Managing Multi-Species Cover Crops in the Southeastern USA
2014 Conservation Innovation Grant #69-3A75-14-233

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USDA United States Department of Agriculture
Natural Resources Conservation Service
Agricultural Research Service

SOUTHERN SARE Sustainable Agriculture Research & Education

North Carolina ADFP Trust Fund

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NC STATE UNIVERSITY Crop & Soil Sciences

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Executive Summary of NRCS Conservation Innovation Grant #69-3A75-14-233

Cover crops are a conservation tool that have a key role to play in sustaining agriculture in the Southeast US. Year-round living roots and abundant biomass of high quality are needed to build soil organic matter and enhance soil fertility. There are a variety of cover crops that can be utilized, so producers can pick and choose to suit their local conditions.

Goal

Demonstrate and quantify the impacts of multi-species cover crops in different production systems common to the Southeast.

Approach

Work with a group of farmers from a dozen conservation districts in North Carolina in a team consisting non-profit project coordinator, conservation district specialists, resource specialists from USDA-Natural Resources Conservation Service, and scientists from NC State University and USDA-Agricultural Research Service. The initiative demonstrated to producers that a diverse mixture of cover crop species could be planted in a timely manner, allowed to grow and accumulate biomass and nitrogen, and then be terminated without using tillage to maximize soil health benefits. Quantifiable impacts of multi-species cover crops were determined to promote rapid information transfer from county level demonstrations to producers throughout the mountains, piedmont, and coastal plain areas of North Carolina.

Demonstrations intended to broaden adoption of appropriate multi-species cover cropping and build soil health for a more robust sustainable agriculture in the Southeast. Over 1000 producers were exposed to the value of multi-species cover crops and approaches to assess soil health.

Conservation district specialists have firsthand knowledge of how multi-species cover crops work in their counties; they are better equipped to promote cover crop adoption by leveraging lessons learned and communication tools developed. Project partners are committed to continuing demonstration plots, especially at the same locations to measure longer term impacts, pending availability of funding to support activities.

Overall, participating producers were pleased with the project and the process.

Phillip Whitaker, Henderson County Producer, said “One positive I have noticed is that even without a pre-emergent pesticide, the no-till planting has very few weeds.”

Frank Lee, Stanly County Producer, said “Cover crops are beneficial if they are properly managed.”

Plant and soil properties were characterized, and included the following:

Biomass – Sufficient cover crop biomass is critical for controlling erosion, preserving soil water during the summer growing season, and improving surface-soil properties. Relatively low biomass was recorded for many of the 2015/16 demonstrations. In the 2016/17 demonstrations, three of eight sites achieved a biomass rate greater than a minimum target of 3000 lb/A. In only one of seven demonstrations did multi-species cover crop biomass produce less than a single-species cover crop, but in two cases multi-species cover crop produced more than a single-species cover crop. In all cases, biomass production was greater in demonstration sites with either cover crop type compared to no cover crop (i.e. winter weeds).

Nitrogen (N) – Soil fertility can be enhanced with cycling of N from cover crop biomass to cash crops through slow decomposition of residues throughout the year. Cover crop biomass was enriched in N compared with no cover crop (i.e. winter annual weeds). There was no difference in N content between single and multi-species cover crops in the 2015/16 demonstrations. We set a minimum target of 50 lb N/A in cover crop biomass to enhance long-term soil fertility, but this was attained at only one site in 2015/16. Although data are not yet available, we project that at least three of the eight sites in 2016/17 will have achieved this minimum N content in cover crop biomass.

Carbon (C) – Storage of C in soil as organic matter is a key to enhancing soil fertility in the long-term. Transfer of C from cover crop biomass to soil organic matter is a slow process with only a small fraction of cover crop C eventually retained as soil organic C. Only one demonstration in 2015/16 had enough biomass C to potentially enhance soil organic C, provide a thick enough layer to benefit surface-soil moisture retention, and act as a biological source for microbial activity. No changes in total organic C were recorded; we didn't expect it to, as changes require several years before differences are detectable.

Surface residue – Like cover crop biomass, surface residues (i.e. combination of cover crop biomass and previous crop residues) are critical for controlling erosion, preserving soil water during the summer growing season, and improving surface-soil properties. When measured in 2015/16 demonstrations, surface residue mass was greater with single or multi-species cover crops compared with no cover crop in two of three direct comparisons.

Soil bulk density – Compaction is a concern in some soil types when no-tillage management is utilized. Bulk density was not impacted by cover crop treatment at any of the demonstrations in 2015/16. When measured in spring of 2016/17 near cover crop termination, soil bulk density was significantly greater with multi-species cover crops at three sites as compared with single-species or no cover crops. We will want to monitor this assessment over a number of years and pair it with in-field observations of water runoff or infiltration.

Soil biological activity – Energy embedded in soil organic matter and cover crop inputs drives soil biological activity. Trillions of bacteria, fungi, and actinomycetes in soil perform a variety of functions vital to soil health, e.g. decomposing plant litter, cycling nutrients, creating stable aggregates in soil, enhancing and stabilizing rooting channels, and competing with pathogenic organisms. One measure of soil biological activity is the potential of soil to mineralize N, i.e. the conversion of organic N that is unavailable to plants to inorganic N that is available to plants. In 2015/16, one of eight demonstration sites with multi-species cover cropping had greater N mineralization potential than adjacent plots without cover crops. Another measure of soil biological activity is the flush of CO_2 following rewetting of a dried soil. When averaged across eight demonstration sites in 2016/17, the flush of CO_2 in soil from multi-species cover crops was significantly greater as compared to either no cover crop or single-species cover crops. Even though the cover crop demonstrations were short in duration, we observed an increase in soil biological activity – suggesting it was a sensitive measure of soil health.

Lessons learned

- A variety of multi-species cover crop mixes were developed and proven successful based on producer interests, district knowledge, and recommendations from other sources.
- Establishing multi-species cover crops was feasible at each location. Broadcasting seed was possible, but establishment success was dependent on timely rainfall. Drilling may be more successful in many instances.
- Matching cropping sequences with the right cover crop mixture can be a challenge. Adaptive management may be necessary.
- Producer concerns for late planting of cash crop after cover crops are substantial, but could be overcome with continued demonstration of soil and economic attributes of a functioning system.
- Engaging producers fully into seed selection and planting of cover crops is essential to make demonstrations viable.
- Field days enhanced local interest in cover crops and structuring events with a focus on producers talking to producers was a key element.
- Successful demonstration activities were possible only with the broad teamwork and skills offered by project partners. We found that an effective network involved a nonprofit serving as project coordinator, conservation districts, resource specialists from USDA-NRCS, and scientists from NC State University and USDA-ARS.
- Funding is secured for further demonstrations in Fall 2017 with eight current and four new Conservation Districts. Partners are mobilizing equipment to measure soil moisture and heat stress in three demonstrations. Project partners will seek ways to share lessons learned throughout 2017 and 2018.

Partners

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NC STATE UNIVERSITY Crop & Soil Sciences

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Cotton Incorporated

2014 Conservation Innovation Grant #69-3A75-14-233 Technical Report
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1. Summary

The project's purpose was to demonstrate and quantify the impacts of multi-species cover crops in different production systems common to the Southeast region. The initiative was designed to demonstrate to producers that a diverse mixture of cover crop species could be planted in a timely manner, allowed to grow and accumulate biomass and nitrogen, and then be terminated without using tillage to maximize soil health benefits. Quantifiable impacts of multi-species cover crops need to be determined to promote rapid information transfer from county level demonstrations to producers throughout the mountains, piedmont, and coastal plain areas of North Carolina. These demonstrations broaden adoption of appropriate multi-species cover cropping and build soil health for a more robust sustainable agriculture system across the Southeast region. Over 1000 producers were exposed to the value of multi-species cover crops and approaches to assess soil health. Conservation Districts have firsthand knowledge of how multi-species cover crops work in their counties. Conservation Districts are better equipped to promote cover crop adoption by leveraging lessons learned and communication tools developed. Project partners are committed to continuing demonstration plots, especially at the same locations to measure longer term impacts, pending availability of funding to support activities.

Potential changes in plant and soil properties were documented, and included the following:

- Biomass – Sufficient cover crop biomass is critical for controlling erosion, preserving soil water during the summer growing season, and improving surface-soil properties. Relatively low biomass was recorded for many of the 2015/16 demonstrations. In the 2016/17 demonstrations, three of eight sites achieved a biomass rate greater than a minimum target of 3000 lb/A. In only one of seven demonstrations did multi-species cover crop biomass produce less than a single-species cover crop, but in two cases multi-species cover crop produced more than a single-species cover crop. In all cases, biomass production was greater in demonstration sites with either cover crop type compared to no cover crop (i.e. winter annual weeds).

- Nitrogen – Soil fertility can be enhanced with cycling of nitrogen from cover crop biomass to cash crops through slow decomposition of residues throughout the year. Cover crop biomass was enriched in nitrogen compared with no cover crop (i.e. winter annual weeds). There was no difference in nitrogen content between single and multi-species cover crops in the 2015/16 demonstrations. We set a minimum target of 50 lb N/A in cover crop biomass to enhance long-term soil fertility, but this was attained at only one site in 2015/16. Although data are not yet available, we project that at least three of the eight sites in 2016/17 will have achieved this minimum N content in cover crop biomass.

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carbon. Only one demonstration in 2015/16 had enough biomass carbon to potentially enhance soil organic carbon, provide a thick enough layer to benefit surface-soil moisture retention, and act as a biological source for microbial activity. No changes in total organic carbon were recorded; this may be attributed to the fact that such changes are known to require several years before differences are detectable.

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Photo 1. Left (left to right) New River (Ashe County) Conservation District Specialist Andrew Cox and participating producer Ryan Huffman, standing in no cover crop field with cover crop strip in foreground. Franzluebbers 5.16.17

Photo 2. Right (left to right) Halifax County Producer Zeb Winslow, NRCS East Technology Support Center Agronomist Steve Woodruff, Fishing Creek (Halifax County) Conservation District Specialist Will Mann. Franzluebbers 12.17.15

2. Introduction

2.1. Background

Conservation partners across North Carolina are facilitating efforts to promote the national Soil Health Initiative. Conservation partners recognize that the Southeastern USA has a preponderance of low quality soils as a result of historical tillage practices and lack of attention to carbon-sequestering agronomic practices. Soil degradation across the nation is similarly affected by excessive tillage and lack of surface cover, but the hot and humid conditions in the Southeast exacerbate the impacts of these traditional practices on soil health. To address the issue of poor soil health, project partners developed an education and outreach program in 2013 to promote the benefits of multi-species cover crops. A key component was to identify and quantify soil health improvements during early stages of using multi-species cover crops.

Soil health is defined as the continued capacity of soil to function as a living ecosystem. Soil functions are improved by the following principles: minimize soil disturbance, increase plant diversity to positively impact microbial diversity and nutrient cycling, keep a living root growing year-round, and keep residual cover at the surface as long as possible. The primary goal of this project was to demonstrate to producers that a properly managed diverse mixture of cover crops would increase soil functions and lead to improved farm economics. According to *Managing Cover Crops Profitably, 3rd Edition, Sustainable Agriculture Research and Education, June 2012,* cover crops improve soil structure, increase infiltration and water holding capacity, increase cation exchange capacity (allowing for more nutrient storage), and improve long term nutrient storage (later referred to as nutrient banking). Although scientific studies have been conducted on different cover crops in the US, widespread adoption of species mixtures and establishment guidelines require validation on individual farms. The longer-term benefits could include reductions in input costs and providing effective mitigation against droughts and pest infestations.

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Although single-species cover crops have been historically used in conjunction with conservation tillage production systems in the Southeast, multi-species cover crops have only recently been explored and are far less prevalent. Consequently, information on multi-species cover crop establishment guidelines and soil health benefits has been borrowed from Midwest farming systems. Cropping systems, soil types, and climatic environments in the Southeast are notably different from those in the Midwest, such that scientifically documented and practical knowledge may not be readily transferrable.

Photo 3. Comparison of multi-species cover crop (left; rye, pea, clover) and no cover crop with weedy fallow (right; buttercup dominate) in Henderson County. Franzluebbers 5.16.17

In the national 2012-2013 Cover Crop Survey conducted by the Conservation Technology Information Center and North Central SARE (Sustainable Agriculture Research and Education), the top challenges of adopting cover crops were establishment, cost, species selection, and management. USDA Natural Resource Conservation Service's 2014 listening sessions in North Carolina indicated producers were interested in soil health and cover crops, but they wanted to see practices and approaches demonstrated on working farms before they would consider whole farm adoption. Demonstration projects are an effective way to reinforce proper management of multi-species cover crops such as proper time of planting, allowing for a greater accumulation of biomass and nitrogen, and proper time of growth termination that can be done effectively without using tillage.

North Carolina has many representative land resource areas typical of the Southeast region to act as a pilot evaluation area for refinement of best management practices for multi-species cover crops for the region. It also has a relatively mild winter climate to help determine short-term changes expected in soil chemical, physical, and biological properties. North Carolina has a variety of diverse cropping systems, soil types, and climate variations across the three main physiographic regions of Mountains, Piedmont, and Coastal Plain. We expected that knowledge gained from these three physiographic regions would be transferable to similar landscapes throughout the southeastern USA.

2.2. Purpose / Project Goals

The overall goal of this project was to demonstrate to producers in North Carolina and the Southeast region that multi-species cover crops, when properly managed, would increase soil ecosystem functions and lead to improved farm economics. The project focused on the following specific objectives and goals:

1. Engage North Carolina producers in the soil health benefits of multi-species cover crops.

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a. Partner with up to 14 producers and their respective Districts.
b. Establish ~10-acre multi-species cover crop demonstration plots on 14 farms for two growing seasons for a total project impact of 280 acres.

Outcomes – From 2013 to 2016, the project worked with a total of 12 producers in 12 Districts. A total of 5 demonstrations have been in place for 2 or more growing seasons, with 8 continuing in 2017. Field maps are provided in Appendix A. Projected goals were not completely satisfied due to difficulty in finding mountain producers to participate, on-farm situations causing a producer to drop out, and funding timelines not aligning.

2. Quantify short-term changes in soil chemical, physical, and biological properties as a result of using multi-species cover crops in various no-till and reduced till production systems across three physiographic regions of North Carolina.
    a. Measure soil organic matter fractions by using national standards for field observations and soil testing.
    b. Measure soil biological activity as reflected from soil respiration using soil testing methods following national standards.
    c. Measure increased water infiltration rates thus improving rainfall capture and soil moisture retention by using in-field tests following national standards.

    Outcomes – Soil organic matter and biological activity were measured and are reported in Section 4.2. Although statistically significant changes in soil organic matter were not found, there was an instance of greater soil biological activity with multi-species cover crop compared with no cover after just one year of comparison. Evaluation of data across sites in 2017 suggests that biological activity in the surface 2" of soil was the most sensitive soil property to differences in cover crop management. Another key result was observation that long-term no-tillage management on several of the demonstration sites revealed strong depth stratification of soil organic matter fractions – an important property to help reduce erosion, enhance water infiltration, and improve nutrient cycling (Franzluebbers, 2002). Due to a communication issue and in-field time constraints, water infiltration rates were not measured in 2016 as expected. In 3 of the sites in 2017, soil moisture and heat stress is being measured in the current crop to demonstrate an increase in water holding capacity in the demonstrations.

3. Relate short-term changes in soil properties to broader concerns for nutrient cycling within and from agro-ecosystems, overcoming soil water limitations, and improved crop yield and growth.
    a. Quantify enhanced yield, expected to be 2-5% greater by comparing adjacent fields with and without multi-species cover crops.
    b. Quantify improved nutrient cycling potential, with increases in surface-soil carbon, nitrogen, phosphorous, and potassium concentrations; as well as greater soil biological activity to support nutrient retention in organic matter with a benchmark of nutrient banking cost savings of $200 per acre within a few years.
    c. Evaluate economic benefits by analyzing input costs and impacts on producer's bottom line with an expected benchmark to be achieved of $10 per acre return.

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Outcomes – Limited improvements were noted related to nutrient cycling potential. Since most measurements were not statistically significant an economic analysis related to yield improvements or input costs was not conducted.

4. Refine best management practices for multi-species cover crops in production systems common to North Carolina and neighboring states in the region.
    a. Assess different seed mixes and their impact on soil health; with a benchmark of 4 or more species and at least one legume and one grass in the mixture.
    b. Determine best seeding practices (dates and methodologies) based on the quality of stand establishment in each physiographic region.
    c. Evaluate the most effective cover crop termination strategies (dates and methodologies) according to type of seed mixes in each physiographic region.

Photo 4. Comparison of single-species (left; barley) and multi-species (right; rye, clover, vetch, radish) cover crops in Alamance County after harvesting 0.25 m^2 area in each for biomass determination. Franzluebbers 4.28.17

Outcomes – Each demonstration site was able to get multi-species cover crops planted and established, although in some cases the extent of biomass production was limited due to weather conditions and potential residual herbicide effects. The intent was not to evaluate seeding date and methodology at each site, but compiled across sites we concluded that early planting with drilling was the most effective. The demonstration in Nash County had the planting date as a variable at the same site in 2015/16 and found that broadcasting early into standing soybean crop was not as successful as later planting with no-till drilling. Termination of cover crops was almost exclusively by chemical spray. Both early and late termination were effective with this approach. Future efforts should evaluate the potential for roller-crimper with or without chemical spray to assess effectiveness and reduce chemical inputs.

5. Promote soil health improvements from use of multi-species cover crops in North Carolina and the Southeast to increase agricultural sustainability.
    a. Host Field Day events during the time of multi-species cover crop termination with an anticipated county attendance of 30 local producers for a project impact of 420 people over two growing seasons.
    b. Share results by developing producer-focused handouts that will be distributed to all District offices.
    c. Share results in at least one peer-reviewed scientific publication and present results at one national technical meeting.

Outcomes – Since 2013, over 1000 producers and technical assistance providers have attended a field day. Due to secondary funding requirements, not all events were held at

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the time of cover crop termination. Producer pamphlets have been prepared and are attached as Appendix B. A graduate student assigned to this project presented scientific details of the project: (a) as poster at the Annual Meeting of the Soil Science Society of America (see Appendix C), (b) as oral presentation at the Annual Meeting of the Soil Science Society of North Carolina (Pritchett, 2017), and (c) as graduate seminar to the Department of Crop and Soil Sciences at North Carolina State University (see abstract in Appendix C). Project partners have been invited to speak at the upcoming NC Cotton Growers Association Meeting and Eastern NC Certified Crop Advisor Training. As other opportunities arise, project partners will offer their services, pending funding and time availability.

2.3. Project Partners

The NC Foundation for Soil and Water Conservation (Foundation), a nonprofit in North Carolina that works to improve the environment, educate the citizens and build conservation capacity, served as project facilitator. The Foundation partnered with NC State University's College of Agriculture and Life Sciences' Department of Crop and Soil Sciences and USDA Agriculture Research Services' affiliate at the university to analyze soil health improvements noted in the multi-species cover crop plots as compared to single species cover crops and / or no cover crops. USDA Natural Resources Conservation Service's East National Technology Support Center (NRCS-ENTSC) provided project guidance and consultation during demonstration plot establishment. Participating local soil and water conservation districts (conservation districts) selected a producer in their county that had some experience in soil health and was willing to manage the multi-species cover crop demonstration for multiple years. More details are provided in the Methodology section. A variety of conservation partners and soil health advocates spoke at the county level field days held throughout the life of the project.

Photo 5. Sampson Conservation District Specialists Henry Faison and Melanie Harris assessing site conditions for multi-species cover crop planting after soybeans. Franzluebbers 10.8.15

As with any initiative, funding is a key element. Participation and timing were driven by specific funding source guidelines. Starting in 2013, Cotton Incorporated (Cotton) funds were directed to focus on demonstration sites in counties with a high acreage of cotton planted. Farmers selected were required to have cotton in the demonstration field's rotation. The NC Agriculture and Farmland Preservation Trust Fund's (ADFP) grant was leveraged to supply funds for the 2016 and 2017 plantings. ADFP funds allowed the geographic scope to expand into the Piedmont and Mountain regions and allowed for the testing of crop fields without cotton in the rotation. Participation gaps noted were due to changes in funding streams or situations that required a producer to drop out of the program. Below is a chart of participating conservation districts by physiographic region and by year of demonstration planting. Please note that analytics and

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project facilitation were funded through this Conservation Innovation Grant, and due to timing issues, testing was only conducted on the 2015/16 and 2016/17 demonstration plots.

Table 1. Participating Conservation Districts and Funding Sources

Physiographic Region	Soil and Water Conservation District	2013	2014	2015	2016	2017	Funder
Coastal Plain	Edgecombe		X	X	X		Cotton
	Fishing Creek (Halifax Co.)	X	X	X			Cotton
	Nash		X	X	X	X	Cotton
	Pitt	X		X			Cotton
	Sampson	X	X				Cotton
Piedmont	Alamance				X	X	ADFP
	Davidson				X	X	ADFP
	Rowan				X	X	ADFP
	Stanly	X	X	X	X	X	Cotton
	Wake				X	X	ADFP
Mountain	Henderson				X	X	ADFP
	New River (Ashe Co.)				X	X	ADFP

3. Methodology

3.1. Conservation Districts Partnering with Producers

Conservation Districts established a county level technical support team to help with project management. Technical support team members included Conservation District staff, NRCS field staff, county level Cooperative Extension, NC Department of Agriculture and Consumer Services' regional agronomists and soil scientists, as well as producers with a history of utilizing cover crops. The technical support team selected a producer to establish demonstration plots. The following were guidelines for producer selection. See Appendix D for the interview form used to gather data and the program's guidance document.

- EQIP-eligible producers currently using conservation tillage practices that would be interested in the next level of soil health management.
- Preference for producers that would be willing to continue beyond the timeline of funding availability.

3.2. Demonstration Plot Requirements

Conservation Districts selected a field that was easily accessible for field days and had a minimal range of soil types. Demonstration plots in the Coastal Plain and Piedmont were required to be a minimum of 10 acres. Mountain demonstrations were allowed a smaller size of 2 to 5-acre plots. The reason for the acreage difference was that in many mountain counties the best farmland is on the floodplain of creeks in a narrow valley, and therefore many fields might not be as large as 10 acres. Starting in 2015, fields were required to accommodate the establishment of 4 test strips with a minimum width of 40 feet, allowing for comparison of test and control strips side-by-side. In the control strips, producers could plant either a single-species cover crop (to compare with

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more typical conservation practice) or no cover crop (to compare most typical conventional practice and address soil erosion concerns).

3.3. Cover Crop Requirements

Each Conservation District and producer were allowed to select their own seed mixes, based on the producer's management goals and to highlight mixes that would work well in their county. Each seed mix was required to include 4 species at a minimum, including 2 legumes. Producers were allowed to broadcast or no-till drill the seed mix. If broadcasting, it was recommended to consider 25% more seed than if no-till drilling. All producers had access to a no-till drill through Conservation Districts. Chosen establishment methods were based on preference and cash crop harvesting needs. For termination, producers were permitted to roll down the cover crop and/or apply a chemical treatment. Termination method chosen was influenced by equipment available to the producer, as not many producers had access to a roller-crimper. The following planting and termination dates were selected as target dates. In some cases, deviation from the established date was approved due to issues beyond the producers' control such as weather events.

Photo 6. Left Tillage radish as cover crop at the Piedmont Research Station in Rowan County. Franzluebbers 12.12.15. 7. Photo Right Multi-species cover crop (rye, radish, clover, vetch) growth in early spring in Nash County. Franzluebbers 4.4.16

Photo 8. Emergence of multi-species cover crop (rye, clover, radish) after late planting into soybean, Pitt County. Franzluebbers 12.10.15

Table 2. Establishment and Termination Guidelines

Physiographic Region	**Establishment**		**Termination Date** (no earlier than)
	Method	**Date** (no later than)	
Coastal Plain & Piedmont	Broadcast	September 30	April 15
	No-Till Drill	October 31	
Mountain	Broadcast	September 15	May 1
	No-Till Drill	October 15	

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3.4. Demonstration Details

Table 3. 2013 Demonstrations

District	Acreage	Establishment	Termination	Multi-Species Seed Mix
Fishing Creek (Halifax Co.)	10 A	Broadcast Oct 1 – 4	1st week May	Cereal Rye + Crimson Clover + Hairy Vetch + Nitro Radish
Pitt	15 A	No-Till Drill Sept 27-30	Chemical April 15	Austrian Winter Pea + Daikon Radish + Dixie Crimson Clover + Wrens Abruzzi Rye + Tri 342 Triticale
Sampson	5 A	Oct 28	April 15	Proprietary mix
Stanly	20 A		2nd week April	Radish + Winter Pea + Crimson Clover

Table 4. 2014 Demonstrations

District	Acreage	Establishment	Multi-Species Seed Mix
Edgecombe	10 A	Broadcast Oct 29	Tillage Radish + CCS Crimson Clover + Austrian Winter Pea + Abruzzi Rye
Fishing Creek (Halifax Co.)	10 A	Broadcast 2nd week Oct	Cereal Rye + Crimson Clover + Daikon Radish
Fishing Creek (Halifax Co.)	10 A	Broadcast 2nd week Oct	Austrian Winter Pea + Cowpea + Crimson Clover + Sunn Hemp + Cereal Rye + Pearl Millet + Radish + Flax + Rapeseed + Sunflower
Nash	6 A	No-Till Drill Oct 31	Austrian Winter Pea + Daikon Radish + Crimson Clover + Cosaque Black Oats
Sampson	5 A	No-Till Drill Oct 28	Rye + Oats + Crimson Clover + Radish
Stanly	20 A	2nd week Oct	Radish + Winter Pea + Wheat

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Table 5. 2015 Demonstrations								
Conservation District	**Soil Type**	**Acreage Strips**	**Previous Crop**	**Following Crop**	**Establishment**	**Termination**	**Control Treatment**	**Multi-Species Seed Mix**
Edgecombe	Cape Fear loam	6.19 A 4 strips 150ft wide	Soybean	Soybean	Broadcast by plane October 20	Chemical	Single-species cover crop (rye)	1 lb/A PT Turnip + 4.5 lb/A Winter Pea + 1 lb/A Hairy Vetch + 1 lb/A Tillage Radish + 10 lb/A Triticale + 4 lb/A Crimson Clover + 5 lb/A Black Oats + 20 lb/A Abruzzi Rye
Fishing Creek (Halifax Co) (East)	Emporia loamy fine sand, Goldsboro loamy sand	10 A 3 strips 300ft wide	Cotton	Cotton	No-Till Drilled October 31	Chemical	No cover crop	15 lb/A Center Seed Holcomb Seed Blend + 3 lb/A Forage Collard + 15 lb/A Walnut Creek Seeds Super Soil Builder + 3 lb/A Phacelia
Fishing Creek (Halifax Co) (West)	Gritney sandy loam, Noboco fine-loamy	10 A 2 strips 400ft wide	Soybean	Cotton	Broadcast October 1 week	Chemical	No cover crop	15 lb/A Center Seed Holcomb Seed Blend + 3 lb/A Forage Collard + 15 lb/A Walnut Creek Seeds Super Soil Builder + 3 lb/A Phacelia
Nash	Norfolk loamy sand, Rains fine-loamy	22.4 A 12 strips 100ft wide	Soybean	Soybean	October 20 Broadcast December 8 January 8 No-Till Drill	Chemical and Disk April 20	Single-species \cover crop (rye) and no cover crop	45 lb/A Rye + 8.5 lb/A Crimson Clover + 6.5 lb/A Tillage Radish + 15 lb/A Austrian Winter Pea + 1 lb/A Woolypod Vetch
Pitt	Ocilla loamy, Norfolk loamy sand, Goldsboro loamy sandy	10 A 3 strips 120ft wide	Soybean		Oct 27 Broadcast with 20 lb/A potash	Chemical April 20	No cover crop	20 lb/A Rye + 20 lb/A Triticale + 5 lb/A Crimson Clover + 15 lb/A Winter Pea + 5 lb/A Daikon Radish
Stanly	Badin channery silt loam	20 A 4 strips 300ft wide	Corn	Cotton	Oct 15 No-Till Drill	Chemical May 2	No cover crop	10 lb/A Crimson Clover + 2 lb/A Radish + 15 lb/A Triticale + 15lb/A Ryegrass

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Table 6. 2016 Demonstrations								
Conservation District	**Soil Type**	**Acreage Strips**	**Previous Crop**	**Following Crop**	**Establishment**	**Termination**	**Control Treatment**	**Multi-Species Seed Mix**
Alamance	Tirzah silt loam, Georgeville silt loam	6.6 A 4 strips, 198ft	Corn	Soybean	No-Till Drill October 17	Chemical May 2	Single-species cover crop (barley)	31 lb/A Cereal Rye + 7 lb/A Crimson Clover + 7 lb/A Hairy Vetch + 2 lb/A Tillage Radish
Davidson	Enon fine sandy loam	11.2 A 4 strips 120ft (2) 180ft (2)	Corn	Corn	No-Till Drill October 25	Chemical April 20	Single-species cover crop (rye)	30 lb/A Cereal Rye + 15 lb/A Triticale + 10 lb/A Oats + 10 lb/A Crimson Clover + 10 lb/A Hairy Vetch + 2 lb/A Daikon Radish
Henderson	Suncook (Biltmore) loamy fine sand, Comus (Colvard) silt loam, Toxaway silt loam	7 A 4 strips 115ft	Snap Bean	Snap bean	No-Till Drill October 6	May 29 chemical May 31 rolled a plot July 11 rolled 2nd plot	No cover crop	17 lb/A Crimson Clover + 100 lb/A Austrian Winter Peas + 7 lb/A Rackmaster Trophy Radish + 100 lb/A Rhymin Winter Rye
Nash	Norfolk loamy sand, Raines fine-loamy	15.2 A 9 strips 90ft	Field Bean	Vegetables	No-Till Drill Late October	Disk April 13	No cover crop	40 lb/A Rye + 10 lb/A Crimson Clover + 2 lb/A daikon radish
New River (Ashe Co)	Evard sandy loam		Corn	Corn	No-Till Drill October 6	Chemical	No cover crop	8 lb/A Hairy Vetch + 8 lb/A Berseem Clover + 25 lb/A Rye + 25 lb/A Triticale
Rowan	Enon fine sandy loam	2.5 A 4 strips 30ft, 50ft, 70ft, 75ft	Vegetables	Vegetables	No-Till Drill October 25	Chemical April 15	Single-species cover crop (crimson clover)	5 lb/A Crimson Clover + 4 lb/A Hairy Vetch + 5lb/A Austrian Winter Pea + 41 lb/A Barley + 0.5 lb/A Rape
Stanly	Badin channery silt loam	20 A 4 strips 300ft	Cotton		No-Till Drill Late October	Chemical April 20	No cover crop	5 lb/A Crimson Clover + 50 lb/A Triticale + 10 lb/A Ryegrass + 15 lb/A Austrian Winter Pea
Wake	Appling sandy loam	14.5 A 6 strips 86ft	Soybean	Soybean	Broadcast October 15	Chemical April 17	No cover crop	24 lb/A Ryegrass + 18 lb/A Brooks Oats + 6 lb/A Crimson Clover + 12 lb/A Austrian Winter Peas

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Photo 9. Rolled multi-species cover crop (barley, rapeseed, clover) ready for planting, Rowan County, Franzluebbers 4.20.17

3.5. Plant and Soil Analyses

To determine short-term benefits of multi-species cover crops in no-till and reduced till production systems, Project Partners documented cover crop production and nutrient characteristics, surface soil residue accumulation and nitrogen content, and a variety of soil properties. Sampling sites in field demonstrations were typically from three locations within a field-length strip of cover crop treatment. Field strips were either (a) multi-species cover crop, (2) single-species cover crop, or (3) no cover crop. In a typical design of two strips of multi-species cover crop and two strips of no cover crop control, a total of 12 locations would have been sampled (i.e. 3 locations in each of 4 strips). Sampling locations within a strip were typically separated by 100'. Average values for the two treatments would have been derived from six replicate locations in each field.

Biomass from cover crops was collected during a target period of two weeks prior to two weeks following growth termination. Dry matter and C and N concentrations were determined using two approaches. In fields that had relatively low biomass, plant material was cut with a bagging lawn mower (20" width x 20' long strip) at 2" height. In fields that had high cover crop biomass, plant material was cut at 2" height from two squares (20" x 20") separated by ~10'. In both cases, all plant material was placed into a cloth bag to be dried for several days in an oven (130 °F). Dried samples were ground and a subsample analyzed for C and N concentrations using dry combustion (Leco TruMac, St. Joseph MI).

In Spring 2016 only, surface residue samples were collected at the time of soil sampling to obtain a refined estimate of residue cover following termination of the cover crop. Surface residue was a combination of current and previous years' residues in most cases. In Spring 2017, surface residue was not collected since cover crops were typically not yet rolled or laid flat by planting equipment. Surface residues were obtained by collecting all visible plant materials at ground level within either (a) eight, 12" diameter rings within a replicate location or (b) eight, 8" squares within a replicate location. Surface residues were placed into a paper bag, dried at 130 °F for at least 3 days, ground, and subsamples analyzed for C and N concentrations using dry combustion (Leco TruMac, St. Joseph MI) and ash content to adjust mass for soil contamination.Surface-soil samples were collected in spring in a target period of two weeks prior to two weeks following planting of summer crop by compositing 8-16 cores (1.6" diameter) from within each of the replicate locations within a field strip. Soil was collected at depths of 0-2" (16 cores) and 2-6" (8 cores); equal volume sampled from each depth. Soil was dried at 130 °F for at least 3 days, sieved to pass 0.2" openings (4.75-mm), and subsampled for various chemical and biological analyses. Soil bulk density was determined from the dry weight and volume of cores. The following chemical and biological analyses were performed:

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North Carolina Department of Agriculture and Consumer Services Agronomic Services Division (http://www.ncagr.gov/agronomi/pdffiles/ustr.pdf)

- Humic matter (g / 100 cc)
- Density (g / cc)
- Cation exchange capacity (meq / 100 cc)
- Base saturation (meq / 100 cc)
- pH
- Phosphorus (mg / dm3)
- Potassium (mg / dm3)
- Calcium (mg / dm3)
- Magnesium (mg / dm3)
- Sulfur (mg / dm3)
- Manganese (mg / dm3)
- Zince (mg / dm3)
- Copper (mg / dm3)
- Sodium (mg / dm3)

Photo 10. Sampling of surface residue and soil from strips of no cover (left and right strips) and multi-species cover crop (middle) at Stanly County demonstration. Franzluebbers 6.1.16

Soil Ecology and Management Laboratory at NC State (according to Franzluebbers and Brock, 2007)

- Total soil C and N (g / kg); dry combustion with Leco TruMac following ball milling
- Particulate organic C and N (g / kg); dry combustion with Leco TruMac following ball milling of oven-dried sand fraction of soil obtained from dispersion of soil in $Na_4P_2O_7$ solution
- Soil microbial biomass C (mg / kg); chloroform fumigation-incubation
- Mineralizable C and N (mg / kg / 24 days); aerobic incubation at 50% water-filled pore space and 77 °F
- Flush of CO_2 following rewetting of dried soil (mg / kg / 3 days); aerobic incubation at 50% water-filled pore space and 77 °F
- Residual soil nitrate and total inorganic N (mg / kg); colorimetric determination with Bran-Luebbe segmented flow analyzer following KCl extraction

Photo 11. Sampling soil under multi-species cover crop (oat, rye) by Katie Pritchett at Edgecombe County demonstration. Franzluebbers 5.24.16

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

4. Results

4.1. Outreach events

Each Conservation District hosted at least one outreach event per year, consisting of an educational meeting with optional field tours. Conservation Districts with demonstration plots funded by Cotton Inc. were required to host the outreach event in the same calendar year of establishment, other Conservation Districts were free to choose the best time to host the event. Attendees received continuing education related to soil health, cover crops, seed mixes, planting types, pesticide control, and groundwater management as well as information on current conservation cost-share programs. Since the initiative started in 2013, over 1000 people have attended a soil health workshop or field day event. Some representative workshop information is included in Appendix E. Evaluations continue to be positive, with many producers interested in seeing the results in the coming years.

Photo 12. Left Soil health conversation led by Wake Conservation District Specialist Josh Vetter with producers in Wake County. Franzluebbers 3.1.17
Phot 13. Right USDA NRCS District Conservationist Jay Fuhrer leading soil health discussion at Stanly County field day. Franzluebbers 4.29.15

4.2. Analytical Results

Biomass production of multi-species cover crops harvested in April 2016 varied from a low of 460 lb/A to high of 5802 lb/A, with an overall average production across 8 sites of 1514 lb/A (Table 7). Many of the sites had cover crops terminated chemically in late March and early April. The average value would be considered too low to make a significant contribution to long-term soil health. Except for the one production site in Stanly County, which had not yet been terminated at the time of biomass sampling, further refinements will have to be explored to obtain greater biomass production. A target biomass production of at least 3000 lb/A should be a goal. This may be achieved with an appropriate balance of grasses and legumes in the seed mixture, earlier establishment date in the fall, obtaining rapid germination with good seed placement in soil before killing frosts occur, later termination of the cover crop in spring, and avoiding herbicides on summer cash crops that might interfere with cover crop growth and development.

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Table 7. Cover crop biomass from demonstration sites in 2015/16.

Location	2015 Planted	2016 Harvested [1]	Multi-species cover crop	Single-species cover	No cover crop	Significance
			---------- *lb dry matter / acre* ----------			*Pr > F*
Edgecombe Co	Oct 20	Apr 22 b	1281	782	--	**0.03**
Halifax Co (east)	Oct 31	Apr 22 b	460	--	69	**<0.001**
Halifax Co (west)	Oct 1	Apr 22 b	1000	--	351	**0.002**
Nash Co (early)	Oct 20	Apr 24 b	1017	1109	754	0.69
Nash Co (mid)	Dec 8	Apr 24 b	1001	1256	392	**0.004**
Nash Co (late)	Jan 8	Apr 24 b	524	448	487	0.87
Pitt Co	Oct 27	Apr 22 b	1027	--	543	**0.02**
Stanly Co	Oct 15	Apr 19 a	5802	--	1399	**<0.001**

[1] a = from 5.6 sq. ft. area, b= from 33.3 sq. ft. area

Biomass production of multi-species cover crops harvested in April 2017 varied from a low of 804 lb/A to high of 9170 lb/A, with an overall average production across 8 sites of 4098 lb/A (Table 8). Average production in this second year of evaluation would have met the minimum target of at least 3000 lb/A, as well as at three of the individual sites, including Alamance, Ashe, and Henderson Counties. Estimation of biomass may have been slightly underestimated at Davidson, Rowan, and Stanly County sites, as biomass was still green and elongated (not ideal conditions for collecting all biomass with the rotary mower).

Multi-species cover crops were not different in production potential as compared to single-species cover crops at three of the eight demonstration sites in April/May 2017 (average of 4098 and 4188 lb/A in multi-species and single-species cover crops, respectively). Compared with no cover crop at five sites, multi-species cover crops produced greater biomass at all sites (average of 3623 and 1093 lb/A in multi-species and no cover crops, respectively).

Table 8. Cover crop biomass from demonstration sites in 2016/17

Location	2016 Planted	2017 Harvested [1]	Multi-species cover crop	Single-species cover	No cover crop planted	Significance
			---------- *lb dry matter / acre* ----------			*Pr > F*
Alamance Co	Oct 17	Apr 28 a	9134	9554	--	0.56
Ashe Co	Oct 6	May 16 a	4759	--	473	**<0.001**
Davidson Co	Oct 25	Apr 20 b	1545	1688	--	0.70
Henderson Co	Oct 6	May 16 a	9170	--	2500	**<0.001**
Nash Co	Late Oct	Apr 3 b	1179	--	580	**0.009**
Rowan Co	Oct 25	Apr 20 b	1616	1321	--	0.07
Stanly Co	Late Oct	Apr 18 b	2205	--	1642	**0.01**
Wake Co	Oct 15	Apr 28 a	804	--	268	**0.001**

[1] a = from 5.6 sq. ft. area, b= from 33.3 sq. ft. area

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Quality of biomass from multi-species cover crops harvested in April 2016 was favorable for decomposition (Table 9). The C:N ratio of multi-species cover crops was 28 +/- 4. Due to low biomass production, total N stored in cover crop residues was only 8-90 lb N/A, with an average of 23 lb N/A. This was a significant improvement in N content over that in weedy biomass without cover crop planting (average of 9 lb N/A), but no difference from that with single-species cover crop (in all cases grasses) (average of 14 vs 12 lb N/A in four directly comparable sites). A minimum cover crop biomass N content of 50 lb N/A would seem reasonable as a target to enhance long-term soil fertility (scientific guess), which would equate to biomass production requirement of 5000 lb/A if N concentration were 1% (grass only), 2500 lb/A if N concentration were 2% (legume-grass mixture), or 1500 lb/A if N concentration were 3% (legume only). Only the multi-species cover crop site in Stanly County met this target in April 2016.

Photo 14. Sampling of soil from Nash County demonstration by Izabel Gomes and Joao Paulo Rigon. Franzluebbers 6.3.20

Carbon content of multi-species cover crop biomass averaged only 656 lb C/A in April 2016. Assuming 10% retention of this C over time (Franzluebbers et al., 1998), this would be a relatively small contribution to soil organic C sequestration potential. For the site in Stanly County, C accumulation in multi-species cover crop biomass was considerably greater and could provide a good source of C accumulation potential, as well as a source of physical restriction for greater surface-soil moisture retention and biological source for microbial activity.

Analyses of nutrient content for cover crop biomass harvested in April/May 2017 are pending, but we expect that N and C contents to be proportionally greater than in April 2016 like that of total dry matter.

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Table 9. Cover crop C and N contents from demonstration sites harvested in April 2016

Location	Multi-species cover crop	Single-species cover	No cover crop	Significance	Multi-species cover crop	Single-species cover	No cover crop	Significance
	------- *lb carbon / acre* -------			*Pr > F*	------- *lb nitrogen / acre* ---- ---			*Pr > F*
Edgecombe Co	519	333	--	0.06	17	13	--	0.11
Halifax Co (east)	190	--	30	**<0.001**	9	--	1	**<0.001**
Halifax Co (west)	444	--	141	**0.001**	17	--	6	**<0.001**
Nash Co (early)	456	506	344	0.74	15	16	12	0.61
Nash Co (mid)	454	578	169	**0.004**	15	12	6	**0.005**
Nash Co (late)	210	198	215	0.98	8	8	6	0.75
Pitt Co	452	--	232	**0.03**	13	--	7	**0.02**
Stanly Co	2529	--	596	**<0.001**	90	--	23	**<0.001**

Surface residue mass was collected in late May/early June 2016 prior to soil sampling. This dry matter estimate included current cover crop mass, as well as any residue remaining from previous years. Surface residue mass tended to be greater with cover crops than without (Table 10), but the effect was not always significant at individual sites. Only four sites were sampled in 2016 due to suitable cover crop treatment comparisons. These results support the concept that cover crops will contribute to surface-soil protection with residue accumulation.

Photo 15. USDA NRCS Soil Health Specialist Nathan Lowder leading discussion at Stanly County field day. Franzluebbers 4.29.15

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Table 10. Surface residue mass from demonstration sites in 2015/16

Location	Multi-species cover crop	Single-species cover	No cover crop	Significance
	---------- *lb dry matter / acre* ----------			*Pr > F*
Edgecombe Co	6198	4516	--	0.16
Nash Co (early)	1806	2753	1946	0.24
Nash Co (mid)	2572	3718	1037	**<0.001**
Stanly Co	8364	--	5076	**<0.001**

Sampled after desiccation near cash crop planting (May 24 in Edgecombe Co, June 3 in Nash Co, and June 1 in Stanly Co).

Carbon and nitrogen contents also tended to be greater with cover crops than without (Table 11). Quantity of C stored in surface residue varied from 637 to 3399 lb C/A with an average of 1820 lb C/A. Quantity of N stored in surface residue varied from 22 to 116 lb N/A with an average of 59 lb N/A. Average dry matter and nutrient contents across these sites indicated a reasonable amount of surface-soil protection from erosion and potential nutrient contribution, but the large variation among sites suggests that several sites would have had greater potential for improvement. Highest observed surface residue values of 8364 lb dry matter/A, 3399 lb C/A, and 116 lb N/A might be laudable targets for other sites, but we may find greater levels in other locations in North Carolina in the future.

Table 11. Surface residue C and N contents from demonstration sites in 2015/16

Location	Multi-species cover crop	Single-species cover	No cover crop	Significance	Multi-species cover crop	Single-species cover	No cover crop	Significance
	------- *lb carbon / acre* -------			*Pr > F*	------ *lb nitrogen / acre* ------			*Pr > F*
Edgecombe Co	2501	1651	--	0.14	72	52	--	0.23
Nash Co (early)	637	1037	686	0.37	22	35	27	0.39
Nash Co (mid)	741	1520	222	<0.001	26	39	10	**0.006**
Stanly Co	3399	--	1824	<0.001	116	--	60	**<0.001**

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Photo 16. Joao Bonetti sampling multi-species cover crop biomass (triticale, clover) for nutrient content prior to termination in Stanly County. Franzluebbers 4.19.16

Soil physical condition was assessed through soil bulk density, which is an indicator of compaction or consolidation of the soil surface. Soils transitioning to no-tillage management often have greater bulk density than frequently tilled soil, but the effect is a temporary difference due to rapid consolidation in many soil types (Franzluebbers et al., 2007). Loose soil from tillage often requires re-loosening with frequent tillage. The consequences of this loosening is exposure of surface soil to erosion, frequent crusting after rainfall events, disruption of soil pore networks and reduced infiltration, frequent residue incorporation and loss of C from oxidation by soil microorganisms, disturbance of mycorrhizal and other fungal networks, etc. Long-term no-tillage management does, however, lead to reduced bulk density at the soil surface due to organic matter accumulation, preservation of pore networks that allow vertical water movement despite denser soil matrix between cracks and voids, and preservation of root channels to support effective nutrient cycling and rooting patterns through old channels.

Soil bulk density was not affected by cover crop treatment at any of the four sites in 2015/16 (Table 12). Soil bulk density was 1.26 $\pm$ 0.12 g/cc at 0-2" depth and was 1.30 $\pm$ 0.07 g / cc at 2-6" depth. We expected bulk density to increase with depth, but the difference was minimal.

Table 12. Soil bulk density (g / cc) from demonstration sites in 2015/16

	0-2" Soil Depth				**2-6" Soil Depth**			
Location	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**
	---------- *g / cc* ----------			*Pr > F*	---------- *g / cc* ----------			*Pr > F*
Edgecombe Co	1.32	1.16	--	0.12	1.27	1.21	--	0.57
Nash Co (early)	1.32	1.45	1.33	0.45	1.32	1.39	1.19	0.39
Nash Co (mid)	1.17	1.24	1.02	0.24	1.43	1.28	1.27	0.61
Stanly Co	1.25	--	1.38	0.29	1.35	--	1.29	0.56

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Photo 17. Soil health discussion in newly planted multi-species cover crop field following Cotton, Nash County. Franzluebbers 12.16.14

In April/May 2017, soil bulk density was greater under multi-species cover crop than under no cover crop at Henderson and Nash County sites at both 0-2 and 2-6" depths (Table 13). It was also greater under multi-species than under single-species cover crop at the Rowan County site at 2-6" depth. Soil bulk density was 1.21 ± 0.20 g/cc at 0-2" depth and was 1.41 ± 0.19 g / cc at 2-6" depth. As expected, bulk density increased with depth. Although sites were mostly different in 2017 than in 2016, soil bulk density was very similar at 0-2" between the two years and slightly greater at 2-6" depth in 2017 than in 2016.

Table 13. Soil bulk density (g / cc) from demonstration sites in 2016/17

Location	Depth	Multi-species cover crop	Single-species cover crop	No cover crop planted	Significance
	inches	----- *Mean ± standard deviation (g / cc)* -----			*Pr > F*
Alamance Co	0-2	1.11 ± 0.02	1.13 ± 0.05	--	0.43
	2-6	1.36 ± 0.03	1.37 ± 0.04	--	0.72
Ashe Co	0-2	1.02 ± 0.06	--	1.01 ± 0.04	0.52
	2-6	1.32 ± 0.06	--	1.30 ± 0.04	0.27
Davidson Co	0-2	1.30 ± 0.07	1.33 ± 0.10	--	0.63
	2-6	1.48 ± 0.09	1.50 ± 0.08	--	0.69
Henderson Co	0-2	0.97 ± 0.07	--	0.93 ± 0.08	**0.02**
	2-6	1.10 ± 0.07	--	1.03 ± 0.10	0.07
Nash Co	0-2	1.56 ± 0.05	--	1.47 ± 0.08	**0.03**
	2-6	1.73 ± 0.08	--	1.62 ± 0.06	**0.04**
Rowan Co	0-2	1.28 ± 0.05	1.26 ± 0.05	--	0.36
	2-6	1.38 ± 0.02	1.28 ± 0.07	--	**0.03**
Stanly Co	0-2	1.03 ± 0.07	--	1.06 ± 0.04	0.44
	2-6	1.37 ± 0.03	--	1.34 ± 0.06	0.20
Wake Co	0-2	1.46 ± 0.10	--	1.44 ± 0.03	0.55
	2-6	1.67 ± 0.08	--	1.64 ± 0.03	0.29

As an estimate of soil organic matter, total organic C at four sites in 2015/16 was 1.8 ± 1.2 at 0-2" depth and was 1.0 ± 0.4 at 2-6" depth. Generally, there was no difference in total organic C among cover crop treatments, except at the Nash County site planted in December 2015 (Table 14). This was an odd result that did not match our expectation. Variation in soil properties in

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the field were likely responsible for this effect, as the no cover strip tended to be in a lower landscape position than other treatments. At the Stanly County site with robust multi-species cover crop, total organic C averaged 5 and 11% greater with cover crop than without at 0-2 and 2-6" depths, respectively. However, these apparent differences were not statistically different.

Table 14. Total organic carbon (%) from demonstration sites in 2015/16

	0-2" Soil Depth				**2-6" Soil Depth**			
Location	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**
	---------- % ----------			*Pr > F*	---------- % ----------			*Pr > F*
Edgecombe Co	1.93	2.03	--	0.70	1.29	1.38	--	0.65
Nash Co (early)	0.68	0.82	0.95	0.31	0.56	0.54	0.67	0.53
Nash Co (mid)	1.13	0.96	1.58	**0.04**	0.73	0.53	1.08	0.07
Stanly Co	3.93	--	3.74	0.30	1.43	--	1.29	0.42

Soil biological activity as indicated by the ability of microorganisms to convert N from organic to inorganic form (i.e. net N mineralization) was greater under multi-species cover crop than without cover crop at the Stanly County site at both depths (Table 15). In both cases, the relative difference was for 45% improvement with multi-species cover crop. There were two other differences at the Nash County sites that were opposite of this effect at Stanly County and that were contrary to our expectation.

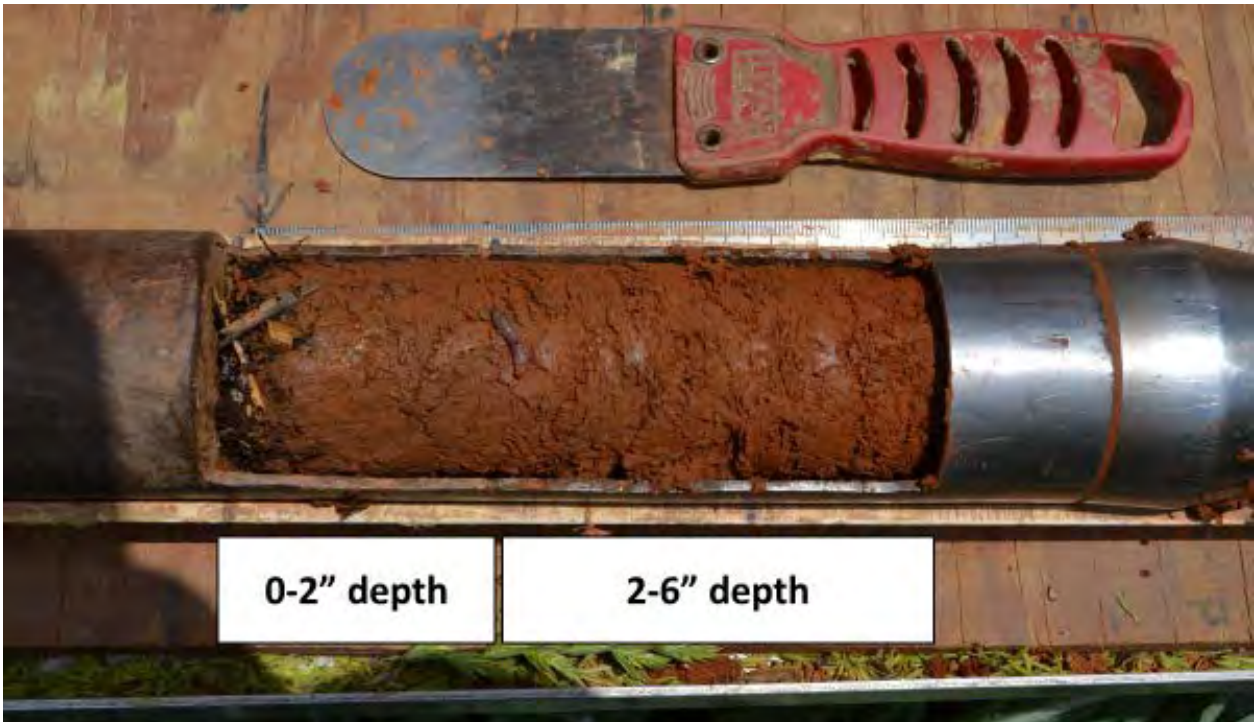
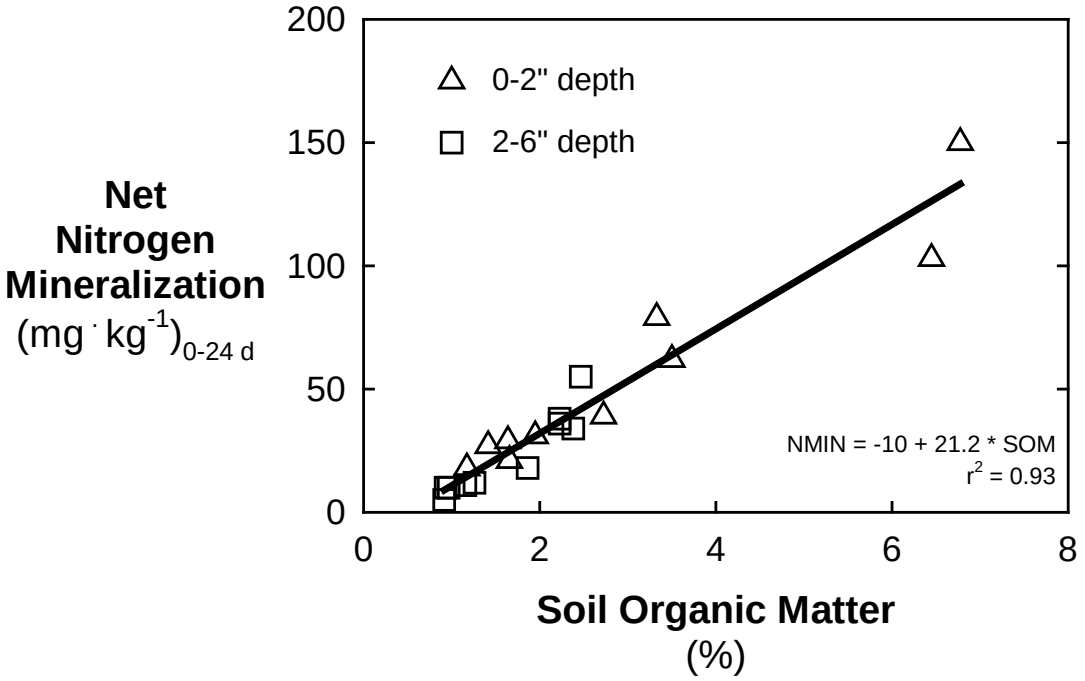


Photo 18. Soil core from Alamance County demonstration. Franzluebbers 4.28.17

Table 15. Net nitrogen mineralization (mg/kg/24 days) from demonstration sites in 2015/16

	0-2" Soil Depth				2-6" Soil Depth			
Location	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**
	---------- mg/kg/24 days ----------			*Pr > F*	---------- mg/kg/24 days ----------			*Pr > F*
Edgecombe Co	79	62	--	0.21	36	34	--	0.51
Nash Co (early)	18	27	29	**0.05**	10	10	11	0.75
Nash Co (mid)	31	21	39	0.40	12	5	18	**0.05**
Stanly Co	150	--	103	**0.02**	55	--	38	**0.04**

The relationship between soil organic matter and net N mineralization was very strong among all sites and depths (Figure 1). This relationship and the strong effect of greater net N mineralization with multi-species cover crop than no cover crop at the Stanly County site suggests that soil biological indicators were reflective of soil organic matter, but also were more discernable of management changes than total soil organic matter.



The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Soil biological activity as indicated by the flush of CO_2 released during the first 3 days of aerobic incubation was also greater under multi-species cover crop than without cover crop at the Stanly County site at the surface depth, and a trend towards that at the lower depth (Table 16). As with net N mineralization, the relative difference between cover crop treatment was similar, but the effect was only 19% for this variable. It was clear that soil biological activity was greater at 0-2" than at 2-6" depth, irrespective of current cover crop treatment (i.e. 2.6 $\pm$ 0.9 times greater at 0-2" than at 2-6" depth). This effect was a reflection of the stratification of biological activity that develops with long-term no-tillage management.

Table 16. Flush of CO_2 following rewetting of dried soil (mg/kg/3 days) from demonstration sites in 2015/16

	0-2" Soil Depth				**2-6" Soil Depth**			
Location	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**	**Multi-species cover crop**	**Single-species cover**	**No cover crop**	**Significance**
	---------- mg/kg/3 days ----------			*Pr > F*	---------- mg/kg/3 days ----------			*Pr > F*
Edgecombe Co	291	303	--	0.82	138	137	--	0.92
Nash Co (early)	82	104	105	0.33	48	50	53	0.89
Nash Co (mid)	155	131	179	0.14	50	28	55	**0.01**
Stanly Co	516	--	435	**0.03**	209	--	174	0.13

From soil sampling in April/May 2017, soil biological activity as measured by the flush of CO_2 at a depth of 0-2" (2-6" depth not yet determined) was significantly greater under multi-species cover crop than under single species cover crop only at the Rowan County site (Table 17). This effect may have been due to greater rooting, as evidenced from the marginally greater above-ground biomass with the multi-species cover crop (Table 8). Similarly, greater soil biological activity with multi-species cover crop than with single-species cover was trending in Davidson County. Soil biological activity with multi-species cover crop was also trending greater than without cover crop at the Wake County site. Averaged across all eight sites, soil biological activity with multi-species cover cropping was significantly ($p < 0.01$) greater than with either no cover crop or single-species cover crop (333 vs 301 mg/kg/3 days, respectively). This was an average of 10% increase in soil biological activity for most sites that were in the first year of comparison (except for the site in Stanly County).

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Table 17. Flush of CO_2 following rewetting of dried soil (mg/kg/3 days) from demonstration sites in 2016/17

Location	Multi-species cover crop	Single-species cover crop	No cover crop planted	Significance
	---------- *mg/kg/3 days* ----------			*Pr > F*
Alamance Co	519	484	--	0.22
Ashe Co	437	--	456	0.48
Davidson Co	428	369	--	0.10
Henderson Co	231	--	187	0.19
Nash Co	97	--	107	0.16
Rowan Co	313	248	--	**0.04**
Stanly Co	590	--	507	0.20
Wake Co	129	--	112	0.06

Other soil chemical properties were not significantly different among cover crop treatments, but variations occurred among sites and depths (Table 18). The sites in Nash County had greater sand contents and lower pH, base saturation, K, Ca, and Mg values. The site in Stanly County had the finest texture and greatest residual nitrate, inorganic N, CEC, P, K, Ca, S, Mn, Zn, and Cu.

Table 18. Soil physical and chemical properties as affected by site and depth in 2015/16

	Edgecombe Co		Nash Co (early)		Nash Co (mid)		Stanly Co	
Property	**0-2”**	**2-6”**	**0-2”**	**2-6”**	**0-2”**	**2-6”**	**0-2”**	**2-6”**
Clay (%)	14	15	6	7	8	9	22	24
Sand (%)	61	60	80	79	73	73	17	17
Density (g/cc)	1.10	1.15	1.43	1.45	1.35	1.44	0.86	0.98
Nitrate (mg/kg)	3	1	9	4	24	7	107	40
Inorganic N (mg/kg)	9	6	12	6	29	10	118	47
pH	6.6	6.3	5.3	5.2	5.3	5.2	6.3	6.3
CEC (meq/100 cc)	9	8	4	3	6	4	18	12
Base saturation (%)	92	87	63	58	75	64	95	92
P (mg/dm3)	79	58	95	95	140	151	569	333
K (mg/dm3)	207	181	53	33	116	59	565	321
Ca (mg/dm3)	1022	796	242	203	485	292	3326	1706
Mg (mg/dm3)	282	222	29	21	76	35	293	185
S (mg/dm3)	9	8	11	10	32	15	42	20
Mn (mg/dm3)	8	5	4	3	9	6	117	97
Zn (mg/dm3)	4	3	1	1	5	4	32	11
Cu (mg/dm3)	1	1	1	1	1	1	13	7

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

5.0 Conclusions

5.1 Project Feedback

Project partners have made the following observations on successes and failures of this demonstration project:

- A variety of multi-species cover crop mixes were developed based on producer interests, district knowledge, and recommendations from reading/listening/engagement in the subject over the past few years.

- Establishment of multi-species cover crops was feasible at each location. Although early planting date is preferred, some hindrances were noted. Broadcasting seed into standing soybean crop is possible, but establishment success was dependent on timely rain and removal of cash crop so that the cover crop could develop properly. Drilling at a later date may be more successful in many instances. Early planting without soil moisture and the prospects of continued dry fall weather is another limitation to good establishment and producing enough biomass prior to winter.

- Matching cropping sequences with the right cover crop mixture can be a challenge, especially with limited winter growth, cost of seeding, and potential herbicide carryover. Structuring a program that allows for adaptive management in seed selection is a key component.

- Allowing cover crop to mature to mid-bloom is still considered a necessary step to make effective use of the cover crop to enhance soil health. Producer concerns for late planting of cash crop are substantial, but could be overcome with continued demonstration of soil and economic attributes of a functioning system.

- Engaging producers fully into the seed selection and planting of the cover crop is essential to make the demonstration viable. As with other conservation technologies, adaptation to specific farm conditions may be necessary, and a fully engaged producer will look for solutions rather than lament the failures only.

- Overall Conservation Districts were pleased with the process. They noted that the field days have increased local interest in cover crops and that structuring the event with a focus on producers talking to producers was a key element. They have also noted an increase in requests for technical assistance as well as demand increases for state and federal cost-share programs.

- Producers have given positive feedback as well, from demonstration hosts to field day participants. Although some producers ended their participation early due to reasons unrelated to project design, many have continued to agree to participate on an annual basis. Soil Health field days are becoming an annual event in several Conservation Districts.

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- Conservation Districts are very excited about the promotional fliers generated for distribution. Project partners plan to create one for each demonstration once all data results are in. Conservation District staff indicated that the fliers are a perfect way to start a conversation with their producers. A producer reviewer noted the fliers were most interesting when cross compared from one region to the next.

- Successful demonstration activities were possible only with the broad teamwork and skills offered by project partners. We found that an effective network involved (1) the Foundation as coordinating lead to arrange demonstrations with (2) conservation districts, who arranged for selection of a (3) key producer and appropriate field. (4) Resource specialists from USDA-NRCS were valuable in field days and guidance and (5) scientists from NC State University and USDA-ARS were important for collecting hard data to support soil health concepts.

5. Project's Next Steps

The Foundation greatly appreciates the support given by NRCS. All partners have enjoyed working on the project and providing information and resources about soil health and how multi-species cover crops work in the Southeast. Project partners plan to continue efforts into the future, pending availability of funds. Funding is secured for planting demonstrations in fall 2017 with 8 current partnering Conservation Districts. The Foundation is enrolling an additional 4 Conservation Districts for a total of 12 demonstrations in 2017. The Foundation is mobilizing equipment to measure soil moisture and heat stress in 3 demonstrations in summer 2017. Project partners will seek ways to share lessons learned throughout 2017 and 2018.

6. References

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The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

Managing Multi-Species Cover Crops in the Southeastern USA
2014 Conservation Innovation Grant #69-3A75-14-233

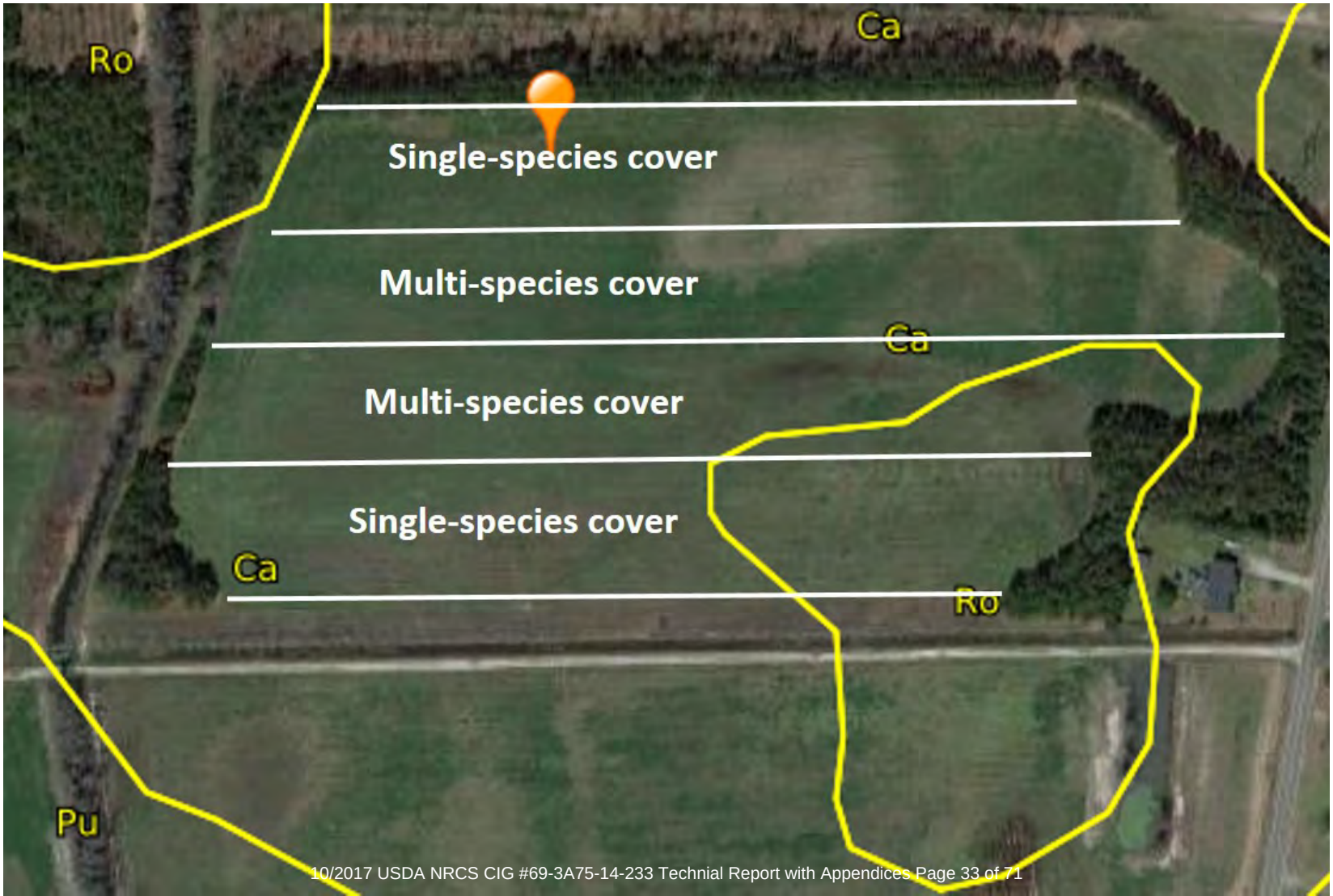
Appendix A
Demonstration Site Maps
with Soil Types

Edgecombe County – 2015/16

Ca – Cape Fear loam (Fine, mixed, semiactive, thermic Typic Umbraquults)

Ro – Roanoke loam (Fine, mixed, semiactive, thermic Typic Endoaquults)

Pu – Portsmouth fine sandy loam (Fine-loamy over sandy or sandy-skeletal, mixed, semiactive, thermic Typic Umbraquults)



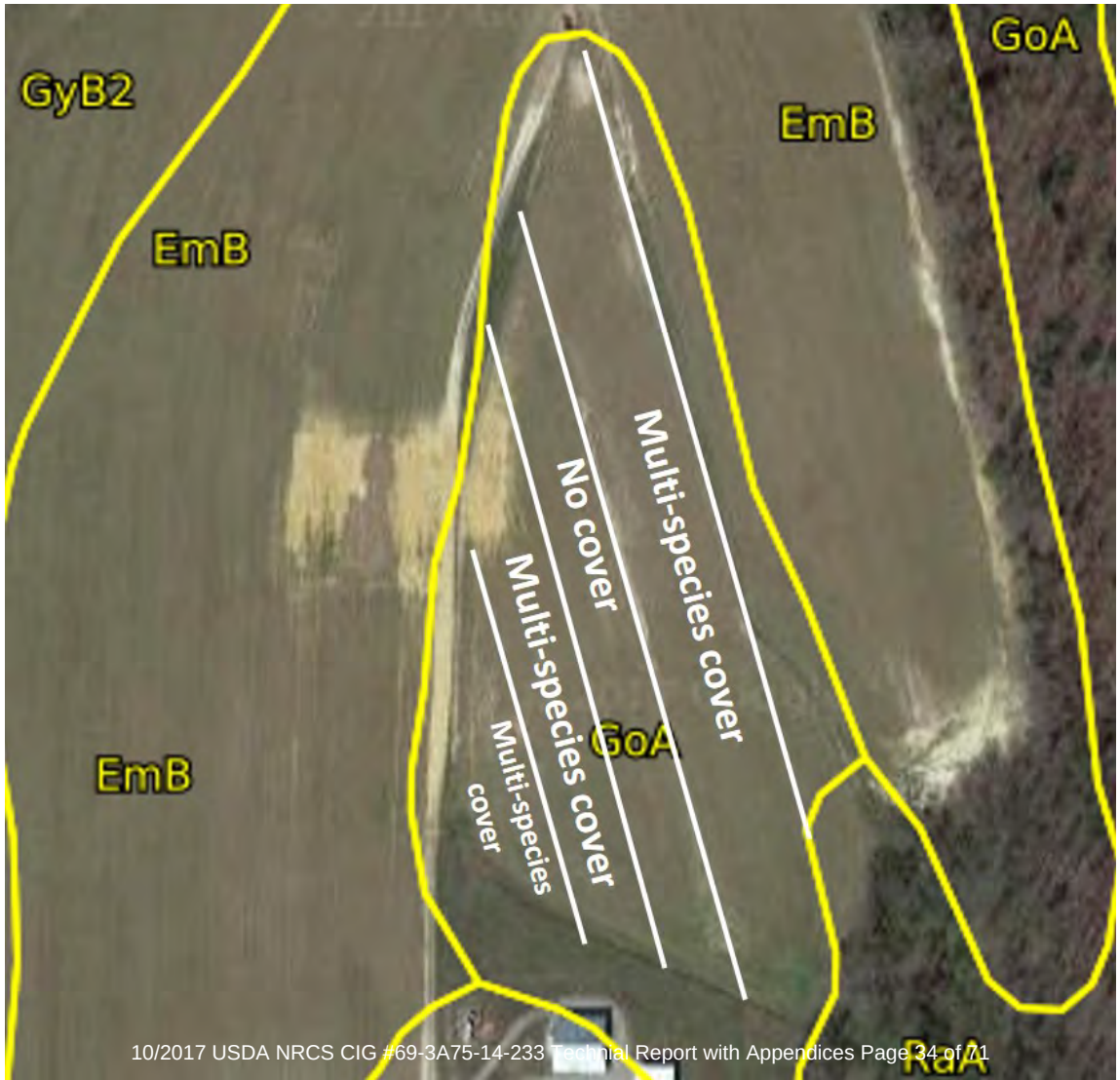
Halifax County (East) – 2015/16

GoA – Goldsboro fine sandy loam (Fine-loamy, siliceous, subactive, thermic Aquic Paleudults)

EmB – Emporia fine sandy loam (Fine-loamy, siliceous, subactive, thermic Typic Hapludults)

RaA – Rains fine sandy loam (Fine-loamy, siliceous, semiactive, thermic Typic Paleaquults)

GyB2 – Gritney sandy clay loam (Fine, mixed, semiactive, thermic Aquic Hapludults)



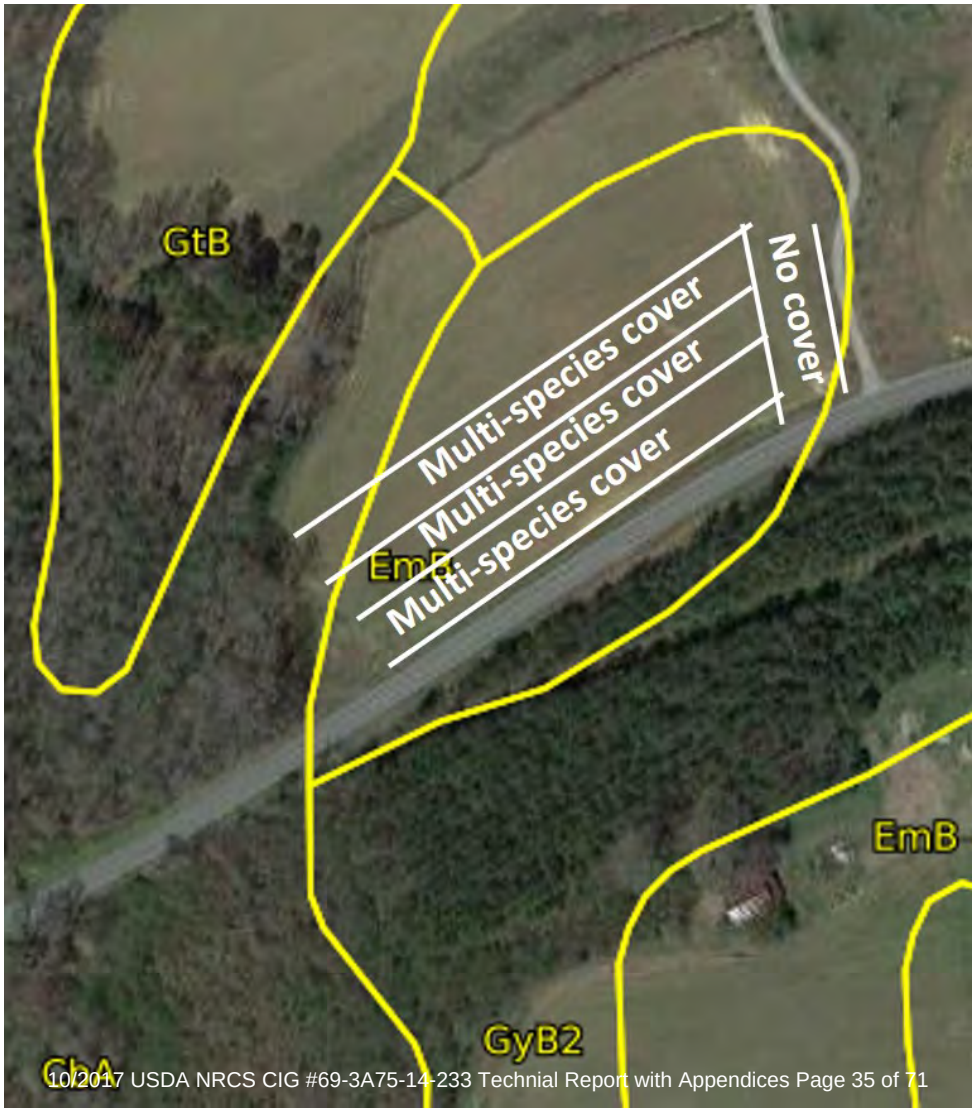
Halifax County (West) – 2015/16

EmB – Emporia fine sandy loam (Fine-loamy, siliceous, subactive, thermic Typic Hapludults)

GyB2 – Gritney sandy clay loam (Fine, mixed, semiactive, thermic Aquic Hapludults)

CbA – Chastain and Bibb soils (Fine, mixed, semiactive, acid, thermic Fluvaquentic Endoaquepts)

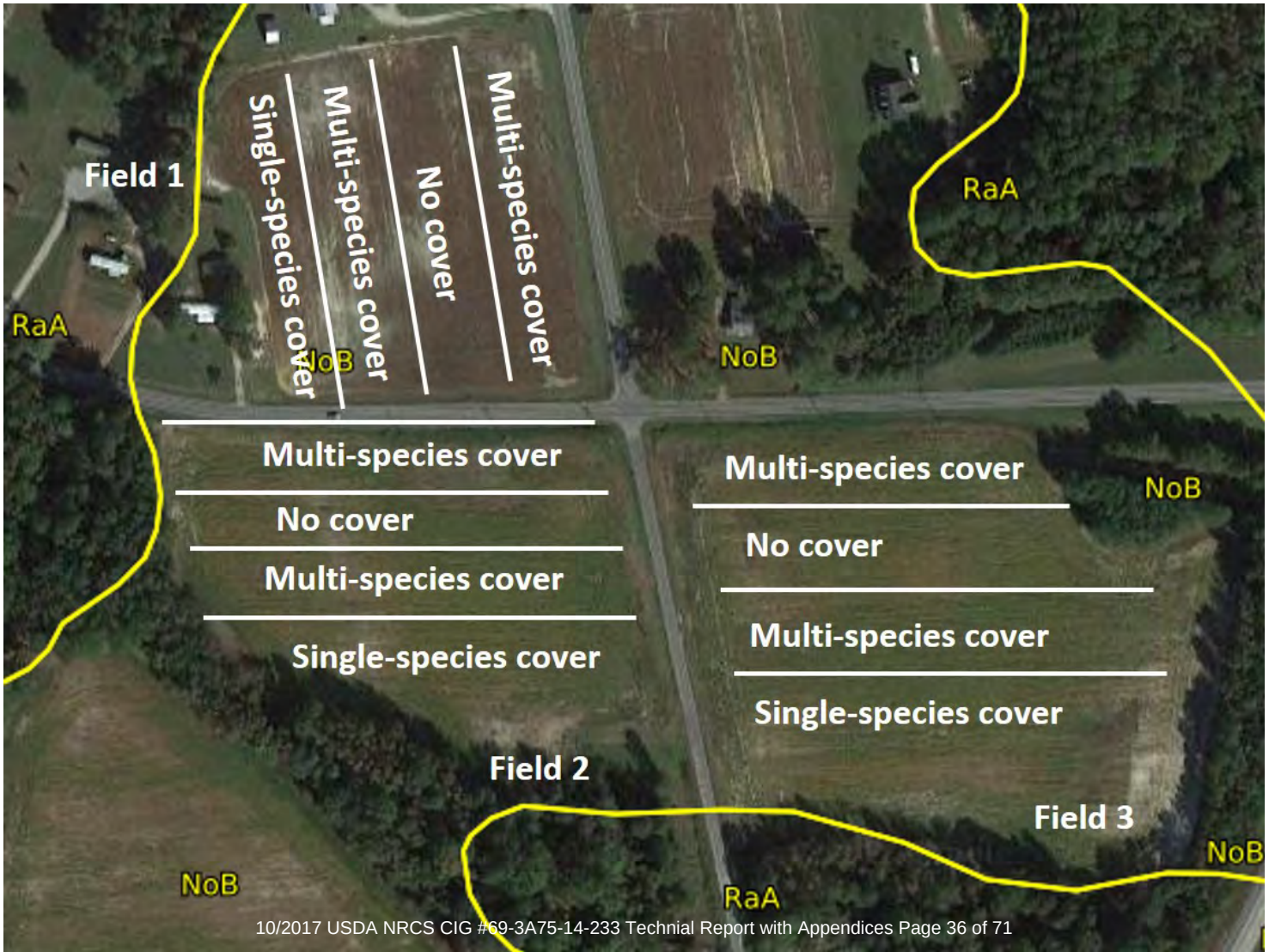
GtB – Gritney fine sandy loam (Fine, mixed, semiactive, thermic Aquic Hapludults)



Nash County – 2015/16

NoB – Norfolk loamy sand (Fine-loamy, kaolinitic, thermic Typic Kandiudults)

RaA – Rains fine sandy loam (Fine-loamy, siliceous, semiactive, thermic Typic Paleaquults)



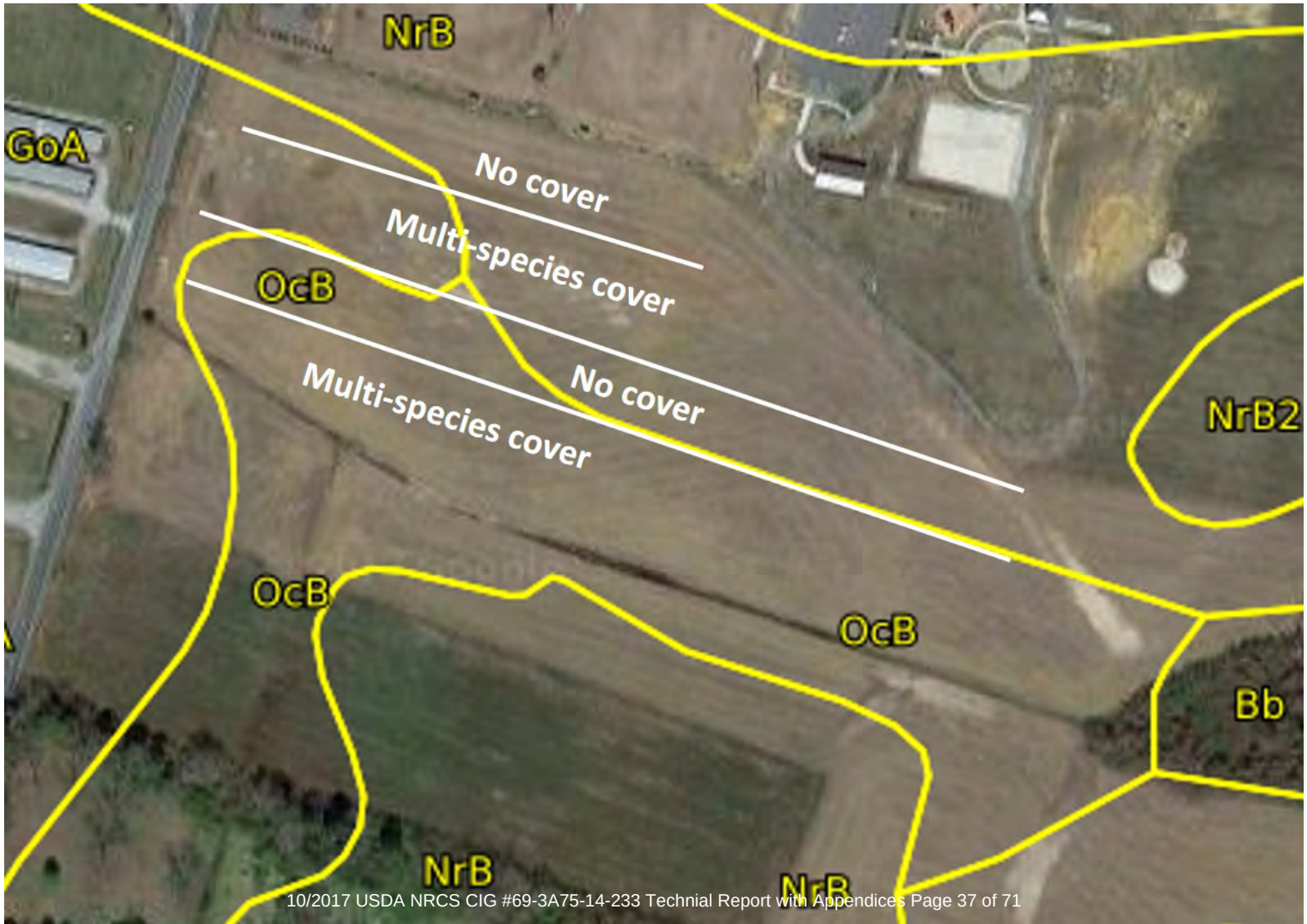
Pitt County – 2015/16

OcB – Ocilla loamy fine sand (Loamy, siliceous, semiactive, thermic Aquic Arenic Paleudults)

NrB – Norfolk sandy loam (Fine-loamy, kaolinitic, thermic Typic Kandiudults)

GoA – Goldsboro sandy loam (Fine-loamy, siliceous, subactive, thermic Aquic Paleudults)

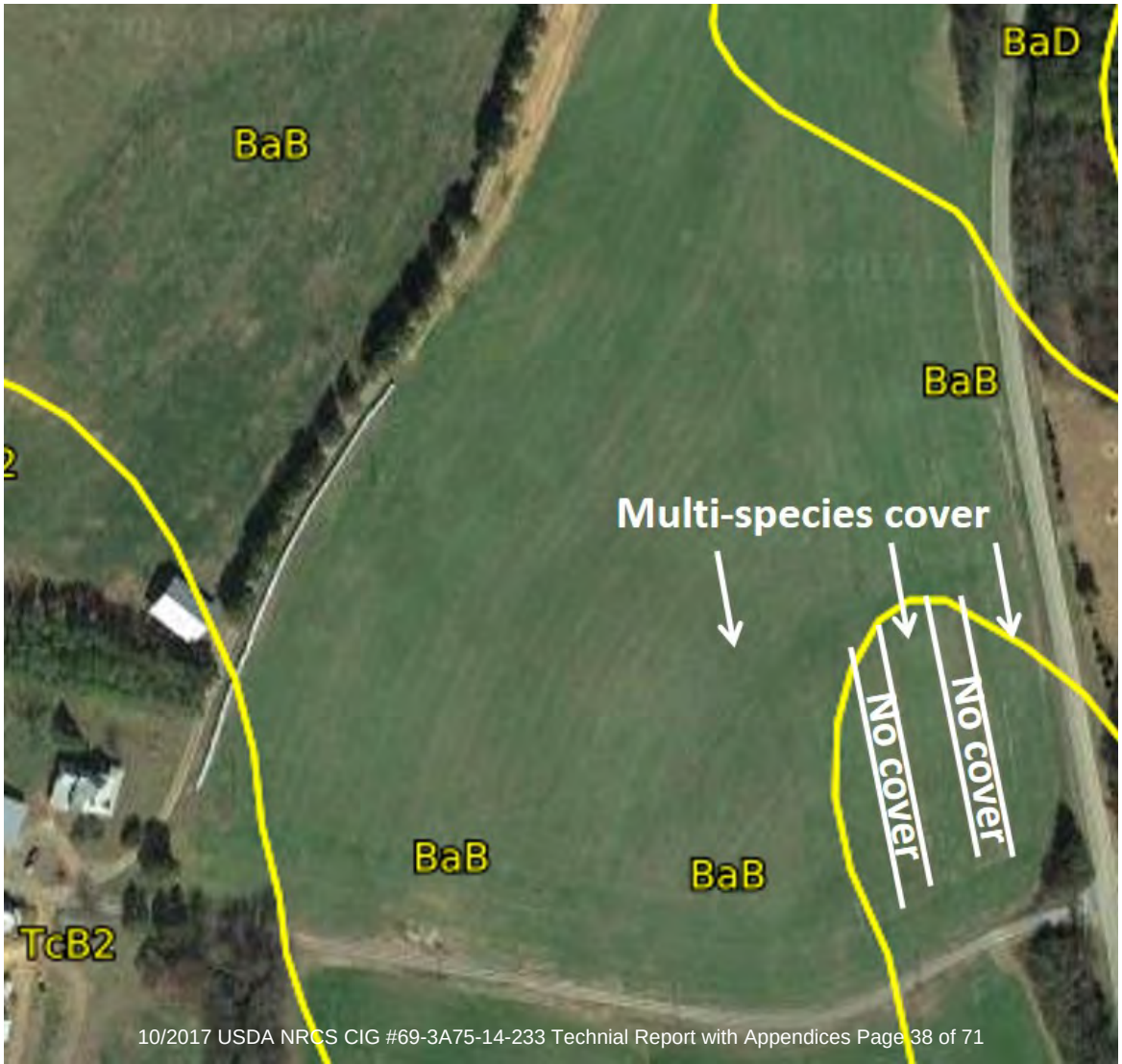
Bb – Bibb complex (Coarse-loamy, siliceous, active, acid, thermic Typic Fluvaquents)



Stanly County – 2015/16 and 2016/17

BaB – Badin channery silt loam (Fine, mixed, semiactive, thermic Typic Hapludults)

TcB2 – Tarrus channery silty clay loam (Fine, kaolinitic, thermic Typic Kanhapludults)



Nash County – 2016/17

NrB – Norfolk, Georgeville, and Faceville soils (Fine-loamy, kaolinitic, thermic Typic Kandiudults)

RaA – Rains fine sandy loam (Fine-loamy, siliceous, semiactive, thermic Typic Paleaquults)

Rowan County – 2016/17

EnB – Enon fine sandy loam (Fine, mixed, active, thermic Ultic Hapludalfs)

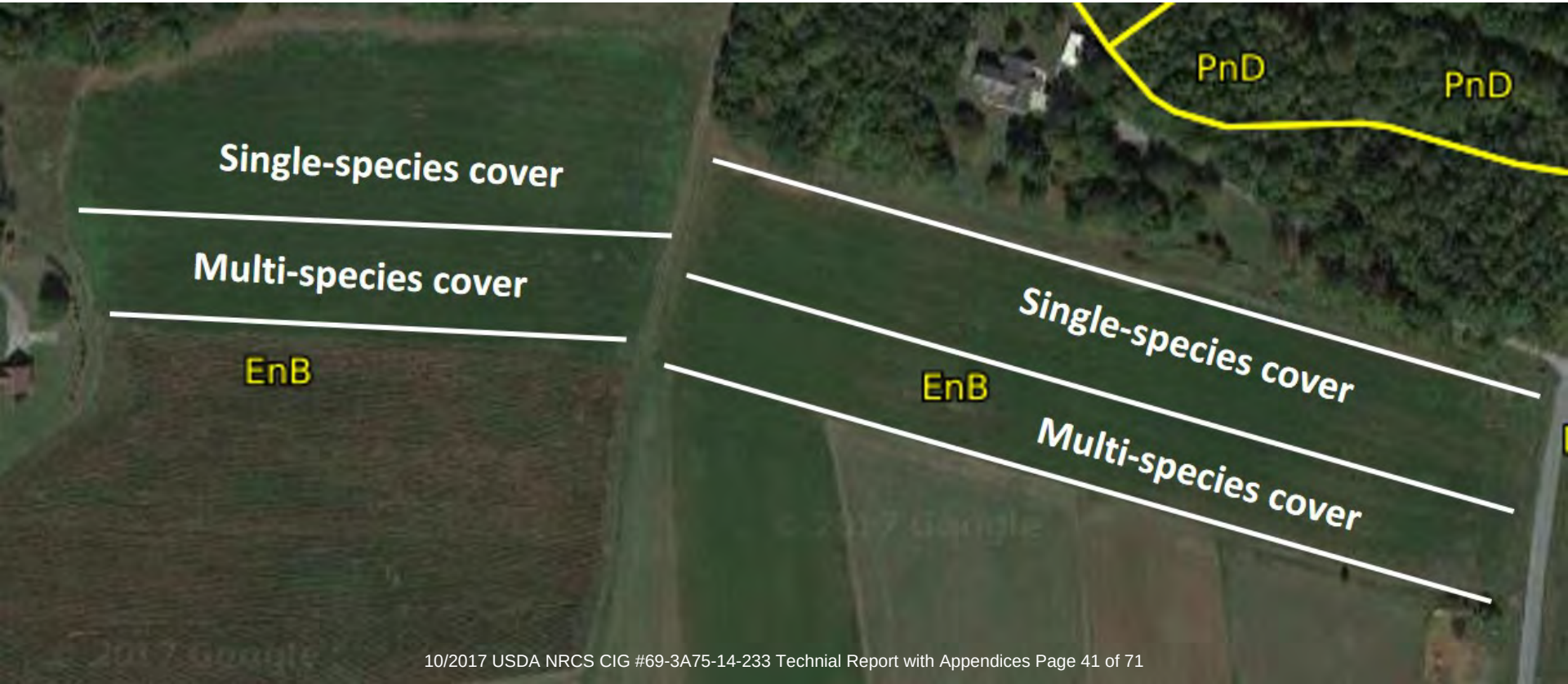
SeB – Sedgefield fine sandy loam (Fine, mixed, active, thermic Aquultic Hapludalfs)

BgB – Badin-Goldston complex (Fine, mixed, semiactive, thermic Typic Hapludults)

Davidson County – 2016/17

EnB – Enon fine sandy loam (Fine, mixed, active, thermic Ultic Hapludalfs)

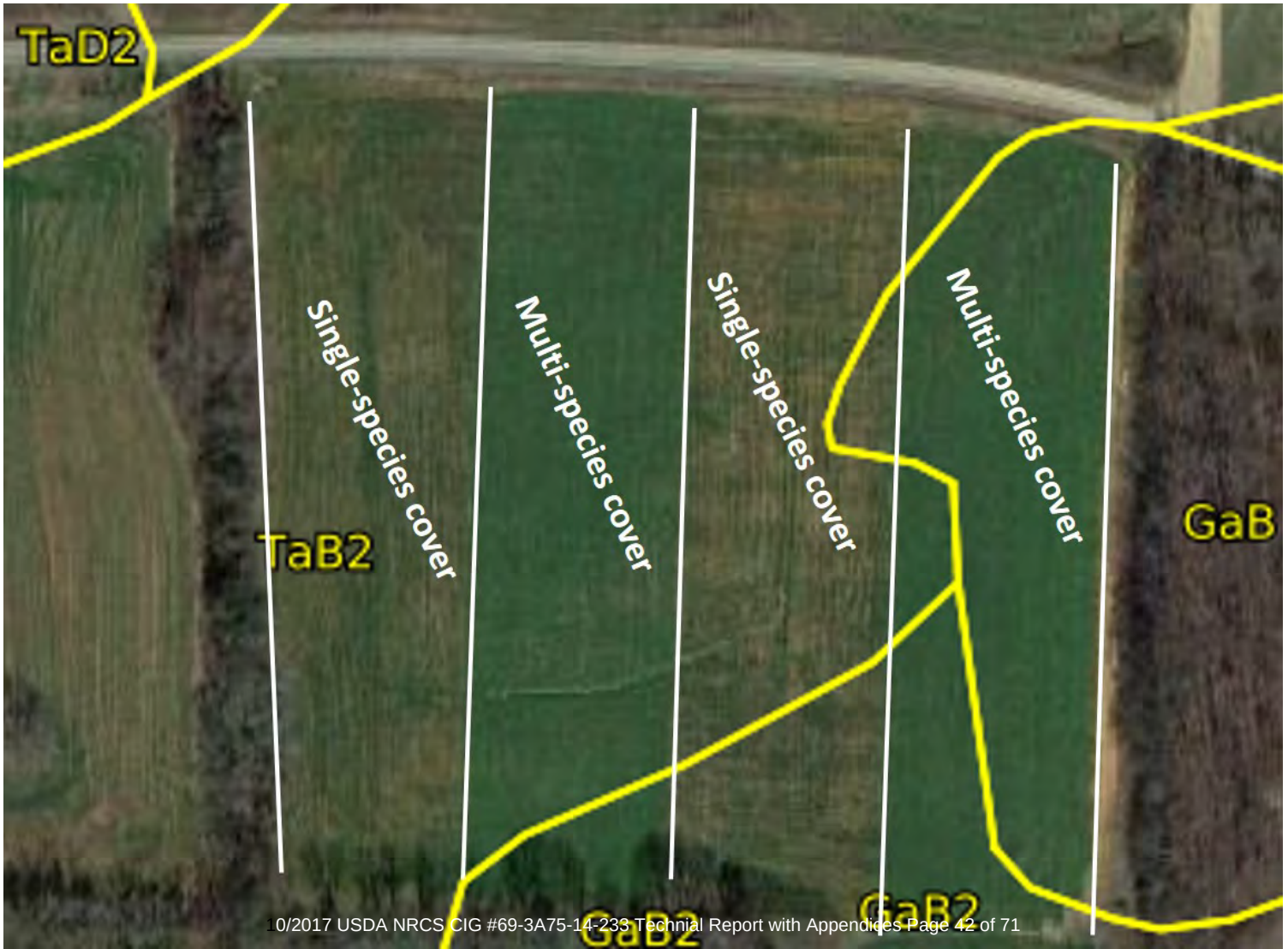
PnD – Poindexter-Wynott complex (Fine-loamy, mixed, active, thermic Typic Hapludalfs; Fine, mixed, active, thermic Typic Hapludalfs)



Alamance County – 2016/17

GaB – Georgeville silt loam (Fine, kaolinitic, thermic Typic Kanhapludults)

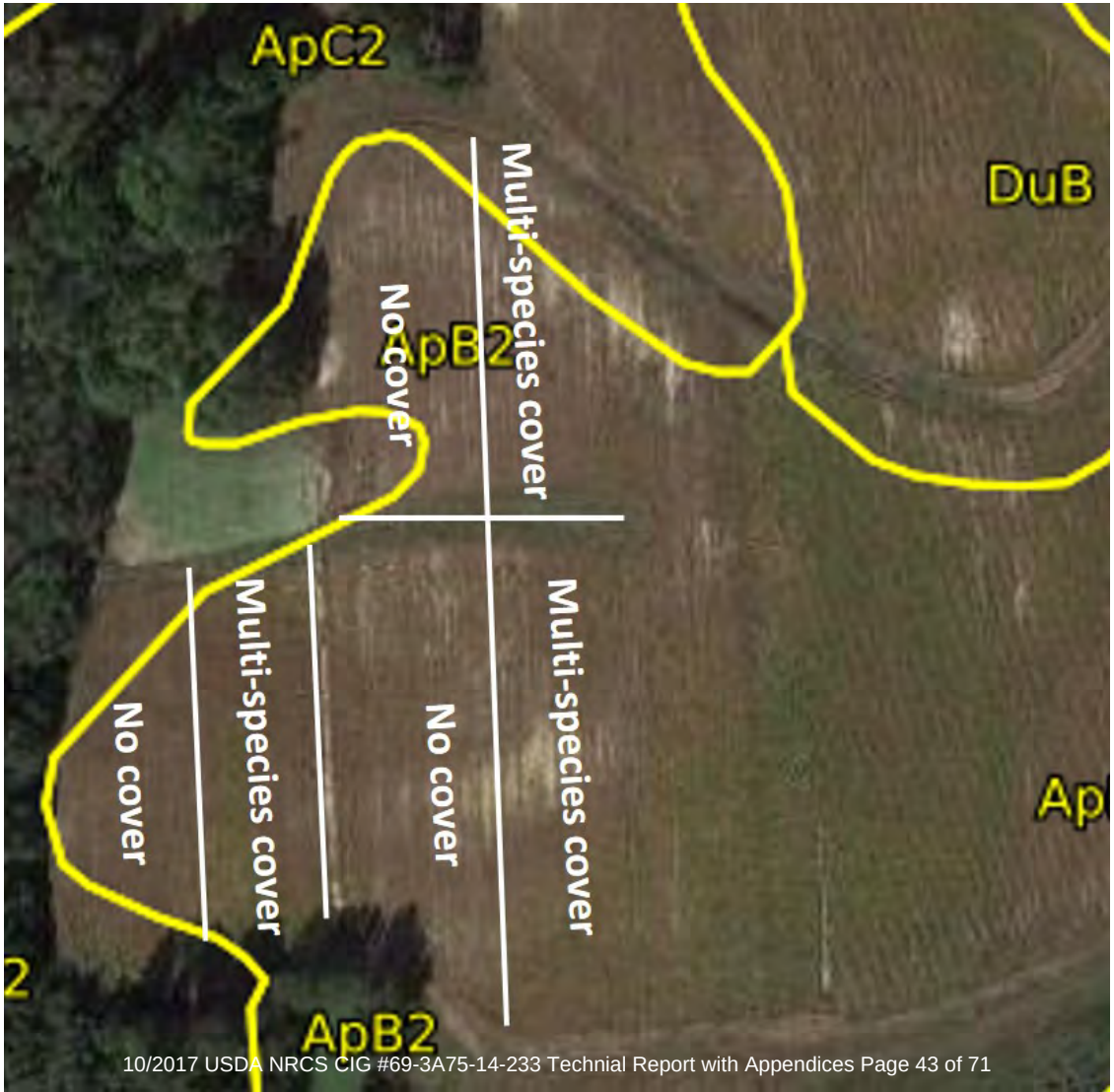
TaB2 – Tarrus silt loam (Fine, kaolinitic, thermic Typic Hapludults)



Wake County – 2016/17

ApB2 – Appling sandy loam (Fine, kaolinitic, thermic Typic Kanhapludults)

DuB – Durham loamy sand (Fine-loamy, siliceous, semiactive, thermic Typic Hapludults)



Henderson County – 2016/17

Su – Suncook loamy sand (Mixed, mesic Typic Udipsamments)

Cu – Comus fine sandy loam (Coarse-loamy, mixed, active, nonacid, mesic Typic Udifluvents)

To – Toxaway silt loam (Fine-loamy, mixed, superactive, nonacid, mesic Cumulic Humaquepts)

Ashe County – 2016/17

EvE – Evard loam (Fine-loamy, parasesquic, mesic Typic Hapludults)

CfD – Clifton loam (Fine, mixed, semiactive, mesic Typic Hapludults)

WaF – Watauga loam (Fine-loamy, paramicaceous, mesic Typic Hapludults)

Managing Multi-Species Cover Crops in the Southeastern USA
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Appendix B

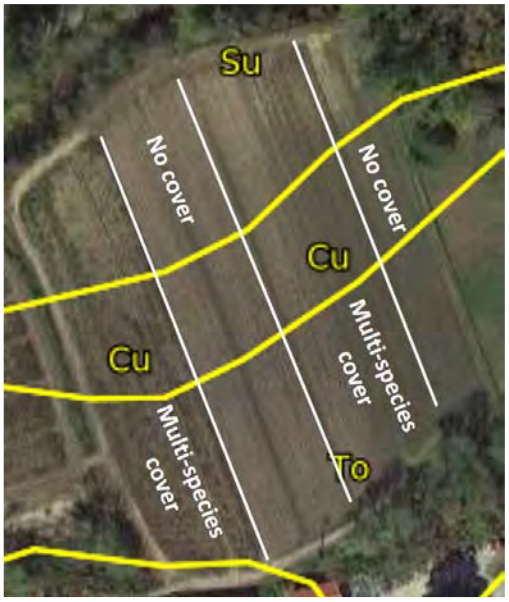
Regional Promotional Fliers

Copies distributed to all Conservation District offices and available online

KEEPIN' IT COVERED IN THE CAROLINAS

NC Mountain Demonstration – see ncsoilwater.org for Piedmont & Coastal regions!

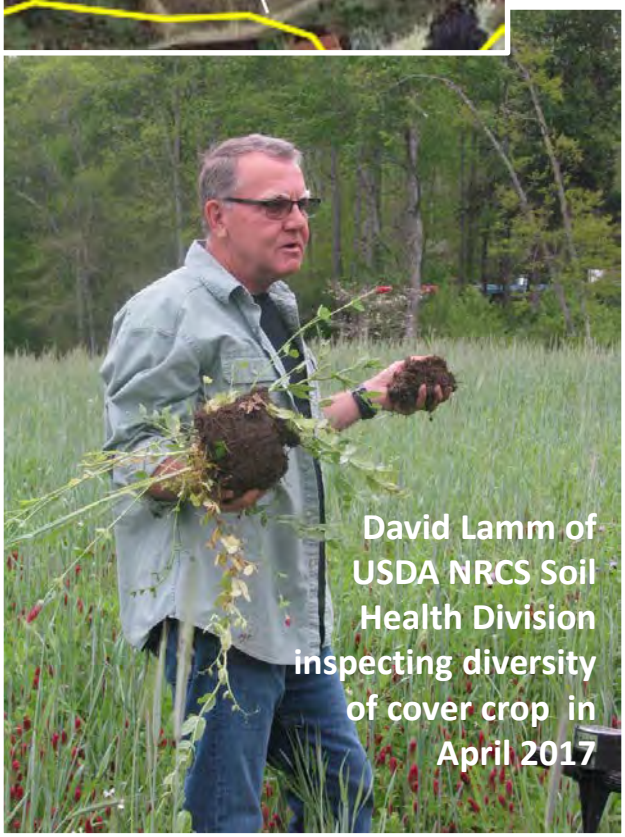
Suppressing weeds and building soil fertility are concerns for producers in the Mountain region of North Carolina. Winter cover cropping could help, but what type of cover crop is most suitable? Are mixtures of cover crops beneficial? Could multi-species cover cropping improve soil health?



Replicated strips of multi-species cover crop and no cover crop were arranged on a bottomland field in Henderson County in 2016/17.

Multi-species cover crop mix in fall 2016:
100 lb/A Rhymin winter rye, 100 lb/A Austrian winter pea, 17 lb/A crimson clover, 7 lb/A Rackmaster trophy radish. No-till planted after sweet corn on Oct 29, 2016. Terminated chemically on May 20, 2017.

Su – Suncook loamy sand (Typic Udipsamments)
Cu – Comus fine sandy loam (Typic Udifluvents)
To – Toxaway silt loam (Cumulic Humaquepts)



David Lamm of USDA NRCS Soil Health Division inspecting diversity of cover crop in April 2017

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

NC Mountain Demonstration – see info at ncsoilwater.org for Piedmont & Coastal regions!

Lessons learned

Although only a few soil properties evaluations were available, there was some indication for improvement with multi-species cover cropping in this on-farm demonstration.

Side-by-side strip trials were useful to make evaluations and to demonstrate performance of cover crops in a systematic manner.

"One positive I have noticed is that even without a pre-emergent pesticide, the no-till planting has very few weeds." – Phillip Whitaker

Soil Biological Activity (mg/kg/3 days)
0-2" depth

No cover	Multi-species cover
187	231

Cover crop production (lb/A) May 20
No cover (weeds) – 2500
Multi-species cover – 9170

Soil bulk density (g/cc)

	0-2"	2-6"
No cover (weeds) –	0.93	1.03
Multi-species cover –	0.97	1.10

Soil sampled on May 16, 2017 at 0-2" and 2-6" depths.

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Natural Resources Conservation Service
Agricultural Research Service

North Carolina ADFP Trust Fund

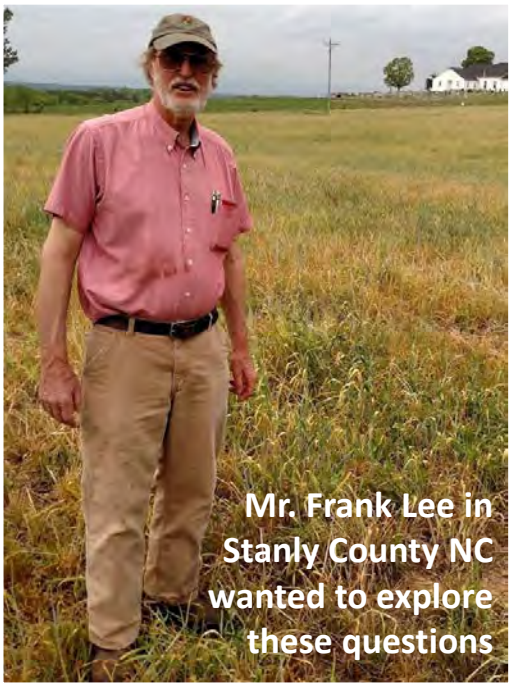
NC STATE UNIVERSITY
Crop & Soil Sciences

MSCC Report 04 – Full report available at:
http://ncsoilwater.org/programs/soil-health-initiative-multi-species-cover-crops/

KEEPIN' IT COVERED IN THE CAROLINAS

NC Piedmont Demonstration – see ncsoilwater.org for Mountain & Coastal regions!

Controlling soil erosion, suppressing weeds, and building soil fertility are concerns for producers in the Piedmont region of North Carolina. Winter cover cropping could help, but what type of cover crop is most suitable? Are mixtures of cover crops beneficial? Could multi-species cover cropping improve soil health?



Replicated strips of multi-species cover crop and no cover crop were arranged on the same field in 2015/16 and 2016/17.

<u>Multi-species cover crop mix in fall 2015</u>:
15 lb/A triticale, 15 lb/A ryegrass,
10 lb/A crimson clover, 2 lb/A radish

<u>Multi-species cover crop mix in fall 2016</u>:
50 lb/A triticale, 15 lb/A Austrian winter pea,
15 lb/A crimson clover, 10 lb/A ryegrass

No-till planted after corn on Oct 15, 2015 and after cotton on Oct 29, 2016. Terminated chemically on May 2, 2016 and Apr 20, 2017.

NORTH CAROLINA SOIL & WATER CONSERVATION DISTRICTS *Yours for Life*

Multi-species cover crop biomass production
5800 lb/A on April 19, 2016
2210 lb/A on April 18, 2017

Weedy overwinter biomass averaged
1400 lb/A in 2016
1640 lb/A in 2017

Badin channery silt loam (*fine, mixed, semiactive, thermic Typic Hapludults*)

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

NC Piedmont Demonstration – see info at ncsoilwater.org for Mountain & Coastal regions!

Lessons learned

Soil properties were improved with multi-species cover cropping in this on-farm demonstration.

Several years of previous no-tillage management and cover cropping were important for improving the soil surface.

Side-by-side strip trials were useful to make evaluations and to demonstrate performance of cover crops in a systematic manner.

"Cover crops are beneficial if they are managed properly." – Frank Lee

Soil Biological Activity (mg/kg/3 days) 0-2" depth

	No cover	Multi-species cover
2016	435	516
2017	507	590

Surface residue (lb/A)
No cover – 5076
Multi-species cover – 8364

Residue nitrogen (lb/A)
No cover – 60
Multi-species cover – 116

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Natural Resources Conservation Service
Agricultural Research Service

North Carolina ADFP Trust Fund

NC STATE UNIVERSITY
Crop & Soil Sciences

MSCC Report 03 – Full report available at:
http://ncsoilwater.org/programs/soil-health-initiative-multi-species-cover-crops/

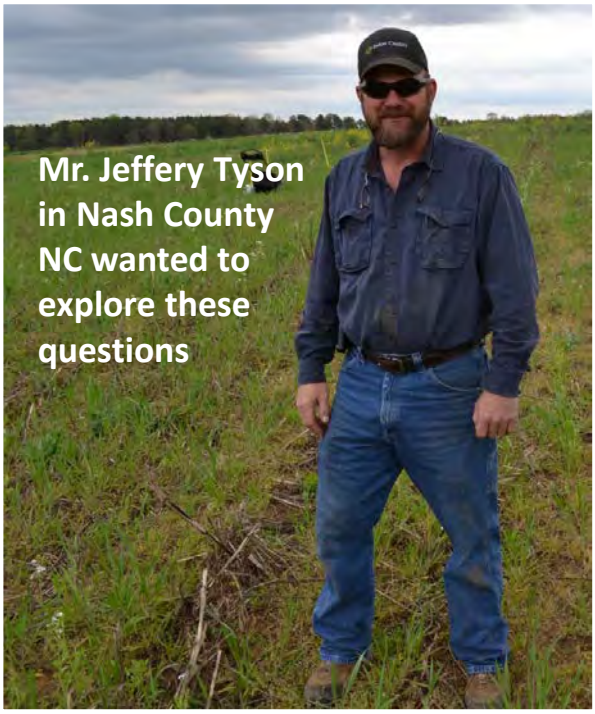
KEEPIN' IT COVERED IN THE CAROLINAS

NC Coastal Demonstration – see ncsoilwater.org for Mountain & Piedmont regions!

Controlling soil erosion and weeds infestations are a concern for producers in the Coastal Plain region of North Carolina. Winter cover cropping could help, but what type of cover crop is most suitable? Are mixtures of cover crops beneficial? Could multi-species cover cropping improve soil health?

At the end of the soybean growing season in 2015, cover crops were sown:

a. broadcast onto green beans on Oct 20
b. drilled after harvest on Dec 8
c. drilled after harvest on Jan 8



Mr. Jeffery Tyson in Nash County NC wanted to explore these questions

Multi-species cover crop mix in fall 2015: 54 lb/A rye, 15 lb/A Austrian winter pea, 8.5 lb/A crimson clover, 6.5 lb/A tillage radish, 1 lb/A woolypod vetch

Compared with no cover and single-species cover of Abruzzi rye (100 lb/A)

Cover crop biomass production on April 24, 2016 averaged 974 lb/A when broadcasted, 1086 lb/A when drilled on Dec 8, and 496 lb/A when drilled on Jan 8

Coastal Plain region

Norfolk loamy sand (*fine-loamy, kaolinitic, thermic Typic Kandiudults*)

The material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture, under number 69-3A75-14-233

NC Coastal Demonstration – see info at ncsoilwater.org for Mountain & Piedmont regions!

Multi-species cover crop
1179 lb/A

Cover Crop Biomass
April 3, 2017

No cover crop
580 lb/A

Lessons learned

- **Soil properties were not affected by multi-species cover cropping in this on-farm demonstration. Multiple years of evaluation will likely be needed to fully assess changes in soil properties.**
- **Side-by-side strip trials were useful to make evaluations and to demonstrate the performance of cover crops in a systematic manner.**

Multi-species cover crop mix Fall 2016:
40 lb/A rye, 10 lb/A crimson clover, 2 lb/A daikon radish

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North Carolina ADFP Trust Fund

NC STATE UNIVERSITY
Crop & Soil Sciences

MSCC Report 02 – Full report available at:
http://ncsoilwater.org/programs/soil-health-initiative-multi-species-cover-crops/

Managing Multi-Species Cover Crops in the Southeastern USA
2014 Conservation Innovation Grant #69-3A75-14-233

Appendix C

Annual Meeting of the

Soil Science Society of America

Abstract & Poster

Soil Science Seminar 11/16/16
Katie Pritchett, Soil Sci. MS Student, Crop & Soil Sci. Dept. NCSU

Title: "**Soil Organic Fractions Under Multiple-species Cover Crops in North Carolina**"

Pre-seminar refreshments are served at 3:15 pm in the McKimmon Room (2223 WMS)
Seminar begins at 3:40 pm in Williams Hall Auditorium (2215 WMS)
Everyone is welcome to attend

Abstract
Agricultural sustainability is linked to soil health. Long-term change in soil health from the use of single-species cover crops is evident in the literature, but how soil health changes with multi-species cover crops is not known, particularly in the North Carolina Coastal Plain. We hypothesized that greater above ground plant diversity would increase the variety of available substrates below ground, which would in turn increase the function of soil microbial communities. High functioning soil microbial communities serve as indicators of soil health due to their key role in storage and cycling of nutrients, formation of water-stable aggregates that resist soil erosion, and promotion of biodiversity. Research was conducted on four farms in the NC Coastal Plain, one farm in the NC Piedmont, and two small plot trials at the Cherry Research Farm in Goldsboro NC and the Peanut Belt Research Station in Lewiston-Woodville NC. Soil was sampled in spring 2016 following a variety of winter cover crops at all locations (e.g. none, single species, or multiple species). Aboveground biomass and surface residues were also collected. A range of soil organic C and N fractions were proposed, from active as C and N mineralization and soil microbial biomass C, to slow as particulate organic C and N, to passive as total organic C and N. Small-plot trials with one-, two-, three-, and six-species mixes were conducted to help support findings from on-farm trials. Completed analyses of active fractions of organic C suggest that soil microbial biomass C, cumulative C mineralization in 24 days, and the flush of CO2 following rewetting of dried soils in 3 days are sensitive to short-term effects of cover crop species, particularly at a shallow depth of 0-5 cm. These results help support a recommendation to utilize winter cover crops for soil erosion control and to enhance biologically active soil C fractions. Further analyses will help determine if multiple-species cover crops are more effective than single-species cover crops in promoting sustainability.

Quantifying Soil Health from Soil Organic C Fractions in Diverse Winter Cover Crops in North Carolina

[1]Katie Pritchett , [2]Alan J. Franzluebbers, [1]Michael Wagger, [1]Chris Reberg-Horton
[1]Department of Crop and Soil Sciences, Raleigh, NC, [2]USDA-ARS, Raleigh, NC

Introduction

- Agricultural sustainability is linked to soil health
- Long-term change in soil health from the use of single-species cover crops (SSCC) is evident in the literature
- How short-term soil health changes with multi-species cover crops (MSCC) is not known, particularly in the North Carolina Coastal Plain
- Soil biological activity is a key indicator of soil health

Hypothesis

- Greater above ground plant diversity would increase the variety of available substrates below ground, which would in turn increase the function of soil microbial communities

Objectives

- Evaluate active C and N fractions as indicators of short-term changes in soil health
- Determine above-ground biomass production and mass of surface residues from on-farm field demonstrations using multi-species cover crops

Experimental Setup

Small Plot Trials

Small Plot Trials Design

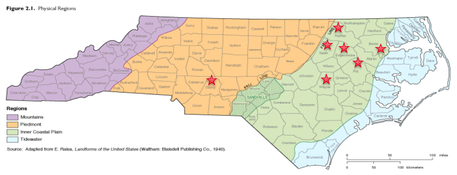
Plot dimensions
8′ x 12′
4′ alley
(64′ x 108′ total)

15 – all six	9 – Rye + Vet	7 – Wht + Clo	12 – Tur + Vet	5 – Rad	1 – Wht	8 – Wht + Rad	13 – Wht + Clo + Rad
16 – None	4 – Vet	14 – Rye + Vet + Tur	3 – Clo	6 – Tur	11 – Rad + Clo	2 – Rye	10 – Rye + Tur
16 – None	7 – Wht + Clo	3 – Clo	8 – Wht + Rad	9 – Rye + Vet	12 – Tur + Vet	4 – Vet	14 – Rye + Vet + Tur
13 – Wht + Clo + Rad	11 – Rad + Clo	15 – all six	6 – Tur	10 – Rye + Tur	5 – Rad	1 – Wht	2 – Rye
4 – Vet	1 – Wht	8 – Wht + Rad	2 – Rye	9 – Rye + Vet	15 – all six	6 – Tur	12 – Tur + Vet
14 – Rye + Vet + Tur	10 – Rye + Tur	13 – Wht + Clo + Rad	16 – None	5 – Rad	11 – Rad + Clo	7 – Wht + Clo	3 – Clo
13 – Wht + Clo + Rad	11 – Rad + Clo	16 – None	14 – Rye + Vet + Tur	6 – Tur	9 - Rye + Vet	10 – Rye + Tur	5 - Rad
1 – Wht	7 – Wht + Clo	4 – Vet	12 – Tur + Vet	15 – all six	3 – Clo	2 – Rye	8 – Wht + Rad

Treatments (lb/a)
1 – wheat (120)
2 – rye (120)
3 – crimson clover (20)
4 – hairy vetch (25)
5 – daikon radish (15)
6 – turnip (10)
7 – wheat (60)-clover (10)
8 – wheat (60)-radish (7.5)
9 – rye (60)-vetch (12.5)
10 – rye (60)-turnip (5)
11 – radish (7.5)-clover (10)
12 – turnip (5)-vetch (12.5)
13 – wheat (40)-clover (6.7)-radish (5)
14 – rye (40)-vetch (8.3)-turnip (3.3)
15 – wheat (20)-rye (20)-clover (3.3)-vetch (4.1)-radish (2.5)-turnip (1.7)
16 - none

On-Farm Trials

County	Soil Series	Design	Cover Crop
Stanly	Badin channery silt loam	None x 2 MSCC x 2	Crimson clover, radish, triticale, rye
Edgecombe	Cape Fear loam and Roanoke loam	MSCC x 2 SSCC x 2	PT turnip, winter pea, hairy vetch, tillage radish, triticale, crimson clover, black oats, abruzzi rye
Nash (3 fields)	Norfolk loamy sand	None x 1 SSCC x 1 MSCC x 2	Rye, crimson clover, tillage radish, winter pea, woolypod vetch, abruzzi rye
Halifax	Goldsboro fine sandy loam	SSCC x 2 MSCC x 2	Holcomb seed blend from center seeds, forage collard, super soil builder from walnut creek seeds, phacelia
Halifax	Emporia fine sandy loam	None x 1 MSCC x 3	Holcomb seed blend from center seeds, forage collard, super soil builder from walnut creek seeds, phacelia
Pitt	Norfolk sandy loam and Ocilla loamy fine sand	MSCC x 2 None x 2	Rye, triticale, crimson clover, winter pea, daikon radish



- Peanut Belt Research Farm
  - Lewiston-Woodville, NC
  - Goldsboro sandy loam
- Center for Environmental Farming Systems
  - Goldsboro, NC
  - Wickham loamy sand

Sample Collection

Soil

- Collected at:
  - 0-10 cm (Small Plot)
  - 0-5 and 5-15cm (On-farm)
- Dried and sieved (4.75mm)

Biomass

- Collected with:
  - Mower- 20” x 20’ strips
  - Metal square – 0.5 x 0.5m

Residue

- Collected with:
  - 30 cm diameter ring

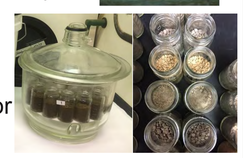
Incubations

Materials

- 1 L mason jar with lid
- 2 60 mL jars with 50 g soil
- Re-wet dried soil to 50% water-filled pore space
- 10 mL NaOH trap for CO_2
- 10 mL water for humidity

Methods

- Incubated at 25°C for 24 days
- Titrated at 3 days for flush of CO_2
- Fumigated 1 50 g subsample at day 10
- Titrated subsample at 21 days for SMBC
- Titrated remaining sample at 24 days for cumulative C mineralization



Results

Peanut Belt Research Farm
Lewiston-Woodville
North Carolina

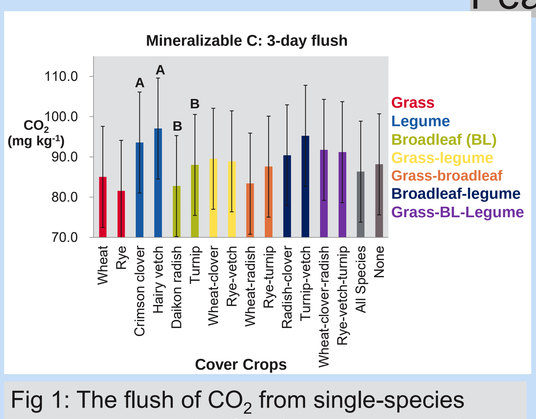


Fig 1: The flush of CO_2 from single-species legume was greater than from single species broadleaf.

Cover Crop growth in April 2016

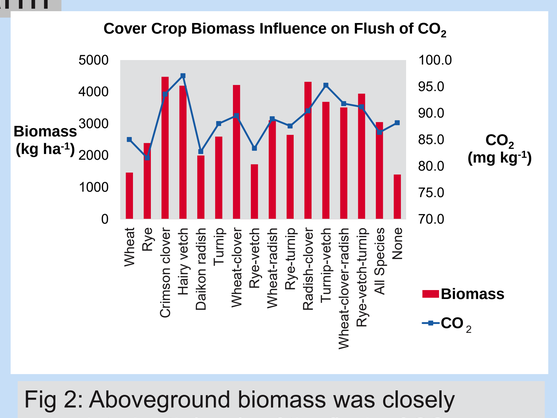


Fig 2: Aboveground biomass was closely associated with levels of the flush of CO_2.

Center for Environmental Farming Systems
Goldsboro, North Carolina

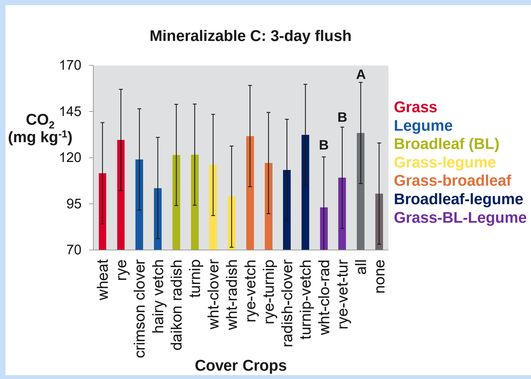


Fig 3: The flush of CO_2 from 6-species cover (all) was greater than from 3-species cover.

Cover Crop growth in April 2016

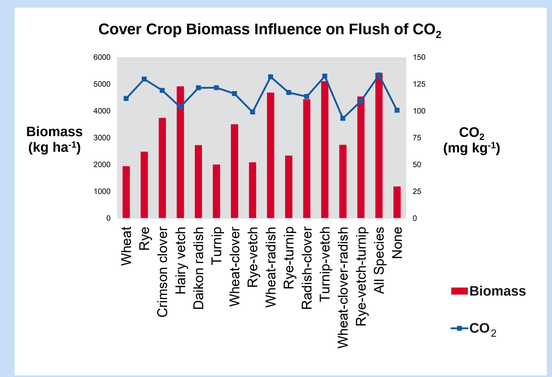


Fig 4: Aboveground biomass was not closely associated with flush of CO_2 at this site.

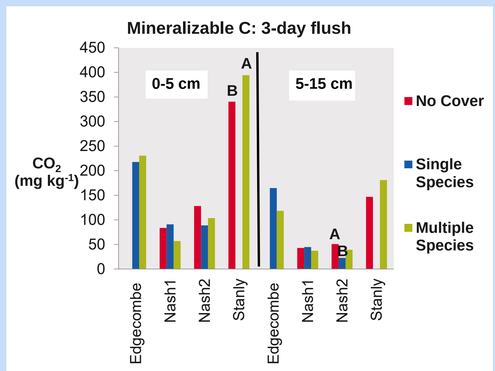


Fig 5: Site and soil depth differences were apparent. The flush of CO_2 was greater with multi-species cover crops than no cover at the Stanly County site.

On Farm Trials

Soil Chemical Characteristics

	CEC, meq/100cc	pH	P, mg/kg	K, mg/kg
0-5 cm				
Edgecombe	9.0	6.0	143	169
Nash1	6.6	5.7	147	125
Nash2	8.1	6.1	142	158
Stanly	6.9	5.8	169	106
5-15 cm				
Edgecombe	6.9	5.5	160	141
Nash1	6.2	5.6	217	118
Nash2	8.0	5.6	178	160
Stanly	10.6	5.9	184	241

Fig 6: CEC and pH were moderately low as typical for southeastern soils, while P was very high at all farms and K was adequate.

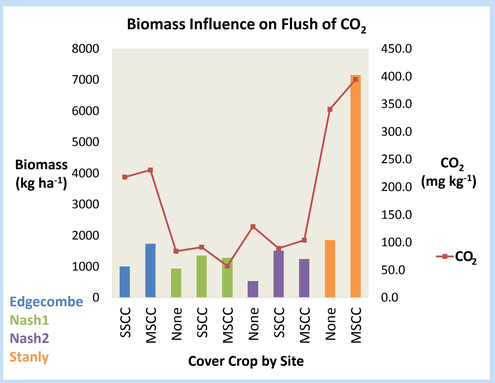


Fig 7: Some association appeared between cover crop biomass and the flush of CO_2 across sites.

Conclusions and Implications

- The flush of CO_2 following rewetting of dried soil during 3 days was sensitive to cover crop species mixtures
- Aboveground biomass appeared to rapidly influence the flush of CO_2
- These results help support a recommendation to utilize winter cover crops to enhance biologically active soil C fractions

Acknowledgements

- Financial support was provided by USDA-NRCS Conservation Innovation Grant (69-3A75-14-133) awarded to North Carolina Foundation for Soil and Water Conservation, Inc.
- NC State University, USDA-ARS, and Cotton Inc. provided additional support
- A contribution from the Soil Ecology and Management Team at NC State University

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Appendix D

Conservation District Guidance Document

Producer Survey

Outreach Event Survey

This guidance document is provided as a set of instructions based on 2013 - 2016 cover crop projects. The steps listed below are minimum criteria steps. For example, the District can choose to host more than one field day event, facilitate more than one demonstration plot, plant more than 10 acres, etc. The Foundation will not be able to exceed the budgeted caps per District as listed in the contract, so keep this in mind during the planning process. The Foundation recognizes that not all of the processes will work for each District. If you need to deviate from any of the criteria, consult with the Foundation in writing and the technical support team will weigh in on the matter.

District Technical Support Team

The District is encouraged to set up a team of experts to lead the project at the county level. Consider the following for the county level technical support team - district staff, district conservationists, county level Cooperative Extension, Department of Ag regional agronomists, Division of Soil and Water soil scientists, staff from other pilot districts, and producers with a history of cover crops. Determine goals at the county level to will help the District promote multi-species cover crops that address any issues unique to your region. As questions arise, the Foundation will rely on the following technical support team to weigh in on the issue at hand: Dr. Alan Franzluebbers with NRCS / ARS and Steve Woodruff with NRCS East Technology Center.

Producer Selection

1. Preference should be given to producers that have interest in continuing beyond the project's timeline.
2. Select a producer that has a working knowledge of the basics of soil health, such as the use of no-till.

Demonstration Plot Selection – Examples to be sent out to selected Districts

1. Select a field that is easily accessible for field day events.
2. Select a site with a minimal range of soil types, the more uniform the better. Preference is given to sites that do not require subsoiling.
3. Consider the following minimum acres for the demonstration plot.
    a. Coastal & Piedmont Districts – 10 acres, if you are partnering with a vegetable grower and need to lower the amount please communicate that to the Foundation.
    b. Mountain Districts – 2 to 5 acres, partners request you find the largest area possible but we understand that many mountain fields are small.

4. Select a field that will allow for 4 strips with a minimum width of 40 feet (wider strips are preferred). If the producer's equipment will better accommodate narrower strips, please consult with the Foundation.
5. Plan to plant the multi-species cover crop mix in alternating strips. On the secondary strips, it is preferable that no cover crop is planted, but a monoculture cover crop is permissible.

Cover Crop Establishment / Removal = TAKE PICTURES

1. After evaluating the goals of the producer and the District, select a seed mix that includes four species at a minimum, two of which are legumes. The technical support team is able to provide guidance as needed.
2. For establishment processes, follow the criteria listed below;
    a. Coast & Piedmont - broadcast the mix on or before September 30th or no-till drill the mix by October 31st. If broadcasting, plan to spread 25% greater amount of seed than if no-till drilling. If producer has concerns with meeting the establishment date, encourage them to harvest this field first so that cover crop can be planted in a timely manner. Prior to deviating from these dates, consult with the Foundation.
    b. Mountain - broadcast the mix on or before September 15th or no-till drill the mix by October 15st. If broadcasting, plan to spread 25% greater amount of seed than if no-till drilling. If producer has concerns with meeting the establishment date, encourage them to harvest this field first so that cover crop can be planted in a timely manner. Prior to deviating from these dates, consult with the Foundation.
3. For termination processes, follow the criteria listed below;
    a. Coast & Piedmont – terminate cover crops no earlier than April 15th by rolling down and/or chemical treatment. If producer has concerns of lateness of removal date, encourage them to save this field for planting last. Prior to deviating from these dates, consult with the Foundation.
    b. Mountain – terminate cover crops no earlier than May 1st by rolling down and/or chemical treatment. If producer has concerns of lateness of removal date, encourage them to save this field for planting last. Prior to deviating from these dates, consult with the Foundation.

Field Day Logistics = TAKE PICTURES

1. The District chooses to host a spring or fall/winter event, only one is required. The District can do a joint event with another District but reimbursement from Foundation cannot exceed total cap. The District is encouraged to seek other sponsors and invite vendors such as sister agencies offering conservation programs, seed dealers, chemical dealers, equipment dealers, etc. Also consider applying for Continuing Education Credits, the Foundation will secure Certified Conservation Planner credits with NRCS.
2. Location – consider an indoor and outdoor setting in case of inclement weather. Consider accessibility, parking, and general safety (emergency contact numbers).

3. Example topics for agenda
    a. Introduction – District Supervisor
    b. Science of soil health – nutrient cycles, living ecosystem discussion
    c. Basics of soil health demonstrations – slake test, particle size demonstration, rainfall simulators, etc. Consider reserving the Mobile Soils Classroom.
    d. Mechanics / Importance of cover crops (general) – management, selecting seed mix, establishment / growth termination processes
    e. Tour of demonstration plot – discuss specifics of cover crop such as seed mix, establishment, growth termination, any issues encountered
4. Example speakers (not listed in order of preference)
    a. Producer and District staff
    b. NRCS – State office agronomists/specialists or East National Technology Support Center staff
    c. Extension – county level or others at university
    d. NC Dept of Ag – regional agronomists or other soil scientists with Division of Soil and Water Conservation
    e. Producers from other areas of state / country actively using cover crops
    f. District staff from other pilot counties
5. Workshop Survey – to be distributed to selected Districts. Turn information in as aggregated data.
6. Workshop Timeline – establish date TWO MONTHS in advance
    a. Notify the Foundation ASAP regarding dates under consideration. The Foundation will work with all Districts to avoid multiple events being scheduled on the same day.
    b. One month prior to event - Send a Save the Date postcard / flier for distribution through mail using known producer lists from the District, Extension, and applicable commodity groups. The announcement should include date, time, location, speakers invited, meals provided, registration cost if any, and continuing education credits requested. Include reference to funders.
    c. Two weeks prior to event – finalize agenda including funder logos.

Project Timeline

1. August 11, 2017 – Submit request to participate
2. August 18, 2017 – Foundation to award funds
3. September 1, 2017 – Submit an electronic copy of the Foundation's signed contract.
4. September 15, 2017
    a. Submit a narrative including the following;
        i. General directions to site from District office
        ii. Establishment and removal methods

iii. Seed mixture to be used

iv. Testing – list field tests you would like to conduct. *PLEASE NOTE – Foundation funds cannot be used to pay for the Haney Test but can be used to pay for any other tests such as Earthfort or Cornell tests.*

b. Submit a completed landowner questionnaire, a form will be shared with selected Districts.

c. Submit electronic photos of field

i. Pick photo spots you can replicate later in growing season.

ii. Send no more than 10 by email or by drop box. *Do not format into a pdf, send each photo as standalone files, this allows for better looking reports compiled by the Foundation for funders.*

iii. Include photo description in word document – number of photo, date of photo, general orientation of photo, details such as plants id, name of person(s), etc. When taking a photo of ground cover include a coin or pen for scale.

d. Submit a project map with location of strips and demonstration plot delineated in Toolkit, Google Earth, GIS or some other electronic mapping program. An example will be provided to select Districts.

e. Field Day plans – The District is required to host one event at a time of District's choosing. For event details include: date, time, location with address, primary point of contact, draft agenda, meal/refreshment details, continuing education credits being requested. Share the workshop details and final agendas for posting to the Foundation website.

5. September to October 2017

a. Complete broadcast cover crop establishment with a minimum 25% increase in seeding rate over the standard drilling rate (Mountain = 9.15; Coast & Piedmont = 9.30). TAKE PICTURES

b. Complete no-till drill cover crop establishment. If producer has concerns of earliness of establishment date, encourage them to harvest this field first (Mountain = 10.15; Coast & Piedmont 10.31). TAKE PICTURES

6. Winter 2017 to Spring 2018 (AT LEAST TWO MONTHS PRIOR TO EVENT) - Submit field day event date/location and any other tentative details available. The District is required to host one event at time of District's choosing. For event details include: date, time, location with address, primary point of contact, draft agenda, meal/refreshment details, continuing education credits requested. Share workshop details and final agendas for posting to Foundation website.

7. April to May 2018 – Begin termination of existing cover crop (rolling and/or spraying). If producer has concerns of lateness of growth termination date, encourage them to save this field for planting last (Coast & Piedmont = 4.15; Mountain 5.1). TAKE PICTURES

8. May 5, 2018 – Submit invoicing including request for payment, final report, all receipts and electronic photos with photo log. *Invoices can be submitted ahead of schedule, to insure prompt billing submit by the 5th of the month. If you need an extension please let the Foundation know.*

INVOICING

1. Cover Letter – signed by Supervisor, list total amount requested, whom to make check out to
2. Final Report - form to include:
    a. Producer name
    b. Location of demonstration plot
    c. Acreage of demonstration plot
    d. Number of strips and average width
    e. Crop rotation in place
    f. Removal process & date
    g. Seed mix and ratios
    h. Establishment process & date
    i. Field Day – number of attendees, how advertized, agenda, summary of evaluations, comments from producers / staff
    j. Any issues / lessons learned
3. Receipts – must equal total amount being requested.
4. Workshop agenda & registration list
5. Pictures – removal, establishment, field work, field day event = no more than 25 total. Include photo description in word document – number of photo, date of photo, general orientation of photo, details such as plants id, name of person(s), etc. When taking a photo of ground cover include a coin or pen for scale.

Soil Health Initiative
Multi-Species Cover Crop Demonstrations

PRODUCER QUESTIONNAIRE

Information collected will be submitted by the District to the NC Foundation for Soil and Water Conservation and NC State University for internal use. Any project level findings made available to the public will be presented at an aggregated level.

1. What is your experience with cover crops?

2. What is the soil type in the field? If you are unsure, record observations of the soil such as color and texture.

3. What is the past five years of cropping history and average yields for the field?

4. What is the general field treatment – establishment and removal methods for cash crops and cover crop?

5. How long has the current crop rotation been in place?

6. How long has the field been no-tilled?

7. Is there a hardpan in the field?

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8. How frequently are soil tests performed and what kind? Provide the past five years of soil tests, if available.

9. What other conservation practices are used on field?

10. What kind of equipment is available for cover crop establishment?

11. What kind of equipment is available for cover crop termination?

12. Discuss and record management goals – what issues do they want to address by using multi-species cover crops?

13. Discuss and record preliminary seed mix chosen (species and ratios/pounds).

14. Discuss and record establishment and growth termination methods.

15. Document any visual observations related to soil health that have been made if this field was a demonstration in 2013 / 2014.

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Soil Health Initiative - Multi-Species Cover Crop Demonstrations Workshop Survey

Information collected will be submitted by the District to the NC Foundation for Soil and Water Conservation and NC State University for internal use. Any project level findings made available to the public will be presented at an aggregated level.

1. Are you and your fields registered with Farm Service?
   ☐ YES or ☐ NO

2. Have you enrolled in any Farm Bill programs (conservation or commodity) in last five years?
   ☐ YES or ☐ NO

3. How many acres do you farm?
   ☐ 0-50 acres ☐ 50-500 acres ☐ 500 or more

4. What is your cash crop rotation?

5. Are you currently using cover crops?
   ☐ YES or ☐ NO

6. Do you utilize rotational grazing on your cover crop areas?
   ☐ YES or ☐ NO

7. Are you considering changing your practices of using cover crops as a result of this workshop?
   ☐ YES or ☐ NO

8. Would you recommend this workshop to others?
   ☐ YES or ☐ NO

9. What topics would you like to learn more about (either something presented today or something new)?

10. How did you hear about this workshop (click all that apply)
    ☐ Email ☐ Newsletter ☐ Social Media (facebook, twitter, etc) ☐ Flier ☐ word of mouth ☐ technical staff recommendation

Demographics

☐ Male or ☐ Female

How do you identify yourself?

☐ African American ☐ American Indian ☐ Asian ☐ Hispanic or Latino ☐ White ☐ Native Hawaiian or Pacific Islander

☐ Other

Occupation

☐ Farmer full time ☐ Farmer part time ☐ Government Agency (NRCS, Soil & Water, etc) ☐ University ☐ Ag Industry Rep

☐ Ag Consultant ☐ Student ☐ Other

USDA United States Department of Agriculture

NC FOUNDATION for SOIL&WATER CONSERVATION

NORTH CAROLINA ADFP TRUST FUND

NC STATE UNIVERSITY

Department of Soil Science
College of Agriculture and Life Sciences

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Appendix E

Example Workshop Material

Agendas and Promotional Fliers

DECEMBER 19, 2016

SOIL HEALTH WORKSHOP

1006 Eastern Ave.

Nashville, NC 27856

Auditorium

9:00 am – 1:30pm

****RSVP by Monday, December 12th**

Lunch will be provided by Hunter Hill, Rocky Mount, NC

Contact Nash County Field Office:

252-459-4116 Ext. 3

Speakers:

Buz Kloot, Research Associate Professor, USC

Passionate about working directly with farmers on soil health projects and research and how they can leverage the cover crop to improve crop performance both in terms of yield and savings in inputs.

Carl Coleman, Farmer of Dillon, South Carolina

Partnered with Dr. Buz Kloot in a number of on-farm research projects and looks forward to pushing soil health.

Russell Hendrick, Farmer of Catawba County

NASH SOIL & WATER CONSERVATION

1006 Eastern Ave., Rm 107
Ag Center Drive
Nashville, NC 27856

Hope to see you there!!!

SOIL HEALTH BREAKFAST

TURNING DIRT INTO DOLLARS

Speaker: Will Mann-Fishing Creek SWCD

Soil Health Topics

- Defining healthy soil
- Increasing yields while decreasing input cost
- Rate of economic return on healthy soil
- Strategies and methods of developing a plan
- Much, much more!
- $$$$$$

When:
Friday
October 28,
2016 @ 7:00am

Where:
Stanly County
Agri-Civic
Center

Free Breakfast
Provided

Call or email
to RSVP by
10/21/2016

STANLY COUNTY
SOIL & WATER
CONSERVATION
DISTRICT
26032-C Newt Rd
Albemarle, NC 28001
(704) 986-3059
cbrooks@stanlycountync.gov
rlittle@stanlycountync.gov

Pitt County Cover Crop Field Day

December 10, 2015

Ayden District Park

~AGENDA~

9:30 am	**–**	**Welcome Pitt SWCD**	**Bryan Evans**
9:35	**-**	**Project Overview**	**Michelle Lovejoy**
9:45	**-**	**Soil Health**	**Alan Franzluebbers**
10:30	**-**	**Cover Crop Programs**	**Diana Irizarry**
10:45	**-**	**Herbicide Considerations**	**Pat Farquhar** **Pat Jones**
11:45	**-**	**Lunch**	
12:45	**-**	**Field Plot Observation**	
2:00	**-**	**Adjourn**	

1 hr of pesticide credits approved for N,O,D and X

Sponsored By:

Cotton Incorporated

NC FOUNDATION for SOIL&WATER CONSERVATION

NC STATE UNIVERSITY
Department of Soil Science
College of Agriculture and Life Sciences

USDA
United States Department of Agriculture

SOUTHEASTERN SOIL HEALTH FIELD DAY

WHEN

April 29th, 2015
2pm-5pm

WHERE

Fork L Farm Inc.
6523 Roberts Loop Rd
Norwood,, NC 28128
MEAL PROVIDED AND DOOR PRIZES

REGISTER ONLINE:

https://www.eventbrite.com/e/southeastern-soil-health-field-day-tickets-16404765094

Additional information please contact:

Stanly SWCD at 704-982-5114, Ext 3

BREAK-OUT SESSIONS

1

Rotational grazing mixed species.

2

Soil Health cotton plot trials.

3

Cover crops biology and diversity.

4

Equipment Comparisons.

SPONSORS

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STANLY SOIL & WATER CONSERVATION DISTRICT

nc cotton PRODUCERS ASSOCIATION

Jay Fuhrer

Jay Fuhrer is a Soil Health Specialist employed by the Natural Resources Conservation Service, in Bismarck, North Dakota. Growing up on a small grain and livestock farm, Jay's interests have always centered on agriculture. Everything that's alive plays a role. In addition, Jay uses cover crops and livestock integration to connect the cropping and grazing systems together, raising the Soil Health bar even higher.

Jay's interest in soil health has resulted in numerous speaking engagements within the US and also includes Canada, France, Germany, Denmark, and Russia.

Dr. Matthew H. Poore

Dr. Matthew H. Poore is an Extension Livestock Commodity Coordinator Professor and Extension Ruminant Nutrition Specialist. His interest are livestock production and nutrition (beef, sheep, goats). Forages and byproducts in animal production systems.

Fork L Farm Inc.

Fork L Farm Inc. is the setting for the Annual Field Day event. The farm tends 500 acres in row crops and 240 acres in pasture. These fields have been no-till since the mid to late 80's. The plot today has been planted in continuous cotton for the past 5 years.

Resources
Nash County Agriculture and www.cals.ncsu.edu

Agenda

2:00-2:15	Welcome and Introductions
2:15-2:45	Rotation Session 1
2:45-3:15	Rotation Session 2
3:15-3:45	Rotation Session 3
3:45-4:15	Rotation Session 4
4:15-4:30	Sponsors and Q&A
4:30-5:00	Meal

Rotation Sessions

- Rotational grazing mixed species.
- Soil Health cotton plot trials.
- Cover crops biology and diversity.
- Equipment Comparisons.

NC FOUNDATION for SOIL&WATER CONSERVATION

2016 Multi-Species Cover Crop Demonstration Project Summary

Project Focus

The primary goal of this project was to demonstrate to producers that a diverse mixture of cover crop species can be planted in a timely manner, allowed to grow and accumulate biomass and nitrogen, and then be terminated without using tillage allowing producers to maximize on soil health benefits. Soil Health is defined as the continued capacity of soil to function as a living ecosystem. Soil function is improved by applying the following principles: minimize soil disturbance, increase plant and animal diversity above ground to increase soil diversity, keep a living root growing year round and keep residue cover on the surface as long as possible. Using cover crops to add diversity along with a diverse crop rotation plus using a no-till system has shown long term and short-term benefits to soil health. These type systems improve soil microbial activity, increased nutrient cycling, mitigated against drought, pests and increased profits over time. Once producers understand these principles, the next obstacle to overcome is to put them into practice.

Project Procedure

Since 2013 five counties in North Carolina with extensive acreages of cotton were selected for this project: Edgecombe, Halifax, Nash, Pitt and Stanly. Nash and Stanly District successfully completed their 2016 demonstration; due to extreme weather events, other Districts had to terminate the project. The participating producers have a working knowledge and interest in promoting soil health to improve profits and are already following some basic practices such as no-till. Districts were allocated funding to plant approximately 10 acres per county. Cover Crop requirements were:

1. A minimum of four species of cover crops (a minimum of two legumes) planted as a mix on land that is in rotation with cotton.
2. The cover crop can be broadcast prior to or drilled after cash crop harvest.
3. Broadcasting must be completed by September 30th at a 25% or higher seeding rate.
4. Drilling must be completed by October 31st.
5. Cover crops cannot be terminated until April 15th or after.
6. Cotton must be part of the cropping rotation and the next crop in rotation must planted into the cover crop residue using no-till methods the following crop year.

Project Results - Visit website for updates - http://ncsoilwater.org/programs/soil-health-initiative-multi-species-cover-crops/

The 2015 cover crops produced a good stand with some producers noting an immediate positive benefit to soil health. Districts were able to establish successfully a total of 35 acres of cover crop for 2016. Producer Outreach Workshops consisted of an educational meeting with optional field tours. A total of 108 attendees received continuing education related to soil health, cover crops, seed mixes, planting types, and groundwater management. Since the partnership with Cotton Incorporated began, 850 people have been directly impacted (workshop attendees and District Boards) and an average of 50 acres in cotton rotation were planted with multi-species cover crops annually. The 2016 demonstration plots include field strips for analyzing changes to multiple soil biological, chemical and mechanical properties by NC State University and USDA ARS, with additional funding provided by a 2014 USDA NRCS Conservation Innovation Grant. Funding was also provided by the NC Agriculture Development and Farmland Preservation Trust Fund for a 2016 and 2017 expansion into the piedmont and mountain regions. The result will be a producer-focused pamphlet sharing lessons learned and cover crop best management practices recommendations for southeaster farming systems.