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Paul W. Unger
Agriculture Research Service
U.S. Department of Agriculture
Bushland, Texas

Water Conservation: Southern Great Plains

The parts of New Mexico, Oklahoma, and Texas that are within the Southern Great Plains lie between about long. 97 and 105°W and lat. 32 and 37° N. Within this region, soils range from deep sands to clays. Water storage in soil is influenced by limited and erratic precipitation, high solar radiation, high summer temperatures, low relative humidity, and high winds. Soil factors that limit water storage are low infiltration rates, which cause runoff during intense storms, and, in some soils, limited storage capacity. With clean tillage and stubble mulch tillage, precipitation storage efficiencies during fallow range from 15 to 25% in the Great Plains (Mathews and Army, 1960). Storage efficiency values generally are lowest in the southern part of the region (Johnson and Davis, 1972; Mathews and Army, 1960; Unger, 1972). Because of the low efficiencies, soils often are not filled to capacity at crop planting, and subsequent yields are low unless precipitation is timely and adequate.

Water storage with clean tillage and stubble mulch tillage tends to be low; hence, yields generally are low (Johnson and Davis, 1972). Irrigation increases crop yields, but water for irrigation is limited, and irrigation is an energy-intensive practice (Allen et al., 1977). For more reliable crop production without irrigation, a larger percentage of precipitation between crops must be stored in soil, and the stored water and growing season precipitation must be used more efficiently for grain and forage production.

4-1 WATER CONSERVATION PRACTICES

Although precipitation is limited, average annual precipitation in dryland farming areas would be adequate for favorable yields if all of it were effectively used for crop production. For example, grain sorghum in Okla-

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homa yielded 6270 kg/ha of grain using only 17.8 cm of water from soil (Griffin et al., 1966). The soil was covered with plastic to prevent evaporation and rainfall infiltration during the growing season. In the Northern Great Plains, corn on ridged and 90% plastic-covered soil yielded 4330 kg/ha of grain using 37.8 cm of water in 1960 and 3930 kg/ha of grain using 19.8 cm of water in 1961 (Willis et al., 1963). Thus, when evaporation was prevented, crop water use was well below that of average annual precipitation in the Southern Great Plains and, in some cases, below the lowest recorded annual precipitation in the region. This indicates that if water conservation and crop management were improved, yields could be greatly increased.

Improving water storage involves increasing infiltration; reducing runoff, evaporation, and transpiration; and eliminating undesirable plants. Relationships between these factors are complex. The following is a discussion of these relationships and of several principles that are generally involved in the practices for improving water conservation.

4-1.1 Summer Fallow

Two major cropping systems involving fallow are alternate wheat and fallow and wheat-sorghum-fallow. The practice of fallowing becomes more widespread as one moves westward, because precipitation decreases and more water must be stored. Fallowing, however, is not influenced by precipitation alone. Of the total dryland wheat planted from 1968 to 1970, that planted after fallow made up from 4 to 16% in the eastern part of the region and from 29 to 41% in the western part. For 1974 and 1975, these amounts ranged from 0 to 6% and from 15 to 26%, respectively. The shift to planting less wheat on fallowed land in 1974 and 1975 was attributed to improved grain prices and to the policy for increased crop production (Johnson and Unger, 1976). At a given time, grain supplies and land set-aside programs may affect the trend.

Much research with fallow and other water conservation practices has been conducted at the Research Laboratory near Bushland, Texas, on Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll). Taylor et al. (1963) described this soil in detail. The Pullman and closely related soils cover about 4.86 million ha in the Oklahoma and Texas panhandles and eastern New Mexico.

Pullman clay loam at Bushland has a water storage capacity, based on −0.033- and −1.5-MPa matric potentials, of about 23 cm to the 1.8-m depth, the depth to which winter wheat often extracts water. Filling the soil to capacity is difficult, however, because of a very slowly permeable clay horizon at the 23- to 71-cm depth. The infiltration rate decreases to about 1.3 mm/hour after shrinkage cracks and other temporary storage volumes are filled (Taylor et al., 1963). To fill the profile, long wet periods or frequent additions of water are needed.

A study involving wheat-fallow and continuous wheat was conducted at Bushland, Texas, from 1941 to 1977. Tillage methods were one-way and

Table 4-1. Effect of cropping system and tillage method for winter wheat on soil water content at planting, water storage efficiency, and grain yield (Johnson and Davis, 1972).

Cropping system and tillage method	Available soil water at planting†	Water storage efficiency‡	Grain yield†
	cm	%	kg/ha
Continuous wheat			
One-way	9.1	20	585
Stubble mulch	10.3	22	685
Wheat-fallow			
One-way	12.8	10	927
Stubble mulch	15.4	15	1060
Delayed stubble mulch	14.4	13	1040

† Average for 1942 to 1969, determined to a 1.8-m depth.
‡ Average for 1958 to 1969.

stubble mulch for continuous wheat, and one-way, stubble mulch, and delayed stubble mulch for wheat-fallow. For delayed stubble mulch, tillage after harvest was delayed until weed growth began the next spring. Although wheat-fallow resulted in higher water contents at wheat planting than continuous wheat, the trend was opposite for water storage efficiency (water storage divided by precipitation for the period and multiplied by 100) (Johnson and Davis, 1972) (Table 4-1). Differences in storage efficiencies were related to the time intervals between crops, which were about 3 and 15 months for continuous wheat and wheat-fallow, respectively. Since storage is highest in dry soil, as at the time of wheat harvest, precipitation during the first summer is stored rather effectively. Thereafter, storage is lower because water moves more slowly into the soil and evaporation is high, even though the water storage reservoir is not filled to capacity.

Wheat grain yields at Bushland averaged 58 and 54% higher for one-way and stubble mulch tillage, respectively, with the wheat-fallow than with the continuous wheat system. Since yields were not doubled with wheat-fallow, the average total grain production was higher with continuous wheat. Grain yields after conventional and delayed stubble mulch tillage were similar, even though weeds grew and used water the first summer and fall after wheat harvest on the delayed tillage plots. By wheat planting time, soil water contents for the two systems were similar (Table 4-1). Delayed stubble mulch was more economical because it required about 30% less tillage than stubble mulch during the entire fallow, but delayed stubble mulch is seldom used because weed seed production is high (Johnson and Davis, 1972).

In a 13-year study involving stubble mulch tillage in wheat-fallow, continuous wheat, wheat-sorghum-fallow, and continuous sorghum systems on Pullman clay loam, water contents at planting and storage efficiencies for comparable treatments were lower (Unger, 1972) than those reported by Johnson and Davis (1972), apparently because of the precipitation variations. Grain yields were similar in both studies. In the wheat-sorghum-fallow system, water storage efficiencies during fallow before wheat and sorghum were almost identical (Table 4-2), but continuous sorghum resulted in

Table 4–2. Effect of cropping systems for winter wheat and grain sorghum on soil water content at planting, water storage efficiency, and grain yield (Unger, 1972).

Cropping system	Available soil water at planting†	Water storage efficiency	Grain yield
	cm	%	kg/ha
Continuous wheat	5.8	14.8	700
Wheat-fallow	9.3	8.3	970
Wheat-sorghum-fallow			
Wheat	8.6	13.9	850
Grain sorghum	9.4	14.0	1740
Continuous sorghum	7.6	20.1	1270

† Determined to a 1.2-m depth.

higher efficiency than continuous wheat because most of the precipitation between crops occurred within about 45 days of sorghum planting, thus the relatively high water contents at planting. For continuous wheat, precipitation between crops occurs during summer when temperatures and evaporation potentials are high, thus the low water storage. In wheat-sorghum-fallow and continuous sorghum systems, sorghum grain yields were higher than wheat grain yields (Table 4–2) because growing season precipitation was more timely for sorghum than for wheat.

In contrast to results at Bushland, where fallowing resulted in about 40 to 50% higher yields of wheat and grain sorghum than did continuous cropping, fallowing at Woodward, Oklahoma, increased yields only about 5 to 20% for several *Sorghum* species, (kafir, milo, sorgo, and broomcorn) (Locke and Mathews, 1955). The lower yield was attributed to climatic and soil differences. Annual precipitation at Woodward, which was about 120 mm higher than at Bushland, favored continuous cropping. In addition, the soils at Woodward were silt loams, sandy loams, or loamy fine sands, which filled with water more readily than the clay loam at Bushland. Because the sandier soils at Woodward also had lower storage capacities, precipitation between continuous crops was adequate to fill soils to near capacity.

Mathews and Brown (1938) compared fallowing on sandy loam soils at Dalhart, Texas, and Woodward, Oklahoma. Annual precipitation at Dalhart was about 125 mm lower than at Woodward. At Dalhart, both row crops and wheat responded to fallow. At Woodward, wheat responded some, but row crops responded very little to fallow. Row crops responded poorly at Woodward because the soil generally was filled to capacity at planting, even on annually cropped land. Wheat at Woodward responded to fallowing because time between harvest and planting with continuous cropping was too short to permit water storage equal to that stored in fallowed land. When water storage between crops approached that on fallowed land, fallowing did not increase yields. The strong response to fallowing at Dalhart resulted from the lower precipitation, which was too low to fill the soil with continuous cropping. Similar results were obtained on sandy soils at Big Spring, Texas, where most crops yielded more after fallow than with continuous cropping (Keating and Mathews, 1957). Soils and precipitation were similar to those at Dalhart.

Fallowing generally increased yields on harvested areas, especially in the drier western part, but not enough so that total production with fallow equaled that with continuous cropping. However, where large amounts of land are farmed by one individual and production costs are considered, fallowing may be more economical; in addition, fallowing stabilizes crop production.

Although average water storage during fallow is low, storage during individual fallow periods can vary greatly. In general, storage is highest when the soil is dry at crop harvest and precipitation is adequate, and lowest when the soil is wet at harvest and precipitation is low. Water may be lost during fallow when water contents are high at crop harvest (Unger, 1972). Because water contents at harvest vary greatly due to precipitation near harvest, flexible cropping systems are needed. When soil water is adequate at harvest, continuous cropping, or possibly even double cropping with a forage or other short-season crop, would result in more efficient use of precipitation than with cropping systems involving fallow.

4-1.2 Mulching

Mulching is perhaps as old as agriculture itself (Jacks et al., 1955). Ancient Romans placed stones and the Chinese placed pebbles from stream beds on soil to conserve water. These and similar practices were practical when hand labor was plentiful, but they are impractical for modern, large-scale, mechanized agriculture. The current trend is to use crop residues on farmland and artificial mulches for some high-value crops (Unger, 1975).

Mulches conserve water by controlling storm water runoff, increasing infiltration, decreasing evaporation, and aiding in weed control. If they control evaporation, mulches increase yields with less soil water use than the average annual precipitation in dryland crop areas (Griffin et al., 1966; Willis et al., 1963). Many studies have been conducted involving mulches for water conservation. Plastic, paper, crude oil, and gravel mulches generally increased soil water contents and crop yields (Unger, 1971a, b; Wendt, 1973a, b; Wendt and Runkles, 1969). These mulches have potential for use on relatively small areas for high-value crops, but they are neither practical nor economical for large areas. Consequently, crop residue mulches have received much attention for water conservation in practical farming situations. The effectiveness of grown-in-place mulches for conserving water is limited in the Southern Great Plains, however, because of the meager residue generally produced by dryland crops. Even when these residues were left on the soil by stubble mulch tillage or chemical fallow, water storage and crop yields often were low (Johnson and Davis, 1972; Mathews and Army, 1960; McCalla and Army, 1961; Unger, 1972; Wiese et al., 1967; Zingg and Whitfield, 1957) because the residue amounts were too low to enhance infiltration and decrease evaporation.

Greb et al. (1967, 1970) showed that increasing amounts of wheat straw mulch on the soil during fallow increased water storage in the Central and Northern Great Plains. With 0 to 6720 kg/ha of mulch, precipitation stored

Table 4-3. Straw mulch effects on water storage efficiency and grain sorghum yield (Unger, 1978).

Mulch rate	Water storage efficiency†	Grain yield
t/ha	%	kg/ha
0	22.6c‡	1780c‡
1	31.1b	2410b
2	31.4b	2600b
4	36.5b	2980b
8	43.7a	3680a
12	46.2a	3990a

† Water storage determined to a 1.8-m depth. Precipitation averaged 318 mm.
‡ Column values followed by the same letter are not significantly different at the 5% level (Duncan multiple range test).

ranged from 16 to 37%, respectively. Unger (1978) obtained similar increases when he placed 0 to 12 t/ha of wheat straw on Pullman clay loam. Subsequent sorghum grain yields with 8 and 12 t/ha of mulch were about double those with no mulch (Table 4-3).

Because irrigated crops such as winter wheat produce more residue than dryland crops, recent studies on Pullman clay loam have involved the management of irrigated wheat residue during fallow. Unger et al. (1971) used combinations of disk, sweep, and herbicide treatments for weed and volunteer wheat control during fallow from wheat harvest in July until the following June. The irrigated wheat produced 11 000 kg/ha of residue. Water storage with herbicide treatments was about double that of the average for tillage-only treatments.

In 1970, winter wheat was planted after irrigated corn without tillage or after rotary tillage and on a fallowed area to obtain high-, medium-, and low-residue levels, respectively. Within these treatments, different amounts of residue production resulted from irrigating the wheat one to five times. Low-residue treatment plots were disked once after wheat harvest to incorporate some residues with soil. All plots were treated with atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] and 2,4-D [(2,4-dichlorophenoxy)acetic acid] at 3.4 and 1.1 kg/ha, respectively, to control weeds and volunteer wheat. Surface residues, water storage during fallow, and sorghum grain yields were significantly affected by the treatments. Precipitation storage ranged from 11 to 45% and generally increased as residue levels increased. The highest residue level, however, did not result in the most storage, possibly because initial soil water contents were higher or precipitation was intercepted by residues. The sorghum, planted without tillage and not irrigated, yielded from 2970 to 6010 kg/ha of grain. The high yield was about 2240 kg/ha greater than sorghum yielded on an adjacent fallowed area where conventional production practices were used (Unger and Parker, 1975).

No-tillage, sweep tillage, and disk tillage methods were used during fallow for wheat residue management and weed control in an irrigated winter wheat-dryland grain sorghum-fallow cropping system at Bushland. Precipitation storage averaged 35.2, 22.7, and 15.2%; plant available water to a 1.8-m depth at sorghum planting averaged 21.7, 17.0, and 15.2 cm; sorghum grain yields averaged 3140; 2500; and 1930 kg/ha; and water use efficiencies for grain averaged 88.6, 77.3, and 66.3 kg ha^{-1} cm^{-1} for the respective treatments (Unger and Wiese, 1979).

In the Southern Great Plains, cotton bur or gin trash mulches often are used to control wind erosion on sandy soils. Besides controlling erosion, these mulches increase precipitation storage. On Amarillo sandy clay loam (fine-loamy, mixed, thermic Aridic Paleustalf) at Big Spring, Texas, the gain in soil water was nearly 30% as surface coverage by mulch increased from 0 to 100% (Fryrear and Koshi, 1971). About 11 t/ha of gin trash completely covered the surface. For the 0, 11.2, and 22.4 t/ha gin trash treatments, storage efficiencies averaged 41, 58, and 73% with 337 mm of average precipitation in 1968 and 1969. Soil water content was increased to a 3-m depth, and cotton lint yields averaged 197, 260, and 282 kg/ha with the respective treatments.

Davidson and Santelmann (1973) evaluated effects of stubble mulch tillage, clean tillage, chemicals, and no weed control on soil conditions and wheat yields on Grant silt loam (fine-silty, mixed, thermic Udic Argiustoll) at Cherokee, Oklahoma. Although minimum or no-tillage treatments (stubble mulch or chemical) resulted in equal or better soil physical conditions and higher water contents, average grain yields were higher with clean tillage (moldboard plowing). The effect on yield seemed inversely proportional to the amount of residue on the soil in May. At residue sampling in May, wheat seedlings on high-residue plots were chlorotic, similar to that caused by a N deficiency. Nitrogen applications, however, did not change the results, and the reason for plant chlorosis under high-residue conditions has not yet been determined.

4-1.3 Weed Control

Uncontrolled weed growth decreases water storage, and weeds and volunteer crop plants compete strongly with planted crops for stored water. Weeds are strong competitors because of their vigorous growth habits and because their root systems are often more extensive than those of planted crops (Davis et al., 1965, 1967). Competition between weeds and crops is influenced also by the soil water conditions under which they grow (Wiese and Vandiver, 1970). For example, corn, barnyard grass, cocklebur, sorghum, and crabgrass grew best in wet soil and less in relatively dry soil. In contrast, kochia, Russian thistle, buffalobur, and tumblegrass grew much less under wet conditions than the more competitive species, but relatively dry soil did not decrease their growth. In this test, species were grown in competition with each other.

To obtain maximum water storage for a subsequent crop, land generally must be kept weed free. Provided weed control was similar, the control method (disk, sweep, or chemical) had minor effects on soil water content throughout fallow and at planting of the next crop when initial surface resi-

Table 4-4. Effect of tillage frequency and timing during 11-month fallow on average number of tillage operations, soil water, and grain yields in a wheat-sorghum-fallow system (Lavake and Wiese, 1979).

	For wheat crop			For sorghum crop		
Tillage treatment	Tillage operations	Soil water at planting†	Grain yield	Tillage operations	Soil water at planting†	Grain yield
	Number	cm	kg/ha	Number	cm	kg/ha
Every 2 weeks	10.3	11.8a‡	567ab‡	10.6	9.0a‡	2410ab‡
Days after weed emergence						
4	5.3	11.4a	629a	6.1	9.0a	2600a
10	4.3	10.7ab	583ab	5.1	8.9a	2530a
17	3.6	9.7b	564ab	4.0	8.4a	2100bc
24	2.7	9.1b	500b	4.0	7.9a	1900c

† Plant available water determined to a 1.2-m depth.
‡ Column values followed by the same letter or letters are not significantly different at the 5% level (Duncan multiple range test).

due levels were low (Johnson and Davis, 1972; Wiese and Army, 1958). The differences noted (Table 4-1; Wiese and Army, 1958) may have resulted from the different amounts of residue that the various tillage methods maintained on soil. With high-residue levels, however, the weed control method had a major effect on water storage (Unger et al., 1971; Unger and Wiese, 1979).

Timeliness of weed control has a major effect on water storage. Controlling weeds with sweep tillage at 4, 10, 17, or 24 days after emergence or by repeated sweep tillage at 2-week intervals during the growing season affected water storage during fallow in a wheat-sorghum-fallow system. For both crops, controlling weeds at 4 or 10 days after emergence or at 2-week intervals did not significantly affect soil water at planting or grain yields (Table 4-4), but delaying weed control until 17 or 24 days after weed emergence decreased soil water content and yield (Lavake and Wiese, 1979). Because repeated tillage did not increase water content or yield, tillage can be delayed until weeds use more water than that lost by evaporation, thereby affording major savings in production costs and energy. Similar findings were reported by Wiese (1960).

As with tillage, timeliness of weed and volunteer plant control with herbicides is important for water conservation. Treating 15-cm tall pigweed plants with 2,4-D at 0.28 kg/ha stopped growth temporarily but did not kill the plants. Transpiration rate decreased within 2 days and remained depressed throughout the study. Smaller plants undoubtedly would have been killed. Sorghum plants treated with a toxic oil collapsed within 1 day and stopped transpiring within 6 days. For sorghum treated with dalapon (2,2-dichloropropionic acid) at 11.2 kg/ha, evapotranspiration decreased to the same or lower rate than evaporation from bare soil within 3 days. Treating 15-, 17-, or 34-cm tall soybean plants with 2,4-D at 1.12 kg/ha reduced evapotranspiration more than when it was applied at 0.56 kg/ha, regardless of plant height. The 0.56-kg/ha rate reduced evapotranspiration but did not kill soybean plants. Soybean plants 15 cm tall were killed within 2 days by 1.12 kg/ha of 2,4-D, and evapotranspiration by these plants and evaporation from bare soil were similar. The 17-cm tall plants treated with 1.12 kg/ha of 2,4-D died slowly. At 16 days, evapotranspiration was the same as evaporation from bare soil. The 2,4-D did not kill the largest soybean plants, and evapotranspiration remained higher than evaporation from bare soil throughout the study (Wiese et al., 1966). Under field conditions, delayed or incomplete weed kill by herbicides, therefore, would be detrimental to water conservation between crops and while crops are growing. Because weeds continue to use water for several days after herbicide application, whereas tillage kills weeds almost immediately, herbicides should be used earlier than tillage for effective water conservation.

4-1.4 Vertical Mulching

When precipitation rates exceed infiltration rates during intense rainstorms, the excess water normally flows laterally across the surface and collects in depressions or flows into streams. To prevent runoff water from leaving the field, vertical mulching was developed to quickly channel the water into soil. Wendt (1973c) found no benefit from vertically mulching Olton loam (fine, mixed, thermic Aridic Paleustoll) in 1970 because maximum daily rainfall was 31 mm, apparently not enough to cause runoff. In 1971, water content differences among treatments were slight from March until early August because the highest monthly rainfall (in May) was only 56 mm. Rainfall in late August, September, and October (159, 129, and 51 mm, respectively) caused higher water contents at the 30- to 90-cm depth in vertical-mulched plots and the water contents remained higher until the sorghum was killed by frost. Sorghum grain yields were 2090, 2490, and 3110 kg/ha on check, vertical mulch, and vertical mulch plots with oil (sprayed on the soil), respectively. The differences were significant.

Seemingly, vertical mulching would be most beneficial for water conservation on slowly permeable soils, such as Pullman clay loam. However, no vertical mulching studies have been conducted on this soil under dryland conditions. Vertical mulching is not practical for large-scale farming.

4-1.5 Terracing

Runoff from cropland may occur during any month in the Southern Great Plains. Runoff is influenced by crops grown and soil surface conditions as well as other factors. At Bushland, average runoff was low from areas cropped to winter wheat or in fallow after wheat. It was much higher from adjacent areas cropped to grain sorghum or in fallow after grain sorghum (Fig. 4-1) (Jones and Hauser, 1975). To control erosion and conserve runoff water, various types of terraces were studied.

Graded and level terraces have been evaluated for water storage and crop yields at several locations. Early results showed that runoff was lower

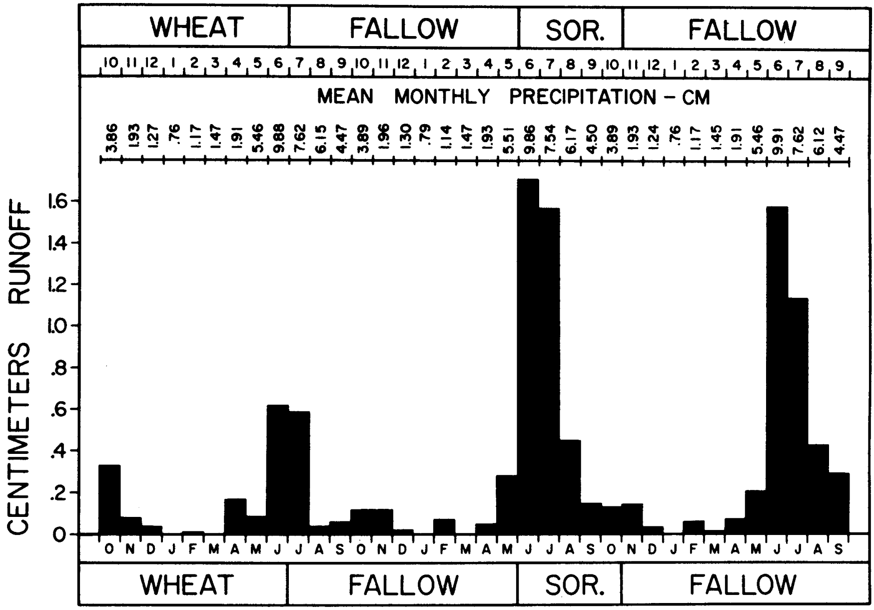

Fig. 4-1. Fourteen-year (1959–1972) mean monthly precipitation and runoff from three graded terraces cropped in a 3-year wheat-sorghum-fallow sequence. One terrace was in each phase of the sequence every year (Jones and Hauser, 1975).

and water contents and crop yields were higher on graded terrace fields than on nonterraced fields (Dickson et al., 1940; Finnell, 1944). Soil water content and yields generally were even higher with level terraces, especially with ends closed and contour furrows between terraces, or when areas between terraces were leveled (Burnett and Fisher, 1956; Dickson et al., 1940; Fisher and Burnett, 1953). When Foard silt loam (fine, montmorillonitic, thermic Typic Natrustoll) in Oklahoma was kept relatively smooth for wheat, runoff water was stored mostly on the upslope side of closed-end level terraces. During dry seasons, this area produced higher wheat yields, but during wet seasons, wheat yield in terrace channels was often less than that on intervals between terraces. During wet periods, water had to be drained from terrace channels to prevent damage to wheat (Harper, 1941).

On Pullman clay loam, wheat and grain sorghum yields from 1949 to 1960 were similar with graded and closed-end level terraces in a wheat-sorghum-fallow system. Since yields were similar, Hauser et al. (1962) suggested using open-end level terraces, which would avoid both the need for high terrace ridges to store large volumes of runoff and the need to drain water from terrace channels during wet periods.

To spread potential runoff water over larger areas and to decrease the need for high terrace ridges and draining of terrace channels during wet periods, bench terraces, with and without a contributing watershed, were evaluated at Bushland and Big Spring, Texas. At Bushland, bench terraces with a contributing watershed (conservation bench terraces) were constructed in 1955 on land with 1.0 to 1.8% slope. The watershed to bench ratio was 2:1. The benches were continuously cropped to grain sorghum, and the watersheds were in a wheat-sorghum-fallow sequence. The conservation bench terraces controlled runoff water, prevented water erosion, and uniformly distributed runoff water for storage in soil on the leveled area (Hauser, 1968; Zingg and Hauser, 1959). Water storage was greater on level benches of the conservation bench terraces than on level benches without a watershed (also under annual cropping) and about the same as on level-terraced fields that were fallowed for 11 months. Crop production was about 1.5 times more with the conservation bench terraces than with level terraces because all of the level-terraced area was cropped in a wheat-sorghum-fallow system, whereas the benches of the conservation bench terraces were continuously cropped to grain sorghum. Total production was highest on bench terraces without a watershed because these terraces were annually cropped to sorghum. Further evaluation of the systems for 1959 to 1972 substantiated earlier results (Jones and Hauser, 1975). Again, overall production was highest on level benches without a watershed, but with this system, the probability of poor yields increased due to low water storage in dry years. The major advantage of the conservation bench terraces over level benches without a watershed was that only one third of the area was leveled for the conservation bench terraces. The higher yields on benches without a watershed were not adequate to offset the additional construction costs compared with yields and construction costs for the conservation bench terraces (Jones and Shipley, 1975). To further decrease construction costs, Jones (1981) developed a system of conservation bench terraces that employed narrow benches.

Armbrust and Welch (1966) evaluated the conservation bench terraces at Big Spring on Amarillo fine sandy loam with a 1.3 to 1.9% slope. Watershed to level bench ratios were 2:1, 4:1, and 6:1. A level bench without a watershed and a check treatment were also evaluated. Using the conservation bench terraces did not increase cotton or grain sorghum yields. The sandy loam had a high infiltration rate and an available water storage capacity of only 10.2 cm to a 1.2-m depth. Because runoff occurred only from large, high-intensity rains or rains that followed previous rains within 1 or 2 days, the soil water reservoir was filled before impounding the runoff by level benches. The impounded runoff water, therefore, was lost through deep percolation.

4-1.6 Contouring

Contouring is normally practiced in conjunction with terracing. The extra water stored with contouring and terracing rather than with terracing alone results from potential runoff water being held on a major portion of a field. When listers are used, each ridge serves as a miniature terrace. At Spur, Texas, runoff averaged 3.6, 2.2, and 0.0 cm from areas with sloping rows, contoured rows, and closed-end level terraces, respectively. Cotton lint yields were 114, 138, and 168 kg/ha on the respective areas (Dickson et al., 1940). For the period from 1927 to 1952, runoff from the three areas averaged 7.0, 5.0, and 0.0 cm, and cotton lint yields averaged 131, 164, and 211 kg/ha (Fisher and Burnett, 1953).

Finnell (1944) attributed only 56 kg/ha of a total dryland wheat yield of 557 kg/ha in 11 areas to contouring. He attributed the relatively poor response of wheat to contouring compared with that of row crops to the flat tillage methods (sweep or one-way plowing) used for wheat. For row crops, ridges were normally formed and maintained during tillage, planting, and cultivation.

4–1.7 Basin Listing and Furrow Blocking

Basin listing was a practice introduced into the Southern Great Plains in the 1930's to more uniformly hold and distribute potential runoff water over the entire field. By 1950, however, the practice was little used because of the slowness of the operation, difficulties of weed control and seedbed preparation, furrow planting, subsequent tillage, and greater erosion when dams washed out during high rainfall. Stubble mulching, terracing, and other conservation practices that were easier to manage became more popular (Clark and Hudspeth, 1976), and yield increases with basin listing were slight (Daniel, 1950; Locke and Mathews, 1953).

With better background information and modern technology, Clark and Hudspeth (1976) felt that most of the problems that caused early failures with basin listing could be overcome. Long-term data for Bushland (Fig. 4–1) showed that runoff was highest just before or soon after the time that grain sorghum and cotton are normally planted. By blocking furrows at this time rather than during fallow after wheat when runoff is low, as was done previously, the extra water could be used almost immediately, and evaporation losses would be minimized.

In early basin listing studies, weeds were controlled by cultivation. Now herbicides are used, and many fields are not cultivated after planting. When cultivation is necessary, furrow blocks can be removed by a device ahead of the tractor, the crop is cultivated, and the blocks are reestablished, all in one operation.

Clark and Hudspeth (1976) reduced dam overtopping and subsequent erosion by using large furrows to increase furrow storage capacity. Also, the crop used the stored water between rains, thus increasing subsequent storage capacity and efficiency. Furrow blocking on Pullman clay loam resulted in higher water contents throughout the growing season for grain sorghum than those resulting from open furrows and flat planting. In 1975, grain yields were 2920, 2580, and 2470 kg/ha on blocked-furrow, open-furrow, and flat-planted areas, respectively. On Amarillo fine sandy loam with a 0.2% slope at Lubbock, runoff occurred from open furrows but not from blocked furrows. Cotton lint yields were 224 and 279 kg/ha with open and blocked furrows, respectively.

4-1.8 Planting Dates

Within limits, dryland crops are planted when soil water conditions are favorable. Wheat is normally planted between 20 August and 15 October, but most is planted by 1 October if soil water conditions are favorable. If the wheat is to be grazed, planting may be earlier, but early-planted wheat may deplete most available water during fall and winter, making grain production largely dependent on spring rainfall. Early planting also increases the potential for damage by insects and diseases. According to Porter et al. (1952), the most desirable time to plant wheat is from 20 September to 10 October. Delayed planting decreases water use by plants, thus conserving the water for later use (Hanway, 1976). However, wheat planted after 15 October may not provide enough ground cover for erosion control. Another consideration is that not all water conserved by late planting is available for plant use because of evaporation.

Planting dates strongly influence growing season length for winter wheat but have less influence on grain sorghum. The growing season for sorghum is largely determined by its maturity class. Although rainfall distribution may influence growing season length, and thereby water use, little water can be conserved by varying sorghum planting dates. Sorghum should be planted so that critical growth stages (booting to grain filling) occur when the probability for rainfall is highest (July to August), yet within limits imposed by soil and climate factors early in the season.

Grain sorghum planting dates are affected not only by soil water conditions but also by location and elevation. In the Texas Rolling Plains, grain yields are similar for April, May, or June plantings, provided soil water and rainfall conditions are similar. At higher elevations, as in the Texas High Plains, temperatures become favorable about 15 May, but grain yields are generally higher when sorghum is planted between 10 and 25 June (Quinby et al., 1958). Sorghum planted after 1 July in the Texas High Plains may be killed by early frost before grain maturity. However, if frost occurs at near-normal dates, yields comparable to those with late-May plantings are possible (Unger and Parker, 1975).

With adequate soil water, time from sunflower emergence to full flowering was 80 and 51 days for 4 April and 27 June plantings, respectively (Unger et al., 1976), suggesting a potential for conserving water by delayed planting. However, total water use may have been similar because of different evapotranspiration at different times in the year. Under limited soil water conditions, water use by sunflower was strongly influenced by growing season rainfall distribution, which also strongly influenced yields (Jones and Unger, 1977). Because rainfall is erratic, sunflower should be planted so that critical growth stages (budding to late flowering) occur when rainfall probability is highest (June, July, or August), with the same early season limitations as for sorghum.

4–1.9 Antitranspirants

Over 99% of the water absorbed by plant roots is lost by transpiration from leaves; therefore, a potential means of conserving water in crop production is reducing transpiration by stomatal control. Factors controlling stomatal movement have been studied extensively and reviewed by Stone (1978) and Zelitch (1963, 1965), but stomatal control is not fully understood (Zelitch, 1965). Consequently, stomatal control for water conservation is not common. Research regarding stomatal control has been limited in the Southern Great Plains (Stone, 1978; Wendt, 1973d).

4–2 EQUIPMENT

The selection of tillage and planting equipment for dryland crop production was discussed in a report by the Food and Agricultural Organization of the United Nations (1971). The equipment used is dictated largely by the management system used. Equipment, especially tillage equipment, differs when clean or conservation tillage systems are used.

4–2.1 Clean Tillage

In a clean-tillage system, most crop residues are incorporated into soil, and weeds are controlled by implements that partially or completely invert the surface layer. One-way disk plows are widely used, but tandem and offset disks have become popular in recent years. Generally, each operation with any of these plows incorporates about 50% of the surface residues. After three or four operations, the surface is essentially bare. In some cases, weed growth after initial plowing is controlled with sweep plows, rod weeders, or other implements that do not invert the soil.

For row crops, such as cotton and grain sorghum, listers may be used once or twice before planting to prepare the seedbed. Weeds on lister ridges are controlled with sweep cultivators, rolling cultivators, or sweep rod weeders.

In eastern areas of the Southern Great Plains, soil is frequently tilled initially with a moldboard plow, which inverts the surface layer and loosens compact soil to the tillage depth. Then tandem disks, sweep plows, rod weeders, or listers are used.

4–2.2 Conservation Tillage

One goal of conservation tillage is to keep crop residues on the surface, which improves erosion control and water storage. Common implements that till soil beneath the residues are sweep plows and rod weeders. Unlike the large (up to 213 cm) sweep or blade plows used in the Central and Northern Great Plains, plows commonly used in the Southern Great Plains have sweeps 50 to 107 cm wide. Sweep plows reduce surface residues about 10% with each operation.

Repeated sweep tillage may be used for weed control between crops. Sometimes rod weeders are used after the soil has been initially loosened by sweep tillage. When residue amounts are excessive or weed growth is lush after prolonged wet weather, one-way or tandem disk plows may be used once to partially reduce the residues or to control weeds.

For reduced tillage, limited tillage, or no-tillage systems, weeds are controlled primarily with herbicides. Occasionally, when herbicides do not control weeds, they are controlled by one or more sweep plow operations. Sweep plowing also loosens surface soil that has been compacted by equipment traffic, livestock, or natural settling.

4–2.3 Planting Equipment

Small grains are generally planted with shovel, hoe, or disk opener drills. Shovel opener drills work well for placing seeds in moist soil that is overlain by dry surface soil, and they form ridges that help control wind erosion. Shovel opener drills perform well in both clean tillage and some conservation tillage systems because of their high clearance and their staggered shanks that support the openers and seed spouts. They do not perform satisfactorily when large amounts of residue are on the soil surface.

Disk openers do not ridge the soil as much as shovel openers do; hence, they are less satisfactory for planting through dry surface soil and less effective for controlling erosion. Disk opener drills also tend to destroy surface clods remaining from previous tillage, which further decreases their effectiveness for controlling wind erosion. If disks are large and spaced wider (25 to 35 cm) than on conventional drills (18 to 25 cm), disk opener drills perform satisfactorily when there are large amounts of residue on the soil. Disk opener drills with close spacing are well suited to planting after clean tillage, especially when the soil is moist at or near the surface.

Lister planters are used widely for row crops, such as sorghum and cotton. The listers open furrows into moist soil and are followed by planting units that have disk, shoe, or shovel openers. Lister ridges help control erosion. Drills with some of the seed spouts closed are sometimes used to plant row crops on lister ridges.

Planters without listers are frequently used to plant row crops on the ridges of lister-plowed land, on flat-plowed land, and on no-tillage land. Where residues do not interfere, double-disk, sweep, shoe, or shovel openers work satisfactorily. Disk openers can operate in more residues than the other types, but with high residues, coulters may be needed to cut residues ahead of the openers.

Table 4–5. Advantages and disadvantages of various water conservation practices.

Practice	Advantages	Disadvantages
Summer fallow	Increases soil water content at planting Increases production reliability (fewer crop failures) Improves control of troublesome weeds Increases yields on harvested-area basis Is possibly more economical than continuous cropping	Results in low water storage efficiency Results in low yields on total area basis Produces less than one crop annually Lowers organic matter content
Mulching	Increases soil water storage Reduces storm water runoff Reduces evaporation Moderates soil temperatures Increases yields Reduces erosion	May require special tillage and planting equipment May require repeated tillage if weeds continue to grow from rainfall occurring soon after tillage May require tillage if herbicides do not control weeds Carries "trash farmer" stigma Requires above-average management May harbor insects, disease pathogens, and small animals May not be economical except for high-value crops
Weed control	Conserves water for crop use Reduces tillage and planting problems Reduces competition with crops for water, nutrients, space, and light Increases yields	May leave surface free of residues, thus permitting erosion
Vertical mulch	Provides path for rapid water entry into soil Reduces runoff and erosion Conserves water for crop use Increases yields	May be costly May not have enough residues grown in place to fill trench Is difficult to maintain slots open to surface Requires intensive management
Terracing	Controls runoff water Reduces erosion hazard Conserves water for crop use Increases yields	May have high initial costs Difficulty in farming with large equipment May need to drain channels during long wet periods Severe rainstorms may cause washouts from overtopping
Contouring	Controls runoff water Reduces erosion hazard Conserves water for crop use Increases yields	Causes difficulty in farming with large equipment Severe rainstorms may cause washouts from overtopping
Basin listing–furrow blocking	Controls runoff water Reduces erosion hazard Conserves water uniformly on area for crop use Increases yields	Requires special equipment for building and removing blocks Severe rainstorms may cause washouts from overtopping

(continued on next page)

Table 4-5. Continued.

Practice	Advantages	Disadvantages
Planting dates	Reduces total evapotranspiration Increases water supply at critical growth stages	May not have favorable soil water conditions at best time for planting Correlates poorly with yields because of low probability of rainfall at critical periods
Use of antitranspirants	Reduces water use Increases yields	Mechanisms of stomatal control not fully established Must apply materials frequently May cause variable results

4-2.4 Specialized Equipment

Most dryland crop production operations are performed with readily available equipment. However, where furrow blocking is used, equipment is needed that builds the blocks and then removes them before cultivation or, if necessary, before harvest. Such special equipment has been developed by Lyle and Dixon (1977) and is commercially available.

4-3 ADVANTAGES AND DISADVANTAGES OF PRACTICES

The advantages and disadvantages listed in Table 4-5 for various water-conserving practices are based on the previous discussions, comments in the literature and by co-workers, and personal experiences. Although the advantages and disadvantages listed are not applicable under all conditions, they are presented without discussion. For example, stubble mulching certainly has advantages different from those of plastic mulches. Where comparative statements are made, the practice listed is compared with no use of the practices, e.g., summer fallow vs. continuous cropping or mulching vs. no mulching.

4-4 PROMISING RESEARCH DEVELOPMENTS

Some water conservation practices that are currently used in the Southern Great Plains are based on research that was conducted more than 30 years ago. Even though the research is still applicable in many cases, recent research has led to improved water conservation. Among the most promising developments are improved herbicides for weed control, improved management practices, and improved and larger implements. Herbicides control weeds and decrease the need for frequent tillage. With less tillage, crop residues can be kept on soils, which enhances water infiltration, decreases evaporation, and helps to control erosion.

Probably the foremost crop management practice developed in recent years is the no-tillage cropping system, which decreases labor, energy, and equipment needs. Although results with no-tillage are limited and may not be as spectacular in the Southern Great Plains as in some more humid locations, these systems have potential for becoming the prime production method wherever crops are grown. Equipment is available for performing no-tillage operations, such as spraying, planting, and harvesting, but careful management is necessary for successful no-tillage crop production.

Other machinery has been developed that permits rapid and more timely weed control in conventional tillage systems; therefore, water use by weeds has decreased. New machinery, along with improved herbicides, has also created renewed interest in furrow blocking for conserving water.

4-5 RESEARCH NEEDS

More tillage than a scientifically determined minimum is undesirable because it exposes the soil to erosion by decreasing surface residues, and it causes water loss by evaporation (Hanway, 1976). Therefore, our ultimate goal should be crop production and water conservation on dryland without tillage. If systems such as no-tillage are to be widely accepted throughout the Southern Great Plains for dryland crop production, research is needed on the following subjects.

More Effective Herbicides. Highly effective and specific herbicides are needed to control weeds and volunteer crop plants between crops and within growing crops. Herbicides must not unduly affect subsequent crops.

Improved Equipment. Although planters are available for no-tillage crop production, residues sometimes clog them, which makes planting slow and causes uneven plant populations. Planters capable of trouble-free operation and of producing uniform populations under high-residue conditions are needed.

Better-adapted Cultivars. Present cultivars were developed for clean-tillage conditions. Cultivars need to be adapted for the higher residue conditions, higher soil water contents, lower soil temperatures, and different fertilizer status than those under older conventional dryland conditions.

Increased Applicability of Research Results. Most conservation tillage research has been conducted on a limited number of soils at a few locations. For general applicability, research must be conducted on more soils at different locations.

More Comprehensive Research. Most tillage research involves two to four controlled variables that are studied by one or two researchers. Research and development teams are needed to simultaneously study more variables and to develop widely applicable, practical, and functional integrated cropping systems.

Better Education and Extension. Even though improved water conservation practices are available for most crops, ineffective practices are still widely used. To promote adoption of improved practices, producers must be informed of these practices through education and extension activities. Tradition has no place in crop production when water, soil, and other resources are not effectively conserved.

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