HISTORICAL DEVELOPMENT OF CONSERVATION TILLAGE IN THE SOUTHERN GREAT PLAINS

Paul W. Unger and R. Louis Baumhardt[1]

AUTHORS: [1]Soil Scientist (retired) and Soil Scientist, U.S. Dept. of Agriculture, Agricultural Research Service, P. O. Drawer 10, Bushland, TX 79012. Corresponding author: Paul W. Unger, USDA-ARS, P.O. Drawer 10, Bushland, TX 79012. Email: pwunger@tcac.net

ABSTRACT

Tillage that qualifies as conservation tillage according to the general and operational definitions of the term has been used in the southern Great Plains (SGP) for many years, well before the term as currently used became popular. In this report, we discuss early efforts to control soil losses, especially those that occurred during the drought of the 1930s and those associated with cotton (*Gossypium hirsutum* L.) production on sandy soils where soil erosion by wind commonly occurs. We also discuss the development of equipment and practices that are used to control erosion and conserve water throughout the region and their effects on crop production, soil conditions, and related factors. Although adoption of conservation tillage is limited in the SGP, we believe its use is important for conserving soil and water for successful dryland crop production, especially because water for irrigation is limited and being depleted in much of the SGP.

INTRODUCTION

Tillage methods designed to reduce soil losses became available in the southern Great Plains (SGP) following the devastating wind erosion during the 1930s 'Dust Bowl'. The methods used qualify as conservation tillage, based on the broad definition of the term, because they were and are used to control soil losses. Unfortunately, they do not meet the "operational" part of the conservation tillage definition (SSSA, 1997) because inadequate amounts of crop residues were or are available. This definition is based on a 30 percent cover of the soil surface after the next crop is planted. In this paper, we mainly discuss conservation tillage based on the operational definition, but also discuss tillage to conserve soil where adequate or effective residues are not available, as on the sandy soils devoted primarily to dryland cotton (*Gossypium hirsutum* L.) production. However, before discussing development of those and subsequent methods, we give some information about the SGP and the conditions that resulted in development of those methods.

CHARACTERISTICS OF THE REGION

The U.S. Great Plains cover the vast midcontinental region of the United States from about the 100th meridian westward to the Rocky Mountains and from Texas north to the Canadian border. Early explorers called it the "Great American Desert" (Webb, 1931) because precipitation was limited, there were few perennial rivers or springs, and the land was treeless and relatively flat. The explorers viewed the region as undesirable and wholly uninhabitable for people from the eastern United States, a view that persisted until after the Civil War, but it was native range for the bison and home for Native Americans.

The SGP region covers parts of Kansas, New Mexico, Oklahoma, and Texas (Fig. 1). Climate of the region is subhumid in the eastern part and semiarid in the western part. Annual precipitation ranges from about 24 inches at the east to about 12 inches at the west. For 1939 to 1999, it averaged 18.75 inches at the USDA-ARS Laboratory at Bushland, TX, near the center of the region. Besides being limited, much of the precipitation has little or no value for agricultural purposes because it occurs in low amounts per storm (Fig. 2). Other climatic factors at Bushland include average temperatures of 90EF maximum in August and 21EF minimum in January, mean annual wind run of 52,000 miles, and mean annual pan evaporation of 104 inches. In all months, average potential evaporation exceeds average precipitation at Bushland (Fig. 3).

Surface soil textures in the region range from sand to clay. Surface slopes range from <1% in the High Plains to up to 10% in the Rolling Plains. The Ogallala Aquifer, which underlies part of the High Plains, supplies water for irrigation. However, there is little recharge to the aquifer and the water supply is being depleted (Nativ and Smith, 1987). As a result, dryland (nonirrigated) crop production is gaining importance in that part of the region (Musick et al., 1990) and is the usual mode of crop production in other parts of the region. Because of the limited precipitation, water storage in soil is highly important for successful dryland crop production.

The major crops in the SGP are winter wheat (*Triticum aestivum* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], and cotton, which are grown with and without irrigation, and corn (*Zea mays* L.), which is grown only with irrigation. Much of the wheat is grazed by cattle in the fall and winter, with cattle removed in time to allow for grain production. Some wheat is "grazed out," especially when prices are more favorable for cattle than for grain production.

DEVELOPMENT OF THE REGION

The region was settled for agricultural purposes mainly in the late 1800s and early 1900s by cattle and crop producers. Early crop production, however, was limited. For example, a total of only about 650 acres were cultivated in the 26 counties of the Texas Panhandle in 1879 (Price and Rathjen, 1986), but crop production expanded considerably when precipitation was favorable during the 1882 to 1887 and the 1895 to 1906 periods (Johnson and Davis, 1972). Further expansion of the cropland areas occurred during World War I due to the increased demand for wheat in Europe (Hurt, 1981). Expansion continued from 1918 to 1929 due to a "booming" wheat market and annual precipitation that averaged about 4 inches above average in the region. The expansion was aided by agricultural mechanization. As a result, about 40 million acres were developed for crop production by 1929, mainly for monoculture wheat, in the SGP and adjacent portions of the central Great Plains (CGP) (Johnson and Davis, 1972).

For crop production, farmers used tillage methods they had used in the eastern United States or Europe, from which they migrated. The common practice was to "plow up" the native sod, grow the crops, and continue to use clean tillage for successive crops. The method was satisfactory during the early years when precipitation was generally favorable (average or above average), but it led to a major "disaster" during the devastating drought of the 1930s (Johnson and Davis, 1972).

THE "DIRTY THIRTIES"

A major drought occurred in the region from 1931 until 1939, and clouds of dust filled the air for days at a time due to wind erosion on rangeland and cropland. The affected area totaled about 100 million acres. Most severely affected was roughly the area bounded by Big Spring, Texas (south of Lubbock); Pueblo, Colorado; Colby, Kansas; southwestern Nebraska; and Great Bend, Kansas. This area became known as the "Dust Bowl" with the most severely affected farmland being within 100 miles of Liberal, Kansas, which is at the northern edge of the SGP.

The severe wind erosion resulted from the drought that made crop growth largely impossible and the long-term use of clean tillage that buried all crop residues. Practices and equipment were not available to control the erosion, and many farmers abandoned the land when commodity markets collapsed.

Improved management practices now used throughout the "Dust Bowl" area of the 1930s have diminished the potential for wind erosion over much of the region. The cotton producing area on sandy soils around Big Spring and Lubbock, Texas, however, remains at risk, and wind erosion occurs in that area most years. In general, the emergency tillage practices used to control soil losses in that area are covered by the general definition of conservation tillage, but not necessarily the operational definition.

TILLAGE AND RELATED PRACTICES FOR WIND EROSION CONTROL IN THE COTTON-PRODUCING AREA

Dryland cotton on the South Plains of Texas produces small amounts of residues (usually less than 500 pounds per acre of small grain equivalent) (Dollar, 1988), with similar amounts produced on the Rolling Plains. The cotton usually is grown continually and the residue typically is destroyed soon after harvest, thus leaving the surface mostly bare and highly subject to wind erosion during winter and early spring months. Although many factors affect the potential for wind erosion in a given field, some type of tillage that roughens the surface usually is needed because adequate residues are not available to provide erosion control benefits. Most producers for many years have used some "clod-forming" tillage to roughen the soil surface.

Chisel implements often are used to bring large clods to the surface on medium-textured soils. These clods resist the forces of wind and shelter the other erodible soil on the surface. On more sandy soils, the lister-bedder is widely used to form ridges (12 inches tall at 30- to 40-inch spacing) that roughen the surface. The ridges and furrows alter the windspeed and deflect the wind energy away from the erodible soil particles. Lister-bedding is most effective when the ridges are made perpendicular to prevailing winds and when the soil water content is adequate to help form soil clods. Even use of the lister-bedder, however, may not be effective on soils with high sand contents to depths greater than the tillage depth. On such soils, deep plowing that brings clod-forming materials to the surface from the sandy clay loam subsoil horizon is effective for controlling erosion (Dollar, 1988).

Under emergency conditions, that is, when wind erosion is occurring, any practice that can be used to rapidly roughen a rain-smoothened soil surface can help bring erosion under control. For this purpose, commonly-used tools are the "sandfighter" (Woodruff et al., 1972) and rotary hoe. These tools provide a cloddy surface and can be operated at relatively high speeds, thus quickly helping control erosion on large areas. Use of a chisel implement or lister-bedder at wider-than-normal spacings can also provide for erosion control under emergency conditions (Soil Conservation Service, 1955). A major disadvantage of using any surface-roughing operation is that the benefits are not long lasting, often only until the next rain. For erosion control without surface-roughening tillage, practices that involve vegetative materials (residues) have received more attention in recent years.

Producers prefer to grow cotton annually rather than in a rotation with other crops because of economics, i.e., profitability. Growing crops that produce more residues in rotation with cotton that produces little residues can greatly reduce the amount of soil loss. For example, annual soil losses were estimated at 142.8 tons per acre from cotton fields and 3.2 tons per acre from adjacent grain sorghum fields in the Gaines-Dawson County, Texas, area (Brandt and Harris, 1988). When grown in rotation with sorghum and wheat, cotton yield was greater than when grown continually (Keeling et al., 1988; Lyle and Bordovsky, 1987). The use of a crop such as sorghum or millet (Pennisetum spp.) as a windbarrier that modifies the flow of air over the adjacent leeward area can reduce soil losses, but such crops compete with cotton for water and may reduce cotton yields (Bilbro and Fryrear, 1988).

To achieve the erosion-control benefits of residue-producing crops, several studies have used a green fallow approach where wheat is seeded directly where stalks remain standing after harvesting the cotton (Keeling et al., 1989). Using the late fall rain or an irrigation to establish the wheat, a residue cover is grown until March when the wheat is chemically terminated. The "terminated wheat" residues protect the soil during the high wind erosion spring months and, by using no- or reduced-tillage, cotton production can be resumed during the summer as the principle cash crop. Residues retained from terminated wheat provide an additional benefit in reducing evaporation losses from irrigation, thus providing more water for crop growth and yield (Lascano et al., 1994). However, under dryland conditions, rain in the fall may be inadequate to establish the wheat crop and rain in the spring may be inadequate to provide water for establishing the cotton (Baumhardt and Lascano, 1999).

EARLY SOIL CONSERVING TILLAGE

A consequence of the Dust Bowl era was the development of tillage implements to replace the plow or disk that inverted the surface soil and buried the crop residues and, when used excessively, contributed to the severe wind erosion. Included was the Hoeme[2] cultivator that could rip the soil and bring clods to the surface to help control wind erosion (Allen and Fenster, 1986). Crop residues also were retained on the soil surface, provided any were produced. Development of this implement began in 1933 by Fred Hoeme at Hooker, Oklahoma. Some 2000 Hoeme cultivators were distributed before the production and distribution rights for the cultivator were sold to W. T. Graham at Amarillo, Texas, in 1937. The cultivators had steel shanks, which along with similar plows developed by others, were forerunners of modern chisel plows. They were conservation tillage implements based on the general definition of the term. These cultivators also could be equipped with sweeps for subsurface tillage.

[2] The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by the USDA-Agricultural Research Service. Mention of a pesticide does not constitute a recommendation for use not does it imply registration under FIFRA as amended.

An implement developed by C. S. Noble of Alberta, Canada, undercut rather than inverted the soil surface to control weeds, thus reducing soil disturbance and increasing crop residue retention on the soil surface to conserve soil and water (Allen and Fenster, 1986). When Noble was on a trip to southern California in 1936, he observed the operation of a machine that undercut the rows of carrots (*Daucus carota*) to simplify their harvesting. With this machine in mind, he immediately built the first Noble blade implement in a friend's workshop in Garden Grove, California; tested it in nearby fields; and towed it behind his car to Nobleford, Alberta. He subsequently promoted this implement as far south as the Texas Panhandle. This implement was the forerunner of the stubble-mulch tillage implement that was, in part, developed in the SGP.

STUBBLE-MULCH TILLAGE

Tillage with the Noble blade resulted in crop residue retention on the soil surface, but weed control proved to be a problem in moist, mulched soil. To overcome this problem, Professor J. C. Russel joined Dr. F. L. Duley at Lincoln, Nebraska, to form a team in 1938 that would make soil and water conservation history (Russel, 1976). They adapted sweeps that were used to control bindweed to an implement that undercut the soil surface to control weeds while retaining crop residues on the soil surface to control erosion. The sweeps, which were manufactured by the Case Plow Company, were 22 inches wide with an 85-degree V angle. When mounted on shanks that provided a 22-inch clearance, large amounts of residue could pass through without clogging the implement. Although erosion control was of concern, much of their early research dealt with the effects of crop residues retained on the soil surface for enhancing infiltration and reducing runoff and soil water evaporation. When Duley and Russel in 1939 were debating what to call the tillage method — "noninversion," "subtillage," or "subsurface tillage" — for a manuscript, Director of the Soil Conservation Service, Hugh Hammond Bennett, changed the name to "stubble-mulch tillage," which still is used.

Russel and Duley exchanged information with Noble starting in 1939 (Allen and Fenster, 1986). As a result, Noble replaced the 10-foot wide blade with two 6-foot wide V-shaped sweeps to his implement. The implement with the V-sweeps required less draft and quickly became popular. The early stubble-mulch tillage implements had rigid frames and such implements are still widely used. Also available are hinged-frame models that may have 9 to 11 sweeps for a total width of over 50 feet. These large models can be hydraulically folded into compact units for transport.

Russel, Duley, Noble, and Hoeme did much of the pioneering work leading to or with stubble-mulch tillage. However, they were joined in the early 1940s by others at locations throughout the Great Plains, including Bushland, where the work was done by C. J. Whitfield, F. G. Ackerman, W. C. Johnson, and C. E. Van Doren (Allen and Fenster, 1986). Whereas the early work was directed mainly toward adapting the implement to the hardland soils of the region, subsequent research, which continues to the present time, addresses stubble-mulch tillage effects on storm-water runoff, soil water conservation, crop yields, and soil physical and chemical conditions. A critically important finding for SGP dryland agriculture was that stubble-mulch tillage increased precipitation conservation as soil water. For example, in a review by McCalla and Army (1961), the value of stubble-mulch tillage in conserving soil water was clearly demonstrated together with its fundamental impact for increasing dryland crop production, especially in the semiarid portion of the Great Plains. Provided adequate crop residues are produced, using stubble-mulch tillage results in retaining enough residues on the soil surface to qualify as conservation tillage. Regardless of definitions, stubble-mulch tillage is an effective and widely used management practice for conserving soil and water under dryland conditions.

NO-TILLAGE

A major goal of no-tillage studies in the semiarid SGP was to increase precipitation storage as soil water, which is of major importance for dryland crop production. Although erosion, especially by wind, remains a constant threat throughout the region, it can be controlled by use of conservation tillage methods, provided crops produce adequate amounts of residues. Improving soil water conservation increases the potential for greater plant growth and, hence, more residues become available, thus minimizing the threat of soil erosion.

Chemicals for controlling weeds were developed and marketed during the late 1940s-early 1950s period. Soon thereafter, Allen Wiese and others (Wiese and Army, 1958, 1960; Wiese et al., 1960, 1967) conducted no-tillage research with dryland winter wheat and grain sorghum at Bushland. Soil water contents at planting and grain yields with no-tillage generally were lower or not different than those obtained by using sweep (stubble-mulch) tillage. The generally poor early results obtained with no-tillage were attributed to less than desirable weed control with herbicides available at the time and the lack of sufficient crop residues to adequately suppress soil water evaporation.

Improved herbicides and equipment became available in the late1950s and were coupled with innovative management practices. Phillips (1964) reported that atrazine applied after harvesting wheat controlled all vegetation until grain sorghum was planted by the no-tillage method at Hays, Kansas, in the CGP. The cropping system was a wheat-fallow-sorghum-fallow rotation that results in two crops in 3-years. No weed control measures were needed during the sorghum growing season, and sorghum grain yields on no-tillage plots were greater than on cultivated plots (4220 vs. 2710 pounds per acre). Compared with cultivation, weed control costs (1961-1962) were more with no-tillage ($10.00 vs. $8.25 per acre), but profits were greater with no-tillage ($65.96 vs. $40.53 per acre).

Climatic conditions and cropping practices in Hays, Kansas, are not greatly different from those in the High Plains region of the SGP. Hence, renewed interest in no-tillage soon developed. Instrumental in fostering renewed no-tillage research in the SGP was Jack Musick, Director of the USDA-ARS Laboratory at Bushland in the late 1960s. In an early field study, no-, sweep-, and disk-tillage weed control methods were used during the fallow period after harvesting irrigated winter wheat that produced about 10,000 pounds of straw per acre. Herbicides applied were atrazine at 3 pounds per acre and 2,4-D at 1 pound per acre. At sorghum planting about 11 months later, soil water contents to the 6-foot depth were 8.0, 6.4, and 5.7 inches for the respective treatments (Unger et al., 1971). Sorghum grain yields were not determined, but the study clearly showed that no-tillage had potential for conserving soil water and, thereby, increasing crop yields in the semiarid SGP when adequate crop residues were present.

In subsequent studies that relied on irrigation of wheat to produce large amounts of residues, the use of no-tillage rather than other tillage methods (sweep, disk, rotary, or moldboard) improved soil water contents at planting and subsequent yields of dryland grain sorghum (Baumhardt et. al., 1985; Unger, 1984; Unger and Wiese, 1979) or cotton (Keeling et al., 1988; Lyle and Bordovsky, 1987) in most years. Yields of irrigated corn (Unger, 1986), cotton (Keeling et al., 1988; Lyle and Bordovsky, 1987), and grain sorghum (Baumhardt et al., 1985) usually were not improved when using no-tillage because water stress was prevented. However, under deficit irrigation conditions, residues reduce soil water evaporation and increase transpiration and crop yield (Lascano et al., 1994).

When residue amounts were limited as often is the case with dryland wheat or grain sorghum and for a crop such as cotton in the SGP, yields using no-tillage generally were similar to those with other tillage methods (Jones et al., 1994; Jones and Popham, 1997; Unger, 1994). Contributing to the lack of response was inadequate surface cover to prevent soil surface sealing due to raindrop impact, which then resulted in greater runoff than where tillage was used to disrupt the sealed surface layer (Jones et al., 1994). However, even though runoff was greater, soil water contents at planting usually were greater with no-tillage because evaporation from the undisturbed soil was less. In contrast, tillage brought moist soil to the surface, thereby increasing evaporation that often dried the soil to the tillage depth. The dry soil had to be rewet before any water storage at greater depths could occur. A study involving wheat residues placed on the surface (Unger, 1978) and an analysis of long-term grain sorghum yields (Unger and Baumhardt, 1999) clearly illustrated the crop residue effects for increasing soil water storage and dryland crop yields (Table 1, Fig. 4).

No-tillage is the "ultimate" type of conservation tillage. Other tillage methods, however, are also conservation tillage methods, provided adequate crop residues are retained on the soil surface. They usually are referred to as reduced or minimum tillage.

The wheat-fallow-sorghum-fallow rotation used in the semiarid portion of the SGP has 10 to 11 months of fallow after each crop. In contrast, the period between annual wheat crops is 3 to 4 months. A "Lo-Till" farming system developed in western Oklahoma involves the use of herbicides alone or in combination with tillage to control weeds during the period between wheat crops (Stiegler et al., 1984). Lo-Till provides for a favorable seedbed for the following crop, lower soil temperatures, and better soil water, which allows for more timely planting. Earlier planted Lo-Till wheat can be grazed by cattle and the additional profit offsets the cost of herbicides in many cases. Yields of non-irrigated wheat at three demonstration sites (one site excluded because of storm damage) in Oklahoma in 1983 averaged 3350 pounds per acre with Lo-Till and 2770 pounds per acre on conventionally-tilled cooperator fields. The surface residues reduced evaporation by 15 to 25 percent in some years (Stiegler et al., 1984). Use of the Lo-Till system for annual wheat, however, resulted in severe weed problems [mainly cheatgrass (*Bromus secalinus* L.)] in some locations after several years, which could be overcome by major tillage every 3 or 4 years.

In a study with winter wheat from 1983 to 1991 at El Reno, Oklahoma, the soil water content to the 4-foot depth was consistently higher in no-tillage soil than in plowed soil, except in late fall or early spring when root-zone recharge was similar in both cases (Dao, 1993). In addition, water infiltration into no-tillage soil was higher than into plowed soil when soil water contents were similar, which enhanced precipitation storage as soil water.

For irrigated wheat in the Rolling Plains at Munday, Texas, grain yield with reduced tillage averaged less than with clean tillage (3110 vs. 3690 pounds per acre). The lower yield with reduced tillage was attributed to planting problems and less tillering when large amounts or residue were present (Gerard and Bordovsky, 1984). In other studies at Munday and Chillicothe (also in the Rolling Plains in Texas), crop yields usually were as good or better with reduced tillage than with clean tillage (Clark, 1981; Clark et al., 1991; Unger et al., 1988). In one study with cotton, net return to land, management, and risk was 50 percent greater with reduced tillage than with clean tillage (Clark et al., 1991).

Although water conservation and its effect on crop yields received the main attention in SGP conservation tillage studies, other issues studied include insect populations, soil chemical and physical conditions, and economics. Burton and Krenzer (1985) and Burton et al. (1987) showed that greenbug (*Schizaphis graminum* Rondani) infestations and damage to wheat and grain sorghum were lower under conservation than under conventional tillage conditions. Eck and Jones (1992) found that nitrates moved to a greater depth under no-tillage than under stubble-mulch tillage conditions, which was attributed to greater soil water contents with no-tillage. They suggested that more intensive cropping (less time between crops) than the commonly used wheat-fallow-sorghum-fallow rotation may be possible with no-tillage. Other studies showed that long-term use of no-tillage resulted in an accumulation of organic matter (or carbon) at the soil surface and for the entire profile in some cases (Gerard and Bordovsky, 1984; Potter et al., 1997, 1998; Unger, 1991, 1997). Some physical conditions (aggregate stability, bulk density, and penetration resistance) of a clay loam were affected by using no-tillage, but the trends usually were not consistent and apparently none were severe enough to detrimentally affect crop growth and yield (Unger, 1984, 1997, 2001; Unger and Jones, 1998; Unger et al., 1998). At El Reno, Oklahoma, end-of-season bulk density of a silt loam was lower with no-tillage than with moldboard plowing and stubble mulch tillage treatments (Dao, 1996). Gerard and Bordovsky (1984), however, found that use of conservation tillage for a sandy soil (Miles series, 79% sand) decreased the rate of soil drying. As a result of the prolonged wetter soil condition, they found an increase in bulk density that could decrease crop growth and yield.

In addition to the results of Clark et al. (1991), the economic feasibility of various conservation tillage systems that are adaptable to the SGP have been shown by others (Harman and Martin, 1987; Harman and Wiese, 1985; Harman et al., 1989; Keeling et al., 1989; Wiese et al., 1994a, b), especially when long-term equipment costs and depreciation were considered in the analyses. However, other analyses sometimes showed that conservation tillage was less economical because of high herbicide costs for some systems (Epplin et al., 1983, 1988; Wiese et al., 1994a, b). Certainly, many factors affect the economics of a given conservation tillage system and, hence, whether it will be economically advantageous for producers to use it in their crop production enterprise.

Studies on conservation tillage methods continue throughout the SGP. The use of conservation tillage improves soil water conservation, which potentially makes more intensive cropping possible (reducing the length or eliminating the long fallow periods). More intensive cropping is possible in the CGP (Wood et al., 1990) and the SGP (Unger, 2001), and is being studied at Bushland involving crops other than wheat and grain sorghum. Also, because soil water storage during non-crop periods increases as the amount of crop residues retained on the soil surface increases, methods to increase the carry-over of residues from one crop to the next are being sought. For this purpose, the effect of using a stripper-header for harvesting wheat on residue carry-over, soil water storage during fallow, and subsequent grain sorghum yield is being studied at Bushland. Use of the stripper-header allows more of the plant to remain standing, thus potentially decreasing the rate of residue decomposition and providing conditions for increasing soil water storage. Preliminary results during a growing-season with below average rainfall showed that grain sorghum yielded slightly more where the stripper-header rather than a conventional header was used for harvesting the previous wheat. Further study is needed to determine the potential of such practice for increasing soil water storage and grain yields.

CURRENT STATUS OF CONSERVATION TILLAGE IN THE SOUTHERN GREAT PLAINS

Adoption of conservation tillage varies with crops being grown and areas within the region. Stubble-mulch tillage is commonly used for winter wheat in the drier western areas, but seldom used in the more humid eastern areas where the wheat is grown continually. Problems with cheatgrass control, crop establishment with large amounts of residues on the surface, and poor seedling vigor contribute to low adoption in the more humid areas. Patterns of adoption of conservation tillage for sorghum are similar to those for winter wheat. Stubble-mulch tillage is used in the drier areas, especially when the sorghum is rotated with wheat. Stubble-mulch tillage is seldom used in the more humid areas where the sorghum is grown continually (Unger and Skidmore, 1994).

Under irrigated conditions, some producers use conservation tillage when wheat and sorghum are grown in rotation. For continually-grown wheat, however, some producers view surface residues as a hindrance to economical wheat production and may burn them. Fortunately, with irrigation, timely tillage can provide a rough soil surface to control erosion and the ensuing crop can be established, even when timely precipitation does not occur. For irrigated sorghum and corn, surface residue amounts usually are reduced by disking and other tillage methods that form ridges on which subsequent crops are planted. As for wheat, non-use of conservation tillage is not a major problem under irrigated conditions for these crops because water can be applied as needed for timely tillage and crop establishment.

Although adoption of conservation tillage currently is limited in the SGP, we believe its use is important for conserving soil and water resources. Because water for irrigation is being depleted in part of the region and dryland crops are replacing the irrigated crops, we further believe that use of some type of conservation tillage will be necessary to conserve soil and water for successful crop production.

REFERENCES

Allen, R.R., and C.R. Fenster. 1986. Stubble-mulch equipment for soil and water conservation in the Great Plains. J. Soil Water Conserv. 41:11–16.

Baumhardt, R.L., and R.J. Lascano. 1999. Water budget and yield of dryland cotton intercropped with terminated winter wheat. Agron. J. 91:922–927.

Baumhardt, R.L., R.E. Zartman, and P.W. Unger. 1985. Grain sorghum response to tillage method used during fallow and to limited irrigation. Agron. J. 77:643–646.

Bilbro, J.D., and D.W. Fryrear. 1988. Plant materials for windbarriers in semiarid regions. pp. 150–157. In: Proc. 1988 Wind Erosion Conf., April 1988, Lubbock, TX.

Brandt, J.E., and B.L. Harris. 1988. Assessment of selected wind erosion control practices in Texas. p. 13–22. In: Proc. 1988 Wind Erosion Conf., April 1988, Lubbock, TX.

Burton, R.L., O.R. Jones, J.D. Burd, G.A. Wicks, and E.G. Krenzer, Jr. 1987. Damage by greenbug (*Homoptera: Aphididae*) to grain sorghum as affected by tillage, surface residues, and canopy. J. Econ. Entomol. 80:792–798.

Burton, R.L., and E.G. Krenzer, Jr. 1985. Reduction of greenbug (*Homoptera: Aphididae*) populations by surface residues in wheat tillage studies. J. Econ. Entomol. 78:390–394.

Clark, L.E. 1981. Response of cotton to cultural practices. Progr. Rpt. PR-4175, Texas Agric. Exp. Stn., College Station, TX.

Clark, L.E., H.T. Wiedemann, C.J. Gerard, and J.R. Martin. 1991. A reduced tillage system with furrow diking for cotton production. Trans. ASAE 34:1597–1603.

Dao, T.H. 1993. Tillage and winter wheat residue management effects on water infiltration and storage. Soil Sci. Soc. Am. J. 57:1586–1595.

Dao, T.H. 1996. Tillage system and crop residue effects on surface compaction of a Paleustoll. Agron. J. 88:141–148.

Dollar, M. 1988. Problems and controls of wind erosion in West Texas. p. 7–12. In: Proc. 1988 Wind Erosion Conf., April 1988, Lubbock, TX.

Eck, H.V., and O.R. Jones. 1992. Soil nitrogen status as affected by tillage, crops, and crop sequences. Agron. J. 84:660–668.

Epplin, F.M., K. Berte, E.G. Krenzer, Jr., and W.F. Heer. 1988. Influence of alternative planting dates and tillage systems on winter wheat production response: A random coefficients approach. Professional Paper PP-2743, Dept. of Agric. Econ., Olka. State Univ., Stillwater, OK.

Epplin, F.M., T.F. Tice, S.J. Handke, T.F. Peeper, and E.G. Krenzer, Jr. 1983. Cost estimates of alternative wheat production systems for Garfield County. Bull. B-766, Agric. Exp. Stn., Okla. State Univ., Stillwater, OK.

Gerard, C.J., and D.G. Bordovsky. 1984. Conservation tillage studies in the Rolling Plains. p. 201–216. In: Conservation Tillage, Proc. Great Plains Conserv. Tillage Symp., North Platte, NE. Publ. 110, Great Plains Agric. Council, North Platte, NE.

Harman, W.L., and J.R. Martin. 1987. Economics of conservation tillage research in Texas. p. 24–37. In: T.J. Gerik and B.L. Harris (eds.), Conservation Tillage: Today and Tomorrow, Proc. Southern Region No-Tillage Conf., College Station, TX. Misc. Publ. MP-1636, Texas Agric. Exp. Stn., College Station, TX.

Harman, W.L., G.J. Michels, and A.F. Wiese. 1989. A conservation tillage system for profitable cotton production in the central Texas High Plains. Agron. J. 81:615–618.

Harman, W.L., and A. Wiese. 1985. An economic assessment of conservation tillage practices for the southern Great Plains. J. Am. Soc. Farm Managers and Rural Appraisers 49:14–19.

Hurt, R.D. 1981. The Dust Bowl, An Agricultural and Social History. Nelson-Hall, Chicago, IL.

Johnson, W.C., and R.G. Davis. 1972. Research on stubble-mulch farming of winter wheat. USDA Conserv. Rpt. 16, U.S. Gov. Print. Off., Washington, DC.

Jones, O.R., V.L. Hauser, and T.W. Popham. 1994. No-tillage effects on infiltration, runoff, and water conservation on dryland. Trans. ASAE 37:473–479.

Jones, O.R., and T.W. Popham. 1997. Cropping and tillage systems for dryland grain production in the Southern High Plains. Agron. J. 89:222–232.

Keeling, W.L., E. Segarra, and J.R. Abernathy. 1989. Evaluation of conservation tillage cropping systems for cotton on the Texas Southern High Plains. J. Prod. Agric. 2:269–273.

Keeling, J.W., C.W. Wendt, J.R. Gannaway, A.B. Onken, W.M. Lyles, R.J. Lascano, and J.R. Abernathy. 1988. Conservation tillage cropping systems for the Texas Southern High Plains. p. 19–21. In: K.H. Remy (ed.), Proc. 1988 Southern Conserv. Tillage Conf. Spec. Bull. 88-1, Mississippi Agric. and Forestry Exp. Stn., Mississippi State, MS.

Lascano, R.J., R.L. Baumhardt, S.K. Hicks, and J.L. Heilman. 1994. Soil and plant water evaporation from strip tilled cotton: Measurement and simulation. Agron. J. 86:987–994.

Lyle, W.M., and J.P. Bordovsky. 1987. Integrating irrigation and conservation tillage technology. p. 67–71. In: T.J. Gerik and B.L. Harris (eds.), Conservation Tillage: Today and Tomorrow, Proc. Southern Region No-Tillage Conf., College Station, TX. Misc. Publ. MP-1636, Texas Agric. Exp. Stn., College Station, TX.

McCalla, T.M., and T.J. Army. 1961. Stubble mulch farming. Adv. Agron. 13:125–196.

Musick, J.T., F.B. Pringle, W.L. Harman, and B.A. Stewart. 1990. Long-term irrigation trends--Texas High Plains. Applied Eng. Agric. 6:717–724.

Nativ, R., and D. A. Smith. 1987. Hydrogeology and geochemistry of the Ogallala Aquifer, Southern High Plains. J. Hydrol. 91:217–253.

Phillips, W.M. 1964. A new technique of controlling weeds in sorghum in a wheat-sorghum-fallow rotation in the Great Plains. Weeds 12:42–44.

Potter, K.N., O.R. Jones, H.A. Tolbert, and P.W. Unger. 1997. Crop rotation and tillage effects on organic carbon sequestration in the semiarid southern Great Plains. Soil Sci. 162:140–147.

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.

Price, B.B., and F.W. Rathjen. 1986. The Golden Spread: An Illustrated History of Amarillo and the Texas Panhandle. Windsor Publications, Northridge, CA.

Russel, J.C. 1976. Some historical aspects of stubble mulch tillage. Publ. 77, Great Plains Agric. Council, Lincoln, NE. 12 pp.

Soil Conservation Service. 1955. Facts about wind erosion and dust storms on the Great Plains. Leaflet 394, U.S. Dept. of Agric., U.S. Gov. Print. Off., Washington, DC.

SSSA (Soil Science Society of America). 1997. Glossary of Soil Science Terms, 1996. Soil Sci. Soc. Am., Madison, WI.

Stiegler, J., W. Downs, and F. Hawk. 1984. Lo-Till System. p. 197–200. In: Conservation Tillage, Proc. Great Plains Conserv. Tillage Symp., North Platte, NE. Publ. 110, Great Plains Agric. Council, North Platte, NE.

Unger, P.W. 1978. Straw-mulch rate effect on soil water storage and sorghum yield. Soil Sci. Soc. Am. J. 42:486–491.

Unger, P.W. 1984. Tillage and residue effects on wheat, sorghum, and sunflower grown in rotation. Soil Sci. Soc. Am. J. 48:885–891.

Unger, P.W. 1986. Wheat residue management effects on soil water storage and corn production. Soil Sci. Soc. Am. J. 50:764–770.

Unger, P.W. 1991. Organic matter, nutrient, and pH distribution in no-tillage and conventional-tillage semiarid soils. Agron. J. 83:186–189.

Unger, P.W.1994. Tillage effects on dryland wheat and sorghum production in the southern Great Plains. Agron. J. 86:310–314.

Unger, P.W. 1997. Aggregate and organic carbon interrelationships of a Torrertic Paleustoll. Soil Tillage Res. 43:95–113.

Unger, P.W. 2001. Alternative and opportunity dryland crops and related soil conditions in the southern Great Plains. Agron. J. 93:216–226.

Unger, P.W., R.R. Allen, and A.F. Wiese. 1971. Tillage and herbicides for surface residue maintenance, weed control, and water conservation. J. Soil Water Conserv. 26:147–150.

Unger, P.W., and R.L. Baumhardt. 1999. Factors related to dryland grain sorghum yield increases: 1939 through 1997. Agron. J. 91:870–875.

Unger, P.W., C.J. Gerard, J.E. Matocha, F.M. Hons, D.G. Bordovsky, and C.W. Wendt. 1988. p. 10–15. In: F.M. Hons (ed.), Conservation Tillage in Texas. Res. Monogr. 15, Texas Agric. Exp. Stn., College Station, TX.

Unger, P.W., and O.R. Jones. 1998. Long-term tillage and cropping systems affect bulk density and penetration resistance of soil cropped to dryland wheat and grain sorghum. Soil Tillage Res. 45:39–57.

Unger, P.W., O.R. Jones, J.D. McClenagan, and B.A. Stewart. 1998. Aggregation of soil cropped to dryland wheat and grain sorghum. Soil Sci. Soc. Am. J. 62:1659–1666.

Unger, P.W., and E.L. Skidmore. 1994. Conservation tillage in the southern United States Great Plains. p. 329–356. In: M.R. Carter (ed.), Conservation Tillage in Temperate Agroecosystems. Lewis Publishers, Boca Raton, Ann Arbor, London, and Tokyo.

Unger, P.W., and A.F. Wiese. 1979. Managing irrigated winter wheat residues for water storage and subsequent dryland grain sorghum production. Soil Sci. Soc. Am. J. 43:582–588.

Webb, W.P. 1931. The Great Plains. Ginn and Company, Boston.

Wiese, A.F., and T.J. Army. 1958. Effect of tillage and chemical weed control practices on soil moisture storage and losses. Agron. J. 50:465–468.

Wiese, A.F., and T.J. Army. 1960. Effect of chemical fallow on soil moisture storage. Agron. J. 52:612–613.

Wiese, A.F., J.J. Bond, and T.J. Army. 1960. Chemical fallow in the southern Great Plains. Weeds 8:284–290.

Wiese, A.F., E. Burnett, and J.E. Box, Jr. 1967. Chemical fallow in dryland cropping sequences. Agron. J. 59:175–177.

Wiese, A.F., W.L. Harman, B.W. Bean, and C.D. Salisbury. 1994a. Effectiveness and economics of dryland conservation tillage systems in the southern Great Plains. Agron. J. 86:725–730.

Wiese, A.F., W.L. Harman, and C. Regier. 1994b. Economic evaluation of conservation tillage systems for dryland and irrigated cotton (*Gossypium hirsutum*) in the southern Great Plains. Weed Sci. 42:316–321.

Wood, C.W., D.G. Westfall, G.A. Peterson, and I.C. Burke. 1990. Impacts of cropping intensity on carbon and nitrogen mineralization under no-till dryland agroecosystems. Agron. J. 82:1115–1120.

Woodruff, N.P., L. Lyles, F.H. Siddoway, and D.W. Fryrear. 1972. How to control wind erosion. Agric. Info. Bull. 354, U.S. Gov. Print. Off., Washington, DC.

Table 1. Wheat-straw mulch effect on soil water storage during an 11-month fallow before planting grain sorghum, water storage efficiency, and grain sorghum yield at Bushland, TX (adapted from Unger, 1978).

Mulch rate (pounds/acre)	Water storage† (inches)	Storage efficiency‡ (%)	Grain yield (pounds/acre)
0	2.8 c§	22.6 c	1590 c
900	3.9 b	31.1 b	2150 b
1800	3.9 b	31.4 b	2320 b
3600	4.6 b	36.5 b	2660 b
7200	5.5 a	43.7 a	3290 a
10800	5.8 a	46.2 a	3560 a

† Water storage determined to 6-foot depth. Precipitation averaged 12.5 inches.
‡ Based on water storage as a percent of precipitation received during fallow.
§ Column values followed by the same letter are not significantly different at the *P* # 0.05 level of probability based on Duncan's Multiple Range Test.

Figure 1. Map showing the extent of the southern Great Plains in Kansas, Oklahoma, New Mexico, and Texas.

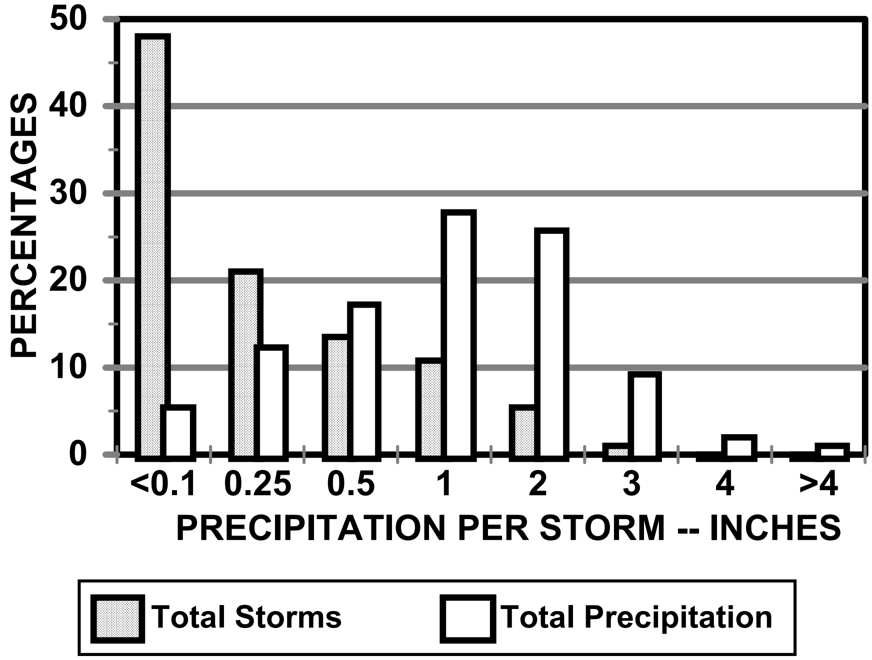

Figure 2. Size distribution of precipitation events (percentages of the total) and percentages of total precipitation associated with the events of different sizes at Bushland, TX, from 1939 to 1998. Total number of events was 4122 and total precipitation was 1126 inches (18.76 inches per year).

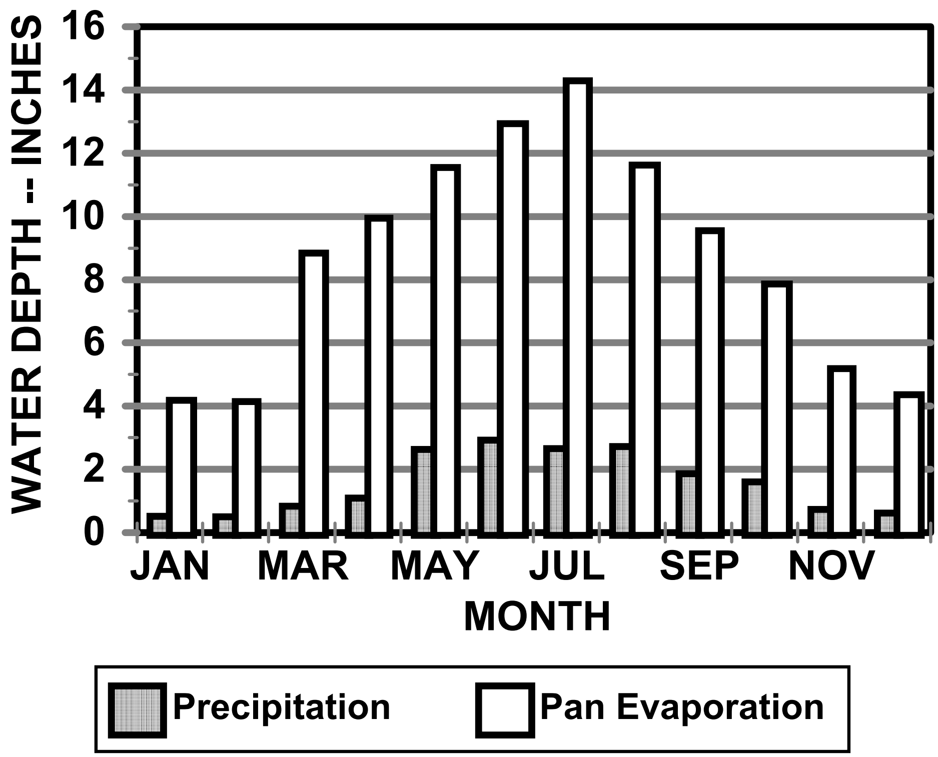

Figure 3. Average monthly precipitation and pan evaporation (4-foot pan) at Bushland, TX.

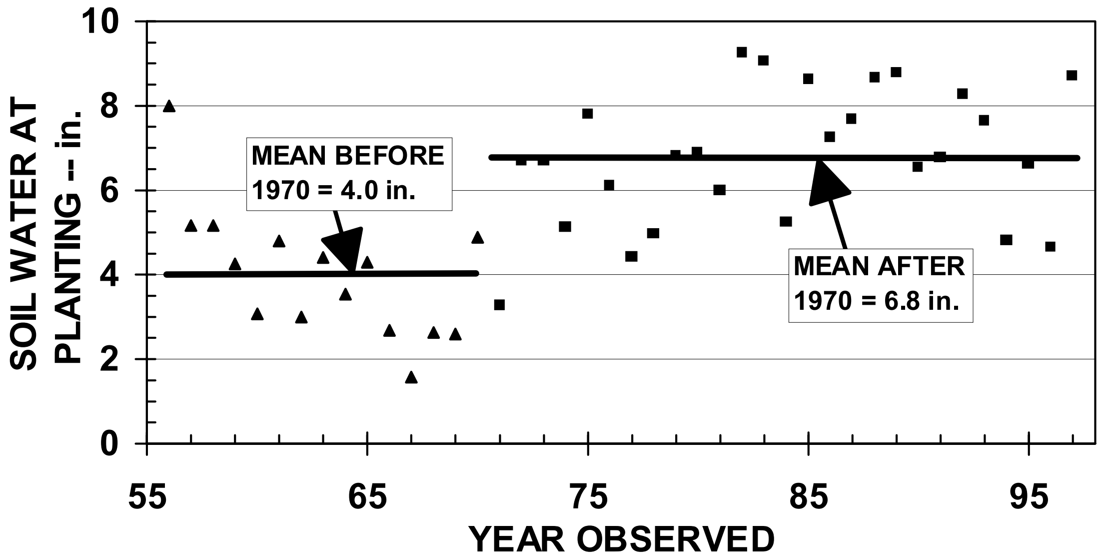

Figure 4. Illustration of crop residue effects on soil water contents at grain sorghum planting time at Bushland, TX. Use of no-tillage after 1970 resulted in retaining more residues on the surface (adapted from Unger and Baumhardt, 1999).

HISTORICAL DEVELOPMENT OF CONSERVATION TILLAGE IN THE SOUTHERN GREAT PLAINS

Paul W. Unger and R. Louis Baumhardt

INTERPRETIVE SUMMARY

The term “conservation tillage” is relatively new. As commonly used, it refers to any tillage method that results in at least 30 percent of the soil surface being covered with crop residues after a crop is planted. Such use of the term is covered by the “operational” definition given by the Soil Science Society of America. According to the general definition of the term, however, any tillage practice that helps to minimize or reduce the loss of soil and water is a type of conservation tillage. Such soil-conserving tillage practices were used in the southern Great Plains for many years before the term “conservation tillage” was introduced. Use of such soil-conserving tillage practices helps control wind erosion on the sandy soils of the southern portion of the region where cotton is the main crop. Cotton produces residues that provide little protection against wind erosion. Tillage practices developed to control wind erosion during the drought of the 1930s also were not based on retaining crop residues on the soil surface. In many cases, the crops failed and no residues were available. The effectiveness of the practices results from roughening the soil surface, either by forming ridges on the surface, forming clods on the surface or bringing clods to the surface, or by bringing less erodible materials to the surface by deep plowing (clayey materials to replace sandy materials at the surface).

The purpose of our report is to give a historical viewpoint of the tillage practices used in the southern Great Plains to conserve soil and water resources. We first give a general description of the characteristics of the region and agricultural development in the region, then discuss the different tillage practices used in the region and their effects of crop production, soil conditions, and related factors.

The region ranges from semiarid at the west to subhumid at the east. Agricultural development occurred in the late 1800s and early 1900s. Early tillage practices used by the settlers were those that they had used in the eastern United States or Europe, from which they immigrated. In the early years when precipitation was average or above average, those “clean” tillage practices were satisfactory. However, during the drought of the 1930s, those practices contributed to the severe wind erosion that plagued the region. Conditions of the 1930s led to the development of tillage practices that helped control wind erosion. Included were implements that roughened the soil surface or retained crop residues, if available, on the soil surface. Those implements were forerunners of the chisel and stubble mulch plows, which are still widely used in the region.

By the 1950s, herbicides for weed control became available, but early no-tillage results generally were poor because of inadequate weed control, improper equipment, and low amounts of crop residues under dryland conditions. Improved herbicides and equipment became available in the 1960s, which resulted in renewed interest in conservation tillage, including no-tillage. Since then, suitable practices have been developed for many crops. With adequate residues

retained on the soil surface, erosion can be controlled and the residues also improve water infiltration and reduce soil water evaporation, thus providing more water for crop production. The additional soil water that results from using no-tillage (from 2 to 3 inches under some conditions) is especially beneficial for dryland crops in the semiarid portion of the region. While some crops are irrigated in the region, water for irrigation is limited and is being depleted in parts of the region. As a result, dryland crop production is becoming increasingly important. While adoption of conservation tillage currently is limited in the region, we believe some type of conservation tillage will be necessary to conserve soil and water for successful and sustained crop production in the southern Great Plains.