WATER CONSERVATION TECHNOLOGY FOR THE SOUTHERN GREAT PLAINS

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ABSTRACT

Irrigation rapidly expanded in the southern Great Plains in the 1940's and 1950's, with most of the water for irrigation being pumped from the Ogallala Aquifer. The aquifer, however, is limited and has little recharge; therefore, the water level has declined rapidly in much of the region and some of the once-irrigated land has reverted to dryland farming. Many practices have been developed to use the remaining irrigation water more efficiently and to conserve and use more of the water received from precipitation for crop production. Practices for irrigated, limited irrigated and combination irrigated-dryland, and dryland crop production systems are discussed. By adopting the practices that are based on extensive research, the remaining water can be used more efficiently and the rate of reversion to dryland can be reduced. Use of available practices also can result in favorable crop yields on present dryland areas and on those returning to dryland farming.

INTRODUCTION

The need to conserve water for improved crop production in arid and semiarid regions has long been recognized. Consequently, extensive research regarding water conservation has been conducted in the southern Great Plains since the early 1900's. Most of the early research pertained to tillage methods, row spacings, fallowing, crop rotations, etc., and crop responses to these practices (Smika and Unger, 1986). In the 1940's, work began on the stubble mulch system, which proved effective for controlling erosion and conserving water (Johnson and Davis, 1972; Johnson et al., 1974). These studies involved dryland crops. After World War II, irrigation greatly increased in the southern Great Plains. This resulted in a major shift in research to irrigated crops with a concomitant decrease in research for dryland crops. Renewed interest in research for dryland crops or crops with limited irrigation has developed in recent years because of the declining supply of water and the sharply rising cost of energy for pumping water for irrigation. In this report, we discuss water conservation practices for irrigated, limited irrigation and irrigated-dryland, and dryland crop production systems.

IRRIGATED LAND

Most irrigated land in the southern Great Plains is in the High Plains portion of that region. The water is pumped from the Ogallala Aquifer that underlies most of the region. Because recharge to the aquifer is slight (< 1/2 inch/year, Jones et al., 1985), the water level declined rapidly in much of the region after irrigation began in the 1940's and 1950's. Where the saturated thickness was thin, the aquifer was soon depleted and the land reverted to dryland farming by the 1960's. Reversion to dryland continues, especially south of the Canadian River. In contrast, some new irrigation development still occurs, especially north of the Canadian River where irrigation development began later and where the saturated thickness was greater, but deeper below the surface.

The furrow method of irrigation is most common in the High Plains portion of the southern Great Plains. In that portion, slowly permeable soils and land slopes usually < 1% permit relatively long irrigation runs and sets without major land leveling or percolation losses of water. Common practices, however, often result in about 20% tailwater runoff, which is allowed so that the lower end of the field is adequately wetted. To minimize loss of tailwater, many operators capture and recycle it through the irrigation system. Other operators allow less tailwater runoff, but often at the expense of reduced crop yields on the lower ends of fields.

Water conservation under irrigated conditions also has been achieved by using improved application methods, water conveyance methods, and irrigation timing methods, and by improved management of entire irrigation systems. Improved application methods include (1) sprinkler systems that apply water at rates compatible with infiltration rates and in response to plant needs; (2) the low-energy precision applicator (LEPA) method, which uses very low pressure and drop tubes and achieves about 98% application efficiency when used in conjunction with furrow diking (Lyle and Bordovsky, 1980); (3) the surge irrigation system for which water is applied intermittently to alternate blocks of furrows, and which results in more uniform distribution of water throughout the length of the field and reduces excessive water percolation on more permeable soils; and (4) drip irrigation, which permits applying water in response to plant needs without significant losses to evaporation and/or deep percolation. Drip irrigation in the southern Great Plains is limited to high-value crops, such as grapes and pecans, and is used only on a few hundred acres (J.T. Musick, Bushland, Texas, personal communication).

Most irrigation water 25 to 30 years ago was conveyed from pumps to fields by open ditches. Now, most water is conveyed by underground concrete or plastic pipelines, which has greatly decreased water losses due to seepage and use by non-crop plants. Losses are further reduced when aluminum or plastic pipes convey water from undergound pipelines to invidividual furrows in the field.

In addition to using improved conveyance and application methods, many irrigators apply water in response to plant needs and at critical growth stages. This results in obtaining greatest crop responses to applied water, reduces water losses due to deep percolation, and reduces nutrient losses due to leaching. When to irrigate and how much water to apply is based on an understanding of a crop's need and response. This understanding may result from practical experiences, use of computer services to predict evapotranspiration and plant responses, or by determining soil water depletion with tensiometers, electrical resistance blocks, neutron attenuation, or gravimetric sampling. By use of the above technologies, along with testing irrigation systems and repairing or replacing inefficient systems, many irrigators now efficiently manage the water that remains available for irrigated crop production.

LIMITED IRRIGATION AND IRRIGATED-DRYLAND SYSTEMS

Full irrigation normally results in the highest crop yields. Where full irrigation is practiced, water from precipitation often is largely ignored. This water, however, can play a major role in crop production where limited irrigation and irrigated-dryland cropping systems are used.

Limited irrigation

Limited irrigation involves either reducing the amount of water applied to a crop or reducing the portion of land area for a crop that is irrigated. One technique that requires less than full irrigation, but still results in favorable yields, is that of applying water at critical growth stages. Although yields are lower than with full irrigation, favorable yields are still obtained. Irrigating at critical stages has been shown to be satisfactory for grain sorghum [*Sorghum bicolor* (L.) Moench] by Musick and Dusek, 1971; for wheat (*Triticum aestivum* L.) by Musick et al., 1984; and for sunflower (*Helianthus annuus* L.) by Unger (1982, 1983). Limiting irrigations is not practical for corn (*Zea mays* L.) in the southern Great Plains (Musick and Dusek, 1980).

dryland crops resulted in a slight (2.3%) increase in total water use, but also an 8.5% increase in water use efficiency.

Average gains in soil water during fallow after irrigated wheat averaged 1.5, 2.1, 2.4, and 2.8 inches with disk-, sweep-, limited-, and no-tillage treatments, respectively, in the wheat-sunflower rotation study by Unger (1981). Seed yields of the dryland sunflower planted after fallow averaged 1,120, 1,100, 1,100, and 1,230 pounds/A, respectively, but the differences were not significant at the 5% level. The wheat-sunflower rotation, however, permitted wheat to be planted soon after sunflower harvest and without a fallow period that is normally used when wheat follows grain sorghum in rotation.

DRYLAND SYSTEMS

Land leveling

Land leveling is the most effective means of conserving water and preventing soil erosion by water; however, it may be expensive, particularly if slopes are steep (> 3%) or benches are wide. With laser-controlled equipment, leveling costs are declining and precision is increasing. Land leveling has no direct effect on erosion by wind. Such erosion is most effectively controlled by a cover of surface residues.

Practical, narrow bench terrace systems (minibenches) can be constructed for $50 to $100/A on gently sloping land (0 to 2% slope). Grain sorghum yield increases of 300 to 600 pounds/A/year are required to pay for installing and maintaining minibench terrace systems. At Bushland, Texas, average grain sorghum yields on land with minibench terraces are 1040 pounds/A higher than yields with graded furrows. With minibench terraces only one or two equipment widths wide, shallow soil cuts reduce soil fertility problems usually associated with land leveling, and much less soil is moved (Jones, 1981).

Conservation bench terrace systems have also proven effective for conserving soil and water on slowly permeable soils (Jones, 1975). With conservation bench terraces, the lower one-third of the terrace interval is leveled to capture runoff from the cropped watershed. At Bushland, Texas, the leveled bench of the conservation bench terrace system receives an average of 4.2 inches more water annually than adjacent sloping land. This conserved runoff provides enough additional water to allow annual cropping of sorghum, wheat, sunflower, and alfalfa (*Medicago sativa* L.) (for seed production) on the level bench.

Furrow diking

Furrow diking was developed in the Great Plains in the 1930's. The practice generally was abandoned by 1950, however, because of problems with the slow operating speed of diking equipment, poor weed control, difficulty with seedbed preparation and subsequent tillage, and increased erosion when dams washed out. Engineers at Bushland and Lubbock, Texas, revived the practice in 1975 by designing improved equipment, using herbicides to control weeds, and applying the practice to summer-grown crops that could benefit more than wheat by preventing runoff during the spring and summer when the potential for runoff is highest (Clark and Jones, 1981). Furrow diking (basin tillage) is a proven soil and water conservation practice that farmers have adopted rapidly for both dryland and irrigated crop production in the Southern High Plains and Red Rolling Plains. An estimated 2 million acres were diked in 1984.

No- and minimum tillage

Dryland farmers are adopting conservation tillage systems, including no-till, in which herbicides replace all or some tillage operations. Increasing fuel and equipment costs often make applying herbicides more economical than performing tillage

The amount of irrigation water required for a crop can be reduced also by eliminating the pre-plant irrigation, which often is the most inefficient irrigation. By eliminating this irrigation, a portion of the soil water reservoir may be left available for storage of more water from precipitation. Also, the loss of water by evaporation is decreased during the period when the potential for evaporation is relatively high because of the bare soil surface.

Further techniques for limiting irrigation are those of not irrigating all furrows or of only irrigating a part of the land area. In the first case, water is applied to alternate furrows. The non-irrigated furrows may be diked or remain undiked. If diked, 50% of the water that would be lost as storm runoff is retained on the area, thus increasing the effectiveness of precipitation for crop production. Where irrigation water is extremely limited, skip-row cropping with two rows planted and one or two rows unplanted may be used. The furrow between planted rows is irrigated and the remainder of the furrows are diked to capture water from precipitation. Skip-row planting and irrigation is used extensively for cotton (Gossypium hirsutum L.) in the southern Great Plains (Jones et al., 1985). Musick and Dusek (1982) used a two-in, one-out cropping pattern for corn and grain sorghum with irrigation of the furrow between the planted rows. Water infiltration during one irrigation was reduced 46% as compared to that for every-furrow irrigation. Skip-row systems reduced yields on a total area basis, but increased yields and water use efficiencies on a planted-area basis.

Limited irrigation-dryland

Stewart et al. (1983) developed a limited irrigation-dryland (LID) system that efficiently uses water from precipitation and irrigation for grain sorghum production on furrow-irrigated, slowly permeable soils. With LID, the upper one-half of a field is managed as fully irrigated, the next one-fourth as a tailwater runoff section to capture runoff from the irrigated section, and the lower one-fourth as a dryland section with furrow dikes to capture runoff from rainfall and, in some cases, from irrigation on the upslope irrigated sections. Seeding and fertilizer application rates are varied according to expected yields on the different sections of the field. Alternate furrows are irrigated; the remaining furrows are diked to capture water from precipitation. The objective is to minimize or prevent runoff from the field. In tests at Bushland, runoff was slight with the LID system as compared with a conventional furrow irrigation treatment. The LID system resulted in an average of 350 pounds of grain/A-inch of applied water compared to 215 pounds of grain/A-inch with the conventional treatment.

In contrast to the above system where a part of the same crop was irrigated and the other not irrigated in a given year, the irrigated-dryland system can be used also to irrigate alternate crops on a given area with the following crop being non-irrigated (dryland). Such systems have been evaluated by Unger (1984) and Unger and Wiese (1979) for winter wheat and grain sorghum in rotation, by Unger (1977) for continuous wheat, and by Unger (1981) for winter wheat and sunflower in rotation. For the wheat-sorghum rotation, wheat was irrigated and yielded an average of about 7,000 pounds residue/A. In the study by Unger and Wiese (1979), 15, 23, and 35% of the fallow period precipitation was stored as soil water with disk-, sweep-, and no-tillage treatments, respectively. The non-irrigated sorghum planted after fallow yielded an average of 1,720, 2,230, and 2,800 pounds grain/A with the respective treatments. Precipitation storage during fallow averaged 29% for moldboard, 34% for disk, 27% for rotary, 36% for sweep, and 45% for no-tillage in the study by Unger (1984). The respective grain yields were 2,280, 2,110, 1,950, 2,470, and 2,980 pounds/A for the non-irrigated sorghum planted after fallow.

When irrigated and dryland winter wheat were alternated on the same area, grain yields averaged 10% greater than where irrigated and dryland crops were grown continuously on the separate areas (Unger, 1977). Alternating the irrigated and

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Addendum

Fertility research by USDA personnel in the southern Great Plains:

1. Evaluation of nitrate-nitrogen levels under no-tillage and sweep tillage conditions in a wheat-sorghum-fallow sequence and in a no-tillage continuous wheat system on dryland. H.V. Eck, Bushland, TX.
2. Effect of applied nitrogen and phosphorous fertilizer on dryland wheat in the tillage systems mentioned above. H.V. Eck, Bushland, TX.
3. Determination of the rates of phosphorous fertilizer needed to obtain optimum yields of irrigated crops. H.V. Eck, Bushland, TX.
4. Interactive effects of nitrogen and soil water on growth, development, and yield of winter wheat at several Great Plains locations. J.L. Hatfield, Lubbock, TX.
5. Effect of long-term cultivation on soil productivity. Fertility treatments are applied to soils (Amarillo series) that have been out of cultivation for 35 years and others in cultivation continuously for 50 years. T.M. Zobeck, Big Spring, TX.

(Wiese and Unger, 1983). While research has shown little difference in soil water accumulation or yield between stubble mulch tillage and no-till on dryland (Wiese et al., 1980; Wiese et al., 1967), the additional crop residues retained on the soil surface with no-tillage provide increased protection against wind erosion.

With no-till, applying atrazine[1/] to wheat stubble immediately after wheat harvest to control weeds through the 11-month fallow and into the sorghum growing season is particularly successful in a wheat-sorghum-fallow sequence. This eliminates three to five subtillage operations and possibly one or two cultivations. Problems with grassy weeds during fallow may require an application of glyphosate or subtillage with sweeps.

Glean (chlorsulfuron) was labeled for use on wheat in 1982. In research trials, Glean has controlled weeds and volunteer sorghum during fallow after sorghum, and during the wheat growing season. The economics of Glean in the wheat-fallow-sorghum-fallow sequence are not as favorable as for the triazine herbicides.

Recent advances in application systems for Roundup (glyphosate) and paraquat make these contact herbicides economically attractive for controlling weeds and volunteer crops on dryland. By applying ultra-low volumes of carrier (3 gallons of water/A) with controlled droplet applicators or less than 7 gallons of water/A with fantips, rates of Roundup or paraquat as low as 0.25 pounds/A have effectively controlled weeds (Green et al., 1982). This is only 50% of the level recommended by the label for use with conventional sprayers.

Crop sequence and fallow

Long fallow (non-cropped) periods result in inefficient use of precipitation under the high evaporative demand conditions prevalent in the southern Great Plains. Thus, most cultivated areas are cropped annually to wheat, cotton, or sorghum rather than in an alternate crop-fallow system which produces one crop in 2 years. Well adapted sequences with shorter 11-month fallow periods are wheat-sorghum-fallow or, farther south where cotton is grown, a wheat-cotton-fallow sequence. These systems produce two crops in 3 years.

A wheat-sorghum-fallow sequence, with the option of following wheat with wheat or sorghum with sorghum if soil water conditions are favorable at planting time (> 5 inches of plant available water in the root zone) is probably the best sequence for maximum water conservation and use for crop production for the southern Great Plains.

SUMMARY AND CONCLUSIONS

Extensive water conservation research has been conducted in the southern Great Plains, which has led to the development of improved practices for irrigated and dryland crop production. By adopting the improved practices, more of the water resources can be used for crop production. For irrigated crops, greater conservation and use of precipitation along with the remaining supply of water in the aquifer can result in favorable crop yields and/or decrease the rate of reversion of the irrigated land to dryland. Use of improved conservation practices on dryland can result in favorable and more reliable yields of crops grown on those areas.

1/ This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.