

# Soil and Water Conservation in the Mid-South United States: Lessons Learned and a Look to the Future

**Martin A. Locke**

USDA-ARS, Water Quality and Ecology Research Unit, National Sedimentation Laboratory, Oxford, MS

**Donald D. Tyler**

University of Tennessee, Biosystems Engineering and Soil Science, West Tennessee Agricultural Experiment Station, Jackson, TN

**Lewis A. Gaston**

Department of Agronomy, Louisiana State University Agricultural Center, Baton Rouge, LA

*The culture and politics* of the Mid-South region of the United States at the beginning of the 20th century were largely driven by a powerful agrarian sector. Over the last one hundred years, major social, economic, technological, and demographic changes have reshaped the agricultural landscape of the Mid-South and its regional and national influence. Although other economic sectors in the Mid-South have gained importance, agriculture, in many ways, is still the forefront, and urban centers within this region are hubs for agricultural commerce.

The Mid-South region as defined here includes Arkansas, Louisiana, Mississippi, southeastern Missouri (Mississippi alluvial plain known as the Bootheel), western Tennessee (area west of the Highland Rim), and eastern Texas (area roughly east of Austin) (Fig. 8-1). What commonalities do these states share that provide a distinct and coherent theme for discussion? The label “Deep South” might loosely apply, although this term generally casts a wider net. Certainly, these states, or portions thereof, possess a culture and history that can be described as “southern.” All the states have the Mississippi River as a border, with the exception of Texas, which can claim to be part of the vast drainage system of the lower Mississippi River because of the Red River Valley in the eastern part of the state. The convenience of geographic proximity is the simplest rationale for linking these states together within the Mid-South region. They are all located in the southern, central area of the continental United States.

The evolution of soil conservation awareness and management in the last century is interwoven with social, technological, and political changes. For example, consider the impacts of government programs on implementation of conservation management, the adoption of sustainable practices enhanced by the

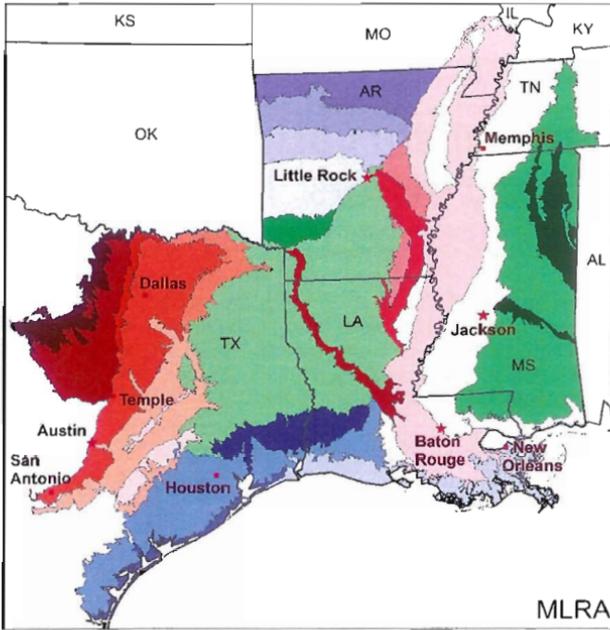


Fig. 8-1. Major Land Resource Areas (MLRA) in the Mid-South region of the United States (USDA-NRCS, 2006).

**East and Central Farming and Forest**

- Ozark Highland
- Boston Mountains
- Arkansas Valley and Ridges, Eastern Part
- Ouachita Mountains

**Southwestern Prairies Cotton and Forage Region**

- West Cross Timbers
- Grand Prairie
- East Cross Timbers
- Texas Blackland Prairie, Northern Part
- Texas Claypan Area, Northern Part
- Texas Claypan Area, Southern Part
- Texas Blackland Prairie, Southern Part

**South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock Region**

- Alabama and Mississippi Blackland Prairie
- Cretaceous Western Coastal Plain
- Southern Coastal Plain
- Western Coastal Plain
- Southern Mississippi Valley Loess

**Mississippi Delta Cotton and Feed Grains Region**

- Red River Alluvium
- Arkansas River Alluvium
- Southern Mississippi River Terraces
- Southern Mississippi River Alluvium

**Atlantic and Gulf Coast Lowland Forest Region**

- Western Gulf Coast Flatwoods
- Gulf Coast Saline Prairies
- Gulf Coast Prairies
- Gulf Coast Marsh
- Eastern Gulf Coast Flatwoods

knowledge from county extension agents, the adoption of tractors rather than mules, and, in stark contrast, the effects of widespread use of transgenic crops on conservation tillage. These are but a few examples of the progress made in preserving and improving soil fertility and productivity. In this chapter we provide an account of the last one hundred years of conservation agriculture in the Mid-South of the United States, with the goal that lessons learned are applied to ensure continued sustainability of soil as a vital natural resource.

## Physiography and Demographics of the Mid-South

The Mid-South area included in this chapter is bounded on the east by the Tennessee River and the eastern border of Mississippi (Fig. 8–1). The northern edge includes the northern border of Arkansas and six counties in the southeast corner of Missouri, while the southern edge is the Gulf Coast of Mexico. The western boundary of the Mid-South region stretches to the edge of the great prairie region of Central Texas. Total area for the Mid-South is 709,104 km<sup>2</sup>, or about 7.5% of the area in the United States (Table 8–1). The topography varies from level to nearly level in the coastal plain and delta plains to the steep hills of northern Arkansas. The elevation of the Mid-South region ranges from 2.44 m below sea level in New Orleans to 839 m above sea level at Mount Magazine in Arkansas.

The climate across the Mid-South can be described as warm and humid, with more temperate regimes in areas to the north and subtropical conditions nearer the Gulf Coast. Climatic variation within the Mid-South generally trends from wetter to drier as one moves from the east to the west or south to north, while temperatures increase from north to south. Mean annual temperature ranges from 14.4 to 16.6°C in the northern portion of the Mid-South to 20.0 to 24.4°C in the southern portion (USDA-NRCS, 2006). Mean annual precipitation for the Mid-South trends from 762 to 1143 mm moving northwest, and 1524 to 2286 mm moving southeast.

The population of the Mid-South in 2000 was 28,935,382, almost a fourfold increase from the 1900 census (U.S. Census Bureau, 1900, 2000). The population as a percentage of the total U.S. population has remained at approximately 10% from 1900 to the present (Table 8–1). The population increase for the Mid-South is in large part due to the dramatic growth of urban centers, particularly in Texas. The population of the Mid-South near the beginning of the 20th century was predominantly rural (<50% of the population living in metropolitan areas), but by 2000, this was

**Table 8–1. Total area and population of Mid-South states. Source: U.S. Census Bureau, 1900, 2000.**

State	Total area km <sup>2</sup>	1900 Population	2000 Population	2006 est. Population
Arkansas	134,856	1,311,564	2,673,400	2,810,872
Louisiana	112,825	1,381,625	4,468,976	4,287,768
Mississippi	121,489	1,551,270	2,844,658	2,910,540
Southeast Missouri†	8,866	94,699	156,516	154,346
West Tennessee‡	28,252	602,055	1,499,802	1,526,816
East Texas§	302,816	2,752,535	17,292,030	19,608,818

† Six counties in Southeast Missouri.

‡ 21 counties in West Tennessee.

§ 133 counties in East Texas.

only true of Arkansas and Mississippi (Hobbs and Stoops, 2002). Similar to 1900, major urban centers at present are Little Rock, AR; New Orleans, LA; Jackson, MS; Memphis, TN; Houston, TX; Dallas-Fort Worth, TX; and Austin, TX. Comparing the figures from the 1900 and 2000 census, population density (persons per square kilometer of total area) increased in the Mid-South from 12 to 38, reflecting the growth of metropolitan areas. Increased urbanization is reflected in how the land is used. The number of farms has decreased in the last century (Fig. 8-2), while the farm sizes have increased (Fig. 8-3) (U.S. Census Bureau, 1900, 2000).

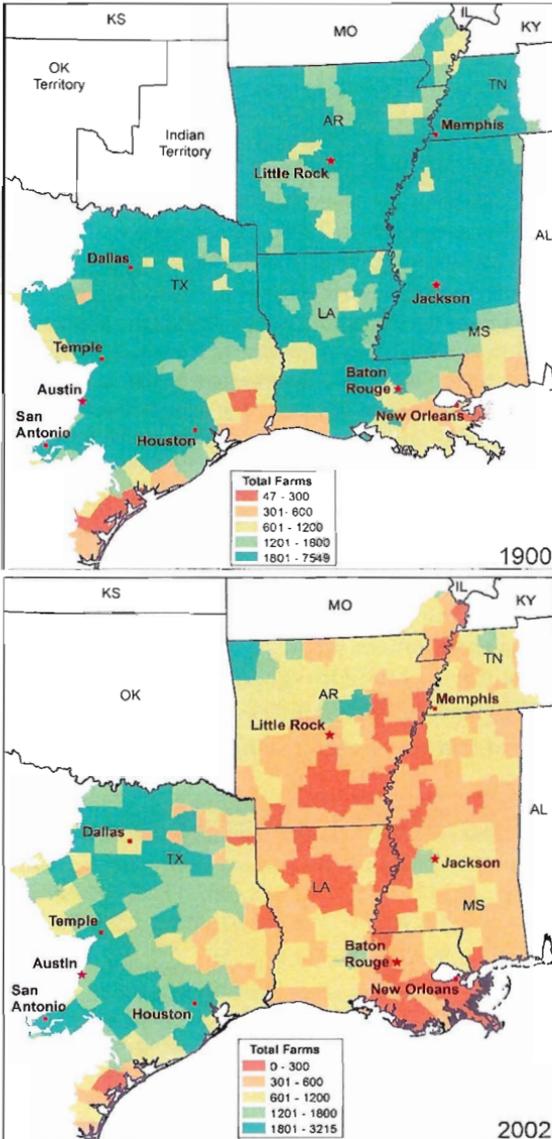


Fig. 8-2. Total number of farms in the Mid-South region of the United States, 1900 and 2002 (Minnesota Population Center, 2004; U.S. Census Bureau, 1900, 2002; University of Virginia, Geospatial and Statistical Data Center, 2004).

### Geology and Topography

The Mississippi Embayment located near the center of the continental United States is a trough formed when the continent began to divide, but failed (Fenneman, 1938). The resulting weakened crustal plate down-warped, allowing seas to form and subside in several cycles throughout geological time. The Mississippi Embayment gradually filled with deposition of marine sediment, emerged from the sea, and now provides a channel for the Mississippi River. West Tennessee, the Missouri Bootheel, most of Mississippi, and eastern Arkansas are within the Mississippi Embayment.

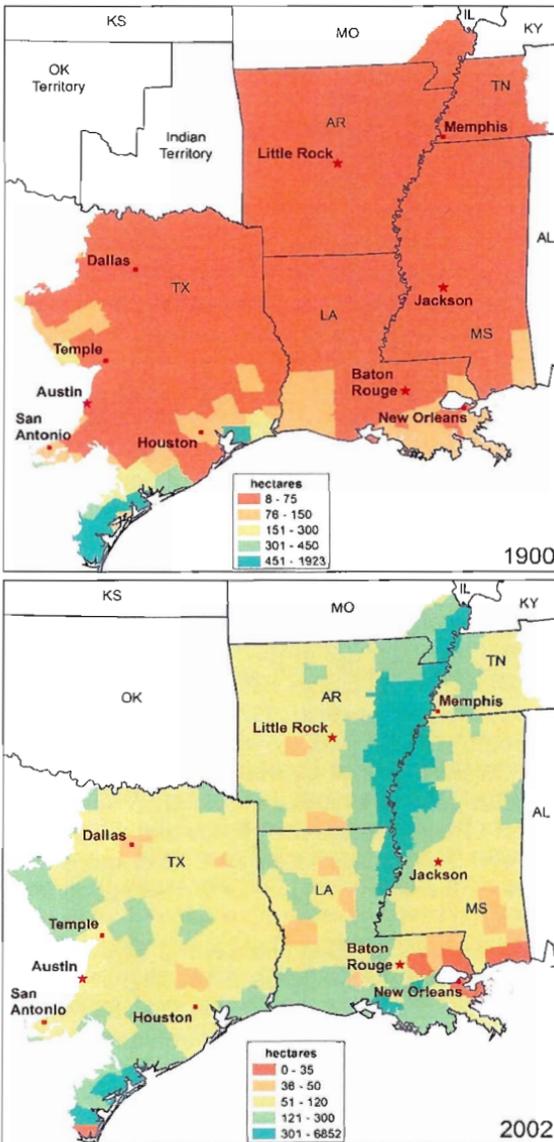


Fig. 8-3. Average farm size in the Mid-South region of the United States, 1900 and 2002. (Minnesota Population Center, 2004; U.S. Census Bureau, 1900, 2002; University of Virginia, Geospatial and Statistical Data Center, 2004).

At the center of the Mid-South region, meanders of the Mississippi River and tributaries shaped the relatively flat topography of the "Delta" regions in northeast Arkansas, Louisiana, Mississippi, and Missouri, overlaying the marine sediments with alluvial sediments. To the south and west, marine sediment deposition formed southwestern Arkansas, Louisiana, most of Mississippi, West Tennessee, and East Texas. The highlands of northwest Arkansas, consisting of the Ouachita Mountains and Boston Mountains of the Ozark Plateau, are part of the Piedmont to the east, but are separated from the Piedmont by the Mississippi Embayment. On the western edge of the Mid-South, the topography of the Blacklands of Texas is characterized by a nearly level to gently sloping, dissected plain.

### Soil and Land Resource Areas

In the early 20th century, scientists were in the process of defining and establishing the discipline of soil science; soil surveys were conducted to classify and group soils according to prescribed criteria. In a treatise on southern soils, Bennett (1921) characterized soils in the Mid-South as Mississippi Bluffs and Silt Loam uplands, Coastal Plain, Stream Bottoms and Second Bottoms, Appalachian Mountains and Plateaus, and Limestone Valleys and Uplands. Reflecting the region's geology, Jenny (1941) described parent materials of soils in the (i) Mississippi Embayment as river alluvium and loess from unconsolidated rocks, predominantly of Pleistocene origin; (ii) Arkansas uplands as limestones, sandstones, and shales from consolidated rocks; and (iii) Gulf Coastal Plain areas of Louisiana, Mississippi, and Texas as sands, clays, and limestones from unconsolidated rocks of variegated origin. Later, soil classifications grouped the Mid-South subregions as Coastal Plain, Loess-covered Coastal Plain, Mississippi Alluvial Plain, and Piedmont (Southern Regional Soil Research Committee, 1959). According to the U.S. Comprehensive Soil Classification System, the soils of the Mid-South include 7 of the 12 taxonomic soil orders, excluding Andisols, Aridisols, Gelisols, Oxisols, and Spodosols (Soil Survey Staff, 1999) (Fig. 8-4). Another useful and more recent geographic classification of areas is that of land resource regions and areas, i.e., a physiographic area that is similar in climate, topography, water resources, land use, and pattern of soils (USDA-NRCS, 2006). This will be the primary basis used here for describing the physiography and land use in the Mid-South, but other sources are used as well (Carter, 1931; Fraps and Fudge, 1937; Godfrey et al., 1968; Krusekopf, 1962; Logan, 1916; Moore, 1916; Nelson et al., 1923; Springer and Elder, 1980; Vanderford, 1975). The Mid-South is comprised of 5 of the 20 land resource regions of the continental United States: East and Central Farming and Forest Region; Mississippi Delta Cotton and Feed Grains Region; South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock Region; Atlantic and Gulf Coast Lowland Forest and Crop Region; and Southwestern Prairies Cotton and Forage Region (Fig. 8-1). Each of these five land resource regions is further subdivided into major land resource areas (MLRAs).

Arkansas is the only Mid-South state in the East and Central Farming and Forest Region, and four MLRAs in Arkansas are applicable to this region: Boston Mountains, Ozark Highlands, Arkansas Valley and Ridges, and Ouachita Mountains (USDA-NRCS, 2006). The Boston Mountains and Ozark Highland areas in northwestern Arkansas are characterized by forested rolling hills and valleys and steep and rugged mountains. Soils in this area were formed under deciduous forest vegetation from weathered residuals of underlying sedimentary rock.

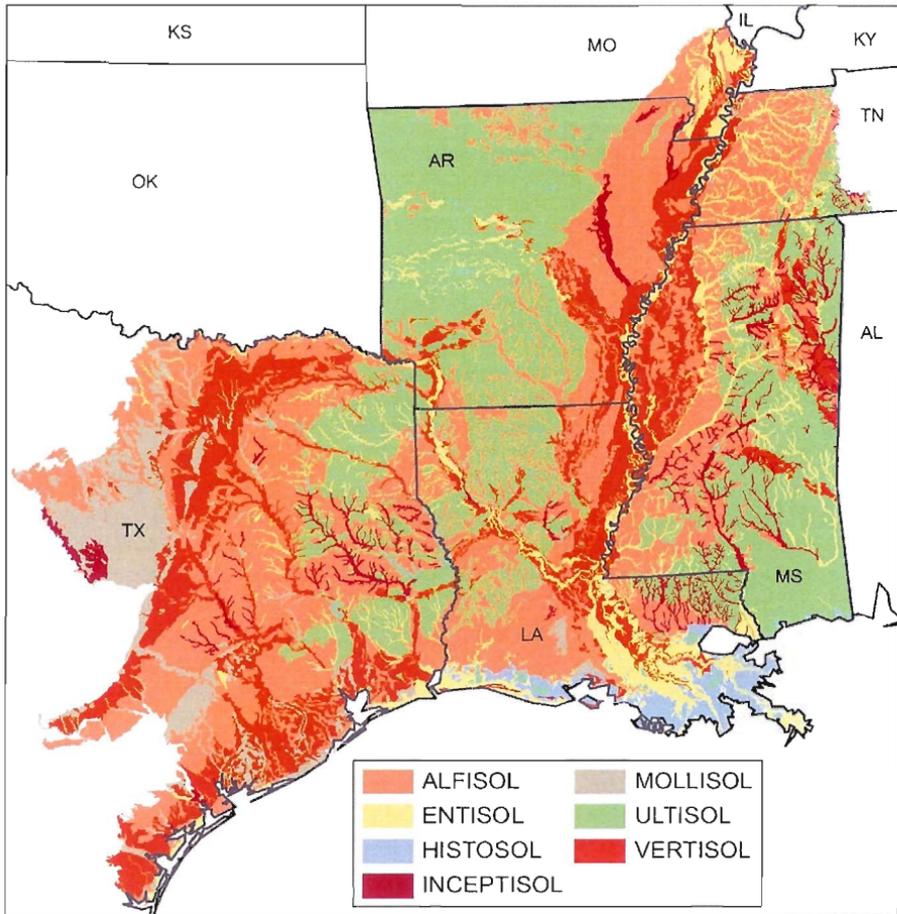


Fig. 8–4. Distribution of major soil orders in the Mid-South region of the United States (USDA-NRCS Soil Survey Staff, 2010; USDA-NRCS, 2010).

The soils are low in fertility, and many have a relatively high chert content that renders them difficult to till, but resistant to erosion. Soils are primarily Alfisols and Ultisols, and the soil series include Captina, Clarksville, and Mountainburg. (See Table 8–2 for descriptions of the soil series mentioned in the chapter.) The Arkansas Valley and Ridges area is aptly described by its name and consists primarily of grassland (48%) and forest (34%). Soils are primarily Ultisols, such as Linker and Nella, with some Inceptisols in river valleys. The Ouachita Mountains occupy the area of north-central to western Arkansas, and this subregion is characterized by rugged terrain, which is more than 60% forested. Soils were developed from sandstones and shales and are medium textured; predominant soil orders are Ultisols and Inceptisols (e.g., Zafra and Bismarck). Relatively little cropping occurs in the aforementioned upland and highland MLRAs (1–6% of the land area), and major management concerns are erosion control in crop and forest production areas and sustainability or improvement of soil productivity.

Table 8–2. Soil series and descriptions for some of the soils of the region.

Series	Description
Ariel	coarse-silty, mixed, active, thermic fluventic Dystrudepts
Austin	fine-silty, carbonatic, thermic udorthentic Haplustolls
Bastrop	fine-loamy, mixed, active, thermic udic Paleustalfs
Billyhaw	very-fine, smectitic, thermic typic Hapluderts
Bismarck	loamy-skeletal, mixed, semiactive, thermic, shallow typic Dystrudepts
Boswell	fine, mixed, active, thermic vertic Paleudalfs
Bowie	fine-loamy, siliceous, semiactive, thermic plinthic Paleudults
Branyon	fine, smectitic, thermic udic Haplusterts
Brenham	fine-silty, carbonatic, thermic udic Calcicustolls
Bruno	sandy, mixed, thermic typic Udifluvents
Bunyan	fine-loamy, mixed, active, nonacid, thermic typic Ustifluvents
Burleson	fine, smectitic, thermic udic Haplusterts
Cadeville	fine, mixed, active, thermic albaquic Hapludalfs
Calhoun	fine-silty, mixed, active, thermic typic Glossaqualfs
Captina	fine-silty, siliceous, active, mesic typic Fragiudults
Clarksville	loamy-skeletal, siliceous, semiactive, mesic typic Paleudults
Coarsewood	coarse-silty, mixed, superactive, calcareous, thermic udic Ustifluvents
Collins	coarse-silty, mixed, active, acid, thermic aquic Udifluvents
Coushatta	fine-silty, mixed, superactive, thermic fluventic Eutrudepts
Crawford	fine, smectitic, thermic leptic udic Haplusterts
Doss	loamy, carbonatic, thermic, shallow typic Calcicustolls
Dowling	very-fine, smectitic, nonacid, thermic vertic Endoaquepts
Dundee	fine-silty, mixed, active, thermic typic Endoaqualfs
Eastwood	fine, smectitic, thermic chromic vertic Hapludalfs
Eddy	loamy-skeletal, carbonatic, thermic, shallow typic Ustorthents
Eufaula	siliceous, thermic psammentic Paleustalfs
Forestdale	fine, smectitic, thermic typic Endoaqualfs
Gillsburg	coarse-silty, mixed, active, acid, thermic aeric Fluvaquents
Grenada	fine-silty, mixed, active, thermic oxyaquic Fraglossudalfs
Houston	very-fine, smectitic, thermic oxyaquic Hapluderts
Houston Black	fine, smectitic, thermic udic Haplusterts
Iuka	coarse-loamy, siliceous, active, acid, thermic aquic Udifluvents
Kirvin	fine, mixed, semiactive, thermic typic Hapludults
Leeper	fine, smectitic, nonacid, thermic vertic Epiaquepts
Lewisville	fine-silty, mixed, active, thermic udic Calcicustolls
Linker	fine-loamy, siliceous, semiactive, thermic typic Hapludults
Mantachie	fine-loamy, siliceous, active, acid, thermic fluventic Endoaquepts
Marietta	fine-loamy, siliceous, active, thermic fluvaquentic Eutrudepts
Memphis	fine-silty, mixed, active, thermic typic Hapludalfs
Mountainburg	loamy-skeletal, siliceous, subactive, thermic lithic Hapludults
Natchez	coarse-silty, mixed, superactive, thermic typic Eutrudepts
Nella	fine-loamy, siliceous, semiactive, thermic typic Paleudults
Oktibbeha	very-fine, smectitic, thermic chromic Dystruderts
Portland	very-fine, mixed, superactive, nonacid, thermic vertic Epiaquepts
Providence	fine-silty, mixed, active, thermic oxyaquic Fragiudalfs
Ruston	fine-loamy, siliceous, semiactive, thermic typic Paleudults
Sharkey	very-fine, smectitic, thermic chromic Epiaquepts
Ships	very-fine, mixed, active, thermic chromic Hapluderts
Shubuta	fine, mixed, semiactive, thermic typic Paleudults
Stephen	clayey, mixed, active, thermic, shallow udorthentic Haplustolls
Vaiden	very-fine, smectitic, thermic aquic Dystruderts
Weswood	fine-silty, mixed, superactive, thermic udifluventic Haplustepts
Whitesboro	fine-loamy, mixed, superactive, thermic cumulic Haplustolls
Wrightsville	fine, mixed, active, thermic typic Glossaqualfs
Zafra	loamy-skeletal, siliceous, semiactive, thermic typic Hapludults

The Mississippi Delta Cotton and Feed Grains Region consists of four MLRAs, and is almost entirely within the confines of the Mid-South, which includes portions of Arkansas, Louisiana, Mississippi, Southeast Missouri, and western Tennessee (USDA-NRCS, 2006). The Southern Mississippi River Alluvium is the largest of these MLRAs, and, as the name implies, is comprised of a narrow floodplain on either side of the Mississippi River from the Gulf of Mexico in Louisiana through Arkansas, Mississippi, and West Tennessee to southeast Missouri. Likewise, the Arkansas River Alluvium and the Red River Alluvium areas located in Arkansas and Louisiana derived from the Arkansas River and Red River, respectively. The generally fertile soils in these three MLRAs developed from alluvium and are very deep and highly variable, and the topography is nearly level to gently undulating (Krusekopf, 1962; Logan, 1916; Vanderford, 1975). Predominant soil orders in these alluvial soils are Alfisols (Dundee, Forestdale), Entisols (Bruno), Inceptisols (Coushatta, Dowling, Portland), and Vertisols (Sharkey). Although these alluvial plains were once covered with hardwood forests and cypress swamps, much of the land was cleared and drained in the early part of the 20th century. Cropland in the MLRAs ranges from 37% in the Red River Alluvium to 70% of the area in the alluvial plains of the Arkansas and Mississippi rivers. The Southern Mississippi Terraces is the fourth MLRA in the Mississippi Delta Cotton and Feed Grains Region and is contained within Arkansas and Louisiana. Soils in this MLRA are mostly Alfisols (e.g., Forestdale, Grenada), and the topography varies from level to gently sloping and steep along terrace escarpments. Cropland (42%) and forest (47%) are the primary uses of the land. The generally fertile loess soils have significant silt contents and are highly erodible in their native level to steep topography.

The South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock Region has five MLRAs and includes parts of Arkansas, Louisiana, Mississippi, West Tennessee, and East Texas (USDA-NRCS, 2006). The Southern Coastal Plain is the largest MLRA in the United States and claims parts of Louisiana, Mississippi, and West Tennessee. The topography is variable and ranges from nearly level and undulating valleys to steep uplands. Soils are derived from marine sediment, consist of sands, clays, shale, and some gravel, and are weathered and low in fertility (Carter, 1931; Logan, 1916; Moore, 1916). The predominant soil orders in this MLRA are Alfisols (Cadeville), Entisols (Iuka), Inceptisols (Mantachie), and Ultisols (Ruston, Shubuta) (Springer and Elder, 1980; USDA-NRCS, 2006; Vanderford, 1975). Most of the land is in forest (64%), with only 17% in cropland. The Western Coastal Plain is almost entirely (99%) contained within areas of Arkansas, Louisiana, and east Texas (known as the East Texas Timberlands), and consists of level to steep uplands, with some flood plains and terraces along streams. Primary soil orders are Alfisols (Eastwood, Wrightsville) and Ultisols (Bowie, Ruston). This MLRA is largely in forest (69%) and grassland (18%), with only 2% in cropland. About 90% of the land area in the Southern Mississippi Valley Loess MLRA is in the Mid-South (Arkansas, Louisiana, Mississippi, southeast Missouri, and West Tennessee). Soils in this area are deep and mantled with loess of varying thickness underlain by unconsolidated gravel, sand, silt, and clay (Carter, 1931). Major soil orders are Alfisols (Calhoun, Memphis), Entisols (Collins, Gillsburg), Inceptisols (Ariel, Natchez), and Ultisols (Providence) (Springer and Elder, 1980; USDA-NRCS, 2006; Vanderford, 1975). The topography is variable, ranging from nearly level on flood plains to sloping to steep on ridge tops and side slopes. Land

use is almost equal in cropland (36%) and forest (40%), with 13% in grassland. The Mid-South portion of the Alabama and Mississippi Blackland Prairie MLRA is in Mississippi. Important soil orders are Inceptisols (Leeper, Marietta) and Vertisols (Houston, Oktibbeha); the terrain ranges from nearly level to hilly (Logan, 1916; Vanderford, 1975). Forest (48%) and grassland (29%) are the major uses of land, with 16% of the area being used as cropland. Arkansas is the only Mid-South state in the Cretaceous Western Coastal Plain MLRA. The topography is nearly level flood plains and uplands to moderately sloping uplands. The soils are moderately deep, with the major soil orders being Alfisols (Boswell, Vaiden) and Inceptisols (Leeper). Forest (63%) and grassland (25%) are primary uses of land, with only 5% in cropland.

The Atlantic and Gulf Coast Lowland Forest and Crop Region includes portions of the coastal states of Louisiana, Mississippi, and Texas (USDA-NRCS, 2006). The Mid-South segment of this region is comprised of five MLRAs: Gulf Coast Prairie, Gulf Coast Saline Prairie, Gulf Coast Marsh, Eastern Gulf Coast Flatwoods, and Western Gulf Coast Flatwoods. This region is characterized by low-lying, flat to gently sloping topography. The soils were developed from marine sediment on coastal lowlands, coastal plains, drowned estuaries, tidal marshes, and beaches (Carter, 1931; Logan, 1916). Dominant soil orders are Alfisols, Entisols, and Ultisols, and this is the only part of the Mid-South where Histosols and Spodosols have developed. The Gulf Coast Prairie (32% cropland, 40% grassland, 5% forest) and Gulf Coast Marsh (16% cropland, 6% grassland, and 8% forest) are the only MLRAs with any significant cropland. Salinity inhibits crop production in the Gulf Coast Saline Prairie, and most land use is for grassland (34%). The Eastern and Western Gulf Coast Flatwoods MLRAs are primarily in forest (67–74%).

The portion of the Southwestern Prairies Cotton and Forage Region that includes the Mid-South is entirely in Texas (USDA-NRCS, 2006). The seven MLRAs from this region that are in Texas are West Cross Timbers, East Cross Timbers, Grand Prairie, Texas Blackland Prairie (Northern and Southern Parts), and Texas Claypan Area (Northern and Southern Parts). Grassland (68%) used for pasture and rangeland is the primary use of land in the West Cross Timbers area of north central Texas. Topography ranges from nearly level to undulating, and soils are predominantly Alfisols (Chaney, Nimrod) and Entisols (Pulexas). The East Cross Timbers area in north-central Texas includes Fort Worth, and 25% of the area is urban. The largest use of land is grassland (51%) in this area of gently sloping to rolling landscape. Major soil orders are Alfisols (Bastrop, Eufaula), Entisols (Bunyan), and Mollisols (Whitesboro). The Grand Prairie area in north-central Texas has a gently rolling to hilly landscape. The deep soils in this area are underlain by limestone and shales; the dominant soil orders are Mollisols (Doss, Lewisville) and Vertisols (Branyon, Crawford). A majority of the area is in grassland (75%). The northern part of the Texas Blackland Prairie in central Texas consists of nearly level to gently sloping dissected plains and includes several major urban areas. Dominant soil orders are Entisols (Eddy), Mollisols (Austin, Stephen), and Vertisols (Burlison, Houston Black); the soil is moderately to very deep, and is underlain by chalk, claystone, marl, and shale (Carter, 1931). Land use in this MLRA is a mixture of cropland (29%) and grassland (49%). The southern part of the Texas Blackland Prairie in east-central Texas has similar gently sloping topography underlain by calcareous clays, sandstones, and marls. The deep to very deep soils include Entisols (Coarsewood), Inceptisols (Weswood), Mollisols (Whitesboro), and Vertisols (Branyon, Crawford).

sols (Brenham), and Vertisols (Ships). Most of the area is in grassland (80%), with only 9% used for cropland. The southern part of the Texas Claypan Area in south-central Texas consists of level to gently sloping plains dissected by river valleys. Major soil orders are Alfisols, Entisols, Mollisols, and Vertisols. Soils are deep to very deep and range from excessively drained to somewhat poorly drained. Grassland as pasture or livestock grazing dominates the landscape (80%), with a minor portion of the area developed as cropland (7%). The northern part of the Texas Claypan Area in northeastern Texas is characterized by nearly level to gently sloping, dissected plains. Soil orders of importance are Alfisols (Wrightsville), Ultisols (Kirvin, Ruston), and Vertisols (Billyhaw). Land use is mixed, with 54% grassland, 27% forest, and 8% cropland.

## Historical Perspectives of Soil Conservation in the Mid-South: 1900–1980

### Agriculture, Society, and Soil Erosion in the Mid-South

Since the settlement of the United States, there have been numerous mentions of soil erosion and the potential problems that resulted from erosion (McDonald, 1941). Predominant farming practices during the 19th century in the United States involved the “pioneering ax and plow,” which meant removing trees, clearing stumps, and intensive tillage (Fig. 8–5). Very severe erosion resulted from this activity (Bennett and Lowdermilk, 1938; Fite, 1984; Maddox, 1915). In some cases, land was abandoned after moderate to severe erosion. The land continued to erode as farmers moved to adjacent fields. It was reported that the practice in the Mid-South became particularly important after the Civil War. In some areas of Tennessee and Mississippi, these abandoned areas were not allowed to naturally revegetate, but instead were kept clean by burning, presumably to make it easier to reuse the abandoned gullied land.

The aftermath of the Civil War of the United States profoundly impacted the economy and agriculture of the Mid-South, and those effects were still evident at the beginning of the 20th century. During the period following the Civil War, state agricultural experiment stations were established by the Hatch Act of 1887, and by the early 1900s were providing local research recommendations to farmers.

The era beginning in the early 20th century was known as the Progressive Era; an active period for agriculture in the largely rural Mid-South region. The Smith Lever Act of 1914 provided federal support for county extension agents. Agricultural organizations such as the Farmers Union in Arkansas, Louisiana, Mississippi, and Texas, and respective state Farm Bureaus emerged as spheres of influence. Drainage of the low-lying delta areas of Mississippi, Arkansas, Louisiana, and Missouri completely transformed the agricultural landscape, and the formation of drainage districts provided local control over the use of water. A variety of agricultural commodities were tried in new areas; for example, rice (*Oryza sativa* L.) began to emerge as an important commodity crop in Arkansas.

During the first two decades of the 20th century, the agricultural industry faced setbacks. World War I depleted the agricultural work force. Soil resources in the Mid-South were exhausted from overuse and poor management. Some farmland reverted to forests. Boll weevil [*Anthonomus grandis* (Boheman)] was a scourge to the cotton (*Gossypium hirsutum* L.) industry. Water-induced erosion following



**Fig. 8–5. Early mechanical tillage methods and equipment, Mississippi Delta. Source: Delta Branch Experiment Station, Stoneville, MS.**

tillage was ruining soils, and proponents of conservation were warning that common practices, such as clear cutting, tilling, and cropping hilly land, had ruinous impacts in terms of nutrient depletion and erosion (Bennett, 1921; Maddox, 1915).

While early southern agricultural leaders such as Nicholas Sorsby warned of the destructive impacts of erosion (McDonald, 1941), the widespread recognition of soil erosion as a societal problem had been almost completely ignored by many until the early 1900s. There was little mention of soil erosion in the Yearbooks of Agriculture from 1894 to 1913. This may have been due, in part, to the arrangement of the books themselves, in that they contain individual chapters dealing with very specific subjects of interest during the time. The 1913 Yearbook has an article dealing with the economic wastes that occurred from soil erosion (Davis, 1913), and another article, “Farms, Forest, and Erosion” (Dana, 1916) appeared in the Yearbook of Agriculture, 1916. Initial concerns about soil erosion in the early 1900s as a national problem came from the Bureau of Soils in the USDA. As a result of the county-based soil surveys that began in approximately 1900, more attention was directed toward soil erosion (Helms, 2009). Meanwhile, farmers of the Mid-South continued practices that were destructive to the land, and a coordinated national effort to address erosion was yet to come.

Although there were some technological improvements, including the use of pesticides against the boll weevil and the use of fertilizers to replenish soil resources (U.S. Census Bureau, 1930), agricultural decline in the Mid-South escalated during the 1920s. Many small farmers lost their lands, resulting in larger

areas of farmland in fewer hands (Fig. 8–2, 8–3). Increasingly, tenants and sharecroppers operated a larger proportion of farms. Farms operated by tenants increased from 55% in 1910 to 65% in 1930 (U.S. Census Bureau, 1910, 1920, 1930). Although there was some diversification of agricultural commodities, cotton was still an important crop, and a fall in cotton prices devastated the economy throughout the Mid-South. High drainage taxes in the Delta areas were prohibitive, and high tariffs that benefitted northern industry hurt agriculture in the South. Highways and automobiles improved, varying transportation options, but the rural population began to decline. The Mississippi River flood of 1927 had a profoundly negative effect on the agricultural economies of the states bordering the river.

During this period, Hugh Hammond Bennett, a legendary observer of the soil erosion problem, noted that in some of the loess soils of the South, farming had been virtually abandoned due to severe gully erosion (Bennett, 1927). He drew national attention to the erosion problem with a publication about soil erosion in 1928 (Bennett and Chapline, 1928).

In one stark example of erosion in the Mid-South, Lentz et al. (1929) described the condition of a Mississippi farm near Oxford settled in the 1830s, relative to observations in the late 1920s. They noted the speed at which gullies formed using the observations in an area called Linder's Pasture. The area was reported in 1884 to be a level cotton field free of gullies. By 1929, the field had become a "maze of deep gullies and washes." One particular gully was approximately 18 m deep and was rapidly growing wider as the sides slumped, filling in the bottom. The soil materials in this area are loess, windblown-silty deposits, over lenses of sand, clay, and gravel that are rapidly removed with subsequent collapse of the overlying loess, increasing the rapidity of severe deep gully formation (Fig. 8–6). This same process was occurring in similar loess soils in western Tennessee, resembling the "badlands of the Dakotas" (Wells, 1933). Gullies 15 m deep or more were reported in 1933, and the surface form of this area was referred to as the "hills of erosion" (Wells, 1933).

Unfortunately, the 1930s brought the Depression Era, and the agricultural economy worsened. Population shifts occurred, and depletion of the rural pop-



**Fig. 8–6.** Gully formation on a cultivated loess hill slope in Western Tennessee. Photo credit Don Tyler, University of Tennessee, circa 1970s.

ulation continued. Many farmers abandoned eroded or drought-stricken lands, resulting in migrations westward. Cotton prices fell even further, and people lost their farms. Landowners lost their land for not paying taxes, and became tenants or sharecroppers.

Along with the rest of the nation, the Mid-South had its share of documented erosion during this time. In addition to the erosion problems reported for loess hill areas, less rolling surface forms in the Southeastern Uplands (Pearson and Ensminger, 1957) and Mississippi Delta Region (Grissom, 1957) also had serious erosion problems documented from the 1930s. In Tyler, TX, on gentle slopes with annual rainfall of 1016 mm, clearing and tillage increased runoff by a factor of 23 and soil loss by a factor of 239 for a 4-yr period as compared to the original soil with native vegetation (Utz et al., 1938). Annual soil losses were 63 Mg ha<sup>-1</sup> on the cultivated areas compared to 0.2 Mg ha<sup>-1</sup> in areas of dense soil surface cover (Bennett and Lowdermilk, 1938). Level areas of the Coastal Plain and Mississippi Valley generally had almost no soil erosion, but even in the flatter Delta regions of the Mid-South, soil movement in fields under cultivation was high during periods of flooding from December of 1931 to January of 1932, resulting in soil losses of 76 Mg ha<sup>-1</sup> (Utz et al., 1938). Even now, a general distinction is sometimes made that soil is removed from flat areas but at slower rates, and that in some cases the soil lost in river bottom areas is replaced by sediment added during floods. This soil movement on and off the land can have tremendous impacts on water quality. The rolling areas of the Black Belt soils of Mississippi, and the rolling parts of the larger Black Belt of central Texas also experienced severe topsoil removal. In Rockwall County in Texas, 14% of the Houston clay was mapped as an eroded phase in 1931 (Bennett, 1931). The surface color in many cases was gray or white because the underlying chalk was exposed.

The interface of societal problems of the Great Depression and the acknowledgment of land degradation and poverty was noted by Hambridge (1938), providing an initial insight into the various consequences of the Depression and the role of government in regulating land use. Williams (1964) summarized these consequences and connected the beginning of the Great Depression in 1929, the severe droughts of the early 1930s, the Dust Bowl, and the pleas from Bennett (Bennett and Chapline, 1928) as major reasons for increased coordinated national emphasis on the soil erosion problem. The initial pleas of Bennett resulted in the Buchanan Amendment of the 1929 Agricultural Appropriations Bill, which provided funding for 10 erosion experiment stations across the United States, including two in the Mid-South located in Tyler and Temple, TX (Bennett, 1939; Harmel et al., 2007). In 1935, the Soil Conservation Act was passed, placing most of the erosion control activities in the Department of Agriculture (Helms, 2009). The 1936 Soil Conservation and Domestic Allotment Act provided funds to help reduce surpluses and conserve soil by shifting to alternative crops, such as legumes and grasses, which helped to improve soil quality.

During the late 1930s and into the period during and after World War II, profound technological advances in farming methods were beginning to transform U.S. agriculture into the breadbasket of the world. Mules gave way to tractors (Fig. 8–5). Men were drafted into the armed forces, leading to labor shortages. The mechanical cotton picker was introduced, but because of initial inefficiencies it did not gain popularity until the 1960s. Thus, laborers were still needed to pick cotton. Sharecroppers in the Mid-South were becoming less needed, but

there was an increased demand for day laborers. With increasingly fewer tenant farmers (reduced from 65% in 1930 to 42% in 1950; U.S. Census Bureau, 1930, 1950), major population shifts continued in the Mid-South, particularly among African Americans, who moved to northern cities in huge numbers.

During the 1950s and 1960s, great strides in agricultural technology were made with new machinery and fertilizer formulations and the introduction of pesticides and crop varieties. Demand for agricultural commodities continued to increase. Farmers began to clear and use more and more marginal, erodible land. Heavier tillage equipment was used, further contributing to the destructive effects of erosion. During this time, the Soil Bank Program was established as part of the Agricultural Act of 1956, which had a conservation reserve component that funded the removal of marginal and erodible land from crop production, primarily to address farm surpluses. Such land was diverted toward conservation practices. As part of this program, millions of acres of trees were planted in the Mid-South. Although the Soil Bank Program was repealed by the Food and Agriculture Act of 1965, it was a model for future legislation establishing the current Conservation Reserve Program.

Environmental issues came to the forefront again during the 1970s. Grain exports from the United States increased, and commodity prices rose sharply. Twenty-four million hectares of new cropland were subsequently brought into cultivation from 1972 to 1982. Some of this land was much more erodible than that previously used for cropland. This was the situation that existed before the passage of the Food Security Act of 1985, one of the first attempts to connect commodity price support programs with soil conservation. Under this legislation, farmers who did not apply Soil Conservation Service (SCS, now known as NRCS) conservation plans would be out of compliance and would be denied some farm program benefits. The SCS was the agency responsible for writing the appropriate farm plans for necessary action on conservation practices. In much of the Mid-South these plans involved cropping systems that included no-tillage (NT) and maintenance of surface residue cover. The Food Security Act also created the Conservation Reserve Program (CRP), which provided incentives for removing highly erodible land out of production for a period up to 10 yr (Helms, 2009) (Fig. 8–7).



Fig. 8–7. (Left) Soybean cropland (summer 2001) that was converted to CRP in 2004. (Right) The same area under CRP in 2009. Beasley Lake Watershed, Sunflower County, Mississippi. Photo credits: (left) Martin Locke, (right) John Massey; USDA-ARS.

## Early Efforts to Reduce Soil Erosion

Much of the literature on soil and water conservation from the first half of the 20th century can be found in state experiment station bulletins. Erosion experiment stations were established in 1929 as a result of the Buchanan Amendment to the Agricultural Appropriations Bill, and a nationally coordinated effort was begun to document the effects of agricultural practices on erosion and runoff. The erosion stations in Texas at Temple and Tyler represented some of the soils in the Mid-South. The Flood Control Act of 1944 provided funds for the USDA to work with the U.S. Corps of Engineers in implementing emergency runoff measures and for developing water resources in 11 watersheds throughout the United States, four of which are in the Mid-South (Little Tallahatchie, Middle Colorado River, Trinity River, and Yazoo River) (USDA-FS, 1988). The USDA-ARS National Sedimentation Laboratory was established at Oxford, MS in 1958 to address erosion and conservation of loess soils. For similar reasons, the University of Tennessee Research and Education Center at Milan was organized in 1962.

## Terracing, Contouring, and Strip-Cropping

Terracing was one of the earliest practices used to attempt to control erosion in the Mid-South (Bennett and Lowdermilk, 1938; Ramser, 1929). Extension bulletins, such as that published in Mississippi by Carpenter and Gross (1918), provided stepwise instructions on the installation of terraces. In the mid-19th century, Sorsby published recommendations for hillside ditching and horizontal plowing based on his studies on farms in Alabama and Mississippi (McDonald, 1941). Bennett was a strong opponent of using terracing as a single erosion control practice, pointing out that terracing is an "important measure in the control of erosion," but that "used, improperly, it may do more harm than good" (Bennett and Lowdermilk, 1938). They continued this discussion with a farmer survey of the perceived effects of terracing alone, with most finding it unsatisfactory in many fields. Bennett and Lowdermilk (1938) promoted a combination of practices such as strip-cropping, crop rotation, winter cover crops, contour plowing, and removing land from cultivation to restore critically eroding areas. These practices were discussed elsewhere in the 1938 Yearbook of Agriculture (Enlow and Musgrave, 1938; Kell, 1938; Nichols and Chambers, 1938), including a discussion on the coordination of practices (Utz, 1938). Researchers at that time were beginning to look at systems of practices. For example, Garin and Gabbard (1941) conducted an analysis in the Trinity River Basin in Texas of a coordinated watershed approach using a combination of terraces, cultivated land retired to pasture or meadow, and strip-cropping to control erosion. In research at the erosion station in Temple, TX, Smith et al. (1954) showed that contouring and strip-cropping consistently reduced runoff and erosion, particularly on fields with higher slopes.

## Limited Tillage, Herbicides, and No-Tillage

Little research on conservation tillage was conducted in the Mid-South in the early part of the 20th century. Problems with excessive tillage became more apparent, and evidence supporting the need to protect and reclaim the land slowly accumulated. In an article on gullied lands of western Tennessee, Maddox (1915) recognized the land as "one of our indispensable natural resources" and that, of the processes that will "injure the soil surface and reduce the productive area, erosion is perhaps the greatest." In a review of the literature on tillage,

Sewell (1919) noted conflicting information on the benefits of plowing and cultivation, other than for weed control. A single study from the Mid-South, located in Welborn, TX, was mentioned in the review; however, Lee in Georgia was cited in the review concluding that "tillage ... especially in the southern States, impaired the natural fertility of the soil" (Sewell, 1919).

With the observed negative erosive effects of tillage, some research focused on critically analyzing the benefits of tillage. Some called into question the use of dust mulch and frequent cultivation to prevent water runoff and concluded that cultivation is mainly important for weed control to prevent weed water use and crop competition. Early research at the Jackson Station in western Tennessee found no response to machine-powered mechanically cultivating weeds versus using a hoe to remove weeds (University of Tennessee, 1915). Later work on depth of soil tillage and mechanical cultivation versus hand hoeing for cultivation was done by Mooers (1944) on soils across Tennessee. He compared different plowing depths and mechanical cultivation versus hand hoeing alone. On some soils, hand hoeing gave equal yields to cultivation, while on other soils, yields were slightly lower. Initial plowing depth had no effect on crop yield on any of the soils. Research by Harris (1964) in Mississippi showed a yield and profit decline when cotton was hand hoed and cultivated with machine power compared with hand hoeing alone. In addition, the possibility of limiting the degree of tillage and depth while still maintaining yield was verified on silty and clayey soils in Arkansas (Phillips, 1968).

The reduction in tillage soon led to consideration of doing no seedbed preparation but instead planting into the existing soil cover with proper equipment and using herbicides for weed control. This could result in optimum erosion protection. In the late 1950s and early 1960s chemical weed control to replace cultivation was becoming more feasible and economical (Goddard and Lard, 1965). Eventually better herbicides and equipment became available (Denton and Tyler, 2002). Soon after, NT cropping research became common in most areas of the Mid-South (Melville and Rabb, 1976; Hinkle, 1975; Graves et al., 1980; Tyler and Overton, 1982).

Research on NT was extensive during the 1960s and 1970s and was summarized by Blevins et al. (1994) and Tyler et al. (1994) for parts of the Mid-South. A number of research studies were conducted on the effects of NT and cover crops relative to water quality. Some examples include studies by Shelton et al. (1983) and a summary of a large number of studies in Mississippi during this period (McGregor et al., 1996). Dramatic reductions in runoff and soil erosion from NT cropping and residue management were shown in most studies.

## Cover Crops

Keeping the soil covered was recognized by Bennett et al. (1919) as the only feasible way of adequately controlling soil erosion on steeper slopes in the soil survey map of Shelby County, TN, which lies in the same loess belt as Lafayette County, MS (Lentz et al., 1929). Bennett observed that gully erosion was still severe, even on much of the sloping land where contoured farming was used. In some cases, he thought terracing would help, but on many fields, conversion to grasses and clover (*Trifolium* spp.) or permanent pasture was the only solution.

At SCS experiment stations (predecessors of the USDA, Agricultural Research Service experiment stations) across the nation, including those in the Mid-South

(Tyler and Temple, TX), early soil loss measurements demonstrated the importance of soil coverage. Summarizing early research at these stations, Bennett (1939) reported that "without exception...annual soils losses from the areas devoted to clean-tilled crops are many times greater than the corresponding losses from the areas heavily covered with protective vegetation." Twenty years after research at the Tyler station began, Smith et al. (1954) reported that rotation of sweetclovers and small grains tended to have less soil loss than continuous small grain. Soils where crops were grown with sweetclover and native grasses with no top growth removed accumulated organic matter and nutrients.

In Arkansas, Bartholomew et al. (1939) measured less runoff and soil loss with a winter cover crop of vetch (*Vicia* spp.), and negligible soil loss was observed from Bermuda grass (*Cynodon dactylon* L.) sod. They also found that soil loss in corn (*Zea mays* L.) rotated with oats (*Avena sativa* L.) and clover was less than that in continuous corn. Differences in soil loss were attributed to an improved ability of rotated soils to absorb water.

In a Lafayette County, Mississippi study, Lentz et al. (1929) noted that terraces, which were considered impractical, and cover crops were seldom used for the production of cotton and corn. They did observe that soil coverage, even with only honeysuckle (*Lonicera japonica* Thunb.) or broomsedge (*Andropogon* spp.), was quite effective in stabilizing gullies and preventing further erosion. Less erosion was also observed with inferior covers of scrubby undergrowth of burned-over hardwood stands when compared with adjacent abandoned fields. Other plants promoted for cover to reclaim eroded soils in the Mid-South included kudzu [*Pueraria montana* (Lour.) Merr.] and black locust (*Robinia pseudoacacia* L.), and loblolly pine (*Pinus taeda* L.) (McGinnis, 1933; O'Brien and Skelton, 1946).

In addition to using cover crops to protect the soil from erosion, considerable research was done in many Mid-South states on the use of cover crops to improve soil productivity. Cover crops were used in rotation with row crops or as winter legumes (Baird and Knisel, 1971; Brown, 1945; Davis et al., 1940; Fox, 1907; Grissom, 1950; Haddon, 1953; Long and Overton, 1963; Mississippi Agricultural Experiment Station, 1934; Mooers and Hazelwood, 1945; Nelson, 1944; Offutt, 1970; Patrick et al., 1957; Reynolds et al., 1950, 1958; Smith et al., 1954). Data from these studies indicated great promise for the use of winter cover crops to provide additional soil cover, enhance crop yields, increase soil organic matter, and, with legumes, potentially supply fixed nitrogen to the following row crop.

## Soil and Water Conservation Trends in the Mid-South: 1980 to Present

**Improved Soil Conservation, Continued Water Quality Problems**  
Data from the Natural Resources Inventory (NRI) for states in the Mid-South show substantial reduction in water erosion of cropland per hectare from 1982 to 2003 (Table 8-3; USDA-NRCS, 2000, 2007b). Within this time, acreage in cropland decreased (Table 8-4; USDA-NRCS, 2000, 2007a), in part due to establishment of the CRP. Thus, recent advances in soil and water conservation may be summarized as reduced water erosion per acre on reduced acreage. The per acre reduction in water erosion from remaining cropland during the past quarter century (Table 8-3) reflects increased conservation management. Major in-field

**Table 8–3. Estimated average water erosion (sheet and rill) from cropland by year for states in the Mid-South (USDA-NRCS, 2000, 2007b).**

State	Year				
	2003	1997	1992	1987	1982
	Mg ha <sup>-1</sup>				
Arkansas	6.9	7.6	7.6	8.3	8.3
Louisiana	6.9	7.4	7.8	9.2	10.5
Mississippi	10.3	11.9	12.8	14.8	17.2
Missouri	9.2	12.5	14.8	18.8	24.4
Tennessee	8.1	17.2	20.4	24.2	24.6
Texas	5.6	5.8	5.8	5.8	5.8

**Table 8–4. Trends in cropland and CRP acreage by year for the states in the Mid-South (USDA-NRCS 2000, 2007a).**

State	Year									
	2003		1997		1992		1987		1982	
	Crop	CRP	Crop	CRP	Crop	CRP	Crop	CRP	Crop	CRP
	1000 ha									
Arkansas	3046	59	3088	93	3131	95	3230	39	3281	0
Louisiana	2201	81	2292	57	2419	582	2548	17	2596	0
Mississippi	2015	320	2168	324	2319	315	2699	118	3003	0
Missouri	5540	592	12859	650	5406	649	5826	231	6075	0
Tennessee	1924	94	1881	151	1967	178	2177	70	2265	0
Texas	10353	1617	10910	1582	11446	1609	12636	641	13496	0

management changes include wider use of some form of conservation tillage/residue management and cover crops. Edge-of-field or pre-discharge practices, such as hedges (Dabney et al., 1995; Meyer et al., 1995) and filter strips (Sanderson et al., 2001), intended to limit input of eroded soil into water bodies have also been adopted to some degree (Lovell and Sullivan, 2006).

However, use of conservation management is not universal. State-compiled water quality inventories provided to the USEPA include lists of impaired water bodies, i.e., 303(d) lists, which commonly cite soil disturbance by agricultural practices as a suspected cause for impairments such as turbidity and low dissolved oxygen due to enrichment in O<sub>2</sub>-consuming substances. Watershed restoration plans typically prescribe better soil conservation by wider adoption of best management practices to meet total maximum daily loads.

The Mid-South also has larger-scale water quality problems due to sediment-bound and dissolved nutrients. Real or potential enrichment of surface water with P from soils fertilized with poultry waste is a problem in the Mid-South, particularly in Arkansas (USDA-NRCS, 2006). A rather large eutrophic-hypoxic zone in the northern Gulf of Mexico off the Louisiana coast is believed to result from enrichment in nutrients, presumably drained from the Upper Mississippi River Valley (Rabalais et al., 1996); however, inputs from the Mid-South may also contribute (Southwick et al., 2002). Control of nutrient loading depends on soil conservation as well as nutrient management.

## Early-Stage Transition to Conservation Tillage

By 1980, the foundation of conservation tillage/residue management in the Mid-South had largely been established by research attempting to quantify their benefits and refine production methods to meet or exceed yield and profitability under conventional practices. While some work in the Mid-South on reduced tillage dates to about 1960 (Phillips, 1968), the rationale was not of soil and water conservation for those Delta soils, although Dendy (1981) and Murphree and McGregor (1991) later showed soil loss of 11 to 27 Mg ha<sup>-1</sup> on flat Delta soils. Within the decade, however, concern about erosion and degradation of loessial, fragipan soils—later confirmed and explained by Rhoton (1990) and Rhoton and Tyler (1990) and further substantiated by Cullum et al. (2002) and McGregor et al. (1992, 1999b)—led to initiation of work on the efficacy and practicability of NT soybeans [*Glycine max* (L.) Merr.], rotations with corn, and double cropping with wheat (McGregor et al., 1975). There had been tentative success with NT elsewhere by that time (Triplett and Dick, 2008).

Intermediate- and long-term soil erosion losses from NT soybeans were 0.10 or less than those from conventional-tillage (CT) (McGregor et al., 1975; Mutchler and Greer, 1984). Data for corn were equally impressive (McGregor and Greer, 1982; McGregor and Mutchler, 1983). Furthermore, yields were not compromised. Commonly this was not the case, but rather than an inherent limitation of the system, Shelton and Bradley (1987) acknowledged lack of experience as a major factor behind early poor yields from NT compared to CT. With increased experience, NT yields were more often equal to or superior to CT yields.

## Cover Crops and Related Systems

Leading into recent times, the traditional use of cover crops as a green manure had waned in favor of commercial fertilizers despite its recognized value for soil conservation. Nevertheless, research and demonstration on cover crops in the Mid-South persisted (Millhollon and Melville, 1991) or had been initiated with low-residue cotton (Scott et al., 1990; Keisling et al., 1994) (Fig. 8–8). Results for the above Red River and Mississippi Delta soils showed increased yields or reduced need for N fertilization. Besides building soil organic C (SOC), a rye (*Secale cereale* L.) and vetch cover also improved soil physical properties beneficial to plant growth (Scott et al., 1990; Keisling et al., 1994). Studies with planted cover crops in NT or reduced-tillage cotton to further improve soil retention (Mutchler and McDowell, 1990) were started at Holly Springs, MS, following initial research by Mutchler et al. (1985). No-tillage reduced erosion to about 1 Mg ha<sup>-1</sup> from 72 Mg ha<sup>-1</sup> for CT (Mutchler et al., 1985). Planting vetch or wheat further reduced erosion from this system, and the effect of the cover crop was much greater for the most erosive system, CT, reducing erosion by approximately 25% (Mutchler and McDowell, 1990).

Data from the cotton erosion studies at Holly Springs, MS, also suggested a residual effect from previous management. For example, erosion from CT cotton on previous NT soil was about one-half that of the same system but with long CT history (Mutchler et al., 1985). Erosion was least from NT cotton grown on previously double-cropped wheat–soybean soil. Later work by Dabney et al. (2004) and Wilson et al. (2004) on the tillage history confirmed the previous findings for NT, but the residual effect due to wheat–soybean is less clear. However, work with NT wheat and wheat–soybean (Dou and Hons, 2006; Franzluebbers et al., 1994, 1995)



Fig. 8–8. Mississippi Delta cotton production under reduced tillage (top) with, and (bottom) without a rye cover crop. Stoneville, MS. Photo by Wade Steinriede, 2009, USDA-ARS.

showed greater accumulation of SOC with greater cropping intensity, including accumulation of organic C extending into subsurface soil (Wright et al., 2007a). Among NT sorghum [*Sorghum bicolor* (L.) Moench], soybean, and wheat, wheat produced a higher accumulation of organic C and greater proportion of macroaggregates (Wright and Hons, 2005), both associated with better water infiltration, and less runoff and erosion (Rhoton et al., 2002). Furthermore, subsurface accumulation of C for the monocultures was greater for wheat and sorghum than for soybean (Wright et al., 2007b). Long-term erosion data in the Texas Blackland Prairie (Harmel et al., 2006) are consistent with such benefits of small grain cover, especially during the wetter parts of the year.

Cover crops produce a much greater mass of residue than native winter annuals, particularly a nonlegume like wheat where soil N fertility is high ( $\sim 4 \text{ Mg ha}^{-1}$ ; Boquet et al., 2004a,b), providing good protection of the surface soil. Since harvesting a wheat cover offers direct return, double-cropped wheat systems were developed throughout the Mid-South about 25 yr ago. Some initial yields were good with NT for sorghum (Gerik and Morrison, 1984; Viator and Marshall, 1981) and soybean (Griffin et al., 1983; Rabb and Melville, 1984), and some were not (for sorghum Hairston et al., 1984; Howard, 1987; for soybean Boquet et al., 1982; Boquet and Walker, 1984; Shelton et al., 1982). However, Boquet and Walker (1984) and Shelton and Bradley (1987) offered several explanations, including height of wheat stubble and lower soil moisture at later planting with NT. Regardless, double-cropped wheat systems help conserve soil, particularly with CT. Shelton and

Bradley (1987) reported only 25% as much erosion with wheat–soybean compared with CT soybean.

### Understanding Conservation Tillage Systems Better

Studies quantifying soil and water conservation with no- and reduced-tillage continued beyond the early work with soybean, corn, cotton, double crops, and cover crops (Fig. 8–9). This research continued some of the earlier work (Mutchler and McDowell, 1990; McGregor et al., 1999b; Cullum et al., 2002) and initiated new studies, as with sorghum (McGregor and Mutchler, 1992). Data on the full suite of systems was necessary for predictive modeling (e.g., Universal Soil Loss Equation, USLE, Wischmeier and Smith, 1978; Revised Universal Soil Loss Equation, RUSLE, Renard et al., 1997) because of differing crop growth habits and amount of crop residue. As an example of the latter, McGregor et al. (1990) found that erosion rates from conventionally tilled soil increased in the order: wheat < corn < fallow residue. Results of Dabney et al. (2004) indicated that surface cover is equally important to holding erosion in check as the development of physicochemical conditions in NT soil that favor infiltration and oppose particle detachment and loading into runoff. Furthermore, development of these conditions is slow and crop-dependent (Rhoton, 2000). Thus, different and long-term studies were needed for better expression of soil biological, chemical, and physical changes under NT that affect soil and water conservation, and agronomic responses. An example of the latter is long-term yield data for soybean that showed steady yields from NT but decreasing yields from conventional tillage due to progressive erosion (McGregor et al., 2006). Long-term tillage and cover crop studies were begun throughout the Mid-South during this time to monitor time-dependent soil and agronomic changes (discussed below).



**Fig. 8–9. Reduced tillage soybeans. Beasley Lake Watershed, Sunflower County, Mississippi. Photo by Martin Locke, 2005, USDA-ARS.**

Given data from the Mid-South region and elsewhere showing that NT worked to reduce erosion and conserve soil (i.e., ~ an order of magnitude or more in better soil conservation), the first objective was to develop and demonstrate systems that matched economic yields of the status quo. Plots were also incubators for changes in soil properties that affect plant growth/yield, soil erosion and other parameters of water quality. Where runoff and erosion were monitored, it made sense to also measure tillage effects on losses of nutrients and other agrochemicals.

### Agronomic Studies

No-tillage has been generally successful with major crops of the Mid-South except rice and sugarcane (*Saccharum officinarum* L.), but it is more challenging with heavier textured soils (Triplett and Dick, 2008) and not always an initial success. As examples of the latter, initial yields of cotton were significantly reduced with NT on a silt loam in Mississippi, but the trend reversed after 2 yr (Dabney et al., 1995), particularly with wheat cover crop (Dabney, 1995; Triplett et al., 1996). Keisling (1993) found significantly reduced cotton yields with NT on a loessial soil in Arkansas, and later (Keisling et al., 1995) compared types of reduced-tillage systems for silt loam and clay soils. However, at least in some years there were no differences in cotton yields between CT and NT (Govindasamy et al., 1996). Pettigrew and Jones (2001) had similarly disappointing results for 2 yr of cotton in the Mississippi Delta.

In some cases, yields never suffered with conversion to conservation tillage. For example, Hutchinson and Shelton (1990) had no cotton yield loss with NT on a Louisiana loessial soil and up to 90% less erosion if combined with wheat cover crop (Hutchinson et al., 1991). These results were confirmed with longer-term cotton studies (Boquet et al., 2004a,b). Similarly, there was no difference between NT and CT sorghum with subsurface banded N fertilizer (Locke and Hons, 1988a). Bradley (1995) summarized cotton yields for studies in Tennessee that began in 1981, reporting no yield loss with NT. Having found no yield problem for cotton with NT, much of the work with NT focused on N (Howard et al., 2001c), P, or K (Howard et al., 1997, 1998, 2001a,b) fertilization, and lime requirements (Cochran et al., 2007). Unlike with cotton, however, placement affects N use efficiency in sorghum (Locke and Hons, 1988b) or corn (Howard and Tyler, 1989), particularly where lime is surface-applied (Howard and Essington, 1998).

Even on heavy-textured soil, NT has been shown to work. Boquet and Coco (1991) found no cotton yield reduction with no- or reduced-tillage on a clay soil in Louisiana and a yield advantage with hairy vetch cover crop regardless of tillage system (Boquet et al., 1995). Early data from Texas were mixed, with Morrison and Chichester (1994) finding no differences in corn, sorghum, or wheat yields between NT and CT, but Potter et al. (1996) reporting a yield reduction in corn but not sorghum with NT. Later, highest yields of corn on a Texas Blackland Prairie clay soil (Torbert et al., 2001) were obtained using NT and wide, raised beds (Morrison et al., 1990) at the highest N rate, 168 kg ha<sup>-1</sup>.

Rice floodwater discharge may degrade downstream water quality. Studies have shown that NT, particularly compared to the practice of tilling or leveling the soil surface under water to control red rice, greatly reduces the loss of suspended sediment (e.g., Feagley et al., 1991). However, yields are reduced and returns poorer (e.g., Pearce et al., 1999), leading to its limited use (Leon et al., 2008;

Snipes et al., 2005). No-tillage following rice harvest and retention of winter rainfall behind levees helps reduce overall soil loss, while increasing waterfowl habitat (Hite et al., 2003), but water quality in such ponds may be highly variable (Maul and Cooper, 2000).

For perennial sugarcane, tillage before planting, spring tillage, and burning of combine harvest residue are traditionally used for best yields; however, chemical control of weeds and old cane during fallow has been shown to be as effective as tillage (Etheredge et al., 2008). Yields with NT equaled those with spring tillage, and returns increased (Judice et al., 2006). No yield loss was observed when residue was swept off row tops rather than burned (Judice and Griffin, 2008).

### Effects on Soil Properties

With time, interrelated biological, chemical, and physical changes consistent with improved soil and water quality and conservation were expected to develop in conservation tillage soils. This was shown in numerous studies from the Mid-South (e.g., Rhoton, 1990). Perhaps the most evident change was an increase in SOC under NT (e.g., Dou and Hons, 2006; Franzluebbers et al., 1994, 1995; Locke et al., 2005; Potter et al., 1998; Potter and Chichester, 1993; Salinas-Garcia et al., 1997a,b; Wright et al., 2007a,b; Zablotowicz et al., 2000; Zibilske and Bradford, 2007). However, the effect was mostly limited to about the upper 5 cm of soil, although deeper with some rotations (Locke et al., 2005; Wright et al., 2007a,b; Zablotowicz et al., 2000). As expected, N content paralleled C content (Salinas-Garcia et al., 1997a,b; Wright and Hons, 2004, 2005; Wright et al., 2007a,b; Zibilske and Bradford, 2007). Microbial biomass C and N followed the same trends (Franzluebbers et al., 1994, 1995; Salinas-Garcia et al., 1997a,b). Together, these measures of soil quality showed that conservation tillage was beneficial. They have also led to physical conditions more favorable to water infiltration and retention (Wright and Hons, 2004; Wright and Hons, 2005; Zibilske and Bradford, 2007). The increase in organic C in the surface soil may also reduce free Al via complexation and increase solubility of K and Si, tending to alter mineralogical transformations in the surface soil (Karathanasis and Wells, 1989), which might further the nutrient stratification that develops under NT (Howard et al., 1999; Potter and Chichester, 1993).

### Effects on Water Quality

Early studies showed that reduced tillage, especially NT, lowered total runoff losses of N and P by decreasing soil erosion but increased the losses of these nutrients in dissolved form, especially P (McDowell and McGregor, 1984), the latter apparently a function of the mass of crop residue at the soil surface. Shelton and Mote (1989) reported a similar shift in nutrient loss with NT soybean to more bioavailable, dissolved forms. Chichester and Richardson (1992), however, found no greater loss of dissolved N or P from a NT clay soil on paired watersheds, but nearly 10 times lower loss of sorbed forms. Besides N and P, loss of C (as a substrate for microbial activity) affects water quality. Thus, the effect of tillage on runoff biological oxygen demand appears to be negligible (Schreiber and Neumaier, 1987), with reduced amount of particle-bound C under NT offset by increased dissolved forms. Similarly, Viator et al. (2008) found no season-long benefit of retaining, rather than burning, sugarcane residue on several measures of water quality, including biological oxygen demand. Regardless of uncertain effects on various water quality parameters, conservation tillage is successful for

its initial purpose, soil conservation and the resulting decrease in suspended solids in runoff (Fig. 8–10).

While much of the conservation research in the Mid-South has involved plot studies, in the past 20 yr, there has been increasing emphasis placed on field or watershed-scale evaluations. In the early 1990s, USDA established a network of studies in a project called the Management System Evaluation Areas (MSEA) to assess the effects of conservation practices on water quality at watershed scales. Early MSEA project research was in the Midwestern states, but the Mississippi Delta MSEA (MD-MSEA) project was established in 1994. Effects of conservation practices on water quality in three oxbow lake watersheds were evaluated for 10 yr (Nett et al., 2004; Zabolotowicz et al., 2006). In 2003, USDA-NRCS and USDA-ARS partnered, along with other state and federal organizations, to conduct watershed studies quantifying the effects of NRCS conservation practices. This ongoing national research effort was called the Conservation Effects Assessment Project (CEAP). Fourteen watersheds across the United States were selected to participate in the CEAP watershed assessment studies, and four of these were in the Mid-South (Beasley Lake, MS; Goodwin Creek, MS; Leon River, TX; and Little Toposhaw River, MS). Initial results from these watersheds have been reported (Harmel et al., 2008; Kuhnle et al., 2008; Locke et al., 2008b; Wilson et al., 2008; Yuan et al., 2008).



**Fig. 8–10.** Effects of vegetative buffers on water quality of runoff from fields in the Mississippi Delta: (a) low sediment in runoff from a field with a vegetative buffer; (b) significant sediment observed in runoff discharged from a plowed field with no vegetative buffer. Photo credits: (a) Wade Steinriede, 2005, USDA-ARS; (b) John Massey, 2009, USDA-ARS.



## **What are the Lessons from the Past? Where Are We Going in the Future?**

Efforts in the early 20th century to control soil erosion lacked national coordination and funding, although many farmers and scientists recognized the negative effects that popular farm practices had on soil productivity. However, realization that erosion was a problem with widespread ramifications that needed to be addressed at a national level did not occur until the disastrous effects of the Dust Bowl era. Legislation by Congress provided the impetus for a concerted and coordinated effort to conduct research to counter soil erosion. The erosion stations established in the Mid-South and elsewhere began to provide the database needed to give substance to conservation recommendations being made to farmers. Other legislation provided funding for the USDA to implement programs to promote soil conservation. Nationally, as well as in the Mid-South, federal and state experiment stations worked with the newly established USDA-SCS in the 1930s and 1940s to evaluate and promote conservation practices. These efforts continued throughout the remainder of the 20th century, and a proliferation of research was published throughout the Mid-South during this time.

Farming in the Mid-South underwent major transformations in the 20th century (Fig. 8–2, 8–3), and conservation methods adapted accordingly. Conservation tillage and renewed use of cover crops, together with edge-of-field controls for nonpoint source agricultural inputs, and enrollment in the CRP have improved soil and water conservation in the Mid-South. However, environmental concerns continue to persist at local and regional scales. While soil loss was the primary focus for the first half of the century, attention has also turned to the loss of agrichemicals in runoff and their effects of water quality and habitats. Furthermore, issues such as hypoxia in the Gulf of Mexico have rekindled the call for nationally coordinated efforts to promote soil conservation.

Where should future efforts in soil and water conservation in the Mid-South be directed? Advances in information technology enable better utilization of large databases and enhance model improvements. Remote sensing could be used to monitor agricultural effects on soil erosion and to develop databases describing soil conditions. At smaller field scales, modeling may aid design of precision fertilizer and pesticide programs by considering various scenarios for off-site transport. Improvement in climate models may provide better information to agricultural producers with decisions to perform operations affecting soil erosion and water quality. Improvements need to be made with field- and watershed-scale models to evaluate the integrated impact of practices on soil erosion, such as in evaluating the use of a combination of practices to control sheet and rill, gully, and channel erosion. Results from simulation modeling (e.g., AnnAGNPS; Yuan et al., 2002, 2008) suggest that certain combinations of conservation practices and their use at more vulnerable sites could improve overall soil and water conservation, reducing sediment loads by up to about 70%. Further refinement in watershed-scale modeling to account for hydrologic details missed in digital elevation models (DEMs), within source area spatial variability, etc. may lead to greater confidence and wider application of this approach. This may improve efforts to target vulnerable sites within a watershed and to ensure minimal site-specific impacts to the soil. At a much larger scale, systematic, detailed modeling

(and changes in practices based on results) may make progress toward mitigating more widespread problems, such as hypoxia in the Gulf of Mexico.

The retirement of highly erodible land into the CRP is effective in reducing erosion and improving soil and water quality (FAPRI, 2007), and in some cases even shifts the focus of water quality to channel erosion and its control (Kuhnle et al., 2008; Wilson et al., 2008). However, a significant portion of the remaining cropland in the Mid-South is still under conventional tillage management. Therefore, although there are direct and coordinated efforts for improved soil and water conservation, serendipity has and may continue to play an important role, and expansion of research is needed on emerging and innovative conservation practices that produce multiple benefits. Examples include genetically modified crops, environmentally friendly biofuel crops, and integrating wetlands into the agricultural landscape.

Widespread and heavy reliance on genetically modified crop cultivars leads to the interesting observation that technology introduced for better, cheaper, and more flexible weed control—herbicide-resistant crops—benefits soil and water conservation by facilitating adoption of conservation tillage (Cerdeira and Duke, 2006; Roberts et al., 2006; Locke et al., 2008a,b). Data from a long-term study on water quality in Mississippi oxbow lakes, for example, showed decreases in suspended sediment, nutrients, and pesticides that paralleled joint adoption of herbicide-resistant varieties and conservation tillage management (Zablotowicz et al., 2006; Locke et al., 2008a). However, it is uncertain what effects the emergence of herbicide-resistant weeds will have on this positive trend. Herbicide programs are being developed to address the problem (Gustafson, 2008). Further, long-term effects of herbicide-resistant crops on soil quality in conservation systems have not been adequately assessed (Locke et al., 2008b).

Crops such as corn and sugarcane that are currently promoted in the Mid-South for biofuel production require large management inputs such as fertilizer and irrigation that may be at odds with efforts to improve the environment. Second generation biofuel crops are needed that not only require less input, but also provide environmental benefits such as improved erosion control. There are many areas in the Mid-South where marginal land is used for row crop production. However, marginal lands are the consensus sites for growing switchgrass (*Panicum virgatum* L.), miscanthus (*Miscanthus × giganteus* J.M. Greff & Deuter ex Hodk. & Renvoize), or other perennial biofuel crops. Data for the performance of switchgrass (Meyer et al., 1995; Sanderson et al., 2001) and miscanthus (Cullum et al., 2007; McGregor et al., 1999a) in controlling erosion are positive. Thus, if these crops prove economically viable (Popp, 2007) and environmentally sound, conversion of substantial acreage in the Mid-South from tilled crops to non-tilled perennials may have an effect analogous to conversion to CRP.

Natural and constructed wetlands, widely used for hunting and fishing, provide valuable habitat for wildlife. Conservation practices such as buffers can be used to integrate wetlands into the agricultural landscape for sediment, pesticide, and nutrient trapping and processing (e.g., Moore et al., 2009). Vegetation in ditches draining agricultural areas can increase retention time of runoff with subsequent reduction in pollutant loss in outflow (Kröger et al., 2009). Retention ponds adjacent to agricultural fields might similarly be used (Dendy and Cooper, 1984; Cooper and Knight, 1990). Temporary wetlands might be created if drainage

outlets to fields were plugged during the fallow seasons to allow accumulation of field runoff.

In the last 20 yr, experimental plot studies for soil erosion have been reduced and concentrated to fewer experiment stations throughout the Mid-South. There is still a need for these smaller-scale studies as well as field- and watershed-scale studies such as CEAP to study the impact of loadings from soil and water conservation practices downstream. Coordinated and integrated plot studies need to be expanded to study emerging practices on the various soils and climatic zones throughout the region. Techniques need to be developed to track and identify the source of sediment loadings within watersheds to target the placement of appropriate practices.

A systematic approach to implementing practices that address and integrate soil, water, chemical, energy, and global climate change issues would provide effective economical and environmental conservation measures to address all these issues. Conservation research in the Mid-South should continue to adapt to changing needs and priorities. Based on past experience, local and national resources should be pooled to provide widely coordinated efforts that are still sensitive to more region-specific needs.

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### References

- Baird, R.W., and W.G. Knisel. 1971. Soil conservation practices and crop production in the blacklands of Texas. *Conserv. Res. Rep. 15*. USDA-ARS, U.S. Gov. Print. Office, Washington, DC.
- Bartholomew, R.P., D.G. Carter, W.C. Hulbert, and L.C. Kapp. 1939. Influence of rainfall, cropping, and cultural methods on soil and water losses. *Arkansas Agric. Exp. Stn. Bull. 380*. Univ. of Arkansas, Fayetteville.
- Bennett, H.H. 1921. *Soils and agriculture of the southern states*. MacMillan, New York.
- Bennett, H.H. 1927. What's new in agriculture. p. 591–593. *In 1927 Yearbook of agriculture*. U.S. Gov. Print. Office, Washington, DC.
- Bennett, H.H. 1931. Cultural changes in soils from the stand point of erosion. *J. Am. Soc. Agron.* 23:434–454.
- Bennett, H.H. 1939. *Soil conservation*. McGraw-Hill, New York.
- Bennett, H.H., and W.R. Chapline. 1928. Soil erosion: A national menace. *USDA Circ. 33*. U.S. Gov. Print Office, Washington, DC.
- Bennett, H.H., and W.C. Lowdermilk. 1938. General aspects of the soil-erosion problem. p. 581–607. *In 1938 Yearbook of agriculture: Soils and men*. U.S. Gov. Print. Office, Washington, DC.
- Bennett, H.H., R.T. Allen, J.V. Davis, and C.R. Watkins. 1919. *Soil survey of Shelby County Tennessee*. U.S. Gov. Print. Office, Washington, DC.
- Blevins, R.L., W.W. Frye, M.G. Waggoner, and D.D. Tyler. 1994. Residue management strategies for the Southeast. p. 63–76. *In J.L. Hatfield and B.A. Stewart (ed.) Crop residue management*. CRC Press, Boca Raton, FL.
- Boquet, D.J., G.A. Breitenbeck, and A.B. Coco. 1995. Cotton yield and growth responses to tillage intensity and cover crops. p. 39–44. *In M.R. McClelland et al. (ed.) Conservation tillage systems for cotton: A review of research and demonstration from across the Cotton Belt*. *Arkansas Agric. Exp. Stn. Spec. Rep. 169*. Univ. of Arkansas, Fayetteville.
- Boquet, D.J., and A.B. Coco. 1991. Tillage and cover crop systems for cotton on clay soil. *Louisiana Agric.* 30:23–24.
- Boquet, D.J., R.L. Hutchinson, and G.A. Breitenbeck. 2004a. Long-term tillage, cover crop, and nitrogen effects on cotton: Yield and fiber properties. *Agron. J.* 96:1436–1442.
- Boquet, D.J., R.L. Hutchinson, and G.A. Breitenbeck. 2004b. Long-term tillage, cover crop, and nitrogen effects on cotton: Plant growth and yield components. *Agron. J.* 96:1443–1452.

- Boquet, D.J., and D.M. Walker. 1984. Wheat-soybean doublecropping: Stubble management, row spacing and irrigation. *Louisiana Agric. Exp. Stn. Bull.* 760. Louisiana State Univ., Baton Rouge.
- Boquet, D.J., D.M. Walker, J.L. Bartleson, and R.L. Hutchinson. 1982. Adapting wheat-soybean double-cropping to Louisiana. *Louisiana Agric.* 26:20-21.
- Bradley, J.F. 1995. Success with no-till cotton. p. 46-48. *In* M.R. McClelland et al. (ed.) Conservation tillage systems for cotton: A review of research and demonstration from across the Cotton Belt. *Arkansas Agric. Exp. Stn. Spec. Rep.* 169. Univ. of Arkansas, Fayetteville.
- Brown, H.B. 1945. Effect of certain summer and winter legume crops in improving corn yield in South Louisiana. *Louisiana Bull.* 396. Louisiana State Univ., Baton Rouge.
- Carpenter, J.W., and E.R. Gross. 1918. The terrace in Mississippi. *Ext. Dep. Mississippi Agric. Mech. Coll. Ext. Bull.* 9. Mississippi Agric. Mech. College, Mississippi State.
- Carter, W.T. 1931. The soils of Texas. *Texas Agric. Exp. Stn. Bull.* 431. Texas Agric. Mech. College, College Station.
- Cerdeira, A.L., and S.O. Duke. 2006. The current status and environmental impacts of glyphosate-resistant crops: A review. *J. Environ. Qual.* 35:1633-1658.
- Chichester, F.W., and C.W. Richardson. 1992. Sediment and nutrient loss from clay soils as affected by tillage. *J. Environ. Qual.* 21:587-590.
- Cochran, R.L., R.K. Roberts, J.A. Larson, and D.D. Tyler. 2007. Cotton profitability with alternative lime application rates, cover crops, nitrogen rates, and tillage methods. *Agron. J.* 99:1085-1092.
- Cooper, C.M., and S.S. Knight. 1990. Nutrient trapping efficiency of a small sediment detention reservoir. *Agric. Water Manage.* 18:149-158.
- Cullum, R.F., K.C. McGregor, C.K. Mutchler, J.R. Johnson, and D.L. Boykin. 2002. Soybean yield response to tillage, fragipan depth, and slope length. *Trans. ASAE* 43:563-571.
- Cullum, R.F., G.V. Wilson, K.C. McGregor, and J.R. Johnson. 2007. Runoff and soil loss from ultra-narrow row cotton plots with and without stiff-grass hedges. *Soil Tillage Res.* 93:56-63.
- Dabney, S.M. 1995. Cover crops in reduced tillage systems. p. 58-60. *In* M.R. McClelland et al. (ed.) Conservation tillage systems for cotton: A review of research and demonstration from across the Cotton Belt. *Arkansas Agric. Exp. Stn. Spec. Rep.* 169. Univ. of Arkansas, Fayetteville.
- Dabney, S.M., L.D. Meyer, W.C. Harmon, C.V. Alonso, and G.R. Foster. 1995. Depositional patterns of sediment trapped by grass hedges. *Trans. ASAE* 38:1719-1729.
- Dabney, S.M., C.E. Murphee, G.B. Triplett, E.H. Grissinger, L.D. Meyer, L.R. Reinschmied, F.E. Rhoton, and W.M. Lipe. 1995. No-till cotton production on silty uplands. p. 49-52. *In* M.R. McClelland et al. (ed.) Conservation tillage systems for cotton: A review of research and demonstration from across the Cotton Belt. *Arkansas Agric. Exp. Stn. Spec. Rep.* 169. Univ. of Arkansas, Fayetteville.
- Dabney, S.M., G.V. Wilson, K.C. McGregor, and G.R. Foster. 2004. History, residue, and tillage effects on erosion of loessial soil. *Trans. ASAE* 47:767-775.
- Dana, S.T. 1916. Farms, forest, and erosion. p. 107-134. *In* 1916 Yearbook of agriculture, What's new in agriculture. U.S. Gov. Print. Office, Washington, DC.
- Davis, F.L., C.G. Hobgood, and C.A. Brewer, Jr. 1940. Growing legumes in Louisiana. *Louisiana Bull.* 318. Louisiana State Univ. Agric. Exp. Stn., Baton Rouge.
- Davis, R.O.E. 1913. Economic waste from soil erosion. p. 207-220. *In* 1913 yearbook of agriculture. U.S. Gov. Print. Office, Washington, DC.
- Dendy, F.E. 1981. Sediment yield from a Mississippi Delta cotton field. *J. Environ. Qual.* 10:482-486.
- Dendy, F.E., and C.M. Cooper. 1984. Sediment trap efficiency in a small reservoir. *J. Soil Water Conserv.* 39:278-280.
- Denton, H.P., and D.D. Tyler. 2002. Making no-till "conventional" in Tennessee. p. 53-58. *In* E. van Santen (ed.) Making conservation tillage conventional: Building a future on 25 years of research. *Proc. 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture*, Auburn, AL. Alabama Agric. Exp. Stn., Auburn University, AL.
- Dou, F., and F.M. Hons. 2006. Tillage and nitrogen effects on soil organic matter fractions in wheat-based systems. *Soil Sci. Soc. Am. J.* 70:1896-1905.
- Enlow, C.R., and G.W. Musgrave. 1938. Grass and other thick growing vegetation in erosion control. p. 615-633. *In* Yearbook of agriculture: Soils and men. U.S. Gov. Print. Office, Washington, DC.
- Etheredge, L.M., Jr., J.L. Griffin, and M.E. Salassi. 2008. Alternatives to tillage/herbicide programs in fallowed sugarcane field. *Louisiana Agric.* 51:30-32.

- FAPRI. 2007. Estimating water quality, air quality, and soil carbon benefits of the Conservation Reserve Program. FAPRI-UMC Report 01-07. Available at [www.fapri.missouri.edu/outreach/publications/2007/FAPRI\\_UMC\\_Report\\_01\\_07.pdf](http://www.fapri.missouri.edu/outreach/publications/2007/FAPRI_UMC_Report_01_07.pdf) (verified 14 Dec. 2009). Food and Agriculture Policy Research Institute (FAPRI), University of Missouri, Columbia.
- Feagley, S.E., G.C. Sigua, R.L. Bengtson, P.K. Bollich, and S.D. Linscombe. 1991. Effects of different management practices on surface water quality from rice fields in south Louisiana. *J. Plant Nutr.* 15:1305–1321.
- Fenneman, N.M. 1938. *Physiography of the eastern United States*. McGraw-Hill, New York.
- Fite, G.C. 1984. Cotton fields no more: Southern agriculture 1865–1980. The Univ. Press of Kentucky, Lexington.
- Fox, J.W. 1907. Report of work at the Delta Station for 1907–08. *Mississippi Agric. Exp. Stn. Bull.* 129. Mississippi Agric. Mech. College, Mississippi State.
- Franzluubbers, A.J., F.M. Hons, and D.A. Zuberer. 1994. Long-term changes in soil carbon and nitrogen pools in wheat management systems. *Soil Sci. Soc. Am. J.* 58:1639–1645.
- Franzluubbers, A.J., F.M. Hons, and D.A. Zuberer. 1995. Soil organic carbon, microbial biomass, and mineralizable carbon and nitrogen in sorghum. *Soil Sci. Soc. Am. J.* 59:460–466.
- Fraps, G.S., and J.F. Fudge. 1937. Chemical composition of soils of Texas. *Texas Agric. Exp. Stn. Bull.* 549. Texas Agric. Mech. College, College Station.
- Garin, A.N., and L.P. Gabbard. 1941. Land use in relation to sedimentation in reservoirs, Trinity River Basin, Texas. *Texas Agric. Exp. Stn. Bull.* 597. Texas Agric. Mech. College, College Station.
- Gerik, T.J., and J.E. Morrison, Jr. 1984. No-tillage of grain sorghum on a shrinking clay soil. *Agron. J.* 76:71–76.
- Goddard, R., and C.F. Lard. 1965. No cultivation vs. limited cultivation of cotton. *Tenn. Farm Home Sci. Progress Rep.* 53. Univ. Tennessee Agric. Exp. Stn., Knoxville.
- Godfrey, C.L., C.R. Carter, and G.S. McKee. 1968. Land resource areas of Texas. *Texas Agric. Exp. Stn. Bull.* B-1070. Texas Agric. Ext., College Station.
- Govindasamy, R., M.J. Cochran, J. Sharma, M. McClelland, and C. Smith. 1996. Conventional tillage vs. conservation tillage in cotton: An economic analysis. p. 4–12. *In* M. McClelland and T. Keisling (ed.) *Conservation technology in Arkansas agriculture*. Arkansas Agric. Exp. Stn. Research Ser. 449. Univ. Arkansas, Fayetteville.
- Graves, C.R., T. McCutchen, L.S. Jeffrey, J.R. Overton, and R.M. Hayes. 1980. Soybean–wheat cropping systems: Evaluation of planting methods, varieties, row spacing, and weed control. *Bull.* 597. Univ. Tennessee Agric. Exp. Stn., Knoxville.
- Griffin, J.L., R.W. Taylor, and R.J. Habetz. 1983. Conservation tillage for double-cropped soybeans in southwest Louisiana. *J. Soil Water Conserv.* 39:78–80.
- Grissom, P.H. 1950. Soil fertility practices for cotton production in the Yazoo-Mississippi Delta. *Mississippi Agric. Exp. Stn. Bull.* 473. Mississippi State Univ., Mississippi State.
- Grissom, P.H. 1957. The Mississippi Delta Region. p. 524–531. *In* 1957 Yearbook of agriculture: Soil. U.S. Gov. Print. Office, Washington, DC.
- Gustafson, D.I. 2008. Sustainable use of glyphosate in North American cropping systems. *Pest Manage. Sci.* 64:409–416.
- Haddon, C.B. 1953. Experiments with legumes at the Northeast Louisiana Experiment Stn. *Louisiana Bull.* 477. Louisiana State Univ., Baton Rouge.
- Hairston, J.E., J.O. Sanford, J.C. Hayes, and L.L. Reinschmiedt. 1984. Crop yield, soil erosion, and net returns from five tillage systems in the Mississippi Blackland Prairie. *J. Soil Water Conserv.* 39:391–395.
- Hambridge, G. 1938. Soils and men—A summary. p. 1–44. *In* 1938 Yearbook of agriculture: Soils and men. U.S. Gov. Print. Office, Washington, DC.
- Harmel, R.D., J.V. Bonta, and C.W. Richardson. 2007. The original USDA-ARS experimental watersheds in Texas and Ohio: Contributions from the past and visions for the future. *Trans. ASABE* 50:1669–1675.
- Harmel, R.D., C.W. Richardson, K.W. King, and P.M. Allen. 2006. Runoff and soil loss relationships for the Texas Blackland Prairies ecoregion. *J. Hydrol.* 331:471–483.
- Harmel, R.D., C.G. Rossi, T. Dybala, J. Arnold, K. Potter, J. Wolfe, and D. Hoffman. 2008. Conservation Effects Assessment Project research in the Leon River and Riesel watersheds. *J. Soil Water Conserv.* 63:453–460.
- Harris, V.C. 1964. Production of cotton without postemergence cultivation or hand hoeing. 1964. Mississippi State Univ. Agric. Exp. Stn. Bull. 685. Mississippi State Univ., Mississippi State.

- Helms, D. 2009. Hugh Hammond Bennett and the creation of the Soil Erosion Service. *J. Soil Water Conserv.* 64:68A–74A.
- Hinkle, D.A. 1975. Use of no-tillage in double-cropping wheat with soybean or grain sorghum. Rep. 223. Univ. Arkansas Agric. Exp. Stn., Univ. Arkansas, Fayetteville.
- Hite, D., W. Intarapapong, F. Kari, and T. Maupin. 2003. Economic and environmental benefits of rice production in the Mississippi Delta. *Mississippi Agric. Forest. Exp. Stn. Bull.* 1122.
- Hobbs, F., and N. Stoops. 2002. Demographic trends in the 20th century. *Census 2000 Spec. Reports*. U.S. Census Bureau, Washington, DC.
- Howard, D.D. 1987. Nitrogen fertilization effects on grain sorghum in conventional and no-till systems. *Tenn. Farm Home Sci.* 141:3–5.
- Howard, D.D., and M.E. Essington. 1998. Effects of surface-applied limestone on the efficiency of urea-containing nitrogen sources for no-till corn. *Agron. J.* 90:523–528.
- Howard, D.D., M.E. Essington, R.M. Hayes, and W.M. Percell. 2001a. Potassium fertilization of conventional- and no-till cotton. *J. Cotton Sci.* 5:197–205.
- Howard, D.D., M.E. Essington, J. Logan, R.K. Roberts, and W.M. Percell. 2001b. Phosphorus and potassium fertilization of disk-till and no-till cotton. *J. Cotton Sci.* 5:144–155.
- Howard, D.D., M.E. Essington, and D.D. Tyler. 1999. Vertical phosphorus and potassium stratification in no-till cotton soils. *Agron. J.* 91:266–269.
- Howard, D.D., C.O. Gwathmey, M.E. Essington, R.K. Roberts, and M.D. Mullen. 2001c. Nitrogen fertilization of no-till cotton on loess-derived soils. *Agron. J.* 93:157–163.
- Howard, D.D., C.O. Gwathmey, R.K. Roberts, and G.M. Lessman. 1997. Potassium fertilization of cotton on two high testing soils under two tillage systems. *J. Plant Nutr.* 20:1645–1656.
- Howard, D.D., C.O. Gwathmey, R.K. Roberts, and G.M. Lessman. 1998. Potassium fertilization of cotton produced on a low K soil with contrasting tillage systems. *J. Prod. Agric.* 11:74–79.
- Howard, D.D., and D.D. Tyler. 1989. Nitrogen source, rate, and application method for no-tillage corn. *Soil Sci. Soc. Am. J.* 53:1573–1577.
- Hutchinson, R.L., R.C. Aycok, G.P. Boquet, S.M. Cruse, P.A. Miletello, C.L. Pinnell-Alison, R.L. Rogers, and W.W. Russell. 1991. An evaluation of conservation tillage systems for cotton on the Macon Ridge. Louisiana Coop. Ext. Ser. Publ. 2460. Louisiana State Univ., Baton Rouge.
- Hutchinson, R.L., and W.L. Shelton. 1990. Alternative tillage systems and cover crops for cotton production on the Macon Ridge. *Louisiana Agric.* 33:6–8.
- Jenny, H. 1941. *Factors of soil formation*. McGraw-Hill Co., New York.
- Judge, W.E., and J.L. Griffin. 2008. To burn or not to burn—Sugarcane crop residue management. *Louisiana Agric.* 51:37–38.
- Judge, W.E., J.L. Griffin, C.A. Jones, L.M. Etheredge, Jr., and M.E. Salassi. 2006. Weed control and economics using reduced tillage programs in sugarcane. *Weed Technol.* 20:319–325.
- Karathanasis, A.D., and K.L. Wells. 1989. A comparison of mineral weathering trends between two management systems on a catena of loess-derived soils. *Soil Sci. Soc. Am. J.* 53:582–588.
- Keisling, T.C. 1993. Reduced tillage for cotton production in Arkansas. p. 18–23. *In* M. McClelland et al. (ed.) *Conservation technology in Arkansas agriculture 1992*. Arkansas Agric. Exp. Stn. Research Series 432. Univ. of Arkansas, Fayetteville.
- Keisling, T.C., R.F. Ford, and H.D. Scott. 1995. Tillage systems for cotton on Mississippi Delta and Loessial Plains soils. *Commun. Soil Sci. Plant Anal.* 26:441–452.
- Keisling, T.C., H.D. Scott, B.A. Waddle, W. Williams, and R.E. Frans. 1994. Winter cover crops influence on cotton yield and selected soil properties. *Commun. Soil Sci. Plant Anal.* 25:3087–3100.
- Kell, W. 1938. Strip cropping. p. 634–645. *In* *Yearbook of Agriculture: Soils and men*. U.S. Gov. Print. Office, Washington, DC.
- Kröger, R., M.T. Moore, M.A. Locke, R.F. Cullum, R.W. Steinriede, S. Testa, C.T. Bryant, and C.M. Cooper. 2009. Evaluating the influence of wetland vegetation on chemical residence time in Mississippi Delta drainage ditches. *Agric. Water Manage.* 96:1175–1179.
- Krusekopf, H.H. 1962. Major soil areas of Missouri. *Univ. Missouri Agric. Exp. Stn. Bull.* B785. University of Missouri, Columbia.
- Kuhnle, R.A., R.L. Bingner, C.V. Alonso, C.G. Wilson, and A. Simon. 2008. Conservation practice effects on sediment load in the Goodwin Creek Experimental Watershed. *J. Soil Water Conserv.* 63:496–503.
- Lentz, G.H., J.D. Sinclair, and H.G. Meginnis. 1929. Erosion report. Lafayette Co., Mississippi. USDA Forest Service, Southern Exp. Stn., New Orleans, LA.

- Leon, C.T., E.P. Webster, S.L. Bottoms, and D.C. Blouin. 2008. Water management and chemical control of red rice (*Oryza punctata*) in water-seeded imidazolinone-resistant rice. *Weed Technol.* 22:132-135.
- Locke, M.A., and F.M. Hons. 1988a. Fertilizer placement effects on seasonal nitrogen accumulation and yield of no-tillage and conventional tillage sorghum. *Agron. J.* 80:180-185.
- Locke, M.A., and F.M. Hons. 1988b. Tillage effect on seasonal nitrogen accumulation of labeled fertilizer nitrogen in sorghum. *Crop Sci.* 28:694-700.
- Locke, M.A., S.S. Knight, S. Smith, Jr., R.F. Cullum, R.M. Zablutowicz, Y. Yuan, and R.L. Bingner. 2008a. Environmental quality research in the Beasley Lake watershed, 1995 to 2007: Succession from conventional to conservation practices. *J. Soil Water Conserv.* 63:430-442.
- Locke, M.A., K.N. Reddy, and R.M. Zablutowicz. 2008b. Integrating soil conservation practices and glyphosate-resistant crops: Impacts on soil. *Pest Manage. Sci.* 64:457-469.
- Locke, M.A., R.M. Zablutowicz, P.J. Bauer, R.W. Steinriede, and L.A. Gaston. 2005. Conservation cotton production in the southern United States: Herbicide dissipation in soil and cover crops. *Weed Sci.* 53:717-727.
- Logan, W.N. 1916. The soils of Mississippi. *Mississippi Agric. Exp. Stn. Tech. Bull.* 7. Mississippi Agric. Mech. College, Mississippi State.
- Long, O.H., and J.R. Overton. 1963. Button clover as a green manure crop for cotton. *Univ. Tennessee Agric. Exp. Stn. Bull.* 370. Univ. Tennessee, Knoxville.
- Lovell, S.T., and W.C. Sullivan. 2006. Environmental benefits of conservation buffers in the United States: Evidence, promise, and open questions. *Agric. Ecosyst. Environ.* 112:249-260.
- Maddox, R.S. 1915. West Tennessee gullied lands and their reclamation. *Resour. Tennessee* 5:8-22.
- Maul, J.D., and C.M. Cooper. 2000. Water quality of seasonally flooded agricultural fields in Mississippi, USA. *Agric. Ecosyst. Environ.* 81:171-178.
- McDonald, A. 1941. Early American soil conservationists. *USDA-SCS Misc. Publ.* 449. U.S. Gov. Print. Office, Washington, DC.
- McDowell, L.L., and K.C. McGregor. 1984. Plant nutrient losses in runoff from conservation tillage corn. *Soil Tillage Res.* 4:79-91.
- McGinnis, H.G. 1933. Using soil-binding plants to reclaim gullies in the South. *USDA Farmers Bull.* 1697. U.S. Gov. Print. Office, Washington, DC.
- McGregor, K.C., R.F. Cullum, C.K. Mutchler, and J.R. Johnson. 2006. Long-term no-till and conventional-till soybean yields. *Mississippi Agric. Forest. Exp. Stn. Bull.* 1146.
- McGregor, K.C., S.M. Dabney, and J.R. Johnson. 1999a. Runoff and soil loss from cotton plots with and without stiff-grass hedges. *Trans. ASAE* 42:361-368.
- McGregor, K.C., and J.D. Greer. 1982. Erosion control with no-till and reduced-till corn for silage and grain. *Trans. ASAE* 25:154-159.
- McGregor, K.C., J.D. Greer, and G.E. Gurley. 1975. Erosion control with no-till cropping practices. *Trans. ASAE* 18:918-920.
- McGregor, K.C., and C.K. Mutchler. 1983. C-factors for no-till and reduced-till corn. *Trans. ASAE* 26:785-788, 794.
- McGregor, K.C., and C.K. Mutchler. 1992. Soil loss from conservation tillage for sorghum. *Trans. ASAE* 35:1841-1845.
- McGregor, K.C., C.K. Mutchler, and R.F. Cullum. 1992. Soil erosion effects on soybean yields. *Trans. ASAE* 35:1521-1525.
- McGregor, K.C., C.K. Mutchler, and R.F. Cullum. 1999b. Long-term management effects on runoff, erosion, and crop production. *Trans. ASAE* 42:99-105.
- McGregor, K.C., C.K. Mutchler, J.R. Johnson, and D.E. Pogue. 1996. USDA and MAFES cooperative soil conservation studies at Holly Springs, 1956-1996. *Mississippi Agric. Forest. Exp. Stn. Bull.* 1044.
- McGregor, K.C., C.K. Mutchler, and M.J.M. Romkens. 1990. Effects of tillage with different crop residues on runoff and soil loss. *Trans. ASAE* 33:1551-1556.
- Melville, D.R. and J.L. Rabb. 1976. Studies with no-till soybean production. *Louisiana Agric.* 20:3, 16.
- Meyer, L.D., S.M. Dabney, and W.C. Harmon. 1995. Sediment-trapping effectiveness of stiff-grass hedges. *Trans. ASAE* 38:809-815.
- Millhollon, E.P., and D.R. Melville. 1991. The long-term effects of winter cover crops on cotton production in northwest Louisiana. *Louisiana Agric. Exp. Stn. Bull.* 830. Louisiana State Univ., Baton Rouge.

- Minnesota Population Center. 2004. National Historical Geographic Information System: Pre-release Version 0.1. Available at <http://www.nhgis.org> (verified 5 Jan. 2010). Univ. of Minnesota, Minneapolis.
- Mississippi Agricultural Experiment Station. 1934. A compilation of experimental and other data on winter legumes. Mississippi Agric. Exp. Stn. Bull. 303. Mississippi Agric. Mech. College, Mississippi State.
- Mooers, C.A. 1944. Depth and method of soil preparation and cultivation for corn and cotton. Univ. Tennessee Agric. Exp. Stn. Bull. 191. Univ. Tennessee, Knoxville.
- Mooers, C.A., and B.P. Hazelwood. 1945. Sericea as a soil-improving crop for corn. Univ. Tennessee Agric. Exp. Stn. Bull. 197. Univ. Tennessee, Knoxville.
- Moore, C.A. 1916. The soils of Tennessee. Resour. Tennessee 5:154-173.
- Moore, M.T., C.M. Cooper, S. Smith, Jr., R.F. Cullum, S.S. Knight, M.A. Locke, and E.R. Bennett. 2009. Mitigation of two pyrethroid insecticides in a Mississippi Delta constructed wetland. Environ. Pollut. 157:250-256.
- Morrison, J.E., Jr., and F.W. Chichester. 1994. Tillage system effects on soil and plant nutrient distributions on vertisols. J. Prod. Agric. 7:364-373.
- Morrison, J.E., T.J. Gerik, R.W. Chichester, J.R. Martin, and J.M. Chandler. 1990. A no-tillage farming system for clay soils. J. Prod. Agric. 3:219-227.
- Murphree, C.E., and K.C. McGregor. 1991. Runoff and sediment yields from a flatland watershed in soybeans. Trans. ASAE 34:407-411.
- Mutchler, C.K., and J.D. Greer. 1984. Reduced tillage for soybeans. Trans. ASAE 27:1365-1369.
- Mutchler, C.K., and L.L. McDowell. 1990. Soil loss from cotton with winter cover crops. Trans. ASAE 33:432-436.
- Mutchler, C.K., L.L. McDowell, and J.D. Greer. 1985. Soil loss from cotton with conservation tillage. Trans. ASAE 28:160-163, 168.
- Nelson, M. 1944. Effect of the use of winter legumes on yields of cotton, corn, and rice. Arkansas Exp. Stn., Bull. 451. Univ. Arkansas, Fayetteville.
- Nelson, M., W.H. Sachs, and R.H. Austin. 1923. The soils of Arkansas. Arkansas Agric. Exp. Stn. Bull. 187. Univ. Arkansas, Fayetteville.
- Nett, M.T., M.A. Locke, and D.A. Pennington (ed.) 2004. Water quality assessments in the Mississippi Delta: Regional solutions, national scope. ACS Symp. Ser. 877. American Chemical Society, Washington, DC.
- Nichols, M.L., and T.B. Chambers. 1938. Mechanical measures of erosion control. p. 646-665. In Yearbook of Agriculture: Soils and men. U.S. Gov. Print. Office, Washington, DC.
- O'Brien, R.E., and D.W. Skelton. 1946. The production and utilization of kudzu. Mississippi Agric. Exp. Stn. Bull. 438. Mississippi State Univ., Mississippi State.
- Offutt, M.S. 1970. Winter legume trials in Arkansas, 1959 to 1967. Univ. Arkansas Agric. Exp. Stn. Bull. 755. Univ. Arkansas, Fayetteville.
- Patrick, W.H., Jr., C.B. Haddon, and J.A. Hendrix. 1957. The effect of longtime use of winter cover crops on certain physical properties of Commerce Loam. Soil Sci. Soc. Am. Proc. 21:366-368.
- Pearce, A.D., C.R. Dillion, T.C. Keisling, and C.E. Wilson, Jr. 1999. Economic and agronomic effects of four tillage practices on rice produced on saline soils. J. Prod. Agric. 12:305-312.
- Pearson, R.W., and L.E. Ensminger. 1957. Southeastern Uplands. p. 578-594. In 1957 Yearbook of agriculture: Soil. U.S. Gov. Print. Office, Washington, DC.
- Pettigrew, W.T., and M.A. Jones. 2001. Cotton growth under no-till production in the lower Mississippi River Valley alluvial flood plain. Agron. J. 93:1398-1404.
- Phillips, R.E. 1968. Minimum seedbed preparation for cotton. Agron. J. 60:437-441.
- Popp, M.P. 2007. Assessment of alternative fuel production from switchgrass: An example from Arkansas. J. Agric. Appl. Econ. 39:373-380.
- Potter, K.N., and F.W. Chichester. 1993. Physical and chemical properties of a vertisol with continuous controlled-traffic, no-till management. Trans. ASAE 36:95-99.
- Potter, K.N., J.E. Morrison, Jr., and H.A. Torbert. 1996. Tillage intensity effects on corn and grain sorghum growth and productivity on a Vertisol. J. Prod. Agric. 9:385-390.
- Potter, K.N., H.A. Torbert, O.R. Jones, J.E. Matocha, J.E. Morrison, Jr., and P.W. Unger. 1998. Distribution and amount of soil organic C in long-term management systems in Texas. Soil Tillage Res. 47:309-321.

- Rabalais, N.N., R.E. Turner, D. Justic, Q. Dortch, W.J. Wiseman, Jr., and B.K. Sen Gupta. 1996. Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf. *Estuaries* 19(2B):386–407.
- Rabb, J.L., and D.R. Melville. 1984. Double cropping soybeans and wheat in northwest Louisiana. *J. Soil Water Conserv.* 39:77–78.
- Ramser, C.E. 1929. The prevention of the erosion of farm lands by terracing. *J. Am. Soc. Agron.* 21:430–432.
- Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). *Agric. Handb.* 703. USDA-ARS, U.S. Gov. Print. Office, Washington, DC.
- Reynolds, E.B., P.R. Johnson, and H.F. Morris. 1950. Hairy vetch, bur clover, and oats as soil-building crops for cotton and corn in Texas. *Texas Agric. Exp. Stn. Bull.* 731. Texas Agric. Mech. Univ., College Station.
- Reynolds, E.B., H.E. Rea, E. Whiteley, P.A. Rich, and J.E. Roberts. 1958. Legumes for soil improvement for cotton and corn. *Texas Agric. Exp. Stn. Bull.* 901. Texas Agric. Mech. Univ., College Station.
- Rhoton, F.E. 1990. Soybean yield response to various depths of erosion on a fragipan soil. *Trans. ASAE* 54:1073–1079.
- Rhoton, F.E. 2000. Influence of time on soil response to no-till practices. *Soil Sci. Soc. Am. J.* 64:700–709.
- Rhoton, F.E., M.J. Shipitalo, and D.L. Lindbo. 2002. Runoff and soil loss from midwestern and southeastern U.S. silt loam soils as affected by tillage practice and soil organic matter content. *Soil Tillage Res.* 66:1–11.
- Rhoton, F.E., and D.D. Tyler. 1990. Erosion-induced changes in the properties of a fragipan soil. *Soil Sci. Soc. Am. J.* 54:223–228.
- Roberts, R.K., B.C. English, Q. Gao, and J.A. Larson. 2006. Simultaneous adoption of herbicide-resistant and conservation-tillage cotton technologies. *J. Agric. Appl. Econ.* 38:629–643.
- Salinas-Garcia, J.R., F.M. Hons, and J.E. Matocha. 1997a. Long-term effects of tillage and fertilization on soil organic matter dynamics. *Soil Sci. Soc. Am. J.* 61:152–159.
- Salinas-Garcia, J.R., F.M. Hons, J.E. Matocha, and D.A. Zuberer. 1997b. Soil carbon and nitrogen dynamics as affected by long-term tillage and nitrogen fertilization. *Biol. Fert. Soils* 25:182–188.
- Sanderson, M.A., R.M. Jones, M.J. McFarland, J. Stroup, R.L. Reed, and J.P. Muir. 2001. Nutrient movement and removal in a switchgrass biomass-filter strip treated with dairy manure. *J. Environ. Qual.* 30:210–216.
- Schreiber, J.D., and E.E. Neumaier. 1987. Biochemical oxygen demand of agricultural runoff. *J. Environ. Qual.* 16:6–10.
- Scott, H.D., T.C. Keisling, B.A. Waddle, R.W. Williams, and R.E. Frans. 1990. Effects of winter cover crops on yield of cotton and soil properties. *Arkansas Agric. Exp. Stn. Bull.* 324. Univ. Arkansas, Fayetteville.
- Sewell, M.C. 1919. Tillage: A review of the literature. *J. Am. Soc. Agron.* 11:269–290.
- Shelton, C.H., and J.F. Bradley. 1987. Controlling erosion and sustaining production with no-till systems. *Tenn. Farm Home Sci.* 141:18–23.
- Shelton, C.H., and C.R. Mote. 1989. Soil erosion and related water quality. *Tenn. Farm Home Sci.* 152:26–31.
- Shelton, C.H., F.D. Tompkins, and D.D. Tyler. 1982. Soil erosion from five soybean tillage systems in west Tennessee. *Tenn. Farm Home Sci.* 122:14–18.
- Shelton, C.H., F.D. Tompkins, and D.D. Tyler. 1983. Soil erosion from five soybean tillage systems. *J. Soil Water Conserv.* 38:425–428.
- Smith, R.M., R.C. Henderson, and O.J. Tippit. 1954. Summary of soil and water conservation research from the Blackland Experiment Station, Temple, Texas 1942–53. *Texas Agric. Exp. Stn. Bull.* 781. Texas Agric. Mech. Univ., College Station.
- Snipes, C.E., S.P. Nichols, D.H. Poston, T.W. Walker, L.P. Evans, and H.R. Robinson. 2005. Current agricultural practices of the Mississippi Delta. *Mississippi Agric. Forestry Exp. Stn. Bull.* 1143. Mississippi State Univ., Mississippi State.
- Soil Survey Staff. 1999. Soil taxonomy, a basic system of classification for making and interpreting soil surveys. 2nd ed. USDA-NRCS *Agric. Handb.* 436. U.S. Gov. Print. Office, Washington, DC.
- Southern Regional Soil Research Committee. 1959. Certain properties of southeastern United States soils and mineralogical procedures for their study. *Southern Regional Bull.* 61.

- Cooperative Regional Research Project S-14. Virginia Agric. Exp. Stn., Virginia Polytech. Inst., Blacksburg.
- Southwick, L.M., B.C. Grigg, T.S. Kornecki, and J.L. Fouss. 2002. Potential influence of sugarcane cultivation on estuarine water quality of Louisiana's Gulf coast. *J. Agric. Food Chem.* 50:4393–4399.
- Springer, M.E., and J.A. Elder. 1980. Soils of Tennessee. Univ. Tennessee Agric. Exp. Stn. Bull. 596. Univ. Tennessee, Knoxville.
- Torbert, H.A., K.N. Potter, and J.E. Morrison, Jr. 2001. Tillage system, fertilizer nitrogen rate, and timing effect on corn yields in the Texas Blackland Prairie. *Agron. J.* 93:1119–1124.
- Triplett, G.B., S.M. Dabney, and J.H. Siefker. 1996. Tillage systems for cotton on silty upland soils. *Agron. J.* 88:507–512.
- Triplett, G.B., Jr., and W.A. Dick. 2008. No-tillage crop production: A revolution in agriculture. *Agron. J.* 100:5153–5165.
- Tyler, D.D., and J.R. Overton. 1982. No-tillage advantages for soybean seed quality during drought stress. *Agron. J.* 74:344–347.
- Tyler, D.D., M.G. Waggoner, D.V. McCracken, and W.L. Hargrove. 1994. Role of conservation tillage in sustainable agriculture in the southern United States. p. 209–229. *In* M.R. Carter (ed.) Conservation tillage in temperate agroecosystems. CRC Press, Boca Raton, FL.
- University of Tennessee. 1915. Twenty-seventh annual report of the agricultural experiment station of the University of Tennessee for 1914. Univ. Tennessee, Knoxville.
- University of Virginia, Geospatial and Statistical Data Center. 2004. Historical Census Browser. Available at <http://fisher.lib.virginia.edu/collections/stats/histcensus/index.html>. (verified 5 Jan. 2010).
- U.S. Census Bureau. 1900. Census of population and housing: 1900 Census. Available at [www.census.gov/prod/www/abs/decennial/1900.htm](http://www.census.gov/prod/www/abs/decennial/1900.htm) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 1910. Census of population and housing: 1910 Census. [Online]. Available at [www.census.gov/prod/www/abs/decennial/1910.htm](http://www.census.gov/prod/www/abs/decennial/1910.htm) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 1920. Census of population and housing: 1920 Census. [Online]. Available at [www.census.gov/prod/www/abs/decennial/1920.htm](http://www.census.gov/prod/www/abs/decennial/1920.htm) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 1930. Census of population and housing: 1930 Census. [Online]. Available at [www.census.gov/prod/www/abs/decennial/1930.htm](http://www.census.gov/prod/www/abs/decennial/1930.htm) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 1950. Census of population and housing: 1950 Census. [Online]. Available at [www.census.gov/prod/www/abs/decennial/1950.htm](http://www.census.gov/prod/www/abs/decennial/1950.htm) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 2000. U.S. Census 2000. Available at [www.census.gov/main/www/cen2000.html](http://www.census.gov/main/www/cen2000.html) (verified 14 Dec. 2009). U.S. Census Bureau, Washington, DC.
- U.S. Census Bureau. 2002. Census of agriculture—2002 census of agriculture. Vol. 1, Chap. 2 County level data. Available at [http://www.agcensus.usda.gov/Publications/2002/Volume\\_1,\\_Chapter\\_2\\_County\\_Level/index.asp](http://www.agcensus.usda.gov/Publications/2002/Volume_1,_Chapter_2_County_Level/index.asp) (verified 5 Jan. 2010). U.S. Census Bureau, Washington, DC.
- USDA-FS. 1988. Yazoo-Little Tallahatchie flood prevention project—A history of the Forest Service's role. U.S. Forest Service Forestry Rep. Feb; R8-FR 8:63.
- USDA-NRCS. 2000. Summary report, 1997 national resources inventory (rev. December 2000). [Online]. Available at [www.nrcs.usda.gov/technical/NRI/1997/summary\\_report/report.pdf](http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/report.pdf) (verified 14 Dec. 2009).
- USDA-NRCS. 2006. Land resources regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. Agric. Handb. 296. Available at <http://soils.usda.gov/survey/geography/mlra/> (verified 5 Jan. 2010). U.S. Gov. Print. Office, Washington, DC.
- USDA-NRCS. 2007a. National resources inventory, 2003 annual NRI, land use. Available at [www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb.pdf](http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb.pdf) (verified 14 Dec. 2009).
- USDA-NRCS. 2007b. National resources inventory, 2003 annual NRI, soil erosion. Available at [www.nrcs.usda.gov/technical/NRI/2003/SoilErosion-mrb.pdf](http://www.nrcs.usda.gov/technical/NRI/2003/SoilErosion-mrb.pdf) (verified 14 Dec. 2009).
- USDA-NRCS. 2010. Distribution maps of dominant soil orders. Available at <http://soils.usda.gov/technical/classification/orders/> (verified 8 Jan. 2010).
- USDA-NRCS Soil Survey Staff. 2010. U.S. general soil map (STATSGO). Available at <http://soildatamart.nrcs.usda.gov> (verified 5 Jan. 2010).

- Utz, E.J. 1938. The coordinated approach to soil erosion control. p. 666–678. *In* Yearbook of agriculture: Soils and men. U.S. Gov. Print. Office, Washington, DC.
- Utz, E.J., and E.C. Kellogg, E.H. Reed, J.H. Stallings, and E.N. Munns. 1938. The problem: The nation as a whole. p. 84–110. *In* Yearbook of agriculture: Soils and men. U.S. Gov. Print. Office, Washington, DC.
- Vanderford, H.B. 1975. Soil and land resources of Mississippi. Mississippi Agric. Forest. Exp. Stn., Mississippi State Univ., Mississippi State.
- Viator, H.P., R. Bengston, S. Hall, L. Gaston, M. Selim, J. Wang, B. Legendre, T. Hymel, J. Flanagan, J. Hoy, C. Kennedy, and J. Prudente. 2008. Influence of sugarcane post-harvest residue management on yield, water quality. *Louisiana Agric.* 51:39–40.
- Viator, H.P., and J.G. Marshall. 1981. No-till grain sorghum production following wheat. *Louisiana Agric.* 25:16–17.
- Wells, F.B. 1933. Ground-water resources of western Tennessee. Water-supply paper 656. Tennessee Div. of Geology. U.S. Gov. Print. Office, Washington, DC.
- Williams, D.A. 1964. Grass in soil and water conservation. USDA-SCS, Washington, DC.
- Wilson, G.V., S.M. Dabney, K.C. McGregor, and B.D. Barkoll. 2004. Tillage and residue effects on runoff and erosion dynamics. *Trans. ASAE* 47:119–128.
- Wilson, G.V., F.D. Shields, Jr., R.L. Bingner, R. Reid-Rhoades, D.A. DiCarlo, and S.M. Dabney. 2008. Conservation practices and gully erosion contributions in the Topashaw Canal watershed. *J. Soil Water Conserv.* 63:420–429.
- Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall erosion losses—A guide to conservation planning, USDA Agric. Handb. 537. U.S. Gov. Print. Office, Washington, DC.
- Wright, A.L., F. Dou, and F.M. Hons. 2007a. Crop species and tillage effects on carbon sequestration in subsurface soil. *Soil Sci.* 172:124–131.
- Wright, A.L., F. Dou, and F.M. Hons. 2007b. Soil organic C and N distribution for wheat cropping systems after 20 years of conservation tillage in central Texas. *Agric. Ecosyst. Environ.* 121:376–382.
- Wright, A.L., and F.M. Hons. 2004. Soil aggregation and carbon and nitrogen storage under soybean cropping sequences. *Soil Sci. Soc. Am. J.* 68:507–513.
- Wright, A.L., and F.M. Hons. 2005. Soil carbon and nitrogen storage in aggregates from different tillage and crop regimes. *Soil Sci. Soc. Am. J.* 69:141–147.
- Yuan, Y., S.M. Dabney, and R.L. Bingner. 2002. Cost effectiveness of agricultural BMPs for sediment reduction in the Mississippi Delta. *J. Soil Water Conserv.* 57:259–267.
- Yuan, Y., M.A. Locke, and R.L. Bingner. 2008. Annualized agricultural non-point source model application for Mississippi Delta Beasley Lake watershed conservation practices assessment. *J. Soil Water Conserv.* 63:542–551.
- Zablotowicz, R.M., M.A. Locke, L.A. Gaston, and C.T. Bryson. 2000. Interactions of tillage and soil depth on fluometuron degradation in a Dundee silt loam soil. *Soil Tillage Res.* 57:61–68.
- Zablotowicz, R.M., M.A. Locke, L.J. Krutz, R.N. Lerch, R.E. Lizotte, S.S. Knight, R.E. Gordon, and R.W. Steinriede. 2006. Influence of watershed system management on herbicide concentrations in Mississippi Delta oxbow lakes. *Sci. Total Environ.* 370:552–560.
- Zibilske, L.M., and J.M. Bradford. 2007. Soil aggregation, aggregate carbon and nitrogen, and moisture retention induced by conservation tillage. *Soil Sci. Soc. Am. J.* 71:793–802.

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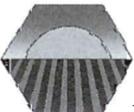
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