CASE HISTORY STUDY TO DOCUMENT THE EFFECTIVENESS OF WATER USE EFFICIENCY RESEARCH

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Conducted by the Directors of the
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ERRATA SHEET
WRRI Report # 133

All dollar figures in table 2 page 16 should be multiplied by 1000 to yield the following corrected figures:

State	Thousands of Acres	Efficiency Improvement 10%	25%	50%
Texas	1,740	536,000,000	1,075,000,000	1,467,000,000
Oklahoma	500	154,000,000	309,000,000	422,000,000
New Mexico	250	77,000,000	154,000,000	211,000,000
REGIONAL TOTAL	2,490	767,000,000	1,538,000,000	2,100,000,000

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INTRODUCTION

In October of 1979, the Office of Water Research and Technology (OWRT) asked state water institutes to assess the effectiveness of OWRT sponsored research and submit proposals to develop documented case history studies. This project is the result of a cooperative proposal developed by the Institutes of the Southern Plains Region.

The objective of the project was to conduct a regional analysis of the effectiveness of water use efficiency research. Due to the wide scope of this field, the study focused on two specific techniques often used together; furrow diking and low energy precision application irrigation.

METHODS

The initial stage of the study was a planning meeting of the institute directors to develop background information and outline the scope of the project. The second stage relied heavily on interviews conducted on site with farm operators, irrigation specialists, irrigation equipment manufacturers, and extension personnel. Figure 1 shows a map of the study area. Information gained at this stage was supplemented with printed material from farming publications, scientific journals, and OWRT project completion reports. The final phase of the project was a review of all information gathered and its synthesis into a report.

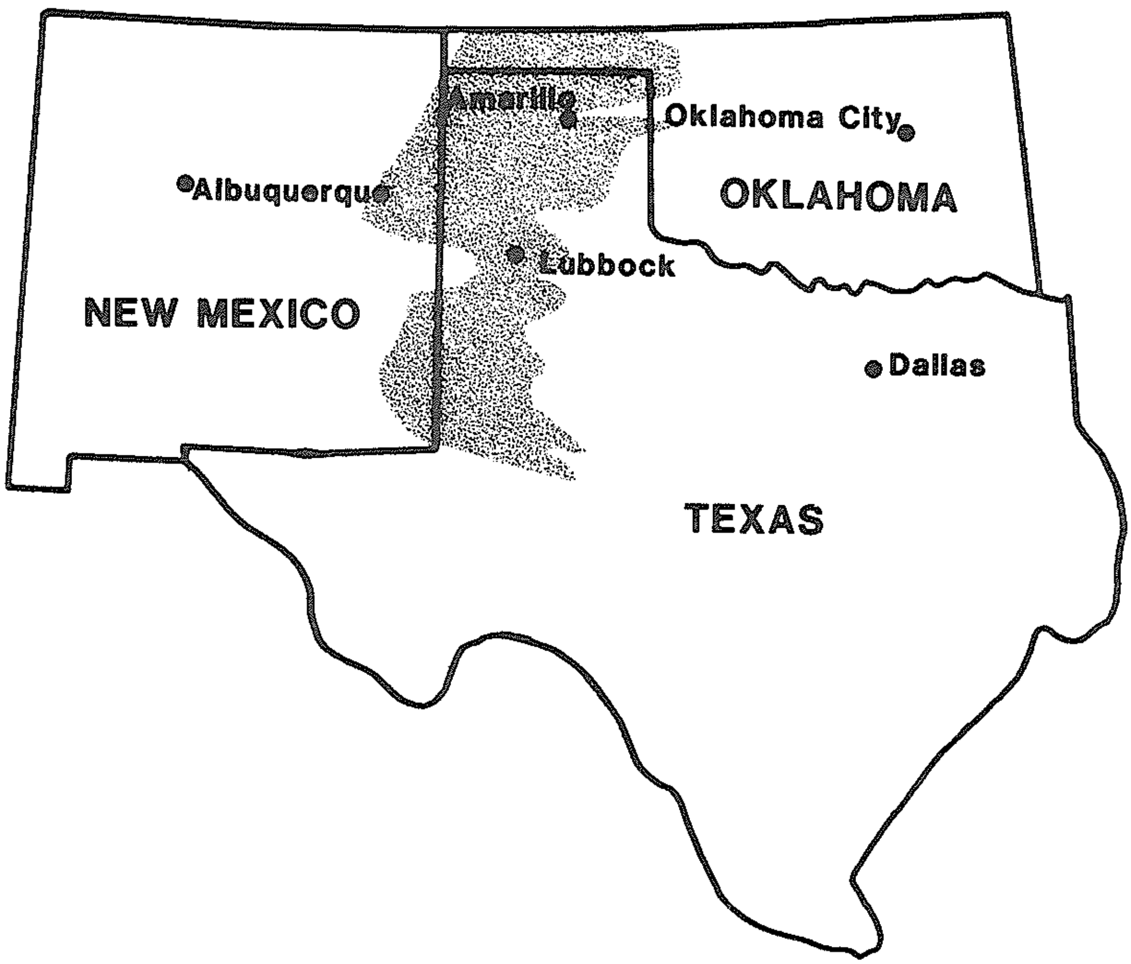

Figure 1. Study Area (Shaded area represents the Southern High Plains of Texas, New Mexico and Oklahoma)

THE PROBLEM

Irrigated agriculture in the semi-arid west depends heavily on groundwater. This is particularly true in the High Plains of Texas, Oklahoma, New Mexico, Colorado, Kansas, and Nebraska. These underground supplies are being depleted faster than they are being recharged by rainfall. This causes water levels to drop requiring water to be pumped from increasing depths. Well yields (flow rates) are often reduced too.

In much of the region, water is pumped from the well and delivered to a center pivot sprinkler boom at sufficient pressure to spray water over the growing crop as the boom moves. Because of the high flow rates and pressures required, the center pivot sprinkler system is an energy intensive process. Pumps are being driven by expensive fossil fuels, usually natural gas or diesel oil. The costs associated with delivering water under the high pressure can be equivalent to lifting the water an additional 180 feet.

In addition, a significant amount of the water is lost to evaporation as the spray is caught in the wind. On the average, over 20 percent of the water pumped into the system is lost before it can be used by the crop. Farm operators are thus faced with three problems: water, energy, and money. As one farmer recently put it, "If energy costs continue to rise, we will run out of money before we run out of water."

THE NEED

In the face of these problems, new technology was needed to make more efficient use of water and energy. Techniques which allow the same level of crop production with less water, water delivered at lower pressure, or both, conserve water and energy. Reductions in the use of either saves money. In addition, techniques to take maximum advantage of rainfall will reduce the need for supplemental water and allow more effective dryland farming when water, energy, or money are not available for irrigation.

SOLUTIONS

There are many possible solutions which can be used alone or in combination to alleviate the problems of diminishing water supplies and increasing energy costs. Sometimes the techniques are already available and all that is needed is to inform the potential users. More often, however, ideas exist which must be synthesized, developed into a potential solution, tested and then proven workable. This is the role of research.

A good example of how research was put to work to save water and energy can be found in the development of furrow diking and drip irrigation techniques. Several OWRT-sponsored research projects are responsible for much of the development necessary to convert these ideas into practical farming techniques. Table 1 lists these projects and the federal contribution which provided the stimulus for the development of furrow diking and drip irrigation.

Table 1

SELECTED OWRT FUNDED PROJECTS ON IRRIGATION EFFICIENCY RESEARCH

Project No.	Project Title	Principal Investigators	Federal $
B-080-TEX	Increasing Water Use Efficiency Through Improved Orifice Design and Operational Procedures for Sub-Irrigation Systems	O. C. Wilke and E. A. Hiler	$22,200
A-024-TEX	Optimization of Water Use Efficiency Through Trickle Irrigation and the Stress Day Index	E. A. Hiler and T. A. Howell	$21,641
B-167-TEX	Increased Water Use Efficiency Through Trickle Irrigation	E. A. Hiler	$19,000
A-041-TEX	New Irrigation System Designed for Maximum Irrigation Efficiency and Increasing Rainfall Utilization	W. M. Lyle and J. P. Bordovsky	$16,686
A-027-NMEX	Utilization of Water in a Semi-Arid Region	H. Dale Fuehring	$4,000
B-029-NMEX	Utilization of Water in a Semi-Arid Region	H. Dale Fuehring	$14,686
B-054-NMEX	Predicting Consumptive Use with Climatological Data	Eldon Hanson and Ted Sammis	$100,000

Furrow Diking

The concept of micro-basin tillage, on which furrow diking is based, is not a recent innovation. The arrangement of furrows to catch and retain rainfall dates to biblical times. During the period 1971-1975, in OWRT-sponsored projects A-027-NMEX and B-029-NMEX, Dr. Dale Fuehring studied the effect of alternating bare rows with cropped micro-basins. He found this an effective technique in years with sufficient rainfall.

Furrow diking is a method of micro-basin tillage which places small dikes of soil in furrows at regular intervals to form basins (Fig. 2). Rainfall or drip irrigation water is retained in the basin to allow time for lateral infiltration (Fig. 3). Very little water is lost to runoff. These small dikes are particularly important where rainfall is intense over a short time period.

The practice dates back to the early 1930s when the method was mechanized on a primative basis. From that time until the mid-1970s only sporadic research was done and the practice was not widely employed. These early applications of furrow diking were used primarily during the winter fallow period. The renewed interest in furrow diking was associated with using it to retain rainfall and irrigation water during the growing season. Dr. William Lyle, during 1976-1979, in research supported by OWRT and the Texas Agricultural Experiment Station, developed efficient workable furrow diking equipment (Fig. 4). Similar designs were developed in the late

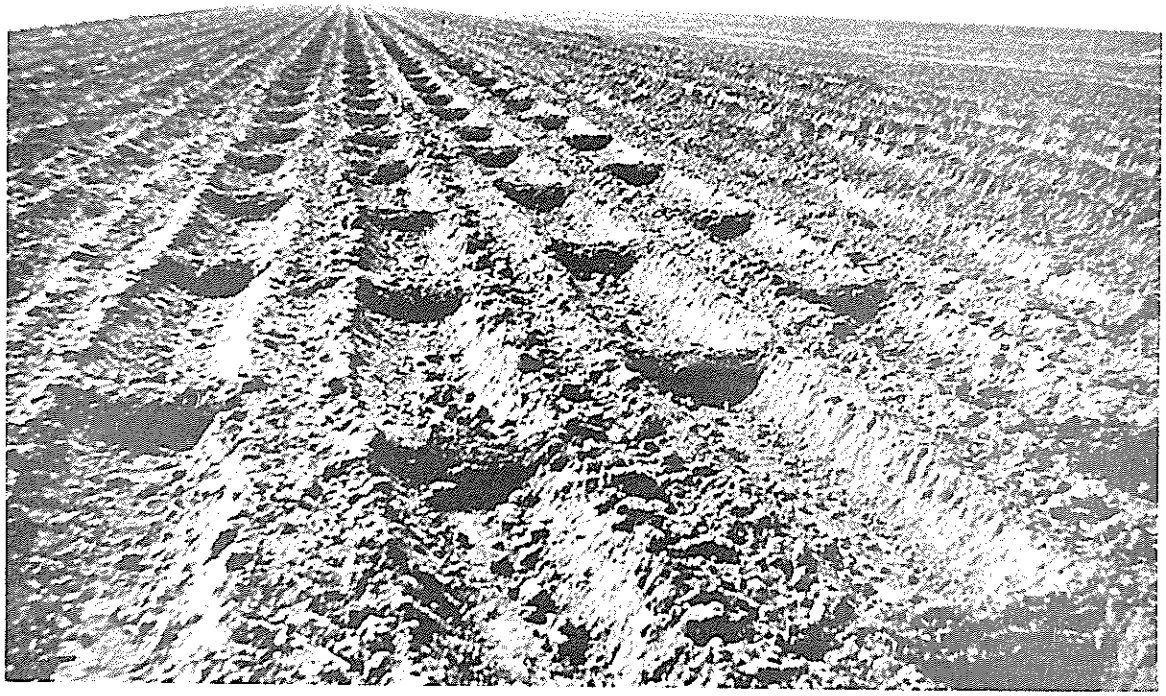

Figure 2. Dry Field with Furrow Dikes

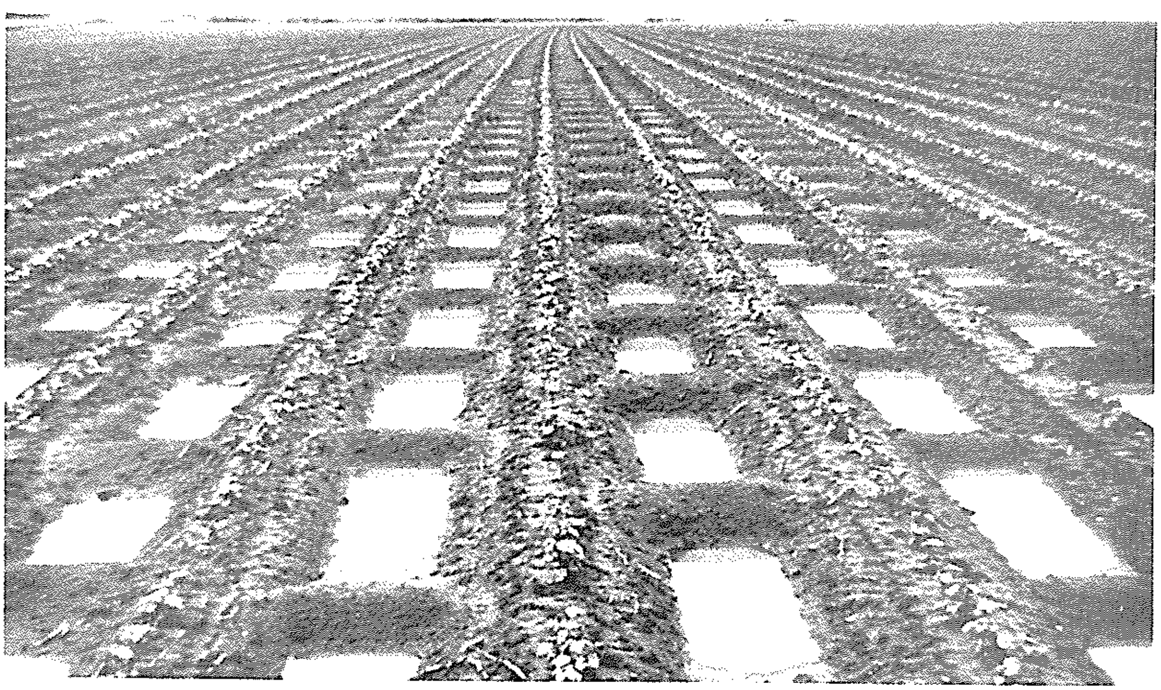

Figure 3. Dikes Retaining Water in Furrows

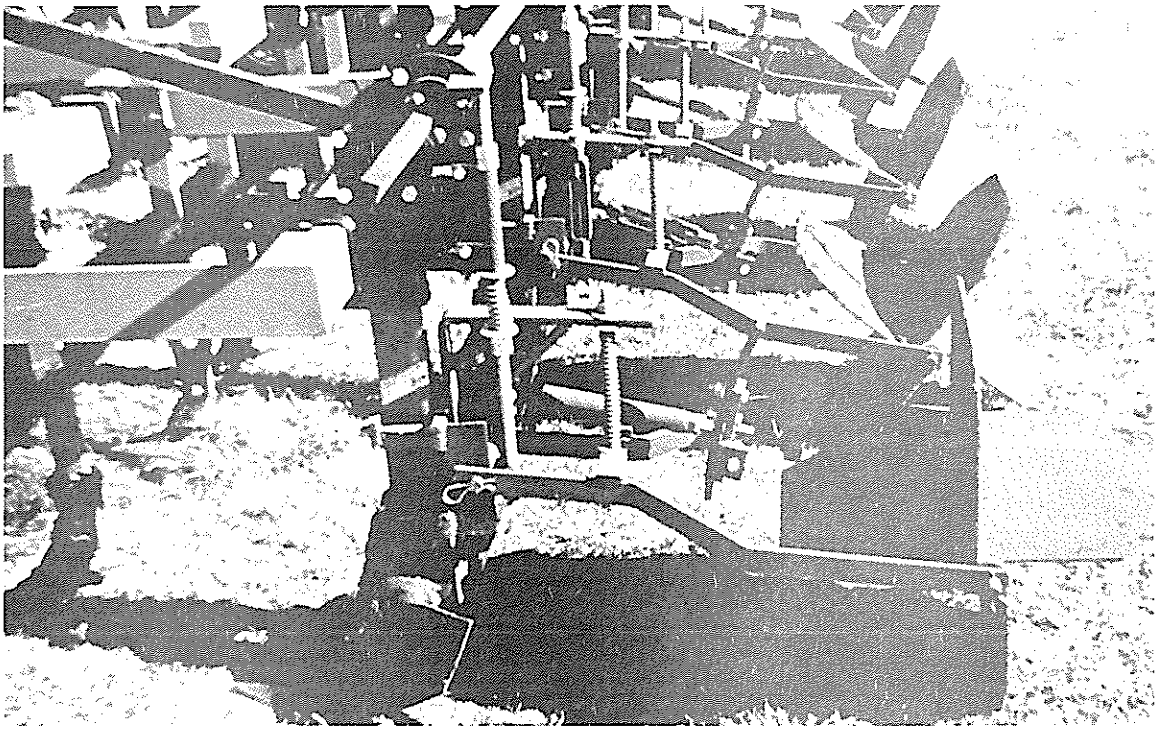

Figure 4. Furrow Diking Equipment

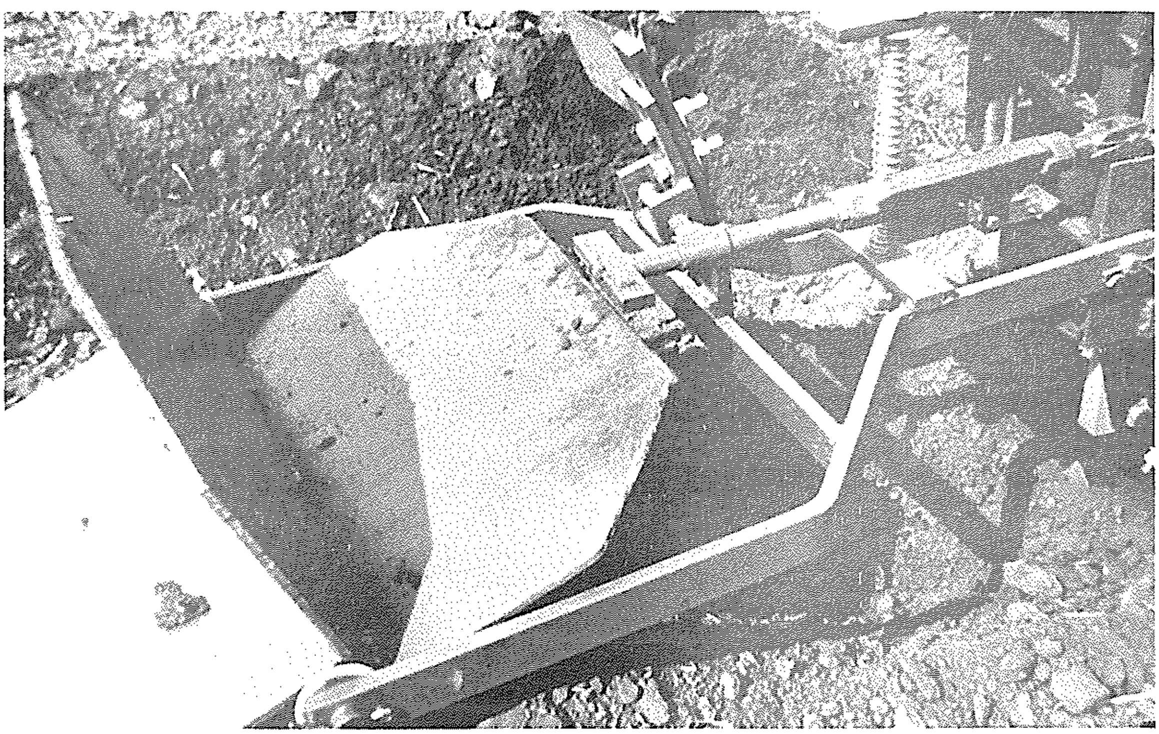

Figure 5. Close Up View of a Furrow Diking Shovel

1970's at the Plains Branch Agricultural Experiment Station in Clovis, New Mexico, by Dale Fuehring.

Early attempts to use furrow diking had many problems, most especially slow operation. This wasted both time and tractor fuel. The criteria used by Dr. Lyle in the design of current furrow diking equipment included low cost and easy maintenance; simple design and construction; easy attachment to existing equipment; control of dike spacing, dike height, and basin shape; and high-speed operation.

Designs developed in OWRT project A-041-TEX have met these criteria. The device can be constructed from materials found in most farm shops with between 14 and 16 components, depending on the specific design. The "dikers" are rear mounted and easily attached to common farm equipment. Spacing may be controlled by a cam and the depth and shape of the basin is controlled by the configuration of the shovel (Fig. 5). A tractor using the device can operate at from five to seven miles per hour.

Low Energy Precision Application Irrigation

For many years, research has been done to improve the efficiency of water delivery to crops. It was clear that there were more efficient ways to deliver water than running it down the open furrows or spraying it over the plants. A series of projects carried out at the Texas Water Resources Institute and the Texas Agricultural Experiment Station (A-024-TEX, B-080-TEX, B-167-TEX) led to the development of a highly efficient irrigation system.

Early work by J. S. Newman in the 1960s, sponsored by the Texas Agricultural Experiment Station, dealt with sub-irrigation, a method of precision water application from below ground piping. This work demonstrated that row crops such as cotton, grain sorghum, soybeans, and corn could produce essentially the same yield as surface irrigated crops with substantially less water use when the water was applied precisely.

Dr. Peter Wierenga, in current work sponsored by the New Mexico Interstate Stream Commission and the New Mexico Water Resources Research Institute, finds that sub-irrigated green and red chile peppers produced above average yields with about half the water application used in conventional flood irrigation. These systems, however, require an extensive network of in-ground tubing. They are successful and widely used in orchard crops and now show promise for row crops as well.

Based on these findings, Dr. E. A. Hiler and his associates conducted a series of OWRT-sponsored experiments on optimization of irrigation water use and improved water management for crop production. This series of experiments demonstrated that a substantial improvement in irrigation efficiency could be obtained in sub-irrigated crops with the application of water directly in the vicinity of plant roots.

The research demonstrated that under controlled experimental conditions, comparable crop yields could be obtained with essentially half of the irrigation water of conventional systems. In OWRT Matching Grant B-054-NMEX, Drs. Ted Sammis and Eldon Hanson determined that yield is directly related to the amount of water consumed by plants. This implies that more efficient water delivery has a high potential for crop yield improvement.

During the time period 1968-1970 several meetings of research personnel interested in improving water use efficiency were held to coordinate their activities. It was clearly evident to these researchers that there was a need for a new irrigation system for row crops incorporating the precision application of sub-irrigation, but with mobility to fit row crop farming. Between 1973 and 1975 in project B-080-TEX, Dr. Otto Wilke began experimenting with changing a center pivot sprinkler system to a drop tube outlet precision delivery system. During this early work a center pivot system was modified on a small scale. In 1976, Dr. Bill Lyle began work on project B-167-TEX which developed the first new mobile drip system of field scale for row crops. The system is called a Low Energy Precision Application (LEPA) irrigation system.

Low energy precision application is an irrigation method in which drip emitters are attached to a moving boom (Fig. 6). These emitters deliver water directly to the vicinity of the plant rather than broadcasting it as a traditional sprinkler

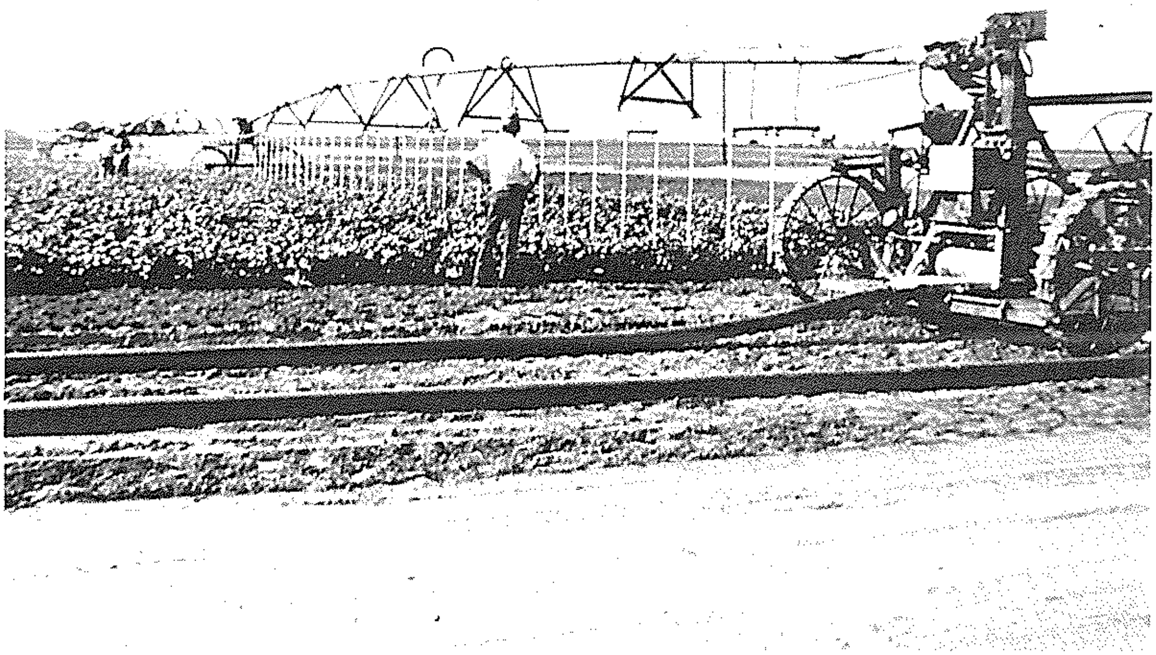

Figure 6. LEPA Sprinkler Boom

Figure 7. LEPA Emitter

system does (Fig 7). Since the water is dripped, rather than sprayed, considerably lower operating pressures can be used, 5-20 pounds per square inch compared to 80 pounds per square inch for sprinkler irrigation. The system is adaptable to all soil types where irrigation is used, and is capable of using a wide range of flow rates from 100 to 1,000 gallons per minute. The amount of water applied to the crop is controlled by the design of the emitter and the speed by which the boom moves over the furrows. Furrow diking is used with LEPA to obtain a very high level of irrigation efficiency.

EFFECTIVENESS

The combined use of LEPA and furrow diking results in savings from the following factors: retention of rainfall, decreased energy costs, and less water per acre. Irrigation efficiency is a measure of the percentage of water applied in irrigation that is actually used by the plant. LEPA systems deliver water at very close to 100 percent efficiency (99.1% to 99.9%). This is a 15 to 30 percent improvement in efficiency over conventional sprinkler systems and a 50 to 150 percent increase over flood irrigation systems. Conventional sprinklers consume 1.5 times as much energy as LEPA systems, while flood irrigation uses 2-2.5 times as much energy per acre.

The cost of converting existing sprinkler systems is modest, ranging from $16,000 to convert a center pivot system to a linear LEPA, to $4,000 for the conversion of a center pivot system to a pivot LEPA. A relatively short period is required for the energy savings to recover the conversion cost. Converting flood irrigation systems is more expensive (up to $51,000), with longer periods of energy savings required to recover the cost of conversion.

A 10 percent improvement in water efficiency could easily be obtained with LEPA compared to conventional systems. In some cases a 25 or 50 percent improvement in efficiency is realistic. The value of the water saved with a 10 percent improvement in efficiency is almost $50,000 over a 20-year period for a 160-acre farm. An additional important consideration is that this 10 percent increase in efficiency saves over eight feet of saturated thickness in the aquifer over the same 20-year period.

For the 1.74 million acres in Texas currently under sprinkler irrigation, the value of the potential water savings is significant. For an efficiency increase of 10 percent over a 20-year period, the value of the saved water would be $536 million. Although the value of saved water does not increase linearly with improved efficiency, increased inefficiency of 25 and 50 percent would result in saved water values of $1.075 billion and $1.467 billion respectivly. The addition of the 250,000 acres in New Mexico and the 500,000 acres in Oklahoma under sprinkler irrigation increases the potential value of water saved to $767 million, $1.538 billion, and $2.100 billion for 10, 25, and 50 percent increases in efficiency on a regional basis. These three states contain about 25 percent of the irrigated acreage in the 17 western states. Comparable savings could be expected elsewhere in the West. A summary of the potential economic benefit of this technique on a state and regional basis is presented in Table 2. This table is based only on sprinkler irrigated acres.

The conversion to LEPA can have a large impact on energy costs. Farms in the High Plains region with above average managment had sprinkler irrigation energy costs of $12-15 per acre in 1978. Savings of $4-5 per acre could be expected by conversion to LEPA. This represents an annual savings of approximatly $10-12 million for Texas, Oklahoma, and New Mexico.

In many cases, the goal is increased production and income from the available land rather than water savings. With the development of LEPA and furrow diking, some farmers in the Pecos Valley of New Mexico previously unable to irrigate their entire farm can now do so. Furthermore, they receive an additional cutting of alfalfa with the amount of water previously available.

The potential impact of furrow diking on dryland crop production in Texas and Oklahoma is great. Based on research conducted at Amarillo and Lubbock by the USDA and the Texas Agricultural Experiment Stations, increased crop yields are obtainable with both cotton and sorghum as a result of furrow diking. Economic analysis conducted by Dr. R. D. Lacewell and

TABLE 2

POTENTIAL VALUE OF WATER SAVED OVER A 20 YEAR PERIOD
WITH THE CONVERSION OF SPRINKLER IRRIGATION
TO LOW PRESSURE PRECISION APPLICATION

		Efficiency Improvement		
State	Thousands of Acres	10%	25%	50%
Texas	1,740	$536,000	$1,075,000	$1,467,000
Oklahoma	500	$154,000	$309,000	$422,000
New Mexico	250	$77,000	$154,000	$211,000
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his associates examined the impact of crop yield increases on both farm income and net social benefits assuming that furrow diking is applied to all dryland crop acres in the high and rolling plains of Texas and Oklahoma. Their results show that the new farm income would be $32.4 million for grain sorghum and $55.2 million for cotton or a net farm income increase of $87.6 million annually in these two states. Since added income is multiplied about 4.5 times as it circulates through the economy, the benefits as a result of this increase in crop production would be $397 million annually to the economy of the area.

The federal contribution to the OWRT-sponsored projects instrumental in developing furrow diking and LEPA was $198,213. While this modest investment did not pay the entire cost of the development of this technology, it was the incentive necessary for state and private interest to provide financial support. In most institutes in the area each federal dollar generates three non-federal dollars, making the estimated cost of development about $900,000. This seed money investment represents less than one hundredth of one percent of the savings which can be realized by implementing this technology at its present state of development.

USE

To have maximum impact, research results must be used. As a measure of the acceptance of these techniques, Dr. Lyle estimates that about one million acres in the High Plains are currently farmed with furrow diking. LEPA has gained acceptance in the Pecos Valley and in the High Plains. A variety of crops have been grown with these techniques including cotton, grain sorghum, forage sorghum, alfalfa, and corn. Use on corn is limited because it is difficult to move the machines through fields of tall corn.

Another measure of the acceptance of these techniques is what farmers say about them. Some responses of farmers when asked about furrow diking include:

"If I hadn't had furrow diking, I wouldn't have made a crop last year."

"It's the first time I have had the same uniformity in crop size on my farm, including the slopes."

"If energy costs continue to rise, we will run out of money before we run out of water and furrow diking will be our salvation for dry land farming."

INFORMATION DISSEMINATION

Results, not reports, are what count in getting farmers to try new techniques. Some farm operators originally saw these techniques as field day demonstrations at Experiment Stations. The largest group heard about the innovations from their neighbors or at the local coffee shop. "I'm going to diking this year because I've seen what it has done for my neighbor," summarizes the most widespread mechanism in technology transfer of farming practices. This type of information dissemination can provide a geometric spread of information. The expansion of furrow diking from negligible use to almost a million acres in a period of about three years is a fine example of this.

While some farmers have made their furrow diking equipment from scratch, another mechanism for spreading technology of this type is through farm implement manufacturers. Once initial operators have demonstrated the effectiveness of pilot systems, implement manufacturers start to make this equipment commercially available. Several farm equipment manufacturers in West Texas are currently making furrow diking and dike breaker equipment. They report that they are not able to meet the demand for the equipment at this time.

Additionally, conversion kits to modify traditional high pressure sprinkler irrigation systems into LEPA systems are also coming on to the market. This commercial availability and the activity of implement salesmen will further increase the spread of this technology.

CONCLUSIONS

1. OWRT-sponsored research has resulted in practical designs for two water and energy saving technologies, furrow diking and low energy precision application irrigation systems.
2. The decision of a farm operator to implement the technology is based primarily on positive experiences with the systems on neighboring farms.
3. Low initial investment technology (furrow diking) spreads rapidly compared to technology with a higher initial cost (LEPA).
4. The total federal investment in research to develop these systems represents less than 0.01 percent of a conservative estimate of the realizable savings from using them.

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