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Water Conservation: Central Great Plains

5-1 AREA

Areas of the Central Great Plains that receive less than 560 mm average annual precipitation are southeastern Wyoming, eastern Colorado, and west of the 100th meridian in Kansas and Nebraska. Drought probability for the region increases southward because of increasing temperatures and, to a lesser extent, westward because of decreasing average annual precipitation. Elevation increases from about 670 m along the eastern boundary of this semiarid area to over 1890 m along the western boundary at the base of the Rocky Mountains. About 70 to 75% of the annual precipitation occurs during April to October. Snowfall ranges from about 10% of the total precipitation in southwestern Kansas to over 30% in extreme western Nebraska.

The cropped areas are level to gently rolling and occupy the uplands between drainage systems that include five soil orders: Alfisols (Red-Brown), Aridisols (Sierozen to Light Brown), Entisols (Brown, Sandy, or shallow), Inceptisols, and Mollisols (Brown to Chestnut). The Mollisols include the largest area of cultivated dryland. Some of the more important great groups within the above orders include Argiustolls, Haplargids, Paleustolls, Ustorthents, and Torriorthents.

Before World War II, annual cropping prevailed, with little specialized wheat-fallow in the dryland area. About 9.30 million ha of land is now under cultivation. Of this, 3.64 million ha is usually in winter wheat, 3.52 million ha in fallow, and 2.14 million ha divided among plantings of grain and forage sorghum, barley, foxtail and proso millet, corn, oat, rye, and sunflower.

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5-2 WATER LOSSES

Water losses from precipitation in the Central Great Plains are large. Of the water received, 50 to 70% is lost by evaporation (Greb et al., 1974; Good and Smika, 1978). The second largest loss is to weeds and volunteer crop plants (Greb, 1974; Wicks and Smika, 1973). Losses occur from runoff (Mickelson et al., 1965; Mickelson, 1966, 1968) and snow blowoff from cultivated fields (Black and Siddoway, 1971; Greb and Black, 1971; Greb, 1975). In addition, water is wasted by flooding of crops in drainless basins (Mickelson and Greb, 1970).

Researchers since early in the century have been evaluating the magnitude of these water losses and then devising various strategies to minimize the losses so that more water can be used for crop production.

5-3 REVIEW

Early water conservation studies and practices involved long-term rotations of adapted and nonadapted crops, date and rates of seeding, fall-spring plowing, and some fallow trials comparing various tillage implements (Brandon and Mathews, 1944; Kuska and Mathews, 1956; Zook and Weakley, 1944). Most early implements were not well designed for the existing crop, weed, soil, and weather conditions. Nevertheless, these investigators recognized the need for stubble mulching, better weed control, and short-term fallow-crop rotation systems.

Water conservation research has been greatly expanded in the last 25 years, and the findings have been more rapidly applied in commercial production. Most studies now consider all water aspects with a given cropping method or conservation system:

1. Precipitation: income and outgo during entire year.
2. Improved water use efficiency practices.
   a. Infiltration and storage.
   b. Use by plants.

Recent innovations and progress on water conservation research practices for the semiarid Central Great Plains are described below. Because fallow is dominant in this region, most other water conservation practices involve a fallow system directly or are supplementary to fallow.

5-4 WATER INFILTRATION AND STORAGE

5-4.1 Summer Fallow

Fallow is necessary in the semiarid Central Great Plains because the water requirement for initial grain development of winter wheat begins at about 22 cm of evapotranspiration in relation to the 300 to 560 mm/y of precipitation expectancy in this region (Greb et al., 1974; Good and Smika,

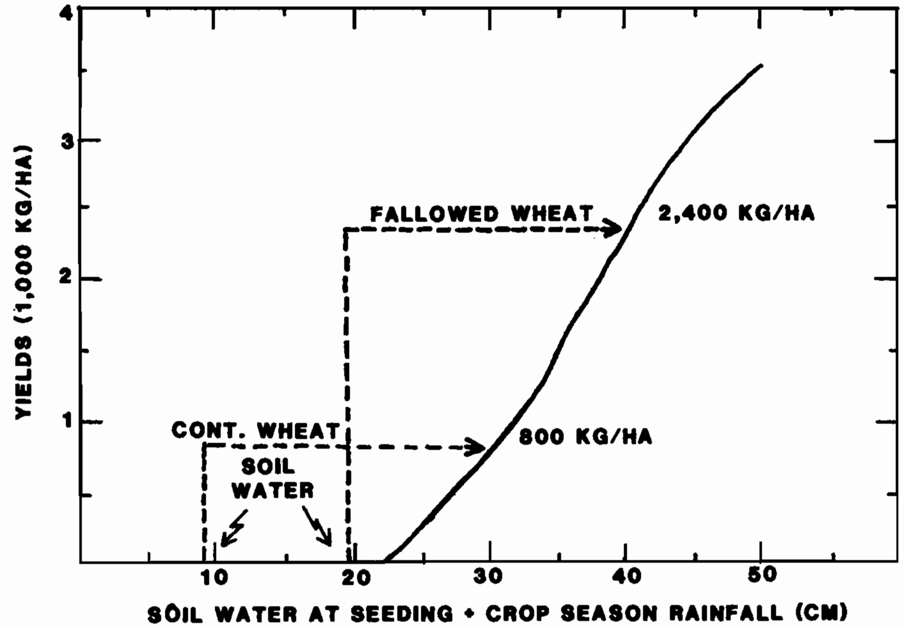

Fig. 5–1. Wheat yield expectancy at North Platte, Nebraska, from 1921 to 1967 (Greb et al., 1974; Smika, 1970).

1978; Smika, 1970). Grain yields then increase about 105 to 180 kg ha^{-1} cm^{-1} of water after the minimum water requirements are satisfied (Fig. 5–1). In a winter wheat-fallow sequence, the fallow period is roughly from harvest early in July to planting early in September of the next season. A 3-year system of fallow-winter wheat-sorghum is commonly used in the 500- to 620-mm average precipitation zone.

Water storage during fallow is subject to many climate, soil, and management factors. Years of research and experience suggest the following requirements for improving water conservation and erosion control in the fallow-crop cycle (Fenster et al., 1969; Fenster and McCalla, 1970; Greb et al., 1967, 1970; Greb, 1974; Harris, 1963; Smika and Whitfield, 1966; Smika and Wicks, 1968; Smika, 1976a, b):

1. Weed control for entire fallow period.
2. Stubble left standing over winter.
3. Straw mulches kept on the surface during the warm season.
4. Hard clods 1 to 8 cm in diameter kept on the soil surface.
5. Management for favorable water content in the seedbed to germinate seeds.

Meeting these requirements maximized available soil water storage and soil NO_3-N, reduces soil erosion potential to near zero, and minimizes the energy and other monetary inputs.

5-4.1.1 Weed Control

For good reason, much of the research with fallow has been devoted to weed control systems. Measurements have shown that uncontrolled weeds may consume soil water at about 0.5 cm/day (Wicks and Smika, 1973).

Certain broadleaf weeds, such as kochia, Russian thistle, and cocklebur, have a feeding depth and radius of root extension equal to or larger than that of most domestic crops. After harvest growth of weeds in undisturbed wheat stubble in the Central Great Plains has produced from 800 to 2700 kg/ha of dry matter (Greb, 1974). Dry matter production of 1000 kg/ha by weeds consumes 8 to 10 cm/ha of water and about 30 kg/ha of available N (Greb, 1974; Wicks and Smika, 1973). Thus, for each 100 kg/ha reduction of potential fall weed growth, wheat yields of grain and straw were increased by about 60 and 120 kg/ha, respectively (Greb, 1974).

Mechanical implements control weeds with varying success. Tillage, however, causes 0.5 to 0.8 cm of evaporative water loss from each disturbance of moist soil (Good and Smika, 1978). Herbicidal weed control, on the other hand, does not disturb the soil, but to be effective, herbicides must rapidly and completely kill all unwanted vegetation. A stunted live weed continues to use water.

5-4.1.2 Standing Stubble Over Winter

In the Central Great Plains north of lat. 39° where snowfall exceeds 600 mm with an average water content of 72 mm/season, from 30 to 55% of the soil water recharge during fallow is from snowmelt (Greb, 1975). Snowfall in standing stubble during the first winter of fallow plus snowfall on wheat in the second winter accounts for an estimated 35 to 45% of this area's wheat production. Snowmelt storage efficiency averaged 53% in undisturbed stubble over a 16-year period (Greb, 1975). Consequently, destroying surface stubble by disking weeds in the fall has proved detrimental. Water saved by controlling weeds with disking was more than offset by the snow blow-off caused by the lack of stubble (Greb, 1974).

5-4.1.3 Straw Mulch

The recent development of large high clearance V-blade implements and rod weeders with attached semichisels (tongs) in combination with increased power has made stubble mulching a widely adaptable type of tillage. By absorbing raindrop impact, mulches help prevent soil puddling and facilitate water infiltration. Mulches also decrease evaporation by cooling the soil by insulation, reflecting the sun's energy, and decreasing wind speed near the soil surface. Table 5-1 compares data for bare fallow and mulched fallow at seven Central Great Plains locations. Water storage during fallow is also influenced by the quantity of mulch available at the beginning of fallow (Table 5-2). Straw available for mulching ranges from 3400 to 4700 kg/ha for most of the Central Great Plains.

Table 5-1. Net soil water gain at end of fallow for bare vs. straw mulches at seven Central Great Plains locations (Smika, 1976a).

Location	Years reported	Soil water gain with No mulch	Soil water gain with Mulch
	Number	cm	cm
Akron, Colo.	6	14.2	17.3
Alliance, Neb.†	8	2.9	3.1
Archer, Wyo.†	2	2.8	4.2
Colby, Kan.	4	11.5	14.1
Garden City, Kan.	6	8.6	9.0
North Platte, Neb.	8	14.6	20.3
Oakley, Kan.	4	8.2	13.1
	Average	9.0	11.6

† Sampled spring to fall (4 months); other locations from harvest to planting (14 months).

Table 5-2. Net soil water gain at end of fallow as influenced by straw mulch rates at four Great Plains locations (Data from Greb et al., 1967, 1970; Smika, 1976a; Unger, 1978).

Location	Years reported	Soil water gain (t/ha of mulch) 0	2.2	4.4	6.6
	Number	cm	cm	cm	cm
Bushland, Tex.	3	7.1	9.9	9.9	10.7
Akron, Colo.	6	13.4	15.0	16.5	18.5
North Platte, Neb.	7	16.5	19.3	21.6	23.4
Sidney, Mont.	4	5.3	6.9	9.4	10.2
	Average	10.7	12.7	14.5	15.7
	Gain by mulching		2.0	3.8	5.0

5-4.1.4 Soil Clods

Only a small amount of moist, fine soil is needed around a seed for germination. Thus, most of the surface soil should be in hard clods. Surface soil clods resist wind erosion, help anchor mulches, slow runoff water, and provide shade and physical protection for young plants, but they do not provide a good medium for weed seed germination (Wittmuss et al., 1973).

5-4.1.5 Seedbed Water Availability

Modern, deep furrow planters can penetrate 12 cm of dry soil to place seeds in moist soil. Mulches maintain soil water closer to the surface and thus permit shallower planting, which is often critical for assuring germination and emergence in dry climate areas (Smika, 1976b). Disk drills are not very good for penetrating dry seedbeds; thus, drilling often results in a low percentage of wheat seed germination. During the drought years of the 1930's and 1950's, poor germination because of lack of surface soil water

Table 5-3. Progress in fallow systems and winter wheat yield at Akron, Colorado (Greb, 1970; Witmuss et al., 1973).

Years	Management system	Average precipitation	Precipitation during fallow received (14 months)	Soil water stored	Fallow efficiency†	Wheat yield
		mm/y	mm	cm	%	kg/ha
1916–1930	Maximum tillage: plow, harrow (dust-mulch)	439	531	10.1	19	1070
1931–1945	Conventional tillage: shallow disk, bare rod weeder	401	467	11.2	24	1105
1946–1960	Improved conventional tillage: began stubble mulch 1957	416	507	13.7	27	1725
1961–1975	Stubble mulch: began minimum tillage with herbicides	389	476	15.7	33	2165

† Based on percentage of soil water storage of precipitation received from wheat harvest in July to end of fallow in September (14-month period).

was a major factor resulting in enormous crop losses. Improving seed-zone water for wheat has increased yields by an estimated 8% in the Central Great Plains (Greb, 1979).

5-4.1.6 Improvements in Fallow Systems

Fallow efficiency, as used here, is the percentage of precipitation stored in the soil profile, measured to the 180-cm depth, from wheat harvest to wheat planting. Data obtained at the U.S. Central Great Plains Research Station (Table 5-3) show that development of improved equipment and new knowledge have improved fallow systems and fallow efficiency. Similar results were obtained at the Colby Branch Station, Kansas, and the North Platte Experiment Station, Nebraska (Greb et al., 1974). All systems mentioned in Table 5-3 are being used today in the Central Great Plains.

Data in Table 5-3 show that improving weed control and straw retention increases fallow efficiency. Wheat yields have doubled from 1916–1930 to 1961–1975, even though annual precipitation from 1961 to 1975 was 51 mm less. Some of the increase in wheat yield was also attributed to better varieties and improved planting and harvesting equipment, but increased fallow efficiency accounted for the largest share (Greb, 1979).

5-4.1.7 Types of Fallow Systems

Maximum tillage (dust-mulch system) involves 7 to 10 operations per season beginning in the spring with plowing and followed by shallow harrowing. Although the system kills weeds, it also destroys all stubble and pulverizes the surface soil. Fallow efficiencies range from 16 to 22%.

Conventional bare fallow begins in the spring and includes several shallow diskings and one rod weed operation for seedbed preparation and requires five to seven operations per season. Surface straw and soil clods are broken down but at a slower rate than with maximum tillage. Fallow efficiencies range from 20 to 24%.

Modified conventional fallow begins in the spring with single disking followed by chiseling with small sweep blades and rod-weeding with tongs attached for the last two seedbed operations. This system saves some straw, results in a moderately cloddy soil surface at planting, and requires four to six operations per season. Fallow efficiencies range from 24 to 27%.

Stubble mulch requires four or five subsurface (V-blades and rod weeder with tongs attached) operations per season when initiated in the spring. During wet springs, however, undercut weeds often reestablish roots. Undercutting of weeds in wheat stubble shortly after harvesting can save an additional 1 to 4 cm of water (Table 5-4) and thereby increase subsequent wheatyields 130 to 560 kg/ha compared with spring tillage (Greb, 1974; Wicks and Smika, 1973). A secondary fall-sweep operation is sometimes

Table 5-4. Effect of fall weed control treatments in new wheat stubble on soil water storage in dryland rotations.

		Soil water storage at		
Rotation and fall weed control treatments	Fall weed growth	Fall dormancy†	Wheat or millet planting‡	Grain yield
	kg/ha	cm	cm	kg/ha
Wheat-fallow			Winter wheat	
North Platte, Neb. 1963-1969 (Wicks and Smika, 1973)				
Check, spring disk	1800	−4.4	14.6	2690
Fall sweep, single	1480	0.5	20.3	2880
Fall sweep + atrazine	400	1.2	21.5	2910
Contact herbicide + atrazine + fall sweep	350	3.4	23.7	3040
Wheat-fallow			Winter wheat	
Akron, Colo. 1969-1972 (Greb, 1974)				
Check, spring disk	1140	2.8	8.9	2420
Fall sweep, single	650	5.3	11.2	2690
Fall sweep, double	370	6.4	12.7	2940
Contact herbicide + atrazine + fall sweep	325	6.4	12.7	2940
Fall-wheat-millet			Millet	
Akron, Colo. 1973-1977 (Greb, 1978a)				
Check, spring disk	1175	0.1	11.4	1990
Fall sweep, double	505	1.9	13.3	2260
Contact herbicides + fall sweep	560	1.3	12.7	2210
Fall sweep + atrazine	390	1.7	13.5	2410

† From 25 October to 10 November.

‡ From 1 to 10 September for wheat and 1 to 10 June for millet.

necessary if volunteer wheat germinates after the first fall-sweep operation. Fallow efficiencies range from 27 to 30% for initial tillage in the spring to 30 to 33% for initial tillage after wheat harvest in the early fall.

Minimum tillage substitutes herbicides for mechanical and weed control during part of the fallow season. The present system implies application of contact or preemergence herbicides shortly after wheat harvesting to rapidly kill all weeds and to inhibit any weeds or volunteer wheat from germinating until late in the following spring. One sweep operation and one or two rod weed (tongs attached) operations are then required until planting in early September. Data in Table 5-4 show the importance of fall weed control in increasing soil water storage and crop yields. When well managed, fallow efficiencies range from 33 to 38%.

No-till relies completely on herbicides, both contact and preemergence, for weed control throughout the entire fallow season. No-till is being tested at Akron, Colorado; Sidney and North Platte, Nebraska; and Tribune, Kansas. Minimum disturbance of stubble and maximum control of weeds should maximize water storage efficiency within today's practical limits of commercial feasibility. Fallow efficiencies have ranged from 40 to 55% (Good and Smika, 1978). Problems with no-till include high cost of certain contact herbicides, possible residual carryover of preemergence herbicides in sandy and high-lime surface soils, and difficulty of planting wheat in heavy stubble.

5-4.1.8 Commerical Wheat Yield Trends

Improved water conservation practices during fallow periods, along with other technical inputs, are being rapidly adopted commercially. Winter wheat yields in the semiarid Central Great Plains have doubled in recent decades (Greb, 1979). Gross yields for western Kansas, western Nebraska, and eastern Colorado averaged 755, 930, 1215, and 1580 kg/ha, respectively, for 1936 to 1945, 1946 to 1955, 1956 to 1965, and 1966 to 1975. These yields were calculated on the basis of planted area, not harvested area, because of the risk factor involved in some districts within the region. Similarly, wheat hectares abandoned decreased from 28% during 1936 to 1945 to 22, 20, and 16% for the next three decades. Wheat yields during 1976 to 1980 averaged 1800 kg/ha with only 12% of the planted hectares abandoned. By 1990, wide spread adaptation of present technology of mulching, minimum tillage, and no-till could increase average wheat yields to 2000 kg/ha, if present climatic conditions prevail.

5-4.2 Runoff Water Control

Annual runoff from dry cropland in the Central Great Plains varies from 0.6 to 5.0 cm on given sites (Mickelson et al., 1965; Zingg and Hauser, 1959). Routine agronomic practices for controlling runoff include (i) using straw mulches, (ii) chiseling to increase surface clods, (iii) planting on the

Table 5–5. Earth-moving practices for capturing water runoff, Akron, Colorado (Mickelson et al., 1965; Mickelson, 1966, 1968; Mickelson and Greb, 1970).

Engineering system	Years reported	Season gain over check runoff water†	Yield increase and crop†	
	Number	cm	kg/ha	
Land leveling	2	6.1	1315	Sorghum grain
	3	4.7	200	Winter wheat grain
Waterway flood pans	3	10.9	2685	Sorghum grain
	3	15.7	5130	Sorghum forage
Conservation terraces	4	3.8	450	Sorghum grain
			280	Winter wheat grain
			540	Winter wheat straw
Lagoon leveling	3	12.7	2275	Corn forage
	2	6.7	1485	Sorghum forage‡

† Based on comparison with check plots composed of contributing area or leveled area receiving no runoff.

‡ Years 1964 and 1966; year 1965 not included because of poor stand.

contour, (iv) stripcropping, and (v) reseeding steep croplands to permanent grass. Using engineering practices to control runoff water, however, involves earth moving. Land leveling, enlarging lagoons, and using waterway flood pans and flat channel terraces have all shown promise on limited site areas (Mickelson et al., 1965; Mickelson, 1966, 1968; Mickelson and Greb, 1970). Earth-moving costs and exposure of less fertile subsoil are weighed against better water utilization and erosion control. Table 5–5 is a summary of engineering practices used to control runoff water. All combined, these systems may be used on 15 to 20% of cultivated dryland.

5–4.3 Snow Control

Average snowfall amounts range from 40-mm water equivalent per annum in southwestern Kansas to 120-mm water equivalent per annum in extreme western Nebraska. About 40% of all snowstorms, which contribute 60% of the snowfall precipitation, are wind transport types that result in the snow being blown off planted wheat land (Greb, 1975). Experimental systems to control blowing snow on croplands include vegetative barriers and wood-slat fences of various porosities (Black and Siddoway, 1971; Greb and Black, 1971; Greb, 1975, 1978b, 1979). Single rows of trees and bushes are not acceptable as other snow barriers in this region because of excessive root extension into adjacent cropped areas (Greb and Black, 1961). Soil water gain per winter from snowmelt, over conventional systems, has averaged 4 to 6 cm across 10-m wide strips of cropland leeward of sudangrass (Greb and Black, 1971) and tall wheatgrass (Greb, 1978b) barriers. This increased water has increased wheat grain yields by 270 kg/ha and forage yields (wheat, rye, hay millet, and sudangrass) by 1200 kg/ha, including the space occupied by the barriers. Snowmelt storage efficiency varied from 45 to 72% and averaged 65%, depending on quantity of snow and exposure time to evaporation. Runoff from frozen soil snowmelt is rare in this region.

5-4.4 Deep Plowing

Deep plowing is a treatment that increases soil water intake by breaking up and diluting thin layers of impervious clay and hardpans that are shallow in the soil profile. An example is the Weld silt loam (Aridic Paleustoll), a benchmark soil of the semiarid Central Great Plains that contains a 10- to 12-cm thick Argillic horizon at the 10-cm depth. Native sod of this soil was plowed to a 45-cm depth as a dilution technique in the spring of 1967 at Akron, Colorado (Greb, 1970, 1979). Soil water storage during five fallow seasons was improved an average 1.8 cm by deep plowing compared with shallow-disk plowing. Straw mulches applied at the rate of 2.2 to 4.4 t/ha as a secondary treatment saved an additional 2.0 cm, thus showing that water conservation practices can give additive benefits. Total dry matter yields of five small grain crops (millet 1 year, barley 1 year, winter wheat 3 years) were increased an average of 765 kg/ha with deep plowing alone and 1550 kg/ha with deep plowing plus straw mulching. Likewise, barley and wheat grain yields were increased an average of 300 kg/ha with deep plowing alone and 490 kg/ha for deep plowing and straw mulch combined.

The benefits of deep plowing tended to diminish with time, suggesting that a second deep plowing would be necessary after about 6 years.

5-5 WATER USE EFFICIENCY BY PLANTS

Systems to improve water use efficiency by plants is another broad area of water conservation. High soil fertility, crop selection, improved crop varieties, evaporation suppression, and varous cultural manipulations increase crop production from a given water supply. These items are discussed below.

5-5.1 Soil Fertility

Many experiments have shown much higher water use efficiency by plants in high fertility soils compared with lower fertility soils. Plants are either not growing or growing slowly because of a lack of nutrients to promote new growth (Viets, 1962). For example, from 1966 to 1969, average water use efficiency of three grass species at Akron, Colorado, was increased from 81 kg ha^{-1} cm^{-1} of water without supplemental N to 110 and 135 kg ha^{-1} cm^{-1} of water with application rates of 28 and 56 kg/ha of available N, respectively (Greb and Black, 1971).

In the semiarid Central Great Plains, most loams as well as silt loams and clay loams are fertile with a moderate-to-good reservoir of organically bound N, plus mineral P and K, concentrated mostly in the surface 30 cm of soil. However, continued erosion and crop consumption of nutrients can reduce these reserves to deficiency levels in relation to water supply. This condition has already occurred on about 35% of the cultivated land area involving coarse-textured soil and on eroded hillsides of finer-textured land. Thus, soil fertility relationships are expected to play a larger future role in maintaining good water use efficiency.

5-5.2 Crop Selection

Crops do not vary much in daily water requirements, but peak demand can be double the average daily use (Viets, 1971). However, crops do vary in length of growing season. For example, the sugar beet has a long growing season, requires more water, and therefore yields poorly on semiarid dryland. Various crops also have peak growth periods at different times of the year. For example, fall-planted winter wheat has a peak water demand from mid-May to mid-June. Soil water accumulated during fallow maintains wheat through a low water demand winter, and wheat can then use peak spring rainfall for peak growth demands. In contrast, dryland corn and grain sorghum have peak water demands in August when rainfall is lower and more erratic and evaporation rates are high. Today, corn and sorghum are seldom grown without irrigation where annual precipitation averages less than 450 mm.

Short-season crops, like the millets, grain, and hay types, are quite water efficient. Maximum total water demand for grain millet is only 30 to 35 cm/season compared with 40 to 50 cm/season for winter wheat (Greb, 1978a). Second, most grain millet has a low straw-grain ratio (1.1) compared with modern wheat varieties (1.7) and dryland corn and sorghum (over 2). Field results at Akron, Colorado, showed that grain production for millet begins at 14.6-cm water consumption compared with 22.2-cm water consumption for winter wheat. Millet has yielded 2800 kg/ha of grain at Akron with a total water use of 33 cm, whereas, wheat yielded only 1000 to 1200 kg/ha of grain with the same water use.

5-5.3 Crop Varieties (Cultivars)

The advent of shorter straw and stalks for small grains and other crops was a logical outgrowth of the water use efficiency concept. Tall and thick plant stems consume too much water in relation to the grain produced, if grain is the desired product. Breeding of winter wheat in the Central Great Plains has followed this trend historically, and new varieties at Akron, Colorado, now have a 30% grain yield advantage over the original 'Turkey' and 'Kharkof' varieties introduced early in the century (Greb, 1979). Breeding for disease and pest resistance has also improved wheat varieties, and, there is evidence of varietal differences in water use efficiency.

5-5.4 Cultural Adaptations

A listing of some of the most widely used cultural practices adaptable to limited water supply are given below.

1. Reducing row-crop populations to match water supply is still used on limited areas of dryland corn, grain and forage sorghums, and sunflower (Brown and Shrader, 1959; Carlson et al., 1959).
2. Wide row spacing promoted root extension into untapped stored soil water and delays drought stress until more rainfall arrives (Greb, 1962).
3. Preemergence herbicides are used for summer crops such as millet. Each kilogram of weed tissue produced during the noncrop and crop season reduces the yield of desired dryland crop by 1.8 to 2.0 kg (Greb, 1974, 1978a).
4. Cropping on the contour is used to control runoff water and soil erosion potential.
5. Using deep-furrow planters for winter wheat provides a better microclimate for snow catchment and for protecting plant crowns from high velocity wind and soil impact.

5-5.5 Exotic Water Conservation Schemes

Several water conservation schemes have been tried for suppressing evaporation or improving water utilization by plants. These approaches to date are severely limited in dryland cropping because the effects are often short lived, expensive, labor intensive, and interfere with conventional farming operations. None of these schemes has proved successful. Details of data can be obtained from the literature cited for each water conservation practice listed below:

1. Applying chemicals to reduce transpiration by stomatal closure (Van Bavel and Ehrler, 1968).
2. Applying long chain organic monomolecular films (hexadeconal) to soils to suppress evaporation (Olson et al., 1964).
3. Applying polyethylene films between crop rows to suppress evaporation and increase soil temperature (Black and Greb, 1962; Harrold et al., 1959; Willis, 1962; Willis et al., 1963).
4. Using metal, cement, butyl rubber, plywood, etc. for water concentration on microslopes and microwatersheds (Aase and Kemper, 1968; Fairbourn and Gardner, 1974).
6. Using plastic films and pellets to prolong soil-clod stability and straw mulches needed for improving erosion control, water infiltration, and evaporation suppression (Fairbourn and Gardner, 1975).
7. Using reflectance shields to change heat radiation and thereby change plant development and timing of water utilization (Aase and Kemper, 1968).

Presently, these approaches seem to be more applicable to small-scale gardens and highly intensive truck farming situations than for large-scale dryland agriculture.

5-6 RESEARCH NEEDS

5-6.1 Source Value of Water

The semiarid Central Great Plains receives precipitation as rainfall, fog, hail, snow, and dew in variable quantities throughout the crop and noncrop seasons where temperatures range from −40 to 40°C. What percentage of these forms of water contributes to plant growth under all these different conditions? Little detailed information is available. Some preliminary estimates on the source value of water for Akron, Colorado, were recently tabulated, as shown in Table 5-6 (Greb, 1979). Although these data do not include a uniform set of crops and years, they do show that water availability for plants is related to evaporation potential. The overwhelmingly greater value of stored soil water compared with randomly occurring rainfall is conclusive evidence that crop yields, dryland or irrigated, are greater when the soil profile is wetted to the expected rooting depth at seeding. As shown, stored soil water per unit is worth four to five times as much as warm season rainfall. The data also show nearly identical benefits from snowmelt water, sprinkler irrigation, and captured runoff. Greater

Table 5-6. Estimated source value of water by descending order for Akron, Colorado (Greb, 1970).

Water source	Crop (data-base years)	Water use efficiency†	Comparative index
		$kg\ ha^{-1}\ cm^{-1}$	%
Soil water at seeding	Winter wheat (21), winter rye (4) grain millet (9), hay millet (4) sudangrass (4), grain sorghum (5)	377	100
Sprinkler irrigation	Corn (1), grain sorghum (1)	234	62
Captured snowmelt	Winter wheat (4), winter rye (4) hay millet (4), sudangrass (4)	216	57
Captured runoff	Winter wheat (5), grain millet (6) corn (7), grain sorghum (9)	216	57
Crop season rainfall, cool season	Winter wheat (4), winter rye (4)	95	25
Crop season rainfall, warm season	Hay millet (4), sudangrass (4)	81	21

† Based on total dry matter for combined group of crops and data years for each water source, planting to harvest.

knowledge in this concept of source value of water may provide clues for filling water loss voids using simple cultural changes.

5-6.2 Chemical Fallow

The technology for complete no-till chemical fallow is undergoing experimentation and development. The implications of reduced tillage in fallow made possible by herbicides are impressive: (i) near elimination of wind erosion threats, (ii) doubling of soil water storage compared with conventional bare fallow, and (iii) much higher wheat yields obtained with a significant decrease in energy expenditure per unit of production.

A substantial decrease in the cost of certain contact herbicides would make this system commercially feasible in the foreseeable future. Experimentation should continue to test both broader spectrum and more highly specific herbicides than those available today. As a supplement to experimentation with chemical fallow, water consumption by various weed types during specific noncrop periods should also be accurately determined.

5-7 CONCLUSIONS

Excellent progress in water conservation concepts and practices has been made in the last 25 years in the Central Great Plains. Much of this work has been concentrated on summer fallow. The easier means of filling water loss voids have been largely accomplished on experimental plots and to some degree in commercial dryland fields. Additional refinements in water management on all land sites in combination with continued improvement of plant varieties are needed to maximize water utilization.

5-8 LITERATURE CITED

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