Sprinkler and Furrow Irrigation Trends — Texas High Plains

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ABSTRACT

DECLINING groundwater storage, high pumping energy costs, and low farm profits are causing major changes in irrigation in the Texas High Plains. Irrigation surveys indicated that during a "decade of decline" starting about 1974, furrow irrigated crop area has declined by 39%, while sprinkler irrigated area continued to expand through 1979 and declined by 3% by 1984. The decline in furrow irrigation is associated with systems that have relatively low estimated application efficiencies, primarily associated with deep percolation loss on moderately permeable soils. Two expanding technologies that will continue to improve irrigation application efficiencies are Low Energy Precision Application for center pivot and lateral move systems and surge flow application in graded furrow systems.

INTRODUCTION

Irrigation expansion began in the Texas High Plains during the major drought of the 1930's. Dryland farmers began drilling irrigation wells in the Ogallala aquifer when improved technology developed involving rotary well drilling, turbine pumps, right angle gear drives, and internal combustion engines. Development accelerated during the late 1940's and during the major drought of the 1950's.

Irrigation developed on soils having less than 1% slope. Sprinkler irrigation developed on the loamy soils in the southern part of the area. However, the major irrigation development was in graded furrow systems, with furrow grades mostly in the 0.2% to 0.8% range. Improvements in sprinkler systems after World War II stimulated the major irrigation expansion on the soils that were not suited to furrow irrigation. Developments in center pivot systems continued the expansion of sprinkler irrigation through the 1960's and 1970's. As the use of center pivots expanded, use of hand-move and side-roll sprinkler systems declined.

Irrigation surveys indicated that graded furrow crop area in a 41-county area peaked at about 1.86 million ha (4.60 million acres) in 1974 and has since declined to 1.14 million ha (2.81 million acres) in 1984. Sprinkler irrigation expanded to 0.70 million ha (1.73 million acres) in 1979 and declined by 3% through 1984. The two irrigation application methods accounted for 99.9% of the irrigated crop area in 1984.

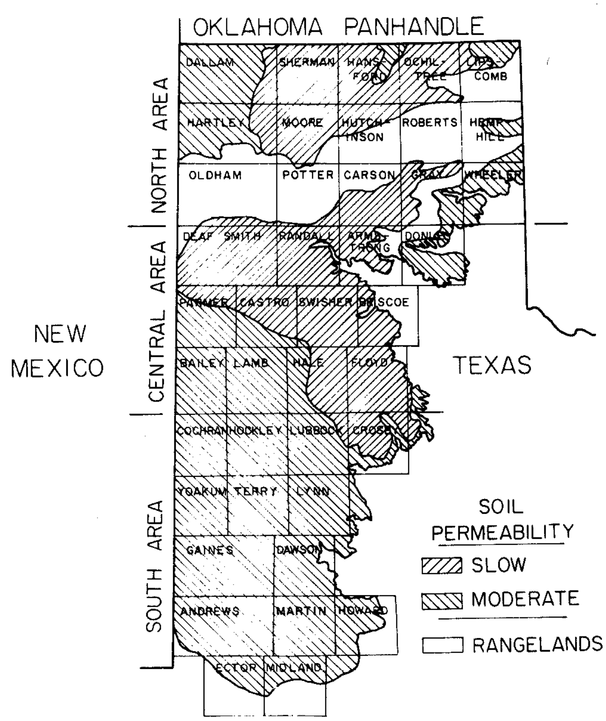

Fig. 1—The irrigated area of the Texas High Plains overlying the Ogallala aquifer divided into the North 15-, Central 12-, and South 14-county areas and into the major soil groups of slow and moderate permeability.

Forty-one counties in the Texas High Plains partially or totally overlie the Ogallala aquifer. For evaluating irrigation trends, the area was divided into North, Central, and South subareas based on cropping patterns and irrigation development, Fig. 1. The 15-county North area has major irrigated crops of corn, grain sorghum, and winter wheat; and 12-county Central area has irrigated corn, grain sorghum, winter wheat, and cotton; and the 14-county South area has cotton as the major irrigated crop and small areas of wheat and sorghum. The four crops, corn, wheat, grain sorghum, and cotton, accounted for 89% of the irrigated cropland and 86% of the estimated groundwater pumped for irrigation in 1984 (Texas Water Development Board, 1986).

For the 41-county area, irrigation surveys conducted at 5 year intervals by the Soil Conservation Service (SCS)

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for the Texas Water Development Board (TWDB) indicated that estimated groundwater use for irrigation increased from 6.37 km^3 (5.17 million acre-ft) in 1958 to irrigate 1.84 million ha (4.55 million acres) to a peak use of 10.03 km^3 (8.13 million acre-ft) in 1974 to irrigate 2.45 million ha (6.05 million acres). By 1984, estimated groundwater use declined to 6.21 km^3 (5.04 million acre-ft) to irrigate 1.84 million ha (4.54 million acres). The survey data through 1984 suggest that an approximate "decade of decline" in Ogallala aquifer pumping has occurred. The decline in irrigated crop area from 2.45 million ha (6.05 million acres) in 1974 to 1.84 million ha (4.54 million acres) in 1984 reflects a transition to dryland agriculture that is primarily associated with groundwater depletion but also reflects economic effects of increased pumping energy costs and decline in commodity prices in recent years.

Depletion of stored groundwater in the Texas High Plains by 1980 had increased to 143 km^3 (116 million acre-ft) since predevelopment (Gutentag et al., 1984). Depletion in Texas accounted for 70% of the total depletion from a regional groundwater aquifer that underlies parts of eight Great Plains states. About 95% of the aquifer depletion was attributed to irrigation pumping.

By 1980, groundwater depletion is sizeable areas of five counties in the Central area of the Texas High Plains (Parmer, Castro, Swisher, Hale, and Floyd) exceeded 50% and most of the Central 12-county area exceeded 25% of predevelopment storage (Luckey et al., 1981). In the south and North areas, the aquifer underlying most of the land area was in the 10% to 25% depletion range. In the South area, parts of three counties (Lubbock, Crosby, and Martin) had depletion exceeding 50%. In most areas where groundwater depletion exceeded 50%, groundwater level decline exceeded 30 m (100 ft) since predevelopment. In most counties north of the Canadian River, water level decline exceeded 15 m (50 ft) by 1980, while the maximum decline in the High Plains of 60 m (200 ft) occurred in Floyd county (Weeks, 1986).

The objectives of this study were to examine (a) the declining trend in furrow irrigated crop area relative to expansion in sprinkler irrigated area; (b) irrigation application efficiencies of sprinkler and furrow irrigation; (c) sprinkler and furrow irrigated crop area in slowly and moderately permeable soil groups; (d) recent technology trends of Low Energy Precision Application (LEPA) in sprinkler systems and surge flow application in graded furrows.

STUDY METHODS

Data on irrigated area were taken by counties from irrigation surveys conducted by the SCS for the TWDB in 1958, 1964, 1969, 1974, 1979, and 1984 (TWDB, 1986). The areas in sprinkler and trickle irrigation were entered in the county survey reports. Since sprinkler and graded furrow irrigation accounted for approximately 99.9% of total irrigated area (trickle irrigated area totaled 0.07%), the difference in sprinkler and total irrigated crop area was used to determine furrow irrigated crop area. In 1986, SCS personnel divided the 1984 sprinkler and furrow irrigated areas by counties into slowly and moderately permeable soil groups for use in this report. The number of irrigation wells was taken from TWDB Rpt. 294. Data on miles of underground pipeline and estimated irrigation application efficiencies were taken from the 1984 county survey reports.

Irrigation survey information and data were determined for each county from the "best sources available" by SCS Field Offices and Area Office personnel conducting the surveys. Irrigated areas were delineated on county general soils maps and maintained on file by SCS and TWDB. Most county reports indicated data accuracy for irrigated area and groundwater pumped to be ±5% and ±10%, respectively.

Sprinkler application efficiency and lower one-quarter distribution uniformity data were summarized from 223 center pivot evaluations in the SCS Amarillo, Lubbock, and Pampa areas during 1980 to 1984. These data were used as the "best estimates" available for sprinkler application efficiencies. Data were grouped by impact and spray nozzle application by windspeed groups of 0 to 2.4, 2.9 to 4.8, and greater than 4.8 m/s (0 to 5, 6 to 10, and greater than 10 mph). Maximum windspeeds during evaluation tests did not exceed 8 m/s (17 mph) except for an occasional test. Applications efficiency was determined from a line of 9.1-m (30-ft) spaced 1-L (quart) cans. The procedure determined application efficiency from combined evaporation and wind drift losses and did not consider the minor losses due to deep percolation (mostly associated with moderately permeable soils) and surface runoff (mostly associated with slowly permeable soils).

Estimates of irrigation efficiencies made by the SCS for the 1984 surveys were taken from the county survey reports and used as "best estimates" of furrow application efficiencies for the slowly and moderately permeable soil groups.

To present a clearer understanding of the soil resources as they relate to geographical location, the irrigated area was divided into two general soil permeability groups of slowly and moderately permeable. The soil series, which comprise these two broad permeability groups, encompass the intake characteristics which are most practical for irrigation.

The slowly permeable soil group is mainly comprised of two series: Pullman (fine, mixed, thermic Torrertic Paleustoll); and Sherm (fine, mixed, mesic Torrertic Paleustoll). These soils typically have dark brown clay loam or silty clay loam surfaces about 0.15 m (6 in.) thick. The subsoil is a brown clay or silty clay that extends to a depth of more than 1 m (40 in.).

The moderately permeable soil group consists primarily of the Acuff (fine-loamy, mixed, thermic Aridic Paleustoll), Amarillo (fine-loamy, mixed, thermic Aridic Paleustoll), Dallam (fine-loamy, mixed, mesic Aridic Paleustoll), Estacado (fine-loamy, mixed thermic Calciorthidic Paleustoll), Olton (fine, mixed, thermic Aridic Paleustoll), and Gruver (fine, mixed, mesic Aridic Paleustoll). These soils typically have a brown, loamy surface layer about 0.15 m (6 in.) thick. The subsoil is a reddish brown sandy clay loam or clay loam that extends to a depth of more than 0.75 m (30 in.). Geologic erosion has stripped away the High Plains mantle in some areas in the eastern and southern parts of the region, exposing the loamy Ogallala sediments.

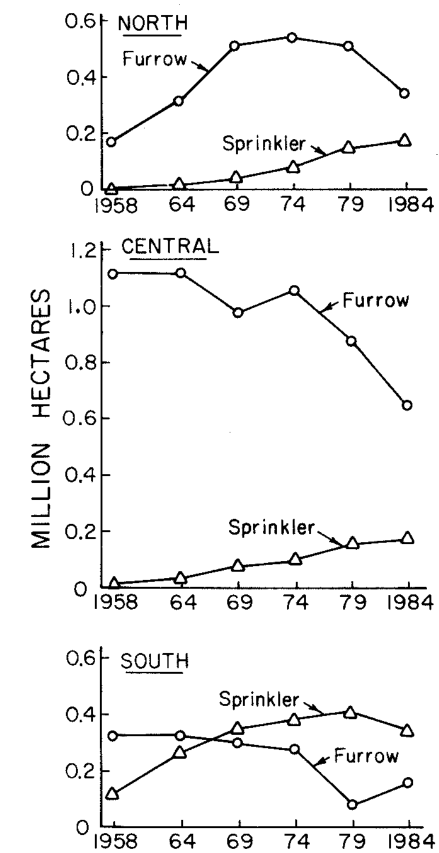

Fig. 2—Irrigated crop area in furrow and sprinkler irrigation systems, North, Central, and South areas, Texas High Plains, 1958-84 survey years.

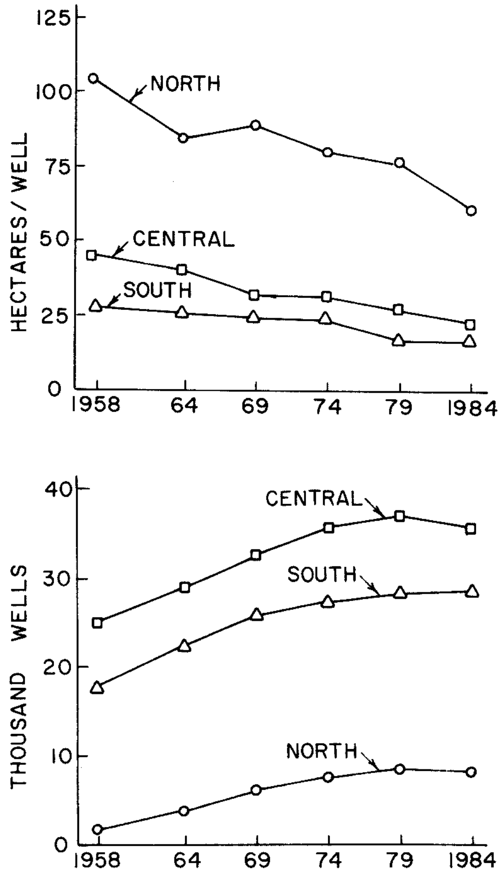

Fig. 3—Irrigation wells and average crop area irrigated per well, North, Central, and South areas, Texas High Plains, 1958-84 survey years.

RESULTS AND DISCUSSION

Irrigation Trends

The earliest and most intense irrigation development occurred in the shallow groundwater areas of the Central counties of the Texas High Plains, where the irrigated area peaked by the late 1950's (Fig. 2). Development continued at a slower pace in the South area and peaked during the late 1960's to the early 1970's. Irrigation developed later in the North area, particularly in the deeper groundwater area north of the Canadian River; and development continued into the late 1970's.

The number of irrigation wells in the 41-county area continued a rather uniform increasing trend through the 1979 survey year, when the total number peaked at 73,700 (Fig. 3). The decline in average irrigated area per well, illustrated in Fig. 3, reflects the influence of groundwater depletion. The effects were most pronounced in the North area that has the greater thickness of saturated aquifer and higher yielding wells. The total crop area irrigated in 1984 was almost identical to the area irrigated in 1958. During this 26-year period, the number of irrigation wells increased from 44,200 to 72,500 and average irrigated area per well declined from 41 to 25 ha (102 to 62 acres). By 1984, on-farm water distribution was almost entirely by the 28,800 km (17,900 miles) of underground pipe in the 41-county area.

Over the 26-year period of irrigation surveys, sprinkler irrigation as a percentage of the total irrigated area expanded from 0.7% to 33.6% in the North area, from 1.1% to 21.3% in the Central area, and from 35.6% to 68.8% in the South area (Fig. 2). By 1984, sprinkler irrigated crop area averaged 37% of the total irrigated area. The continued increase in percentage of crop area under sprinkler irrigation primarily resulted from the decline in furrow irrigation rather than additional land being irrigated with sprinklers.

The high percentage of sprinkler irrigation in the South area resulted from five irrigated counties (Cochran, Dawson, Gaines, Terry, and Yoakum), that had nearly 100% of the irrigated area in sprinkler systems. Center pivot expansion on the medium-and fine-textured soils continued in the North and Central areas through 1984 as crop area under sprinkler irrigation in the South declined after 1979. This decline, compensated by the expansion in the Central and North areas, resulted in no net change in total sprinkler irrigated crop area from 1979 to 1984. The decline in the South area primarily resulted from the reduction in use of stationary systems, which declined from 10% of the total sprinkler systems in the Texas High Plains in 1979 to 4% in 1984. The removal of some obsolete water drive center pivots from use also contributed to the decline.

Data in Fig. 2 indicate the transition to dryland is primarily occurring on furrow irrigated land and is mostly concentrated in counties that have experienced major groundwater decline or where the decline has reached the critical economic limits of continued

TABLE 1. CROP AREA IN 1984 IRRIGATED BY SPRINKLER AND FURROW SYSTEMS ON SLOWLY AND MODERATELY PERMEABLE SOILS FOR THE 41-COUNTY AREA OF THE TEXAS HIGH PLAINS SHOWN IN FIG. 1.

	Sprinkler		Furrow	
Counties	Slowly permeable, ha	Moderately permeable, ha	Slowly permeable, ha	Moderately permeable, ha
North	27,300	112,990	253,740	84,240
Central	30,820	145,040	376,880	273,750
South	1,480	335,270	52,150	100,600
Total	59,600	593,300	682,770	458,590
% of Total	3.3	33.1	38.0	25.6

irrigation because of small well yields. The major decline has occurred since the 1979 survey in the North area and since the 1974 survey in the Central and South areas. Over the 10-year period, the decline in furrow irrigated crop area totaled 38% in both the North and Central areas and 44% in the South area and averaged 39% overall. The South area showed an unusually large decline in the 1979 inventory, which probably occurred because of a wet season in parts of the area. For example, irrigated crop area in the adjoining counties of Hockley and Lubbock declined from 212,100 ha (523,890 acres) in 1974 to 79,300 ha (195,900 acres) in 1979 and then returned to a reduced "normal" level of 154,000 ha (380,400 acres) in the 1980 dry season (the 1980 survey of the Texas High Plains was taken to verify the decline data in the 1979 survey, Texas Dept. of Water Resources, 1981). Cotton is the predominant irrigated crop in the two counties, and many fields in graded furrow systems in 1979 were cropped as dryland. In contrast to the 44% decline in furrow irrigated crops in the South area since 1974, sprinkler irrigated area peaked in the 1979 survey and declined by 8% from 1979 to 1984.

Soils and System Application Efficiencies

The crop area irrigated by sprinkler and furrow systems for the two major soil permeability groups is presented in Table 1. Slowly permeable soils occupied 41% and the moderately permeable soils 59% of the total irrigated area. Sprinkler irrigation was strongly concentrated on the moderately permeable soils (91%). On these soils, water application by sprinklers has potential application efficiency advantage from smaller application depths and reduced losses to deep percolation compared with furrow irrigation. Application depths from 122 center pivot evaluations by SCS personnel in the Amarillo and Pampa areas averaged 27 mm (1.06 in.). Only 9% of the 122 tests exceeded 50 mm (2 in.) application. Therefore, deep percolation losses are considered minimal.

Slowly permeable soils account for 60% of the furrow irrigated soils in the Texas High Plains (Table 1). Furrow application depths to slowly permeable soils are commonly in the 80- to 120-mm (3.2- to 4.7-in.) range. Water intake rates during initial wetting are commonly quite high due to shrinkage crack effects or effects of a loose surface soil layer from tillage. After initial wetting, intake rates rapidly drop to a basic rate of about 2 mm/h (0.08 in./h), which limits water movement through the profile and greatly reduces losses to deep percolation compared with the more permeable soils. Because of the low basic intake rates and the relatively high profile water storage capacity, seasonal irrigations mostly result in partially wetting the slowly permeable soils. In a study involving deep coring of the slowly permeable clay loam and underlying Pleistocene sediments, Aronovici (1971) concluded that little or no measurable deep percolation occurs except for irrigated areas with extended intake opportunity time. Significant deep percolation had occurred on two of the sites tested (a) in a nearly level graded furrow field (0.2% slope) that had been frequently irrigated for 20 years and (b) in a level border area where large applications had been used.

The major loss from furrow irrigating the slowly permeable soils is tailwater runoff. Tailwater reuse systems (designed by SCS for 67% reuse) are commonly used on these soils. Application efficiencies considering tailwater reuse are relatively high (80% to 90% range) and compare favorably with the 83% average application efficiency from 223 center pivot evaluation tests in the Texas High Plains.

Although 41% of the irrigated area was surveyed as having slowly permeable soils in 1984, only 9% of the sprinkler irrigated area was on these soils. This low percentage probably reflects the lack of an application efficiency advantage of these soils. Instead, center pivot systems are used primarily to reduce irrigation labor requirements. An exception is the LEPA system, which increases application efficiency and reduces energy requirements.

Furrow irrigation depths on the moderately permeable soils are higher than on the slowly permeable soils and are commonly in the range of 120 to 180 mm (4.7 to 7.1 in.). Because of the higher water intake rates, tailwater runoff is normally less than occurs on the slowly permeable soils. The major application loss of these soils is associated with deep percolation. The 0.60 million ha (1.48 million acres) reduction in irrigated area over the 1974-84 survey period is almost entirely in graded furrow irrigation (Fig. 2) and is mostly concentrated on moderately permeable soils that have lower estimated application efficiencies.

When county data were grouped by the subareas shown in Fig. 1, the range in soil texture and permeability was associated with a range of 55% to 72% in estimated average furrow application efficiency without considering tailwater reuse. The maximum range was from 40% in four counties where soils are

TABLE 2. AVERAGE CENTER PIVOT SPRINKLER APPLICATION EFFICIENCY AND DISTRIBUTION UNIFORMITY FOR 223 EVALUATION TESTS BY WINDSPEEDS FOR SPRAY NOZZLE AND IMPACT SPRINKLERS. THE CENTER PIVOT EVALUATION DATA FROM TESTS BY SCS IN THE TEXAS HIGH PLAINS ARE COMPARED WITH SOLID SET RESEARCH DATA FROM BUSHLAND, TX, BY CLARK AND FINLEY (1975).

System and nozzle type	Windspeed, m/s	No. of tests	Application efficiency, %	Distribution uniformity, %† DU	Distribution uniformity, %† UC
Center pivot					
Spray nozzle:	0 to 2.4	26	90	76	
	2.9 to 4.8	47	85	69	
	> 4.8	27	80	67	
	Total or Avg.	100	85	70	
Impact sprinkler:	0 to 2.4	26	89	76	
	2.9 to 4.8	49	84	74	
	> 4.8	48	77	77	
	Total or Avg.	123	82	76	
Solid set*					
Impact sprinkler:	1 to 3	7	92	80	90
	3 to 5	7	91	71	82
	5 to 7	7	83	62	76
	7 to 8.1	5	73	47	67
	Total or Avg.	26	86	66	79

*Average data for simultaneous duplicate tests by Clark and Finley (1975).
†DU (lower one-quarter distribution uniformity) is the same as SCS pattern efficiency. UC (Christiansen's coefficient of uniformity) was calculated for the solid set impact sprinkler data, and DU values were calculated from the equation DU = -60 + 1.6 UC by Warrick (1983).

dominantly moderately permeable (three counties in the southwest and Dallam in the northwest) to 80% in three counties having mostly slowly permeable soils.

Musick (1985) considered tailwater runoff data available from research and demonstration tests and farmer irrigation practices in the North area and concluded that tailwater runoff probably averages about 20% of applied water. Considering probable losses to deep percolation, the range of estimated furrow application efficiencies in the North area of 59% for moderately permeable and 72% for slowly permeable soils appears reasonable.

Although graded furrow irrigation on the moderately permeable soils had declined substantially by 1984, 44% or 458,500 ha (1.13 million acres) of the total crop area were furrow irrigated, with an average estimated irrigation application efficiency of 56%. Considering that center pivot sprinkler application efficiencies for 223 evaluation tests averaged 83% suggests that application efficiency can be improved substantially by conversion to sprinkler irrigation. Field test by the Texas Agricultural Extension Service in the Texas High Plains "indicated that center pivots improve water application efficiency enough to irrigate 20% to 25% more acreage than can be covered with furrow irrigation with the same water" (New, 1986).

Irrigation application efficiency evluation tests in Oklahoma (23 center pivots and 16 graded furrow systems) averaged 84% for sprinkler and 68% for furrow systems ("Oklahoma irrigation evaluation data 1983-1984," SCS unpublished report). Furrow application efficiencies have a relatively wide range of values, depending on soils and management, while sprinkler application efficiency data, when averaged by windspeed groups, are more consistent. Thus, the application efficiency advantage of sprinkler irrigation depends on the comparative application efficiency of furrow irrigation. The advantage can range from 20% to 25% indicated by New (1986) to little or none on efficiently irrigated slowly permeable soils. The advantage depends primarily on soil properties and management.

System Technology Trends

Center pivot systems designed for low pressure application are widely used in the Texas High Plains. Low pressure systems apply water mostly through low angle impact sprinklers, spray nozzles, or LEPA. The 223 system evaluation tests performed by SCS personnel in the Texas High Plains and summarized for this study were conducted primarily to evaluate the low pressure application systems under a range of environmental conditions.

Comparitive data for impact sprinkler and spray nozzle application for three ranges of windspeeds are presented in Table 2. The spray nozzle systems were mostly low pressure (operating pressures taken at the top of the pipe near the pivot averaged 223 kPa or 32.3 psi), while the data for impact sprinkler systems represent both low and high pressure systems. When the data were grouped by windspeeds, the average values indicated the application efficiencies were similar for both low and high pressure application and for impact sprinkler and spray nozzle application for similar windspeeds, particularly in the low to moderate range (0 to 2.4 and 2.9 to 4.8 m/s or 0 to 5 and 6 to 10 mph).

The lower one-quarter distribution uniformity of impact sprinklers was rather stable over a wide range of windspeeds, while the moderate to high windspeeds lowered the distribution uniformity of low pressure spray nozzle application. The smaller droplet sizes of spray nozzles are subject to greater distortion of the distribution pattern by high windspeed. Detailed solid set tests with impact sprinklers by Clark and Finley (1975) indicated that increasing windspeed had a significant effect on lowering Christiansen's coefficient of uniformity and the lower one-quarter distribution uniformity. In general, the extensive evaluations indicated that well-designed low pressure systems were equally as efficient as high pressure systems in water application when evaluated by catch can methods.

Windspeed had the most effect on sprinkler application efficiency of any of the factors evaluated (Table 2). The data indicate that an increase in windspeed from low (mostly 1 to 2 m/s or 2 to 4 mph) to relatively high (greater than 4.8 m/s or 10 mph) approximately doubled the application losses. These data are similar to data obtained by Clark and Finley (1975) from tests of stationary impact sprinklers at Bushland, TX, in which a highly significant exponential equation was developed between windspeeds greater than 4.5 m/s (9.4 mph) and application losses. The data by Clark and Finley were grouped by windspeeds and included in Table 2 for comparison. These data clearly show the effect of higher windspeeds on reducing application efficiency.

Application efficiencies averaged 86% for the 26 duplicate tests by Clark and Finley, in which windspeeds ranged from 1.3 to 8.1 m/s (2.7 to 17 mph). After examining windspeeds at locations in the Texas High Plains and considering the test results at Bushland, they concluded that the yearly irrigation season application loss from sprinklers in the Southern Plains could be expected to average about 17%. This predicted average application loss is identical to the average application loss obtained from the 223 center pivot evaluation tests conducted by the SCS. The test condition for the data reported in Table 2 may underrepresent high wind conditions commonly encountered during the spring irrigation season in the Texas High Plains. However, most tests were conducted during the day when diurnal windspeeds were high and underrepresent the lower windspeeds during the nighttime and early morning hours. Therefore, the 17% average losses from 223 center pivot evaluations are believed to adequately represent the irrigation season windspeed environment of the Texas High Plains.

The Low Energy Precision Application (LEPA) with spray nozzle or bubblers on center pivot drops operating 0.2 to 0.4 m (8 to 16 in.) above the furrow elevation (for adequate clearance of moderate to high beds) is the most efficient water application system in use in the Texas High Plains. Tests by Lyle and Bordovsky (1983) consistently indicated application efficiencies around 98% when applicators were operated near the soil surface and microbasin tillage was used to prevent surface runoff. Because of groundwater depletion and declining well yields, some center pivots are operated with inadequate water supplies. Considering the average 83% application efficiency obtained for conventional center pivot systems and the 98% reported for LEPA, conversion to LEPA can provide about 15% additional water as potentially available for plant use. This assessment of approximately 15% additional water application available for plant use is less than the reported 20% to 25% by New (1986).

LEPA equipment is available for most new center pivots and for conversion of existing systems. While some farmers are using microbasin tillage (furrow dams) to prevent runoff from the high intensity water application, others are using deep tillage in furrows, surface management of crop residues, and circular bed-furrow systems to reduce or minimize runoff (New, 1986).

The newest technology being widely adopted in graded furrow systems is surge flow application. Surge flow consists of using an electronic controller to operate one or more valves in a surface pipeline tee directly downstream of a main pipeline riser. Water is alernately applied in repeated on and off cycles through gated pipe in a set of furrows on each side of the tee. Extensive literature indicates that surge flow is effective in reducing water intake rates and furrow application depths. The effect on reducing water intake on Olton clay loam in the Texas High Plains was reported by Musick et al. (1987) as 32% when the soil was in a loosened condition by tillage and about 17% for seasonal irrigations after surface layer consolidation from previous irrigations. Olton clay loam is a moderately permeable soil in which intake can be excessive and most losses occur as deep percolation (Musick et al., 1985; Musick and Pringle, 1986). Surge flow reduced deep percolation losses on Olton clay loam to about one-third of conventional continuous flow irrigation.

The use of surge flow application to reduce application depths, combined with the use of tailwater reuse systems, offers opportunities for substantial reductions in water application losses on the moderately permeable soils. Surge flow application to the slowly permeable soils is likely to be most beneficial during preplant irrigation, when application depths are large and the soil profile frequently has limited additional water storage capacity. Seasonal irrigation depths on these soils are normally not excessive, and surge flow may be of limited value in improving application efficiencies. However, under conditions where its use does not improve application efficiency, surge flow offers potential for system management to reduce tailwater runoff losses.

Following introductory sales in the Texas High Plains in 1983, industry sources indicate about 3,500 units were sold during the next three years through 1986. Reports of reduced yields were not uncommon in 1984, the first year of major sales. However, after two additional years of experience, surge-flow has become well established and accepted by graded-furrow irrigators in the Southern High Plains; and sales have expanded into furrow irrigated areas of the Central High Plains.

SUMMARY

The 5-year surveys of irrigated crop area in the Texas

High Plains, conducted by the Soil Conservation Service for the Texas Water Development Board, indicated a "decade of decline" has occurred since 1974. During a 10-year period, furrow irrigated crop area from North to South in a 41-county area declined by from 38% to 44%. During the period of decline in furrow irrigated area, sprinkler irrigated area continued an expansion trend in the North and Central subareas and declined since 1979 by 8% in the South area. The decline in the South was associated mostly with the reduced use of stationary systems and some decline in use of obsolete water drive center pivot systems.

Data from 223 center pivot evaluation tests indicated application efficiency averaged 83%. A grouping of sprinkler data by windspeeds indicated that an increase in windspeeds from low (less than 2.4 m/s or 5 mph) to high (greater than 4.8 m/s or 10 mph) doubled sprinkler application losses. Low pressure impact sprinkler and spray nozzle systems were equally as efficient in application as high pressure impact sprinklers where runoff was not a problem with low pressure systems. However, distribution uniformity of spray nozzle application was adversely affected to a greater extent by high windspeeds.

When the 1984 irrigated area was classified into moderately and slowly permeable soils, moderately permeable soils accounted for 59% of the total irrigated area and 91% of the sprinkler irrigated area. Furrow irrigation efficiencies estimated for the 1984 survey indicated that moderately permeable soils averaged 59% application efficiency, while the slowly permeable soils, predominantly occurring in the North area, averaged 72% without considering tailwater reuse. Considering the average application efficiency of 83% for sprinkler system and the 59% for furrow systems on the moderately permeable soils, the 0.60 million ha (1.48 million acres) reduction in furrow irrigated soils and continued expansion of center pivot systems over time no doubt has substantially improved the overall irrigation efficiency in the Texas High Plains.

When considering reuse of tailwater runoff, applications efficiency of furrow irrigated slowly permeable soils compares favorably with conventional center pivot systems. Low Energy Precision Application sprinkler systems and surge flow application to furrow systems are being adopted as new technologies that offer potential for substantial improvement in application efficiency. Adoption of LEPA systems will likely continue the expansion of sprinkler irrigation irrigation beyond the 37% of total area irrigated in 1984, while the adoption of surge flow may slow the transition of furrow irrigated land to dryland cropping.

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