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Soil and Water Conservation in the Southeastern United States: A Look at Conservation Practices Past, Present, and Future

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Soil and water conservation in the southeastern United States has changed over the years, and new challenges will call for more changes in the future. The first conservationists were Native Americans, followed by early European settlers. Both groups conserved the land by rotating fields in and out of crop production. As demands for agricultural output increased, producers began to crop the land continuously, and this caused the soil to deteriorate. In the Piedmont, soils eroded into the streams and lakes, where they still reside today. In the Coastal Plains, soils became compacted, infertile, and held little water available for crop growth. Today, many soils in these areas require stringent management to be productive. New management systems have been developed that rely on the use of cover crops in combination with reduced tillage. These systems have been shown to increase organic matter near the soil surface, which improves fertility and physical properties, increasing infiltration for plant use. Irrigation was introduced to maximize productivity and help offset high labor and input costs; irrigation filled in the gaps of unevenly timed rainfall. Recently, these new management practices are being challenged by the demand for organic matter to make fuel and the demand for water to meet the needs of industry and a growing population. These new challenges have to be met with research on new production systems, carbon sequestration management, irrigation management that uses less water, and new water storage sites that can satiate population and industrial growth while satisfying ecological, hydrological, and political expectations.

The Piedmont and Coastal Plain regions of the southeastern USA have subtropical climates, with hot, humid summers and mild to chilly winters. This climate typically occurs in subtropical latitudes at the southeastern side of continents.

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Weather patterns typically move from west to east, with significant precipitation year-round. Summer rains come in the form of thunderstorms, tropical storms, and hurricanes. In the southeastern USA, much of the rainfall comes from water vapor that is carried north and east from the Gulf of Mexico along weather frontal boundaries. The coldest month is above 0°C, the warmest month is above 22°C, and the least mean monthly rainfall is 60 mm (McKnight and Hess, 2000).

Average annual rainfalls in the southeastern USA range from 1000 to 1700 mm, with fairly uniform mean distribution throughout the year (SERCC, 2007). These averages suggest abundant water, but they do not reflect the large fluctuations of drought and excess rain that occur over time (Fig. 7–1) and space (Fig. 7–2). The fluctuations affect not only soil water contents and irrigation for agriculture, but they also affect dependability of water supplies for industries, municipalities, and power plants (Davis, 2002; Foskett et al., 2007). Water supplies are being overtaxed during summer growing seasons, and surpluses are dwindling as the population increases and droughts grip the region (Auchmutey, 2007; Morris, 2007). Water shortage fears plague southeastern states, and lawsuits abound over the diminishing supplies (Henderson, 2007; WRLB News, 2007), while there is little action to increase storage (Pittman, 2007). In recent times, the Southeast has gained only one desalinization plant and few regional reservoirs or aquifer storage/recovery units.

Coastal Plain soils were generally formed from sandy marine sediments in a warm, wet climate. They have kandic or oxic horizons that are similar to argillic horizons but have low activity clays (Soil Survey Staff, 1999). Inceptisols and entisols can be found in the alluvial areas around the rivers. Many soils need to be drained to be productive (see http://www.soilinfo.psu.edu, verified 30 Nov. 2009). Further inland, the Piedmont (Virginia into Alabama) is an erosional landscape with gently rolling uplands and moderate to steep valley slopes that grade down to adjacent streams. In this region, soils developed from residuum that is several meters thick. Soil nutrient contents are low because most weatherable minerals

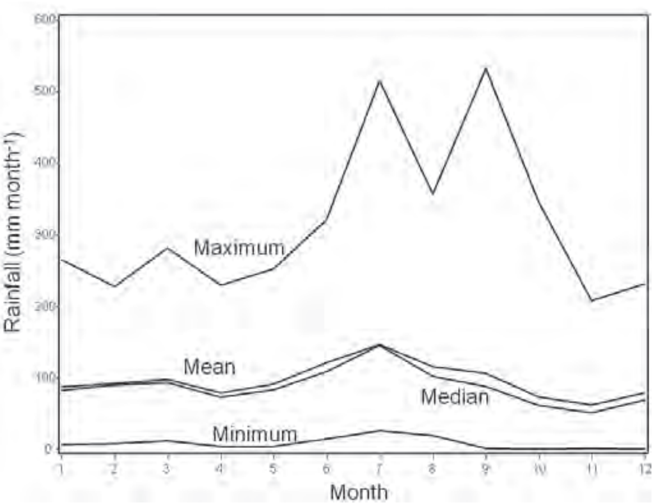

Fig. 7–1. Rainfall statistics for Florence, SC for the years 1892 to 1992.

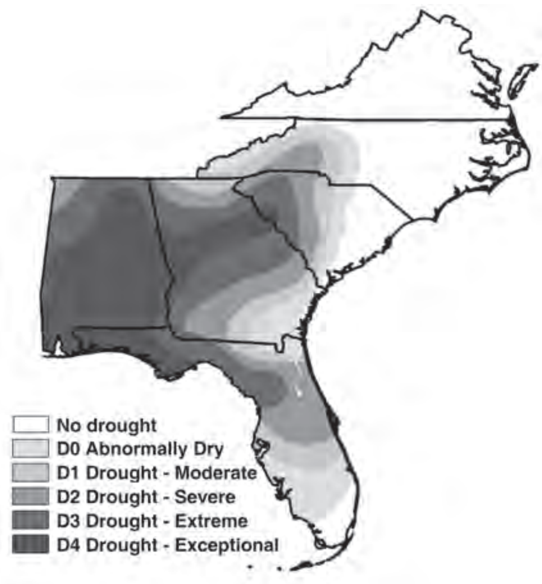

Fig. 7–2. Palmer Drought Severity Index for the southeastern USA averaged from January 1999 to January 2000. The image was provided by the NOAA/ESRL Physical Sciences Division, Boulder, CO, from their web site at http://www.cdc.noaa.gov/ (verified 1 Dec. 2009).

that were present in the original igneous and metamorphic rocks have leached from the upper soil horizons. Alfisols and entisols form on ridgetops, on steep slopes, in clayey deposits, and in alluvial materials along the rivers.

Most land in the Southeast is privately owned. Much of it is forested and managed for timber, recreation, and, near the cities, for development. Land cleared for cropping has declined over the past century, particularly in the piedmont. Much of it has reverted to forests, while cropland continues to be viewed as the easiest to develop for home and commercial interests. On a county-wide basis, cropped land consists of anywhere from 5 to 30% of the area. Most counties have less than 15% cropland, but this adds up to 8 to 16 × 10^6 ha (http://usda.mannlib.cornell.edu/, verified 30 Nov. 2009). Because soils are not as fertile as many other parts of the country, they require more management and higher energy inputs.

Farming Trends in the Southeastern Coastal Plain

The average Coastal Plain farm is less than 200 ha (NASS, 2002). The number of farms and the number of hectares farmed are decreasing as a result of drought, urbanization, and the economics of large farm sizes. Eighty-five percent of the farms are operated by families or individuals, and the majority of producers list something other than farming as their primary occupation. Farm production runs the economic gamut, with net incomes from less than $10,000 to more than $200,000 (NASS, 2002). Although the incomes quoted are net, gross receipts and expenses can run into the millions, even for operations of modest size. Because of the warm wet weather and sandy soils, producers spend more than the U.S. average on pest control and fertilizers. Producers generally irrigate to supplement rainfall rather than using it as a primary crop water source; this accounts for low irrigation rates compared to other parts of the United States. However, dependency on irrigation and sophisticated management continue to grow.

Farming Trends in the Southern Piedmont

The Piedmont has about 5.7 million ha of agricultural land. About 1.5 million ha are used for crop production. The rest is used for forage or hay production (NASS, 2002). Most Piedmont farms are small, with an average size of 49 ha and median size of 29 ha. The number of farms and amount of farmland has declined, while farm size has increased. A decline in farm production is attributed to poor soil productivity and urbanization. The greatest amount of harvested Piedmont agricultural land is in North Carolina, with 486,000 ha; Alabama has the least, with 27,000 ha. North Carolina produces 65, 77, 76, and 68% of the corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], and wheat (*Triticum aestivum* L.), respectively, grown in the Piedmont. Beef cattle, dairy, and poultry contribute substantially to Piedmont farm incomes.

Most Piedmont cropland is used to grow soybean, wheat, corn, and cotton. These four crops are grown on 36, 19, 16, and 11%, respectively, of the row-cropped land. Corn acreage in the region is expected to increase because of the greater demand for its use in ethanol production. Other crops grown in the region include sorghum [*Sorghum bicolor* (L.) Moench], tobacco (*Nicotiana tabacum* L.), sweet potato [*Ipomoea batatas* (L.) Lam.], bean (*Phaseolus vulgaris* L.), orchard crops, and vegetables. The vegetable industry has grown rapidly in the past 10 yr because of urban markets in Atlanta, Charlotte, Raleigh-Durham, and Greenville-Spartanburg. This trend is expected to continue as high transportation costs discourage shipping from the West to eastern cities. Typically, vegetables are produced using conventional practices, but adoption of cover crops and conservation tillage systems has increased. A variety of vegetables are produced in the region including sweet corn, tomato (*Solanum lycopersicum* L.), squash (*Curbita* spp.), and pea (*Pisum sativum* L.) in the summer; and broccoli (*Brassica oleracea* L. var. *italica* Plenck), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), cabbage (*Brassica oleracea* L.), winter squash (*Cucurbita maxima* Duchesne), and pumpkin (*Cucurbita pepo* L.) in the fall. The Piedmont relies less on farm program crops or dairy products than other areas of the United States. The Piedmont has the highest proportion of farmers with full-time off-farm jobs. Farming provides less than the average portion of total household income. Full-time farmers make up only a small fraction of the rural population.

Historical Perspective

The first agriculturalists in the southeastern United States were the Native Americans. As archeologists are beginning to discover, the Native Americans had a greater influence on the environment than was earlier believed. They were descendants of Paleo-Americans (Mann, 2005), who crossed the land bridge from Siberia over 14,000 yr ago. As the southeastern United States changed from paraglacial to a more temperate climate and populations increased, the Native Americans changed from hunter-gatherers to urban societies with Mississippian characteristics (King, 2002) imported from the west. The settled Native American societies, as seen by Desoto in the middle 1500s, grew crops on fields where several plants such as maize, beans, and squash were cultivated together; this type of planting scheme was capable of sustaining large populations with nutritious food. Crops were planted on cleared land for 2 yr, and then the land was allowed to rest for 8 yr (Mann, 2005). As these societies died out due to disease and war, European settlers entered the area.

During the decline of the Native American society and before the Europeans moved in, the southeastern Piedmont was described as having clear, clean streams and deep, dark soils (Harper, 1998; Trimble 1974). Closer to the coast, soils were wet and sandy but productive. The area was ripe for settlement. After attempts with several crops, early European settlers found rice (*Oryza sativa* L.) and indigo (*Indigofera hirsuta* L.) to be profitable along the coast (New York Times, 1901). With time, settlements moved inland, and the rice–indigo combination along with cotton, cattle, tobacco, and timber set the stage for the arguably "idyllic" antebellum south that benefited a few select landowners (Boyle, 1996).

During the early years of European settlement, producers practiced shifting cultivation where part of the land would be cleared and farmed for a few years until the soil was depleted. Then more land would be cleared and farmed while the depleted land rested. This farming practice was similar to that used by Native Americans and by farmers in some areas of Europe. During the late 1700s, settlers moved into the North Carolina and Virginia Piedmont and continued to practice shifting cultivation. In the early 1800s, settlers from North Carolina and Virginia moved into the Georgia Piedmont (Trimble, 1974). They cleared land and grew tobacco, corn, cotton and other crops. Cotton served as a cash crop, while corn was grown for consumption by farm animals, such as mules for plowing, cows for dairy, swine for meat, and poultry for eggs. Based on the agricultural data from that time (Brown, 2002), many growers were subsistence farmers. Small farmers were usually tenants who had little incentive to conserve soil because they often stayed only through one or two cropping seasons. Poor land management practices during the cotton-farming era (1820–1930) left the surface of the sloping Piedmont soils bare for long periods of time, which exposed them to the erosive forces of rainfall. Significant erosion occurred, with cumulative losses of 14 to 24 cm throughout the region (Trimble, 1974). Soil eroded from the uplands into reservoirs, floodplains, and stream bottoms (Jackson et al., 2005), where much of it is predicted to remain for several millennia. It is not surprising that Hugh Hammond Bennett, the Father of Soil Conservation came from the southeastern Piedmont (USDA-NRCS, 2009), where he personally witnessed the devastating impacts of soil erosion.

In the early 20th century, eroded soil, the boll weevil [*Anthonomous grandis* (Boheman)], and low cotton prices abruptly ended cotton cultivation in the Southeast (Fig. 7–3 and 7–4). Cotton was replaced by tobacco, peanut (*Arachis hypogaea*

Fig. 7–3. Cotton after defoliation. Photo by David Nance, USDA-ARS Image Gallery.

Fig. 7–4. Dedicated in 1919, the Boll Weevil Monument, in Enterprise, AL, is symbolic of just how important the boll weevil was in the South. Photo from the USDA History Collections, National Agricultural Library.

L.), corn, and soybean (Haney et al., 1996), all of which can leave the surface relatively bare and prone to erosion. Crop productivity in the Piedmont is still limited today by the almost total loss of topsoil from fields as a result of previous mismanagement. Losses included not only the topsoil but also its nutrients, organic matter, fertility, and water-holding capacity. Many Piedmont soils today consist of exposed subsurface soil horizons that are dense because of their high clay content and that restrict plant production because of high exchangeable Al contents. Soil productivity problems of the region would not be this severe if early on we could have developed greater wisdom and foresight, a stronger land ethic, and a desire to use better management practices (Trimble, 1974).

As bad as the situation may have been in the Southeast, soil conservationists could not attract the attention of the public and government until the Dust Bowl of the 1930s when dense clouds of eroded soil blackened midwestern skies. This led to the establishment of the Soil Conservation Service (SCS) as an agency within USDA (Helms, 1990). It was led by the strong conservation advocate Hugh Hammond Bennett. The SCS (now Natural Resources Conservation Service), along with other USDA agencies, developed and continue to develop modern methods of soil and water conservation for use in the Southeast and other areas of the country. Practices like terracing (Fig. 7–5), contouring, and cover crops, along with conversion of land to permanent cover, reduced soil loss by more than an order of magnitude. As the majority of Piedmont row-crop agriculture moved to the flatter, less-erodible soils of the Coastal Plains, Piedmont land production shifted to forestry and pasture, resulting in even less soil loss. Trimble (1974) estimated that a relative erosive factor of 1 applied to row-crop land in 1920 to 1930

Fig. 7–5. Building terraces in the Piedmont. Photo from the archives of the USDA-ARS, J. Phil Campbell, Senior, Natural Resource Conservation Center, Watkinsville, GA.

Fig. 7–6. Mule and disk. Photo from the archives of the USDA-ARS, National Soil Dynamics Laboratory, Auburn, AL.

would now be 0.45 due to improved production and conservation practices. But row crops were not the only problem; agricultural mechanization and soil management both helped and hindered the restoration of southeastern soils.

Over the years, soil management and crop production systems have advanced with corresponding advances in mechanization. Because Native Americans did not have draft animals, they developed, maintained, and harvested their fields by hand. Draft animals were introduced by the Europeans. By the late 1800s, mules (Fig. 7–6) were the standard method of providing power for plows and other field operations. With mules, land could be plowed almost to the stream bank as wet alluvial soils drained in late spring. Plowing and in-season cultivation resulted in erosion, and, in the Piedmont, sediments filled stream channels. In the Coastal Plain, sediment-laden streams took on braided channel patterns, turning lowlands into riparian wetlands with ill-defined stream channels, decreasing land area that could be used for crops.

As the 20th century dawned, agricultural mechanization began to develop. In the early 1900s, tractors made their way to the farm. But they were not readily adopted until the 1920s when competition among manufacturers forced prices down to about $400 (Leffingwell, 1994), not too far above the cost of an automobile (Fig. 7–7 and 7–8). In the early 1930s, rubber tires were introduced to tractors (Macmillan and Jones, 1988). Tires provided more power and the ability to move tractors quickly between fields. Two and three bottom plow tractors provided a relatively quick and easy method to prepare large tracts of land or multiple small tracts. Tractor weights prevented their use in poorly and somewhat poorly drained areas; low-lying areas that had subsurface water necessary to sustain

Fig. 7–7. Early Minneapolis-Moline tractor. Photo courtesy of Brian Rukes, http://www.angelfire.com/ok/mmreg/book.html.

Fig. 7–8. Early cotton harvester. Photo from the archives of the USDA-ARS, National Soil Dynamics Laboratory, Auburn, AL.

plant growth during dry summer months had to be abandoned. Tractors also permitted deeper plowing than was possible with mules. As a result, subsoil was mixed into the now erosion-thinned surface layer bringing to the surface acidity and reduced organic-matter soil. This mixing degraded the quality of soil needed for crops, especially crops that were grown without the benefit of much added lime and fertilizer.

More recently, equipment companies have focused on efficiency and speed of operation. As a result, agricultural equipment has increased in size and cost. This increase is perhaps most evident at the Nebraska Tractor Tests. In their 1948 tests, vehicles weighed less than 4500 kg; now, a 170-kw (225 hp) tractor weighs about 9000 kg, although some can weigh more than 25,000 kg. Increased vehicle size leads to increased pressure on soils and deterioration of compaction-susceptible soils like those of the Southeast. Increased compaction then leads to more dependence on large machinery to break up the hard soil—a vicious cycle. Increased tillage leads to increased erosion, reduced organic matter, and reduced productivity. These debilitating effects are being reversed by newer reduced tillage systems, controlled traffic, and organic residue and carbon management. Indeed, agricultural compaction problems of the area might have been solved by modern no-till or reduced-tillage management if it had not been for new challenges.

Recent Advances

Coastal Plains, Plant Water Availability

Except for years of drought, which can be devastating for the southeastern Coastal Plain (Sheridan et al., 1979), rainfall is abundant. Yet, almost every year, water is the limiting growth factor because the sandy soils have low water-holding capacities (0.08 g g^{-1}), and crops normally experience periods of no rain for 2 wk or more (Sheridan et al., 1979), which causes yield-reducing stress (Sadler and Camp, 1986). More water can be made available to the plant by opening up the soil profile to root growth through deep tillage.

Coastal Plain Tillage

Deep tillage helps many Coastal Plain soils remain productive by physically disrupting its massive structure. Soil horizons, especially the eluviated (E) horizon just below the Ap, can have strengths high enough to reduce or prevent root growth (Busscher et al., 2002), even when soil water contents are at field capacity (Campbell et al., 1978). Deep tillage disrupts the E horizon (Fig. 7–9), increasing root growth, water uptake, and yield (Busscher et al., 2002; Raper et al., 2000).

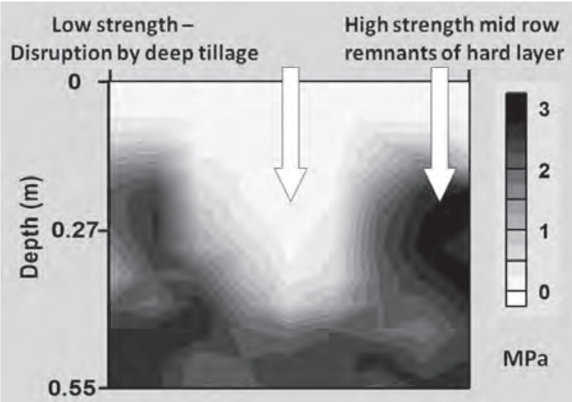

Fig. 7–9. Soil strength pattern for noninversion tillage in the Coastal Plains. The hard layer is basically the E horizon.

Once the roots penetrate the tilled E horizon, they can grow below it into the B horizon that generally has weak blocky structure. Even when the B horizon hardens as it dries, roots can grow along the fracture planes, that is, the faces of the aggregated structural units.

With time, the loosening effects of tillage diminish as the soil reconsolidates (Raper et al., 2000; Shukla et al., 2003), causing reduced crop yields (Arvidsson et al., 2001; Radford et al., 2000). Although the effects of deep tillage can be seen for years (Busscher et al., 2002; Munkholm et al., 2001), incomplete reconsolidation reduces yield from one growing season to the next as soil strength increases enough to restrict root growth. As a result, deep tillage for these soils is recommended annually (Threadgill, 1982; Porter and Khalilian, 1995). On the negative side, deep tillage is expensive; it requires large tractors (14–20 kw per shank), 20 to 40 min ha^{-1} of labor, and 20 to 25 L ha^{-1} of fuel (Karlen et al., 1991). On the positive side, deep tillage is noninversion; several deep tillage implements can disrupt the soil without disturbing much of the surface, thus, leaving residue to protect the surface from erosion.

Piedmont Region

Current Piedmont conservation tillage is based on practices that started in the 1970s. These practices, such as reduced tillage and the use of cover crop residues, improve soil physical, chemical, and biological properties through the beneficial effects of added organic matter. The most apparent improvement is with water. When organic matter is not incorporated, it can act as surface mulch, reducing runoff from rainfall, increasing infiltration, and improving plant water uptake and growth (Bruce et al., 1988; Freese et al., 1993; Raczkowski et al., 2002; West et al., 1991).

System Response to Adoption of Reduced Tillage

Changes in soil properties associated with reduced or conservation tillage and increased biomass inputs were the keys to improving crop productivity and sustainability of agriculture in both the Coastal Plan and Piedmont regions. Bruce et al. (1995), using data from a series of studies, illustrated how increasing biomass and reducing tillage altered the distribution of carbon within the soil profile and improved soil surface physical properties that regulated water infiltration and availability. Conservation tillage was the critical management factor required to keep residues on the soil surface (Reeves, 1997). The beneficial effects were more apparent in systems that rely on high-residue producing crops (corn, sorghum, small grains) and in double-crop systems. Using a wheat–sorghum double-crop system in Georgia, Langdale et al. (1984) demonstrated that soil C in the top 1 cm increased 57% in a no-till system compared with a conventional tillage system. Carbon from crop residues was critical for improving aggregate stability and water infiltration (Langdale et al., 1990; Bruce et al., 1992). Measurable changes in soil physical and biological properties usually required 3 to 5 yr to demonstrate because of the large variability in most soil properties. However, yield changes could often be seen in the first year, depending on producer experience and management, soil physical factors, and environmental conditions.

Although early conservation studies demonstrated little or no yield advantage (Brown et al., 1985; Langdale et al., 1984), improvements in planters, residue management accessories, and development of best management practices (BMPs) increased the success of conservation systems by optimizing edaphic factors affecting seed germination and vigor. For example, soil temperature, soil water, crop rotation sequence, and cover crops directly impact seed germination through influences on root pathogens and allelopathy. A critical lesson learned was the value of cover cropping for high residue production. The lack of tillage alone created problems, but lack of tillage coupled with cover crops produced large amounts of residue for weed suppression and water conservation. This coupling allowed conservation tillage to have immediate positive effects on yields. The benefits of improved BMPs were illustrated in several recent studies from Alabama.

In a study in the sand mountain region, Schwab et al. (2002) showed that cotton yields were the same or better for conservation tillage systems with and without noninversion subsoil tillage compared with conventional tillage. Using the same soil, Raper et al. (2000) observed a need for some type of in-row disruption of the shallow hard pan in the first year, whereas in subsequent years the presence of a cover crop resulted in equal or greater yields for the no-till system compared with the conventional tillage system. Siri-Prieto et al. (2007a) worked in an integrated winter-annual grazing cotton–peanut–cotton cropping system on a Coastal Plain soil in south Alabama and found that the best tillage system for optimum infiltration, cone index, and bulk density was paratilling without disking. After 3 yr, this system increased SOC and total N at the soil surface (0–5 cm) by 38 and 56%, respectively. In addition, paratilling without disking resulted in the highest seed cotton and peanut yields (Siri-Prieto et al., 2007b).

Terra et al. (2006) showed an immediate yield response for cotton in a corn–cotton conservation tillage system. During the first 3 yr, yields were 10, 24, and 14% greater in the conservation system than in the conventional system. In the first 2 yr (dry seasons), greater yields with the conservation system were attributed to improved soil water use efficiency (Lascano et al., 1994; Reeves, 1994). The third year was a wet year, and yield advantages for the conservation system again may have been related to greater water use efficiency although the authors did not speculate. In the same study, after one rotation cycle (30 mo), no-till increased soil organic C (0–5 cm; 0–2 in depth) by approximately 50% compared with conventional tillage (7.34 and 7.62 vs. 5.02 Mg ha^{-1}, respectively). Conservation systems had greater soil organic C increases relative to conventional systems at low soil quality landscape positions. They concluded that the potential was great to sequester C using high-residue producing conservation systems for degraded soils throughout the southeastern United States.

Soil Amendments and Soil Productivity

Because Piedmont soils have low organic matter, limited amounts of basic cations, low cation exchange capacity, and predominance of 1:1 clays, they are prone to surface sealing by crust formation. Crusts can form during rainfall events and can dramatically increase runoff and erosion. Zhang and Miller (1996) showed that soil cover, gypsum, or a combination of the two were effective in significantly reducing crusting and increasing infiltration rates in a Cecil sandy loam compared with the control (no treatment). Infiltration rates increased 26% for either cover or gypsum and 132% for the combined treatment. Soil cover and gypsum treatments were effective in modifying both chemical (dispersion) and physical (raindrop impact) forces critical in crust and seal formation. Also using gypsum, Sumner (1993) demonstrated its beneficial effects on reduction of subsurface Al toxicity. Reducing Al in the subsoil allowed roots to extract water and nutrients from a greater volume of soil, improving crop productivity. These effects could last for many years, as indicated by Toma et al. (1999). Sixteen years after application of gypsum, soil profile Ca and SO_4, were increased and exchangeable Al was decreased compared to the untreated control soil profile. The addition of gypsum improved corn and alfalfa (*Medicago sativa* L.) yields by 25 to 50%.

Other amendments beneficial to soils came from animal byproducts. Manure and litter provide additional nutrients and positively influence soil properties important for soil and water conservation. Researchers from Alabama (Kingery et al., 1994) studied the impact of long-term (15 yr) land application of broiler litter on environmentally related soil properties and found soil pH was 0.5 higher to a depth of 0.6 m under littered vs. unlittered soils because of the Ca and Mg in the manure. Litter additions were found to significantly increase organic matter. After 3 yr of additions, Nyakatawa et al. (2001) reported organic matter increases of 55 to 80% in silt loam soils of northern Alabama. Increases were due to both the manure and greater plant growth in response to nutrients.

Manure additions promoted formation of water-stable aggregates important for maintaining soil structure (Haynes and Naidu, 1998). Manure applied to soils increased the protected pools of C in small macroaggregates (Aoyama et al., 2000) and microaggregates (Kapkiyai et al., 1999); this helped maintain aggregate stability. When compared with the control, up to 22.4 Mg ha^{-1} of poultry litter applied to bare plots on a sandy loam Piedmont soil decreased runoff and soil loss (Giddens and Barnett, 1980) by as much as 50%. Dairy manure also reduced soil losses on corn plots (Mueller et al., 1984).

Adding poultry litter in conservation tillage management (Endale et al., 2002) resulted in a positive synergistic effect on cotton yields. In no-till treatments, poultry litter improved yields 35 to 50% over conventionally tilled and fertilized cotton. Apparently, poultry litter provided slow release of nutrients and increased water availability, which provided a superior condition for cotton production. More recently, when Endale et al. (2008) compared no-tillage management with conventionally tilled and fertilized corn, no-till increased grain yield by 11%, poultry litter increased grain yield by 18%, and the combination increased grain yield by 31%.

Future Outlook

Water Storage

Although three-fourths of our planet is covered with water, most of it is tied up in saline oceans or ice (USGS, 2009), leaving less than 1% for human, animal, and crop plant use. In humid regions, much of that 1% is renewed by annual rainfall. It flows in perennial streams, moves through aquifers, and is taken up by plants for transpiration. In the Southeast, the perennial streams are relatively short, typically 500 linear (nonmeandering) km (300 miles) or less. This limits our ability to use and reuse water before it enters the ocean. The Floridan aquifer ranges from southern South Carolina to eastern Mississippi. It is a productive aquifer whose water is used extensively by industry, agriculture, and municipalities in the coastal plains (USGS, 2008). Aquifer water is replenished from its overlying surficial aquifer or from rainfall in areas where the surficial aquifer is thin or absent. Plants take up water mainly throughout the summer growing season when evapotranspiration exceeds rainfall. During this time, shallow water tables fall until the weather turns cold, leaves drop from trees, and winter rains replenish the soil.

Because of high rainfall rates in the Southeast, consumptive water use is only about 3% of the total renewable water supply (USGS, 1984). We consume 0.23 of 8.86×10^{11} L (6 of 234 billion gallons) per day. With this amount of water, there does not appear to be a deficit—yet crops wilt, municipalities regularly request voluntary water restrictions, and states argue about how much water they and their neighbors can take from various rivers (Rowles et al., 2008). Water systems are being taxed by increasing population, urbanization, and industrialization. New water capture and storage facilities are needed to slow water flow from the Piedmont to the ocean and retain winter/early spring rains. Building new surface water storage facilities proceeds at a slower pace than needed because of legal, social, political, engineering, hydrological, and environmental hurtles. Other than conservation, new facilities are the only option for water-hungry areas, especially the Piedmont, where groundwater is not as plentiful as on the Coast.

Even though the Coastal Plain has the highly productive Floridan Aquifer, overpumping of groundwater has been seen in areas with large populations, heavy industrial use, and extensive irrigation. Although groundwater in these areas is recharged, the recharge area is often some distance inland from the area that needs recharge. Excessive drawdown and salt water intrusion force Coastal areas to depend more and more on surface waters. In the Atlantic coastal area of Georgia alone, more than 60,000 human-made structures are used to supply water to farms, cities, industry, and golf courses. More or larger facilities will be needed as the population of the area continues to grow.

Soil Organic Matter

For the past decades, soil scientists and producers have been trying to increase organic matter in southeastern soils to improve fertility, water-holding capacity, and production. But, now that fuel prices have soared, organic matter residue in the form of cellulose may be removed from fields to produce ethanol. How much residue can southeastern soils afford to lose before soil properties and/or production are affected? To determine this, research has begun, again—research was started during a previous fuel crisis, but because the crisis (Margolis and

Kammen, 1999) did not continue, the research priority decreased and funding ceased. Previous results (Karlen et al., 1984) showed that some residue could be removed from cropping systems on southeastern soils provided that nutrients were replaced with fertilizer, but fertilizer production requires large amounts of energy (Williams et al., 2005). More research needs to be done to determine if an acceptable level of removal can be found that is economical and sustainable.

Fuel and Deep Tillage

For proper soil management, deep tillage of many coastal soils is required to loosen subsurface compacted horizons. Because deep tillage requires more than 20 L ha^{-1} of fuel, it is becoming prohibitively expensive as diesel prices increase. Deep tillage needs to be replaced by other forms of management. One management system attempted in the past with some success is irrigating the soil with drip tubes buried just above the hard layer to keep it soft and supply crop water needs (Fig. 7–10). However, this requires careful management to avoid overwatering or underwatering. Overwatering prevents roots from penetrating a flooded layer, while underwatering does not loosen the hard layer. It is likely that both will occur simultaneously between and at the buried tubes or between and at emitters along the tubes (Camp et al., 2000). Because water is not at the soil surface, this type of irrigation can create risks during stand establishment for years with dry early seasons.

Deep tilling on a multiple-year rotation has also been studied. In many cases, not tilling every year reduces yield to levels that may be acceptable given the increase in fuel costs. For some crops, such as cotton, annual deep tillage may not be necessary to maintain yields. Deep tilling every 2 to 3 yr may be just as efficient as deep tilling annually (Busscher and Bauer, 2003). This will depend on the variety grown (Kasperbauer and Busscher, 1991) and on the amount of rainfall that recompacts the soil between seasons (Busscher et al., 2002).

Subsoiling is often performed at a standard depth, while the compacted layer's depth varies throughout a field. If subsoiling is based on the deeper zones of the compacted layer, its disruption is too deep for the zones of the field where the compacted layer is shallow. If subsoiling is based on the shallower zones of the compacted layer, it will not disrupt the whole compacted layer, leaving hard zones that will limit root growth. Technologies are now available that allow subsoiling to vary with the depth of the compacted layer. This can save energy without sacrificing crop yields. A 4-yr experiment was conducted in southern Alabama to evaluate the concept of site-specific depth of subsoiling. Site-specific subsoiling produced yields equivalent to those produced by the uniform deep

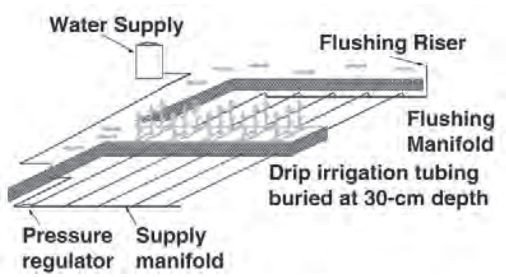

Fig. 7–10. Buried microirrigation tubes that keep the hard layer wet and soft.

subsoiling, while reducing draft forces, drawbar power, and fuel use (Raper et al., 2005; Raper et al., 2007).

Another way to reduce energy demand is to amend the soil so that deep tillage would be drastically reduced or eliminated. Two potential amendments are polyacrylamide (PAM) and biochar. Older formulations of PAM were used as soil conditioners in the early 1950s (Weeks and Colter, 1952). They improved plant growth by stabilizing aggregates in the surface 30- to 40-cm depths. Hundreds of kilograms of PAM per hectare were needed, limiting PAM use to high value crops and nurseries. By the 1980s, polymer formulations and purity improved, making them more effective at lower concentrations. In the 1990s, water-soluble environmentally safe anionic PAM was identified as an effective erosion-preventing and infiltration-enhancing polymer when applied at 1 to 10 mg L^{-1} in furrow irrigation water (Lentz et al., 1992; Sojka and Lentz, 1997). For PAM to be effective deeper in the profile, larger amounts are needed and deeper mixing will cost several hundred dollars per hectare. But given the high cost of fuel, this might be economically feasible if the PAM could last multiple years. Current estimates are that PAM breaks down at a rate of 10% per year (Azzam et al., 1983; Tolstikh et al., 1992; Entry et al., 2008).

Another amendment that has attracted attention in the past few years is biochar. It gained prominence as a result of archeologists finding charcoal-amended soils in the Amazon and other historically old areas that are more productive than expected (Mann, 2005). If biochar is effective in improving productivity for long periods of time, it could be an economically feasible soil amendment, especially if the amendment would eliminate or reduce tillage for extended periods. Biochar's effectiveness depends on its source material, how it is produced, and how it is activated during its production.

Conservation Organizations

There are many conservation organizations and societies, such as the Sierra Club, Ducks Unlimited, the Soil and Water Conservation Society, and the Soil Science Society of America, that work toward the betterment of our environment. One governmental organization that developed out of the Dust Bowl conservation movement was the local conservation district. In 1937, President Franklin Roosevelt wrote every governor recommending state legislation that would allow local landowners to form conservation districts. Because of the recent Dust Bowl, legislation was passed by every state, and today the country has nearly 3000 conservation districts. Districts are run by local boards of commissioners or supervisors who are either elected or appointed. Board members are local citizens who are concerned about the conservation of soil, water, and other natural resources in their region. Boards are supported by small administrative and/or natural resource professional staffs. Board members and their staffs draw on help from various state and federal such as the USDA-NRCS; NGOs, including the National Association of Conservation Districts (NACD, www.nacdnet.org, verified 1 Dec. 2009) or their respective State Association of Conservation Districts; and professional organizations, such as the Soil and Water Conservation Society. Because districts are local, board members have knowledge of and experience with their specific conditions; and because they have national/state governmental support systems, board members can make informed decisions on local management of natural resources. Local districts were initially developed to support rural resource conservation, but because urban land issues increased and resource problems developed there, the districts have had to widen their scope of involvement. Regardless of whether concerns are rural or urban, conservation management systems that the districts implement are voluntary, incentive-driven programs aimed at benefiting all citizens. As populations increase in the Southeast and as we make more demands on our resources, organizations like the local conservation district and the state associations of districts, as well as the NACD will be challenged more and require more of the population, both rural and urban, to become educated and involved for our own wellbeing and that of our environment.

Conclusions

Southeastern conservation practices have had to keep pace with progress and current events, starting with the Native Americans and early European settlers clearing the land to support growing populations, continuing with the adaptation of management systems to larger farms and mechanized agriculture, and now continuing with reduced tillage systems that maintain surface cover. But new challenges will make us rethink our current paradigm. Recent rapidly escalating fuel prices have challenged our practices of noninversion tillage. Increasing population has challenged agriculture's access to water and created a demand for more water storage. And the need for fuel cellulose is beginning to question how much organic residue we need on the surface for erosion control and sustainable development while maintaining the quality of the soil.

If we would have had more foresight, we might have developed erosion control techniques earlier than we did to prevent the loss of topsoil from thousands of productive hectares. We could have researched and developed more water storage sites for our growing populations. We could have developed more energy efficient crop management systems to save fuel. But that did not happen. As a result, research on these and other problems may be more important than today than ever—research to save and conserve our soil and water resources for our use and the use by future generations.

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