COVER CROP BENEFITS AND NOVEL MANAGEMENT STRATEGIES FOR THE SOUTHEASTERN UNITED STATES

Eric D. Billman[1], W. Tillman Myers[1]

[1]Coastal Plains Soil, Water, and Plant Research Center, USDA-ARS, 2611 W. Lucas St., Florence, SC 29501

Corresponding author email: eric.billman@usda.gov

Abstract

Soils used for agricultural production in the southeastern United States are traditionally known to be highly weathered and have low nutrient-holding capacities. Consequently, regenerative and sustainable cropping practices are necessary to maintain high crop yields, soil health, water conservation, carbon sequestration, and environmental sustainability. Cover crops may offer various solutions in all these areas. This review-in-brief highlights the historical use, common cover cropping species and management systems, water-usage, and soil relationships of cover crops in the southeastern US. Current and future research directions being investigated by federal and state institutions are also discussed to inform stakeholders of ongoing projects related to cover crops in the Southeast.

Keywords: cover crops, southeastern USA, soil health, water conservation

Introduction

Cover crops have been critically important to improving agricultural cropping systems around the world. Their benefits have been widely documented amid both agronomic and horticultural crop production. Soil health has been one of the largest beneficiaries of cover crop adoption, with focus on minimizing soil erosion, improving soil structure and tilth, increasing soil fertility, increasing soil organic matter, and increasing water infiltration. Ecosystem services, such as weed and pest suppression, and provision of pollinator habitat are also noted to benefit from the production of winter annual cover crops in modern agricultural production. This review highlights the historical use of cover crops in the southeastern United States (North and South Carolina, Georgia, Alabama, Mississippi, Tennessee, and Florida), as well as the benefits that cover crop adoption has provided to crop production specific to the region. Additionally, novel uses of cover crops will also be discussed, along with their potential uses for different agronomic or horticultural cropping systems unique to the Southeast.

Historical Use and Dissemination in the Southeast

Widespread cover crop implementation is a somewhat novel concept for much of the southeastern United States. Most row-cropping systems (i.e., cotton, corn, soybean) only began implementing cover crops in the mid-late 1980s and expanded through the 1990s (Raper et al., 2000). Prior to this, fields remained in fallow following fall harvest until the subsequent spring (a period ranging from 5 – 7 months, depending on crop rotation scheme). When coupled with conventional tillage,

G. Uzochukwu et al. (eds.), *Proceedings of the National Conference on Next-Generation Sustainable Technologies for Small-Scale Producers (NGST 2022)*, Advances in Biological Sciences Research 34,
https://doi.org/10.2991/978-94-6463-282-8_16

this practice exacerbated the risk of topsoil erosion to wind and precipitation during winter months. Recognition of these issues increased expansion of no-till agriculture during the late 20th century, but soils are still at risk of significant erosion losses when no root or organic matter is present to hold soil in place (Frasier et al., 2016). This led to greater adoption of cover crops into the Southeast in the 1990s, but the practice is not ubiquitous in the region as of the early 2020s.

Recent research examining the additive effects of no-till or conservation (> 30% residue remaining) tillage in combination with cover crops has found that soil erosion is reduced when both are paired together (Jacobs et al., 2022). Long-term research (1979 – 2020) from the USDA's Agricultural Research Service (ARS) and Natural Resource Conservation Service (NRCS) has also found that combining conservation tillage with cover crops can improve soil organic matter and nitrogen concentration when using a simple three species cover crop mixture (Novak et al., 2020). Much of the southeast U.S. is comprised of heavily depleted sandy soils with low pH and nutrient-holding capacities, which has been further exacerbated due to centuries of monoculture production and conventional tillage dating back to colonial times (Trimble, 1974). While no-tillage can minimize further soil depletion, cover crops offer ways to rejuvenate soils by providing vital organic matter, macro- and micromineral fertility, soil structure, and increased microbial activity.

There are, however, factors that have limited adoption of cover crops in the southeastern US. Additional costs are a particular barrier to adoption. Not only does the seed cost growers an additional expense, but there is also time, labor, and equipment costs associated with the practice of cover cropping. Most cover crops do not provide an immediate economic benefit, i.e., they do not produce a sellable commodity that brings in additional income. This makes much of the benefits of cover crops less tangible to producers, and limits willingness to invest in their use. Current and future research is focused on providing profitable options for cover cropping, while also providing data that determines how effective cover crops are at improving on-farm profits of the subsequent cash crop.

Common Plant Families and Species

Cover cropping is defined as growing an off-season, low-input crop between primary cash crops, maintaining it through winter, and terminating it the following spring prior to planting of the next cash crop (Roesch-McNally et al., 2018). Because of this, winter annual grass and legume species are well-suited to filling this niche. Traditionally, cereal grain species such as winter wheat (*Triticum aestivum* L.), cereal rye (*Secale cereale* L.), or triticale [×*Triticosecale* Wittm. ex A. Camus (Secale × Triticum)] have been used in the southeastern US because they can provide rapid accumulation of biomass and are tolerant of sub-freezing temperatures (Mirsky et al., 2012). As for legumes, crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth), or balansa clover (*Trifolium michelianum* Savi) are commonly incorporated into binary or trinary mixtures with cereal grain species (Vann et al., 2019). This is primarily done to replenish soil nitrogen and minimize the need for fertilizer applications on the companion cereal grain species. Aside from these benefits, there is conflicting information on the efficacy of weed control with diversifying cover crop mixtures. Weed suppression has been found to be generally poorer under leguminous cover crops compared to grasses (Baraibar et al., 2018; Bybee-Finley et al., 2017; Elsalahy et al., 2019). However, there have been some reported instances of increased cover crop mixture diversity providing increased weed suppression (Tracy et al., 2004). Tall, fast-growing species are most effective at suppressing weed populations, which tends to favor the cereal grasses.

Limitations to Current Cover Crop Species and Practices

Over the last 20 years there has been little attempt to broaden the species or methods used for cover cropping in the southeastern US (Nouri et al., 2019; Lewis et al., 2018). This may be problematic to future agricultural production in the region for several reasons. Excessive growth of cereal grains both depletes soil nutrient reserves and increases soil carbon-to-nitrogen ratios (C:N; DeLaune et al., 2019). This can negatively affect nutrient availability to subsequent cash crops by reducing soil microbial activity. High C:N can effectively immobilize macronutrient (N, P, K, Mg, and S) availability by preventing microbial breakdown (Tahir and Marschner et al., 2017). Cereal rye is particularly problematic in this regard, as it produces more biomass than other cereal grasses. If allowed to reach reproductive maturity, cereal rye tissue builds up more secondary cell wall components, including lignin, which further increases C:N. Therefore, it is recommended that most cereal grass cover crops be terminated prior to flowering if lower C:N is desired (Balkcom et al., 2015). However, if weed suppression or soil insulation are desired into the life of the subsequent cash crop, higher C:N can allow cover crop residue to persist longer into the season, since it resists rapid microbial degradation (Decker et al., 2022). This provides a mat of residue to limit weed germination and reduce evaporative losses from bare soil.

Cover Crops and Soil-Water Relationships

Complicating the act of cultivating cover crops tin the Southeast is the potential for undesirable soil moisture loss. Evapotranspiration (ET) is one of the primary driving forces behind soil water loss (Katul et al., 2012), and is exacerbated when plants are grown on low water-holding-capacity soils. High temperatures and wind further increase water loss from ET, with these losses causing risks to subsequent cash crops (Messinger et al., 1991). This often necessitates earlier termination of the winter cover crop to allow time for soil moisture to be replenished. However, cool-season winter annual cover crops often pose lessened risk to soil water loss from ET due to the combination of cooler temperatures and more abundant rainfall during winter months (Gates and Hanks, 1967).

Past assessment of cover crop water-use under semi-arid conditions has found that presence of cover crops significantly reduces evaporative water losses from bare soil (Bodner et al., 2007). Furthermore, cover crop residues have been demonstrated to insulate soils, allowing for greater moisture retention and overall cooler soil temperatures (Nouri et al., 2019). Conversely, if cereal grass cover crops (wheat and rye) are killed just prior to corn or soybean planting, it can result in less available water for the incoming grain crop (Wagger and Mengel, 1988) due to water uptake occurring just before planting. The practice of mulching, i.e., chemical or mechanical killing of annual grass and legume cover crops without harvesting or reincorporating via tillage, has also been demonstrated to minimize surface water runoff, improve rainfall infiltration, reduce evaporation, and maintain cooler soils later into the growing season (Montenegro et al., 2013). Cooler soil temperatures, however, may result in delayed germination or slower seedling growth for certain cash crops such as cotton. Therefore, the amount of mulched material should be limited or controlled so that summer crop germination is not impeded or delayed.

Benefits to Soil Fertility and Carbon Sequestration

One of the primary benefits of cover crops is reducing soil macronutrient leaching and runoff losses via nutrient cycling (Delgado et al., 2007). This process involves the uptake of nutrients by the cover crop, which then incorporates these nutrients into biomass. The cover crop is then terminated prior to planting of the subsequent cash crop to make nutrients available for seedling corn, beans, or cotton. This is particularly important with labile nutrients such as nitrate (NO_3^-) nitrogen, which is readily leached in heavy rainfall. Cover crops have been shown to significantly reduce nitrate leaching or runoff from soils across the US (Kaspar et al., 2011; Staver et al., 1998; Wyland et al., 1996). Regarding labile soil phosphate (PO_4^{3-}), southeastern soils have generally been oversaturated with phosphorus by decades of repeated livestock manure and poultry litter applications (Novak and Watts, 2004). This makes binding of any excess phosphate difficult and may exacerbate runoff risks into local watersheds. In a fallow system, there is nothing to bind excess soil phosphate, but cover crops can bind readily available excess phosphate (Ye et al., 2020). Past research has found that *Brassicaceae* species (e.g., rapeseed, *Brassica napus* L.) exhibited the greatest uptake of soil phosphorus leachate and the greatest amount of phosphorus in its plant tissue, followed by annual ryegrass (*Lolium multiflorum* Lam.), while red clover (*Trifolium pratense* L.) was the least efficient at binding phosphorus (Miller et al., 1994).

Additionally, double cropping of cover crops (i.e., harvesting for grain or forage) can remove large portions of absorbed nutrients from the soil altogether (Blanco-Canqui et al., 2015; Pederson et al., 2002). This can be beneficial in soils saturated with phosphorus and potassium, but problematic when soils have moderate-to-deficient quantities of these macronutrients. If possible, double cropping should be alternated to every-other-year to allow for some return of nutrients to soil by an off-year cover crop.

Carbon sequestration is another major benefit of annual cover crops, as they fix carbon from CO_2, which can then be returned to soil when the cover crop is terminated. However, this effect is markedly lower in no-tillage and conservation tillage, compared to conventional tillage (Baker et al., 2007). Multiple studies have found that no-tillage or conservation tillage simply changes the distribution of soil organic carbon in the soil profile (i.e., keeping it at shallower depths), but does not increase the amount of total carbon sequestration throughout a soil profile (Tautges et al., 2019; Dolan et al., 2006; Carter, 2005).

Alteration of cover cropping strategies may improve carbon sequestration in soil. Recent focus has shifted to converting cropland into perennial forage or range production, as consistent groundcover and root mass aids in buildup of soil organic carbon (O'Rourke et al., 2015). For example, growing the perennial cool-season forage grass tall fescue [*Schedonorus arundinaceaus* (Schreb.) Dumort] following 15-years of winter wheat production allowed for a 17% increase in soil organic carbon over the course of 7-years (Carter and Gregorich, 2010). There is also substantial interest from stakeholder organizations and the public for increasing the amount of perennial pastures or grazing areas to increase environmental sustainability and promote healthy crop rotation practices (Follet and Reed, 2010). However, there are reports that perennial forage crops only slowed carbon emissions, but did not increase carbon sequestration (Sanford et al., 2012). These contradictory results were likely due to differing soil properties across regions of the country, but should be further investigated in the southeastern US. With continued discussions of carbon-credits for growers, it may become more critical to advance carbon sequestration by incorporating cover crops into crop rotations to take advantage of potential government economic incentives (Chahal et al., 2020).

Summary and Future Research with Cover Crops

Thus far, this review has covered how cover crops have historically been or are currently being used in the southeastern US. This has focused primarily on a narrow range of annual grass and legume species, along with the benefits that cover crops provide to soil nutrient availability, moisture retention, and carbon sequestration. However, cover cropping is a constantly evolving practice and science. Due to the relatively low regional adoption and diversity of cover crops in the southeastern US, there are several potential research elements that are being or will be examined in the near future. Current USDA-ARS research from Florence, SC is assessing the efficacy and viability of growing cool-season perennial cover crops in tandem with a summer cotton crop to minimize inputs and reduce evaporative losses from soil. Early results suggest that the practice provides substantial weed population and weedy biomass reductions while simultaneously reducing the quantity and frequency of herbicide applications. The perennial species also provide potential biomass for spring beef cattle grazing. Additional collaborative research between ARS and Clemson University is examining carbon sequestration between a conservation tillage system and a 4-species cover crop mixture compared to conventional tillage with and without a cover crop. Diversifying cover crop species and plant families is also of interest, as it promotes different seasonal availability of biomass and may provide greater benefits to soil health and water holding capacity with increasing species density. Findings from these ongoing and future projects will be reported over the next several years.

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