>
<td>3.25</td>
<td>2.44</td>
<td>4.59</td>
<td>3.23</td>
<td>3.92</td>
<td>1.63</td>
<td>3.51</td>
</tr>
</tbody>
</table>
Figure 3.1 Distribution of the highest degree earned by Extension agent survey respondents by state of employment.
Figure 3.2  Distribution of the experience level of Extension agent survey respondents by state of employment.
3.6 References


75


76


APPENDIX A

WATER RESOURCE CONSERVATION NEEDS ASSESSMENT SURVEY
Water Resource Conservation Survey

Q1 CONSENT:

We are conducting a research project at Mississippi State University titled "Water Resource Conservation Survey of Extension Agents" (Protocol ID: IRB-19-229). This survey is part of the project and will help us determine competencies and training opportunities for Extension agents on topics relating to water resources on agricultural lands.

We would like to invite you to voluntarily participate in our research project. If you choose to participate, you will be asked to complete a survey that will take approximately 8 minutes of your time.

Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue your participation at any time without penalty or loss of benefits. Answers to the survey are anonymous and no identifiable information is recorded. You are free to exit the survey at any time. If you decide to participate in the survey, your participation includes your consent. Please print this page for your records.

If you have any questions about this research project, please feel free to contact me, Audrey McCrary, at akm401@msstate.edu, or Dr. Leslie Burger at leslie.burger@msstate.edu.

By clicking yes below, you agree that you have read the above information and wish to participate in the following survey. If you click no, the survey will not begin. Click on the arrow in the bottom right corner to submit your answer.

O Yes, I will participate. (1)

O No, I do not wish to participate. (2)
Q2 Over the course of a full calendar year, how much time do you dedicate to the following areas of responsibility?
Use your best estimate. Please total your choices to 100%.

_____ Plants (e.g., crop production, nematology, pest management, plant breeding, plant health) (1)
_____ Environment (e.g., ecosystems, invasive pests, climate change) (2)
_____ Natural Resources (e.g., air, forests, grasslands, soil, water) (3)
_____ Farming and Ranching (e.g., agriculture technology, farmer education, organic agriculture, small/family farms) (4)
_____ Animals (e.g., breeding, health, production, aquaculture) (5)
_____ Food Science (e.g., food quality, food safety) (6)
_____ Health (e.g., nutrition, wellness, obesity) (7)
_____ 4-H and Youth Development (8)
_____ Other (please specify) (9)
Q3 In the last year, how often have you shared information with landowners about the following issues?

<table>
<thead>
<tr>
<th>Issue</th>
<th>Never (1)</th>
<th>Rarely (2)</th>
<th>Sometimes (3)</th>
<th>Often (4)</th>
<th>Very Often (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss from agricultural fields (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-tillage or reduced tillage (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cover crops (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer application (including rate, type, placement, or timing) (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing use of fertilizers (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil erosion (7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrient management (8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals (10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pathogen pollution (disease/bacteria) in waterways (9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water quality in streams or ponds (11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water conservation (12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q4 In your opinion, how important are the following issues?

<table>
<thead>
<tr>
<th></th>
<th>Not at all important (1)</th>
<th>Slightly important (2)</th>
<th>Moderately important (3)</th>
<th>Very important (4)</th>
<th>Extremely important (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss from agricultural fields (1)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>No-tillage or reduced tillage (2)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Cover crops (3)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Fertilizer application (including rate, type, placement, or timing) (4)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Reducing use of fertilizers (5)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Soil erosion (7)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Nutrient management (8)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Pathogen (disease/bacteria) pollution in waterways (9)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals (10)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Water quality in streams or ponds (11)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Water conservation (12)</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>
Q5 Please rate your ability to educate landowners on the following issues.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Below average (1)</th>
<th>Slightly below average (2)</th>
<th>Average (3)</th>
<th>Slightly above average (4)</th>
<th>Above average (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss from agricultural fields (1)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>No-tillage or reduced tillage (2)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Cover crops (3)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Fertilizer application (including rate, type, placement, or timing) (4)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reducing use of fertilizers (5)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Soil erosion (7)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Nutrient management (8)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Pathogen (disease/bacteria) pollution in waterways (9)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reducing use of agricultural chemicals (10)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Water quality in streams or ponds (11)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Water conservation (12)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Q6 Where do you look for supplemental information about land management issues? Please select all that apply.

- [ ] Extension Service resources such as agents, specialists, publications, and/or websites (1)
- [ ] USDA Natural Resource Conservation Service personnel, publications, and/or websites (2)
- [ ] USDA Farm Service Agency personnel, publications, and/or websites (3)
- [ ] USDA Forest Service personnel, publications, and/or websites (4)
- [ ] US Fish and Wildlife Service personnel, publications, and/or websites (5)
- [ ] State natural resource agency personnel, publications, and/or websites (6)
- [ ] Other (Please specify): (7)

Q7 In which state do you work for the Extension Service?

▼ (Select state) (49) ... Virginia (64)
Q8 Which option best describes your scope of responsibility for delivering educational programs?

- County/Parrish (1)
- Regional (2)
- Statewide (3)
- I do not deliver educational programs (4)

Q9 How many counties do you serve?

▼ 1 (1) ... More than 40 (41)

Q10 How many years have you been an employee of the Cooperative Extension Service?

- Less than 1 year (1)
- 1-2 years (2)
- 3-4 years (3)
- 5-6 years (4)
- 7-8 years (5)
- 9-10 years (6)
- More than 10 years (7)
Q11 Which category best represents your highest level of education?

- Bachelor's degree (1)
- Some graduate education, but no Master's degree (5)
- Master's degree (2)
- Doctoral degree (3)
- Other (Please specify) (4) ________________________________________________

Q12 What was your major field of study for your bachelor's degree?
(For example: forestry, animal science, crop science)

__________________________________________________________

Q13 What were your major fields of study for your degrees?
(For example: forestry, animal science, crop science)

- Bachelor's degree (1) ____________________________________________
- Master's degree (2) ____________________________________________

Q14 What were your major fields of study for your degrees?
(For example: forestry, animal science, crop science)

- Bachelor's degree (1) ____________________________________________
- Master's degree (2) ____________________________________________
- Doctoral degree (3) ____________________________________________
Q15 What term best describes you?

○ Male (1)

○ Female (2)

○ I prefer not to answer (3)

Q16 What is your age in years?

________________________________________________________________

Q17 How did this survey reach you?

○ National Association of County Agriculture Agents (1)

○ Association of Natural Resource Extension Professionals (2)

○ My state's Extension administration (3)

○ Other (Please describe) (4) __________________________________________