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COST AND RETURNS OF SPRINKLER IRRIGATION SYSTEMS, North Dakota

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FOREWORD

Water will be available to the first unit of the Garrison Diversion Project by 1976. By 1992, all 250,000 acres of the first stage are scheduled to have water available for irrigation. Farmers will experience a reorganization and combination of their resources and a changed and higher costs and returns situation under irrigation than under typical dryland operations. Most operators will have a combination of dryland and irrigation and will face a whole new set of costs and returns that they have little if any experience with.

This study is part one of a two-part study. Part two is covered in a report, "Financing of Sprinkler Irrigation in North Dakota," published as Agricultural Economics Report No. 90, October, 1972.

This study analyzes costs and returns associated with irrigation agriculture. Variable and fixed costs associated with specific production items are outlined for some specific crop items. Above average management is assumed in these analyses.

It is hoped that this study will serve as a useful guide in helping potential irrigation farmers adjust to and plan for irrigation operations. This research was conducted under North Dakota Agricultural Experiment Station Project Hatch 03-036 entitled "Credit Problems of North Dakota Agriculture."

Deep appreciation is expressed to all farmers and ranchers who cooperated in supplying the data to make this study possible.

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HIGHLIGHTS

The objective of this study was to determine the investment, annual costs, and returns of sprinkler irrigation systems in North Dakota.

The major reason for irrigating of the farmers in the sample was to increase their feed supply. Added profits were another common objective. Other objectives included crop stability and enlargement of the cattle enterprise.

The average age of the 35 farmers was 43.3 years, with an average of 6.7 years of irrigating experience. Fifty-four percent of the irrigators were part owners and 37 percent were owner operators.

Average farm size in the sample was 1,859 acres with 190 acres irrigated. Thirty farmers had native pastureland averaging 816 acres per farm. Thirty irrigators had a livestock operation with the cow-calf enterprise the most common.

Four types of sprinkler systems included in the study were: (1) center pivot, (2) boom, (3) hand-move, and (4) tow-line. The center pivot system, representing the latest technology, was the most common.

Estimated total new investment and average investment per acre were determined for each system. The cost items include the well, pipe, motor, pump, and distribution unit. Total new investment by type of system was: (1) center pivot, $30,260; (2) boom, $33,260; (3) hand-move, $24,260; and (4) tow-line, $25,260. Average per acre investment by type of system was: (1) center pivot, $219; (2) boom, $208; (3) hand-move, $152; and (4) tow-line, $180 (Table 14).

The irrigation annual costs were separated into fixed and variable costs. Fixed costs included depreciation, interest on investment, and insurance. Average fixed costs per acre were: (1) center pivot, $24.28; (2) boom, $23.02; (3) hand-move, $16.79; and (4) tow-line, $19.98 (Table 15). Variable costs included power, lubrication, labor, repairs, and maintenance costs. Average variable cost per acre inch of water applied was $0.71 for the center pivot, $1.36 for the boom, and $1.34 for the hand-move system. The average water applied in 1971 for all systems was 7.925 inches.

Annual production costs were determined for corn silage, corn grain, alfalfa, and wheat. Returns to management were used to determine the feasibility of irrigating specific crops. Average per acre returns to management were $25.78 for corn silage, $29.37 for corn grain, $22.48 for alfalfa, and -$5.21 for wheat (Tables 19-25).

Before investing in a sprinkler irrigation project, a farmer needs to investigate the quantity and quality of his water supply, the suitability of his land for irrigation, and budget his farm program to see if there will be enough additional income from the irrigation enterprise to meet its additional costs.

COSTS AND RETURNS OF SPRINKLER IRRIGATION SYSTEMS, NORTH DAKOTA

by
Fred R. Taylor, Roger W. Erickson, LeRoy W. Schaffner[1]

Water is an essential factor of crop production in North Dakota. Variable and unpredictable amounts of rainfall during the critical growing season cause increasing risk and uncertainty to the farmer. Maximum returns from new technologies, such as better seed, fertilizer, and weed control, are not always possible because of an inadequate supply of moisture for the crop during the growing season. Irrigation or the practice of supplying water as a supplement to rainfall can reduce the risk and uncertainty of crop production for farmers in North Dakota.

Irrigation of North Dakota farmland has increased from 50,548 acres in 1964 to 63,238 acres in 1969.[2] The first phase of the Garrison Diversion Conservancy Project will develop 250,000 acres of land for irrigation beginning in 1976.

Irrigation may take the form of gravity surface systems where the water flows through a canal and floods the field. However, sprinkler systems which pump and force water through pipes and nozzels spraying the water into the air, permitting it to fall as rain on the plants, is the newest irrigation technology.

Recent developments in sprinkler irrigation technology have encouraged use of this type of irrigation system. About half of the irrigated acreage in North Dakota is under sprinkler irrigation and most of the land in the Garrison Diversion Conservancy Project will be irrigated with sprinkler systems. Some advantages often observed of the sprinkler system over gravity surface irrigation are:

1. Drainage costs are lower.
2. Opportunity to substitute capital for labor.
3. Lands considered nonirrigable for gravity irrigation are frequently suitable for sprinkler irrigation.

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[1] Taylor is Professor, Erickson is a former Graduate Research Assistant now with the First National Bank of Wahpeton, and Schaffner is Associate Professor of Agricultural Economics.

[2] Agricultural Census Data for North Dakota, 1964 and 1969, Ag. Statistics No. 16 and No. 27, Statistical Reporting Service, United States Department of Agriculture and Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota.

4. Land leveling is not needed, so the top soil is not disturbed.

5. Soil erosion is minimized.

6. Application of exact, uniform rates of water is possible.

7. Liquid chemicals and fertilizer may be uniformly applied on the crop through the irrigation system.

The effects of more irrigation will be felt on both the local and state economies. Farmers will need considerable amounts of capital to begin an irrigation enterprise. Crop and livestock production will increase with irrigation. Agribusiness firms with irrigation interests must meet the added input requirements caused by irrigation and aid the irrigator in disposing of his output if irrigation is to be a success in North Dakota.

Need for Study

Irrigation is in its initial stage of development in North Dakota. As interest in irrigation increases, the need for basic data concerning its use also increases.

Prior to purchasing a system, the farmer needs to know investment costs, annual costs, expected returns, and management techniques of an irrigation system. He must be aware of added physical input costs of production because irrigation demands more intensive use of seed, fertilizer, and weed and insect control. A farmer should also be certain that his enterprise is suitable for irrigation by testing the quality of his soil and water, observing the topography of his land, determining if he has an adequate water source, and consulting with irrigation experts.

Sprinkler irrigation is increasing in popularity; and improved systems are being developed which require large initial investment expenditures, high annual costs, and efficient managers. Accordingly, a study was needed to determine the investment requirements, annual costs, and management problems encountered by North Dakota irrigators using sprinkler irrigation systems. This study is designed to aid the individual farmer who is irrigating now or plans to develop a sprinkler irrigation system on his farm. This study should be of particular interest to farmers in the Garrison Diversion Conservancy District as they must pay a water usage fee of $7.24 per irrigable acre, whether they irrigate or not.

Objectives

The specific objectives of this study are:

1. To study characteristics of the sample farmers and motivational reasons for irrigating.

2. To determine investment costs and annual costs of sprinkler irrigation systems.

3. To determine costs and returns under sprinkler irrigation.

Method of Investigation

Data for this study were obtained from 35 farmers who owned or controlled sprinkler irrigation equipment in North Dakota. The interviews were conducted in October, 1971, to obtain the operators' 1971 costs and returns.

CHARACTERISTICS OF SAMPLE FARMS AND FARMERS

The farmer's age and irrigating experience, farm size and tenure, crop and livestock enterprise, irrigation development, water sources, and capital sources were obtained.

Location and Source of Data

Data were obtained for this study from 35 irrigation farmers in central and southeastern North Dakota. Figure 1 shows the location of the farmers who were personally interviewed. The names of the farmers were obtained from county agents and the North Dakota State Water Commission.[3]

Criteria for selection were that a farmer must have been irrigating with a sprinkler system for at least one year. The type of systems included in the study were self-propelled or center pivot, boom, hand-move, and the tow-line.

Although gravity or flood irrigation is important and widely used in North Dakota, it was omitted from this study. The newest technology in irrigation is the sprinkler distribution systems, and most of the land involved in the Garrison Diversion Conservancy Districts will use sprinkler irrigation.

Irrigation Development

Emphasis was placed on interviewing farmers with center pivot sprinkler irrigation systems. The center pivot follows the trend of agricultural technology by requiring less manual labor and covering more acres at a setting than other types of sprinkler systems.

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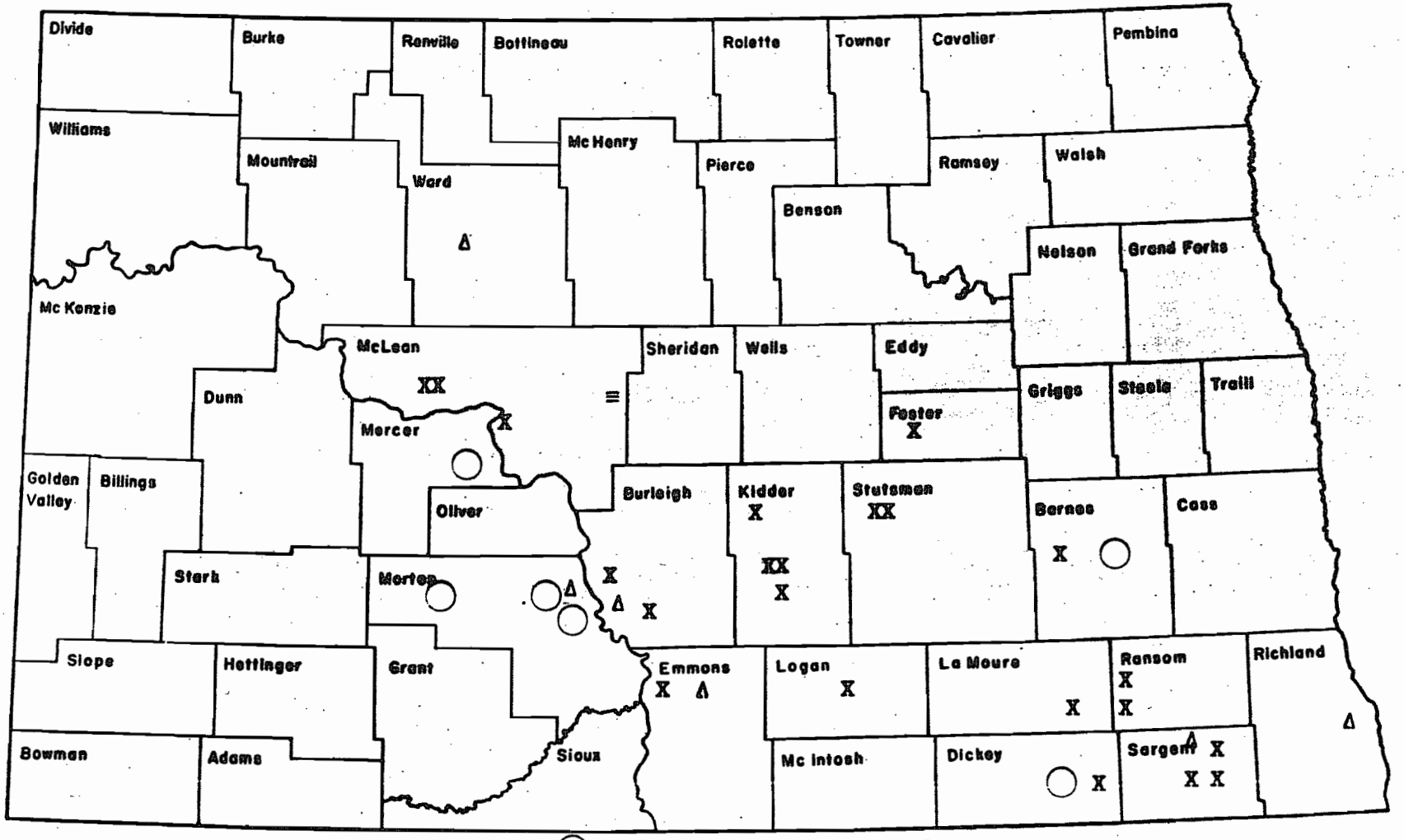
[3]The North Dakota State Water Commission requires all people to purchase a water permit before pumping water. Records are kept of permit owners and the purpose for pumping.



X = Self-propelled Δ = Boom ◯ = Hand-move ≡ = Tow-line

Figure 1. Location of 35 Sample Farms With Sprinkler Irrigation Systems in North Dakota, 1971

Twenty-two (63 percent) of the sample farmers had center pivot systems (Table 1). Twelve irrigators had purchased their units within the past two years. Of the remaining types of systems, two boom systems and one hand-move system had been purchased since 1963. One farmer who purchased a boom system in 1971 indicated that he was the first to irrigate in his area, and if irrigation was profitable he would purchase a center pivot system for his enterprise in the near future. He said that he could determine if his land was suitable and profitable for irrigation without a large capital investment by using the less expensive boom system.

In 1971 a total of 6,710 acres were irrigated with sprinkler systems on the 35 farms, which was about equal to 10 percent of all land irrigated in North Dakota in 1969. The average number of acres irrigated per farm was 190 (Table 1). The average acreage per farm under center pivot systems was 230 acres and the hand-move system had 57 acres.

Four farmers with center pivot systems had more than one unit, with one farmer having five and the others two units each. One farmer had two boom systems and two individuals had two different types of sprinkler systems for their enterprises; one had a boom and hand-move and the other had a boom and center pivot.

Plans are being made by 22 farmers to expand their irrigation acreage for a planned added average acreage of 180 acres. Sixteen (73 percent) of the 22 irrigators with a center pivot system indicated plans to expand their irrigation enterprise. Only 46 percent of the 13 farmers with boom, hand-move, or tow-line systems planned to expand their operations. Some reasons for not expanding were lack of capital, lack of water, and age of the irrigator.

Age and Irrigation Experience of Farmers

The average age of all farmers interviewed was 43.3 years, ranging from 26 to 66 years.[4] The average age corresponded to the technology of irrigation systems. The hand-move, the earliest developed system, had the oldest operators with an average age of 48.2 years, followed by the boom system operators averaging 45.5 years of age. The center pivot operators, the most recently developed system, were the youngest, averaging 41.2 years of age.

Irrigation experience also correlated to the level of technology with the hand-move irrigators having the most experience and the center pivot the least. Average number of years of experience for all irrigators was 6.7 years. Farmers with hand-move systems had been irrigating for an average of

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[4]On three farms, a father-son partnership was in effect and the son's age was used in computing the average age of all farmers.

TABLE 1. NUMBER OF FARMERS SURVEYED, AVERAGE IRRIGATED ACREAGE PER FARM, AND PLANS FOR IRRIGATION EXPANSION BY TYPE OF SPRINKLER SYSTEM

Distribution Unit	Farmers Surveyed	Percent of Total	Systems		Percent of Total Irrigated Acres	Average Irrigated Acreage Per Farm	Plans for Expansion	
			Number	Percent			Number	Percent
Center Pivot	22	63	29	64	81	230	16	73.0
Boom	6	17	8	18	7	67	1	4.5
Hand-Move	6	17	7	16	5	57	4	18.0
Tow-Line	1	3	1	2	7	223	1	4.5
Total	35	100	45	100	100	192[a]	22	100.0

[a]Average irrigated acreage per farm for all farms.

13.7 years, the boom irrigators 7.7 years, and the center pivot for 4.0 years. The sample operators had a range of 1 to 20 years of irrigating experience.

Farm Size and Tenure

Average size farm for all sample farms was 1,859 acres as compared to a state average of 1,012 in 1971.[5] The average number of acres tilled per farm, irrigated and dryland, was 1,169 acres (63 percent). Thirty of the 35 farmers had an average of 816 acres of native pastureland per farm.

Fifty-four percent of the farmers were part owners, 37 percent owner-operators, and only 9 percent were tenants.

Crop and Livestock Production

All farmers supplemented their dryland farming with an irrigation enterprise. Dryland crops represented 52 percent of the total acreage and irrigation 11 percent. Both cash and feed crops were grown under each enterprise.

The most popular dryland cash crop grown was wheat (Table 2). Flax, rye, corn for grain, and potatoes were other dryland crops raised.

Oats, native and tame hay, and alfalfa were the most common feed crops raised under dryland conditions. Corn silage, oat silage, and clover silage were other feed crops grown.

A majority of the irrigated acreage was used for production of feed crops. The common feed crops raised under irrigation were alfalfa and corn silage (Table 2). Oat silage, clover silage, and barley represented the remaining irrigated feed crops. Specialty crops consisting of corn grain, potatoes, sugarbeets, and beans were the most prevalent irrigated cash crops. Rye, wheat, and grass seed were other cash crops grown.

Cash crops represented about one-third of the total irrigated acreage. All farmers who irrigated had a livestock enterprise and were irrigating to stabilize their feed supply. The farmers indicated they had knowledge and experience in raising corn and alfalfa and had the equipment to handle these crops.

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[5] North Dakota Crop and Livestock Statistics, 1971, Ag. Statistics No. 26, Statistical Reporting Service, United States Department of Agriculture and Department of Agricultural Economics, North Dakota State University cooperating, Fargo, North Dakota, May, 1972, p. 50.

TABLE 2. ACRES AND PERCENT OF TOTAL CROPLAND ACREAGE OF DRYLAND AND IRRIGATED CROPS

Crop	Total Dryland Acres	Percent of Total Dryland Acres	Total Irrigated Acres	Percent of Total Irrigated Acres
Wheat	8,820	26.4	358	4.9
Rye	300	.9	270	3.7
Flax	595	1.8		
Potatoes	150	.4	400	5.4
Sugarbeets			260	3.5
Pinto Beans			113	1.5
Grass Seed			115	1.6
Alfalfa	4,320	12.9	1,826	24.8
Corn Silage	1,717	5.1	1,573	21.4
Corn Grain	500	1.5	585	7.9
Hay	1,300	3.9	131	1.8
Barley	1,250	3.7	58	.8
Oats	3,955	11.8		
Oats Silage	1,300	3.9	450	6.1
Clover Silage	500	1.5	320	4.3
Seeded Pasture	4,415	13.2	170	2.3
Other	145[a]	.4	735[b]	10.0
Fallow	4,205	12.6		
Total	33,472	100.0	7,364	100.0

[a]Includes mustard, sunflowers, and soybeans.

[b]Seven hundred thirty-five acres under gravity irrigation.

Eighty-five percent of the farms had a livestock enterprise. The cow-calf operation was the most common enterprise followed by feeder cattle, dairy, and hogs (Table 3).

TABLE 3. LIVESTOCK ENTERPRISE BY TYPE, AVERAGE SIZE, AND PERCENT OF FARMERS REPORTING

Type	Number of Farms	Percent of Total Producers	Average Size Per Farm
Cow-Calf	21	70	161 cows
Feeders	6	20	585 head
Dairy	2	7	95 cows
Hogs	1	3	500 sows
Total	30	100	

Water Availability

Water for irrigation was drawn from two sources--wells and rivers. Twenty-three farmers used well water for irrigation from an average depth of 107 feet per well with a range of 30 to 285 feet. McLean County had the deepest wells with an average of 273 feet, and Sargent and Ransom counties had the shallowest wells with an average depth of 48 feet per well.

Rivers and streams were used as a source of water by 12 farmers. A water usage fee of $1.50 per irrigated acre per year was paid by two farmers who pumped water from the Missouri River.

A landowner is required to obtain a water-rights permit from the State Water Commission before he is allowed to drill a well or pump water from rivers. At times when the water table becomes low, the people with the highest permit number or newest permit are forced to stop pumping water while their neighbor with an older permit is allowed to continue. Operators stated that often during an extremely dry season, when irrigation is critically needed, wells and rivers would dry up, causing the irrigation system to be inoperative.

Climate and Rainfall

North Dakota's climate is characterized by long, cold winters and a relatively short, hot growing season. Precipitation occurs as rain, snow, hail, and sleet; and varies from 20 inches in the east to 10 inches in the west.

The average long-term temperature from 1931 to 1960 was 40.6° F. Average precipitation for the same period was 16.73 inches per year with a monthly mean range of 0.41 inches in December to 3.57 inches in June.[6] The growing season or number of frost-free days above 32° F for the same time period was 110 to 129 days.

The importance and need for irrigation in North Dakota is illustrated by the rainfall patterns in the state and the water demand of selected crops. Rainfall in North Dakota is often of a sudden thunderstorm type which produces large amounts of rainfall in a short period of time. A high percentage of the water drains off before the plants have a chance to use it. Under irrigation, a steady amount of water can be applied at critical periods of plant growth, reducing the degree of uncertainty associated with rainfall.

An example of crop water demand has been estimated by the Agronomy Department at North Dakota State University. It takes approximately 21

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[6] North Dakota Weather-Crop Bulletin, 1950-65, Ag. Statistics No. 14, Statistical Reporting Service, United States Department of Agriculture and Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota, November, 1965, p. 2.

inches of rainfall in the growing season to produce a yield of 3 tons per acre of alfalfa.[7] Therefore, due to the uncertain and unstable moisture patterns and high water demands by crops, irrigation is needed in North Dakota to stabilize production and maximize crop yields.

Irrigable Soil

Sandy and sandy loam soils, characterized by high permeability, will generally yield the best response to irrigation. Soils of low permeability are often associated with a high water table, soil salinity, alkalinity problems, and reduced yields.

Twenty-one farmers irrigated on sandy soil, six on sandy loam, and eight on loam. Most farmers were familiar with the level of the water table and made a practice of applying a large amount of water on the land in the fall to leach out the salt and alkali for next year's crop. The irrigators applied fertilizer at various stages of plant growth instead of a single large amount at planting time. This reduced the chance of the fertilizer leaching out with a heavy rain.

Topography, or degree of slope of the land, for the sample area was obtained through consultation with the Soils Department.[8] Topography of the farms varied, with all areas classified as either nearly level or undulating. Southeastern North Dakota, the Missouri River Bottomlands, and Kidder County have nearly level topography. Farms in Mercer, McLean, Stutsman, and Foster counties were classified gently undulating to undulating topography.

Sources of Capital

No specific questions were asked concerning sources of availability of capital for irrigation equipment because the most recent irrigators were generally successful and established farmers who had few problems obtaining credit. The remaining farmers placed little emphasis on problems of getting credit as they had systems which required much less capital and had often purchased used equipment.

Sources of capital for present sprinkler irrigation development in North Dakota are shown in Table 4.[9] The high percentage of loans from

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[7] Meyer, D. W., Agronomy Department, North Dakota State University, 1971 (Interview).

[8] Sweeney, M. D., Soils Department, North Dakota State University, 1971 (Interview).

[9] Taylor, Walstad, and Schaffner, Financing of Sprinkler Irrigation in North Dakota, Agricultural Economics Report No. 90, Department of Agricultural Economics, North Dakota State University, October, 1972.

TABLE 4. SOURCE OF CREDIT USED FOR SPRINKLER IRRIGATION COMPARED TO EXPECTED SOURCES TO BE USED FOR IRRIGATION EXPANSION

Source of Credit	Percentage Share of Credit Extended[a]		
	Present	Expected	Change
Commercial Bank	45.2	58.3	+13.1
Production Credit Association	16.7	29.2	+12.5
Farmers Home Administration	11.9	4.2	-7.7
Private Funds	26.2	8.3	-17.7
Total	100.0	100.0	

[a]Percent of irrigators to use each financial institution.

commercial banks and use of private funds indicate that most irrigators have established a source of credit and are considered good risks by short-term lenders.

Credit institutions are hesitant to loan money to low-equity farmers to buy costly irrigation equipment because irrigation is still somewhat new in the state.

In conversation with several bankers, Production Credit Association managers, and Farmers Home Administration representatives, it appears they are aware of the credit problems and are looking for solutions to them.

The Bank of North Dakota was also contacted and is exploring different sources of capital to loan to future irrigators. One plan was to attract loan funds from other regions of the country and allocate them among member banks in irrigation districts.

All credit institutions were confident that they would meet future demands for irrigation capital and find workable solutions to make loans available to farmers with low equity.

Leasing irrigation equipment was another solution to the credit problems. Two farmers had leased their equipment. The leases required a certain percentage of the original value to be paid each year for a given number of years. In the last year of the lease the farmer had three options:

1. Buy the system for the present value,

2. Continue to lease at an up-dated value, or

3. Terminate the lease.

The two farmers felt leasing was advantageous as they did not have to go deeply in debt or have a large amount of their present capital invested in

irrigation equipment. The remaining 20 farmers with center pivot systems were reluctant to lease as they felt more secure owning their own equipment.

OBJECTIVES, OPINIONS, AND PROBLEMS OF IRRIGATION

Sprinkler irrigation in North Dakota is in its initial stage of development. Therefore, sprinkler irrigators must be considered innovators and they may lack knowledge and experienced management. Some research has been completed to help new irrigators in North Dakota, but present irrigators said much more is needed. Several operators had traveled to nearby states to view established irrigation units and to gain knowledge on management problems. In the survey of farmers using sprinkler irrigation, questions were asked concerning their objectives, advantages and disadvantages of their present sprinkler system, problems associated with irrigation, and if they were satisfied with their system.

Objectives for Irrigating

The objectives for irrigating were concentrated in the two areas of feed supply and added profits for the farming enterprise (Table 5). The most popular objective was feed stability or increased feed supply because many farmers had livestock enterprises. Increased farm income from irrigation was an objective of farmers who raised cash and specialty crops, such as potatoes, sugarbeets, beans, and wheat.

TABLE 5. OBJECTIVES FOR SPRINKLER IRRIGATION DEVELOPMENT

Objectives	Number of Farmers Reporting				
	Center Pivot	Boom	Hand-Move	Tow-Line	Total
Feed Supply or Stability	16	6	6	1	29
Increase Farm Income	6		1		7
Crop Stability	2				2
Increase Cattle Enterprise	2				2
Grazing	2				2
Others[a]	5	1			6

[a]Decrease soil erosion, raise specialty crops, decrease farm size, use available water, get ahead of Garrison Diversion, and add moisture to crop.

Stability of feed supplies is concerned with reducing the degree of uncertainty associated with rainfall patterns in North Dakota. Irrigation often allows three cuttings of alfalfa as compared to one or two under dryland conditions. Two farmers cut their irrigated alfalfa field twice and then used the field for grazing. One farmer was able to decrease his farm size and maintain the same output with an irrigation enterprise.

One farmer in the Garrison Diversion District felt he could benefit himself and the community by irrigating five years before the Garrison Diversion water would be available. He hoped to gain the experience and knowledge needed to efficiently manage his irrigated land and also help neighboring farmers get started in irrigation.

Advantages of Present System

All farmers were questioned as to the advantages of their present system. They compared different sprinkler systems, such as center pivot and boom, and also compared their unit to a unit of the same type, such as electric-powered center pivot and diesel-powered center pivot. Twenty of the 22 irrigators with center pivot systems said their system had the advantage of low labor requirements over other systems (Table 6). A steady, continuous application of water was another advantage of the center pivot. The remaining irrigators stressed the importance of mobility of their systems as compared to limited mobility of the center pivot. With a minimum amount of labor, the boom, hand-move, and tow-line systems can be moved to another field; the center pivot is usually designed for one setting. It can be moved to another field but requires one day's work for two men and one tractor. The lower initial investment was another advantage of these systems over the center pivot system.

TABLE 6. ADVANTAGES OF PRESENT SPRINKLER SYSTEMS

Advantages	Number of Farmers Reporting				
	Center Pivot	Boom	Hand-Move	Tow-Line	Total
Low Labor Requirements	20	1			21
Steady Application of Water	9				9
Mobility		3	4	1	8
Low Cost		4	3	1	8
Low Maintenance Requirements	1	2	1		4
Irrigate on Rough Terrain	2				2
System Able to Move Dry	2				2
Low Evaporation Rate	2				2
Electric, Automatic Reverse	2				2
Others	2[a]	3[b]			5

[a]Less land preparation and better yield.

[b]Safe system, no soil erosion, and good trade-in value.

In comparing center pivot units, two farmers had electric-powered systems with an automatic reverse switch. A field with obstacles, such as trees or highline towers, can be irrigated because the switch automatically stops or reverses the unit, preventing damage to the system.

The electric- and hydraulic-powered systems had the advantage of moving across a field without applying water. If a 160-acre field was used for two or more crops of different water demands, this feature was beneficial in irrigation management.

Disadvantages of Present System

Disadvantages of their present irrigation system was also asked of farmers. The center pivot irrigators responded with a wide variety of answers, with the loss of corners and the high initial cost the most common disadvantages cited (Table 7). A 160-acre square field will have about 138 acres under irrigation as the center pivot system makes a 360-degree revolution and does not reach the land in the corners.

TABLE 7. DISADVANTAGES OF PRESENT SPRINKLER SYSTEMS

	Number of Farmers Reporting				
Disadvantages	Center Pivot	Boom	Hand-Move	Tow-Line	Total
High Labor Requirements		5	5	1	11
Corners Not Irrigated	7				7
High Initial Cost	5				5
Wind		4	1		5
High Maintenance Requirements	3		1		4
Immobility of System	3				3
Overlap (Uneven Water Application)		2			2
Pipe Breakage	2				2
Ruts in Field	2				2
Mud	2				2
Water Shortage	1				2
Others	4[a]	1[b]			5

[a]Electricity failure, trees in field, lightning danger, and sand in well.

[b]Roadways needed to move system.

The two prevalent disadvantages of the remaining systems were high labor requirements, as the system needed almost constant attention during operation, and wind was a problem with the boom systems. A strong wind occurring during water application would blow most of the water to one area and would result in uneven application of water to the field.

Ruts caused by the wheels of the center pivot system were listed as disadvantages by only two irrigators, but were observed on most fields. Center pivot systems for 160 acres had 13 sets of wheels causing deep ruts around the field.

Problems Encountered With Present System

Only ten farmers in the survey could relate any specific problem areas they had encountered with their sprinkler system. Eight farmers with center pivot systems stated that operating losses the first year and the purchasing of the system in the spring were the most common problems (Table 8). These two problems are closely related, as farmers who bought their system in the spring usually lost money the first year because they did not get the system into operation until midsummer after the critical growth and water demanding stage of the plants. Most farmers agreed that purchasing and installing the system in the fall was essential to eliminate time losses due to mechanical failures associated with new systems.

TABLE 8. PROBLEMS ENCOUNTERED WITH PRESENT SPRINKLER SYSTEMS

	Number of Farmers Reporting				
Problems	Center Pivot	Boom	Hand-Move	Tow-Line	Total
Lost Money First Year	8				8
Bought System in Spring	5				5
Need Stainless Steel Screen for Well	1				1
System Too Old and Small		1			1
Dry Well		1			1

Satisfaction of Present System

Results of the question, "Are you satisfied with your present system?" are listed in Table 9. Irrigators with center pivot systems were pleased with their units. Of the two who were displeased, one said he had steel wheels and wanted rubber tires and the other had been unable to increase net income with an irrigation enterprise. It should be noted he did not have a livestock operation and had concentrated his irrigation efforts on raising cash and specialty crops.

Five of the 13 operators with other types of systems were dissatisfied with their systems and indicated the center pivot as the most desirable.

TABLE 9. SATISFACTION WITH PRESENT SPRINKLER SYSTEMS

Type of System	Yes	No
Center Pivot	20	2
Boom	4	2
Hand-Move	3	3
Tow-Line	1	0
Total	28	7

The role of the farm manager becomes particularly important with irrigation. The farmer must have sources of information and must be able to interpret this information to utilize it for his irrigation operation. Many of the present irrigators had spent considerable time and money traveling and seeking irrigation know-how from experienced irrigators. The general consensus among those interviewed was that a farmer should have dryland experience in raising the crops he plans to produce under irrigation. He would probably have the machinery to handle such crops and an established market for his product whether it is a feed crop for his cattle or a specialty crop that will be transported to a processor.

INITIAL INVESTMENT REQUIREMENTS FOR SPRINKLER IRRIGATION

Farmers in the survey were asked the purchase prices of all items required to install irrigation systems. The cost items included the pump, motor, well, pipe, and distribution unit. The items were classified by size and studied in detail as to number of units and average price per item for the four types of sprinkler irrigation systems. Local dealers selling irrigation equipment provided 1972 prices.

The center pivot systems were divided into two groups--all 29 systems and the 15 systems that were purchased new in 1970 and 1971. Some price variations may exist, such as a decrease in average total cost as equipment increased in size, options of buying new equipment or used equipment, trading in old equipment, or combinations of these. In addition, there may have been some differences in dealers' prices.

Initial Investment Cost

The initial investment costs for specific irrigation equipment were obtained from the 35 sample farmers and irrigation equipment dealers. The farmers were divided into five groups:

1. All center pivot systems.
2. Center pivot systems purchased in 1970-71.
3. Boom systems.
4. Hand-move systems.
5. Tow-line systems.

Motors

Most farmers irrigating with 1970-71 center pivot systems used electric motors for the power source (Table 10). Electric motors were generally purchased at a lower cost and required less maintenance and repairs than diesel, gas, or propane engines.

TABLE 10. NUMBER OF AND AVERAGE INVESTMENT IN MOTORS BY POWER SOURCE

Source	Total Number	Type of Motor: Electric 0-49 hp	Electric 50-99 hp	Electric 100 hp	Diesel 0-99 hp	Diesel 100-200 hp	Propane 0-99 hp	Propane 100-200 hp	Gas 0-50 hp	Gas 50-100 hp
					Number of Motors					
Center Pivot	33	5	13	5	4	4	1	1		
New Center Pivot	18	4	8	3	1	1		1		
Boom	7	2			1		1	1		2
Hand-Move	7				1		1		3	2
Tow-Line	1	1								
					Average Investment Cost of Motors					
Center Pivot	33	$ 832	$2,243	$1,640	$1,966	$1,838	$1,800	$3,200		
New Center Pivot	18	790	1,770	1,933	1,000	3,700		3,200		
Boom	7	450			800		900	1,800		$ 537
Hand-Move	7				1,000		500		$ 667	1,050
Tow-Line	1	2,100								
Dealers	1[a]			2,300	3,600	4,500	2,596	2,770	2,596	2,770

[a]One irrigation equipment dealer.

Pumps

The turbine pump is used by more farmers and is more expensive than the centrifugal or impeller pumps (Table 11). Farmers said that the turbine pump was more dependable and had a greater trade-in value. It is characterized by being more efficient in pumping from wells, particularly where the water level fluctuates.

Pipe

Pipes made of aluminum, cement, iron, and plastic are used by irrigating farmers in North Dakota. The aluminum pipe is more popular because of lower cost and ease of handling (Table 12). The cement and iron pipes have greater durability and longer life but are more expensive. The plastic pipe has the advantage of easy handling but is considered fragile and needs frequent replacement.

Distribution Unit

The center pivot system is the most common and also the most expensive distribution unit (Table 13). The average cost per acre of the distribution unit on the farms in the sample was derived by dividing the average total investment by the average number of acres irrigated per system. Most center pivot systems irrigated 138 acres of a 160-acre field since the corners are not irrigated.

The cost of additional power lines to bring the electricity to the electrically driven systems was included in the annual electric charge and not considered part of the initial investment.

Total Initial Irrigation Investment Costs

The total investment requirements and average cost per acre to install a complete irrigation system for about 160 acres are shown in Table 14. The cost data obtained from 35 sample farmers and the 1972 prices from irrigation equipment dealers were used in deriving the investment in the various types of systems. The well cost used was a 100-foot well at $30.00 per foot.

The investment figures in Table 14 are shown by type of irrigation development--Garrison Diversion Project and private development. The well and pipe investment items change with the type of development. The average per acre investment was $181 for the Garrison Diversion Project where water is furnished by the irrigation district, and increased to $206 for private development where the water source is developed by the farmer.

TABLE 11. NUMBER OF AND AVERAGE INVESTMENT IN PUMPS BY TYPE AND PUMPING CAPACITY

Source	Total Number	Type of Water Pump: Turbine 0-499 gpm	Turbine 500-999 gpm	Turbine 1,000 gpm	Centrifugal 0-499 gpm	Centrifugal 500-999 gpm	Centrifugal 1,000 gpm	Impeller 0-499 gpm	Impeller 500-999 gpm	Impeller 1,000 gpm
					Number of Pumps					
Center Pivot	33	4	14	13			2			
New Center Pivot	18	4	9	4			1			
Boom	7	1	1			2	1	1		1
Hand-Move	7		1	1	1	1	1	1	1	
Tow-Line	1	1								
					Average Investment Cost of Pumps					
Center Pivot	33	$1,385	$1,988	$3,573			$1,675			
New Center Pivot	18	1,385	2,238	2,800			1,350			
Boom	7	1,400	900			$375	300	$350		$2,000
Hand-Move	7		375	700	$550	600	2,200	500	$300	
Tow-Line	1	1,400								
Dealers	1[a]		4,200	4,500			1,300			

[a]One irrigation equipment dealer.

TABLE 12. LENGTH OF PIPE PER FARM AND AVERAGE COST PER UNIT BY TYPE OF PIPE

Source	Total Number	Number of Farms and Average Length Per Farm by Pipe Type								
		Aluminum		Cement		Iron		Plastic		No Pipe
		Number of Farms	Number of Feet	Number of Farms	Number of Feet	Number of Farms	Number of Feet	Number of Farms	Number of Feet	Number of Farms
Center Pivot	22	8	3,054	2	4,200	5	2,338	4	1,667	3
New Center Pivot	15	3	2,143	2	4,200	4	1,048	4	1,667	2
Boom	7	7	2,527							
Hand-Move	6	6	1,392							
Tow-Line	1	1	1,300							

Source	Total Number	Average Cost Per Foot			
		Aluminum	Cement	Iron	Plastic
Center Pivot	22	$1.76	$1.82	$2.50	$1.84
New Center Pivot	15	1.29	1.82	2.42	1.64
Boom	7	1.21			
Hand-Move	6	1.15			
Tow-Line	1	1.50			
Dealers	1[a]	2.05	2.75		2.55

[a]One irrigation equipment dealer.

TABLE 13. TOTAL AND AVERAGE PER ACRE INVESTMENT IN SPRINKLER DISTRIBUTION UNITS

System	Number of Systems in Survey Sample	Avg. Total Investment Cost		Acres Irrigated	Avg. Cost Per Acre	
		Sample Farmers	Dealers' 1972 Prices		Sample Farmers	Dealers' 1972 Prices
All Center Pivot:						
Electric	12	$19,230	$20,720	138	$139.35	$150.14
Oil	6	18,000	19,200	138	130.43	139.13
Water	11	14,049	18,630	138	101.80	135.00
1970-71 Center Pivot:						
Electric	10	20,276		138	146.93	
Oil	2	17,250		138	125.00	
Water	3	16,797		138	121.72	
Boom	8	1,712	1,800[a]	57	30.04	31.59
Hand-Move	7	2,016	2,250	48	42.00	46.88
Tow-Line	1	1,500	2,500	60	25.00	41.67

[a]Ten acres per setting size will cost about $9,000.

TABLE 14. ESTIMATED NEW TOTAL AND PER ACRE INVESTMENT IN SPRINKLER IRRIGATION SYSTEMS FOR THE GARRISON DIVERSION PROJECT AND FOR PRIVATE IRRIGATION DEVELOPMENT

Type of Development and Investment Item	Center Pivot	Boom	Tow-Line	Hand-Move
Garrison Diversion Project:				
Pump and Motor	$ 4,000	$ 4,000	$ 4,000	$ 4,000
Pipe and Misc. Items	4,125	7,260	7,260	7,260
Distribution Unit	18,630[a]	18,000[b]	10,000[c]	9,000
Total Investment	$26,755	$29,260	$21,260	$20,260
Acres Irrigated	138	160	140	160
Investment Per Acre	$ 194	$ 183	$ 152	$ 127
Average Per Acre Investment for All Systems = $181[d]				
Private Irrigation Development:				
Well	$ 3,000	$ 3,000	$ 3,000	$ 3,000
Pump and Motor	5,000	5,000	5,000	5,000
Pipe and Misc. Items	3,630	7,260	7,260	7,260
Distribution Unit	18,630[a]	18,000[b]	10,000[c]	9,000
Total Investment	$30,260	$33,260	$25,260	$24,260
Acres Irrigated	138	160	140	160
Investment Per Acre	$ 219	$ 208	$ 180	$ 152
Average Per Acre Investment for All Systems = $206[d]				

[a]Water drive system.

[b]Includes two boom systems including winch, take-up reel, cable, and hose for a continuous move traveling system.

[c]Includes four systems.

[d]The average was found by weighting the number of systems found on the 35 farms in the sample. The number by type of system was as follows: center pivot 29, boom 8, tow-line 1, and hand-move 7.

IRRIGATION FIXED AND VARIABLE COSTS

Total annual irrigation costs were separated into fixed and variable costs. Fixed costs, which occur whether the system is used or not, include depreciation, interest on investment, and insurance on irrigation equipment. Variable costs depend on the degree of use of the system and include the power, lubrication, labor, and repairs and maintenance costs.

Irrigation Fixed Costs

Fixed costs were determined for the four types of sprinkler irrigation systems. The fixed costs were derived from the purchase price of the well, pump, motor, pipe, and distribution unit.

Depreciation

Depreciation is a fixed cost and is the loss in value associated with wear and absolescence of equipment. Depreciation must be recovered during the life of the machine so it may be replaced at the end of its useful life.

The straight-line method or equal reduction in value of the equipment for each year was used in this study. A salvage value of 10 percent of the purchase price and a useful life of 15 years were used in determining the annual depreciation. The following formula illustrates the method of computing the annual depreciation:

$$\text{Annual Depreciation} = \frac{\text{Purchase Price - Salvage Value}}{\text{Years of Useful Live}}$$

Interest on Investment

A charge for interest must be included as an annual cost because money needed to purchase irrigation equipment was either borrowed or withdrawn from an interest-bearing account. An interest rate of 8.5 percent was used, which corresponded closely to the interest rate charged by commercial banks in North Dakota at the time of the survey. Interest was charged on half of the original investment plus the salvage value:

$$\text{Average Annual Interest on Investment} =$$

$$\frac{\text{Purchase Price + Salvage Value}}{2} \times 8.5\%$$

Insurance

Irrigation equipment insurance against acts of nature and vandalism was carried by 21 farmers. Most farmers insured the systems with all farm equipment under one policy and could not give specific rates. Local insurance companies were contacted and a rate of $4.00 per $1,000 on irrigation equipment was quoted.

Total Fixed Costs

The total annual and average per acre fixed costs in Table 15 were determined for the same groups of sprinkler irrigation systems used in Table 14 except sprinkler investment dates of the farmers in the sample were also included.

TABLE 15. TOTAL ANNUAL AND PER ACRE FIXED COSTS OF SPRINKLER SYSTEMS

Fixed Cost Item	Center Pivot			Boom		Tow-Line		Hand-Move	
	All Sample	1970-71 Sample	Dealers' Price	Sample	Dealers' Price	Sample	Dealers' Price	Sample	Dealer's Price
Total Investment	$29,836.00	$30,018.00	$30,260.00	$9,119.00	$33,260.00	$9,950.00	$25,260.00	$7,658.00	$24,260.00
Depreciation	$ 1,790.13	$ 1,801.07	$ 1,815.60	$ 547.13	$ 1,995.60	$ 597.00	$ 1,515.60	$ 459.47	$ 1,455.60
Interest	1,394.85	1,403.35	1,414.65	426.36	1,554.90	465.12	1,180.90	358.02	1,134.15
Insurance	119.34	120.07	121.04	36.48	133.04	39.80	101.04	30.63	97.04
Total Annual Fixed Costs	$ 3,304.32	$ 3,324.49	$ 3,351.29	$1,009.97	$ 3,683.54	$1,101.92	$ 2,797.54	$ 848.12	$ 2,686.79
Acres Irrigated	138	138	138	57	160	60	140	48	160
Annual Fixed Costs Per Acre	$ 23.94	$ 24.09	$ 24.28	$ 17.72	$ 23.02	$ 18.37	$ 19.98	$ 17.67	$ 16.79

The annual fixed costs per acre irrigated for the sample farms ranged from $17.67 for the hand-move system to $24.09 for the 1970-71 center pivot systems. Annual per acre costs ranged from $16.79 for the hand-move system to $24.28 for the center pivot system when 1972 prices from irrigation equipment dealers were used.

Irrigation Variable Costs

Irrigation variable costs for power, lubrication, labor, repairs, and maintenance were obtained from the 35 farmers.

Power

The cost of power depends on the type of motor used, size of engine, number of hours used, and type of sprinkler system. Average annual power cost for all systems varied from $3.01 per acre for the boom system to $4.33 per acre for the center pivot systems (Table 16).

TABLE 16. PER ACRE VARIABLE IRRIGATION COSTS BY TYPE OF MOTOR AND TYPE OF SPRINKLER SYSTEM

System	Costs Per Acre			
	Energy	Lubricants	Repair and Maintenance	Total Pumping Variable Cost
Systems with Electric Motor				
Center Pivot	$4.55		$0.98	$ 5.53
Boom	8.58		1.58	10.16
Tow-Line	4.17		0.83	5.00
Systems with Diesel Motor				
Center Pivot	$3.12	$0.20	$1.68	$ 5.00
Boom	4.52	0.61	1.16	6.29
Hand-Move	1.14	0.27	2.00	3.41
Systems with Gas Motor				
Boom	$2.04	$0.61	$1.24	$ 3.89
Hand-Move	4.48	0.96	0.35	5.79
Systems with Propane Motor				
Center Pivot	$8.41	$0.48	$1.27	$10.16
Boom	2.53	0.47	1.33	4.33
Hand-Move	3.03	0.58		3.61
All Systems Combined				
Center Pivot	$4.33	$0.23	$1.29	$ 5.85
Boom	3.01	0.55	1.15	4.71
Hand-Move	3.80	0.68	0.66	5.14
Tow-Line	4.17		0.83	5.00

Power costs for the gas, diesel, and propane engines were determined by obtaining the number of hours the power source was used in one year and fuel consumption per hour. Average fuel costs per gallon paid by the farmer were obtained from local fuel dealers and the North Dakota Crop and Livestock Statistics.[10]

The power cost for the electric motor was obtained from the Rural Electric Cooperatives that served the farmers. Their usual minimum charge was $6.00 per horsepower per year. To determine the actual annual power cost, the cooperatives used a formula of charging a specified rate per kilowatt hour, with a rate decrease as additional kilowatt hours were used. The farmer had to pay in excess of his minimum charge in most cases. The cost of additional power lines or bringing the power to the irrigation site was usually included in the minimum charge or final yearly power cost.

Lubrication

Lubrication costs consisted of oil, filters, and grease for the sprinkler irrigation systems. All lubrication costs per acre were less than $1.00 per year, systems having electric motors reporting no cost for lubrication (Table 16). Farmers using diesel, gas, and propane engines generally changed oil every 150 hours of use in addition to changing before and after winter storage. Several farmers reported the engines also consumed oil between changes

Repair and Maintenance

Due to lack of experience, farmers with newer systems had difficulty in determining annual costs of repairs and maintenance and many could only estimate the cost.

The center pivot systems had the largest repair and maintenance costs of $1.29 per acre, largely due to the complexity of the system (Table 16). The hand-move systems, being the most basic and simple of the systems, had the least cost of $0.66 per acre.

Irrigation Labor

Irrigation labor was divided into fixed and variable labor. Fixed irrigation labor includes time spent on repairing, daily maintenance, and preparing the system for spring and winter. Variable irrigating labor refers to the man-hours required during the application of water, time spent on daily observation of the system, and moving the system to a different location.

A charge of $2.00 per hour was used as wages or as a return to family labor. The center pivot system required less irrigation labor than all other systems, as it can be started and left operating for several days with minimal labor requirements. The other systems must be moved every few hours.

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[10] North Dakota Crop and Livestock Statistics, op. cit., p. 71.

Total Irrigation Variable Costs

Total power, lubrication, labor, and repairs and maintenance costs remained rather consistent for the four types of sprinkler irrigation systems (Table 17). Total variable costs ranged from $6.15 per acre for the center pivot system to $9.65 per acre for the boom system.

TABLE 17. PER ACRE VARIABLE IRRIGATION COSTS FOR SELECTED CROPS BY TYPE OF SPRINKLER SYSTEM

System	Costs Per Acre		
	Labor Costs[a]	Variable Pumping Costs	Total Variable Costs
		Alfalfa	
Center Pivot	$1.08	$5.85	$6.93
Boom	2.52	4.71	7.23
Hand-Move	2.64	5.14	7.78
Tow-Line	2.84	5.00	7.84
		Corn Grain	
Center Pivot	$0.30	$5.85	$6.15
Boom	4.94	4.71	9.65
Hand-Move	2.60	5.14	7.74
		Corn Silage	
Center Pivot	$0.64	$5.85	$6.49
Boom	2.94	4.71	7.65
Hand-Move	2.52	5.14	7.66
		Wheat	
Center Pivot	$0.76	$5.85	$6.61
Boom	2.86	4.71	7.67

[a]Irrigation labor costs at $2.00 per hour.

Total Annual Costs

Total annual per acre costs (fixed plus variable costs) were determined for alfalfa, corn grain, corn silage, and wheat (Table 18).

The boom systems had the lowest total annual cost of $24.95 per acre. Center pivot systems, because of high investment costs, had the highest total annual cost of $31.02 per acre when raising alfalfa.

TABLE 18. TOTAL PER ACRE ANNUAL IRRIGATION COSTS AND TOTAL INCHES OF WATER APPLIED FOR SELECTED CROPS BY TYPE OF SYSTEM

System	Total Costs Per Acre			Total Water Applied (inches)
	Variable Cost	Fixed Cost	Annual Cost	
		Alfalfa		
Center Pivot	$6.93	$24.09	$31.02	9.8
Boom	7.23	17.72	24.95	8.2
Hand-Move	7.78	17.67	25.45	11.3
Tow-Line	7.84	18.37	26.21	17.5
		Corn Grain		
Center Pivot	$6.15	$24.09	$30.24	9.1
Boom	9.65	17.72	26.37	6.0
Hand-Move	7.74	17.67	25.41	3.0
		Corn Silage		
Center Pivot	$6.49	$24.09	$30.58	9.8
Boom	7.65	17.72	25.49	5.4
Hand-Move	7.66	17.67	24.33	3.0
		Wheat		
Center Pivot	$6.61	$24.09	$30.70	8.0
Boom	7.67	17.72	24.39	4.0

PRODUCTION COSTS AND RETURNS OF DRYLAND AND IRRIGATED CROPS

A comparison of production costs and returns for alfalfa, corn silage, corn grain, and wheat produced under dryland and sprinkler irrigation was made using the complete budget approach. Corn and alfalfa were the two common crops grown with irrigation on the farms surveyed. A wheat budget was shown to represent a small grain crop. The input and output data used in the budgets are what is being achieved on well-managed farms in North Dakota.

Farmers raising sugarbeets and potatoes were encountered in the survey, but data for a cost and returns analysis were incomplete and were not included in this study. Most sprinkler irrigation cost data used in the budgets were derived from the farm survey. The crop production data were obtained from other studies and sources of data.

The crop budgets are broken down into variable and fixed costs. The assumption was made that the farm operator owned the resources used in the production process.

Variable Cost

Variable or operating cost refers to such costs as seed, fertilizer, chemical weed and insect control, fuel, grease, oil, machinery repairs, custom hire, labor, crop insurance, and interest on operating capital. Variable costs vary with output, and if a crop is not planted it cannot have a variable cost.

The recommended input rates were used for seed, fertilizer, chemicals, and machine operations to obtain the level of yield assumed in the budgets. Inputs for irrigated crops were, in most cases, at a higher rate than for dryland crops.

A crop insurance cost was assumed for corn and wheat. Even though a farmer may not insure a crop he is assuming the risk of a loss himself. The crop was insured for 45 percent of the gross income. To obtain the premium rate per acre the following formula was used:

$$\text{Premium Per Acre} = \text{Base Rate} \times \text{Adjustment Factor} \times \frac{\text{Coverage Per Acre}}{\$100}$$

The base rate was $8.50 for wheat and $6.00 for corn with an adjustment factor of 1.

Interest on operating capital is the amount of money foregone by producing a crop. An interest rate of 7.5 percent for six months was used for all crops.

Fixed Costs

Fixed costs include land charges and real estate taxes. A land charge of $6.86 per acre or 7.3 percent of $94.00 was used. The average land value per acre in North Dakota for 1970 was $94.00 and the average return to North Dakota landlords in 1969 was 7.3 percent.[11]

The real estate tax varies throughout the state and within each county. To establish a uniform rate, the average real estate tax per acre was found for the counties involved in the study. The tax for the five years prior to 1971 varied from $0.82 to $0.96 per acre for the 16 counties. A charge of $1.00 per acre was used.

Fixed costs for machinery and sprinkler irrigation equipment include depreciation, interest on investment, insurance, and housing.

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[11] North Dakota Crop and Livestock Statistics, 1969, Ag. Statistics No. 22, Statistical Reporting Service, United States Department of Agriculture and Department of Agricultural Economics, North Dakota State University, cooperating, Fargo, North Dakota, May, 1970, p. 79.

Corn Silage

Corn raised for silage under irrigation was profitable as long as there was a livestock enterprise on the farm to utilize the silage (Table 19). Corn silage at $6.00 per ton had a negative average return to management of -$7.07 per acre for dryland.

TABLE 19. CORN SILAGE: PER ACRE AND PER TON COSTS AND RETURNS FOR DRYLAND AND IRRIGATION

Expected Returns	Dryland	Sprinkler Systems: Center Pivot	Sprinkler Systems: Boom	Sprinkler Systems: Hand-Move	All Irrigation Systems
Yield Per Acre (Tons)	6	20	20	20	20
Value Per Ton	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 6.00
Total Value Per Acre	$36.00	$120.00	$120.00	$120.00	$120.00
Expected Costs					
Seed	$ 3.00	$ 3.75	$ 3.75	$ 3.75	$ 3.75
Fertilizer	4.86	12.15	12.15	12.15	12.15
Weed & Insect Control	3.35	3.35	3.35	3.35	3.35
Crop Insurance	1.00	3.24	3.24	3.24	3.24
Machinery Variable Cost	4.61	4.61	4.61	4.61	4.61
Irrigation Variable Cost		6.49	7.65	7.66	7.27
Custom Harvest	7.44	17.94	17.94	17.94	17.94
Labor[a]	5.82	8.32	8.32	8.32	8.32
Interest on Operating Capital (7½%)	1.13	2.24	2.29	2.29	2.27
Total Operating Cost	$31.21	$ 62.09	$ 63.30	$ 63.31	$ 62.90
Machinery Fixed Cost	$ 4.00	$ 4.00	$ 4.00	$ 4.00	$ 4.00
Irrigation Fixed Cost		23.56	17.43	17.38	19.46
Real Estate Tax	1.00	1.00	1.00	1.00	1.00
Land Charge	6.86	6.86	6.86	6.86	6.86
Total Fixed Cost	$11.86	$ 35.42	$ 29.29	$ 29.24	$ 31.32
Total Production Cost	$43.07	$ 97.51	$ 92.59	$ 92.55	$ 94.22
Return to Management	$-7.07	$ 22.49	$ 27.41	$ 27.45	$ 25.78
Production Cost Per Ton	$ 7.18	$ 4.88	$ 4.63	$ 4.63	$ 4.71

[a]Charge for labor to irrigate is included in irrigation variable cost.

Using a center pivot system and a price of $6.00 per ton for silage, an additional yield of 9.0 tons per acre is required to pay for the added cost of irrigation (Table 20). Irrigation costs used in the budgets are

TABLE 20. CORN SILAGE: INCREASED COST OF IRRIGATION AND YIELD INCREASE AND PRICE REQUIRED TO BREAK EVEN

System	Added Operating Costs and Added Yields to Break Even at $6.00 Per Ton				
	Cost		Yield (Tons)		
	Operating	Fixed	Operating	Fixed	Total
Center Pivot	$30.88	$23.56	5.1	3.9	9.0
Boom	32.09	17.43	5.3	2.9	8.2
Hand-Move	32.10	17.38	5.4	2.9	8.3
All Systems	31.69	19.46	5.3	3.2	8.5

Break-Even Yields for Corn Silage (Tons)

Net Production Cost Per Acre	Price Per Ton				
	$6.00	$6.50	$7.00	$7.50	$8.00
$ 80	13.3	12.3	11.4	10.7	10.0
85	14.2	13.1	12.1	11.3	10.6
90	15.0	13.8	12.9	12.0	11.3
95	15.8	14.6	13.6	12.7	11.9
100	16.7	15.4	14.3	13.3	12.5
105	17.5	16.2	15.0	14.0	13.1
110	18.3	16.9	15.7	14.7	13.8

Break-Even Prices Per Ton for Corn Silage

Net Production Cost Per Acre	Yield Per Acre				
	12.0	14.5	17.0	19.5	22.0
$ 80	$6.67	$5.52	$4.71	$4.10	$3.63
85	7.08	5.86	5.00	4.36	3.86
90	7.50	6.21	5.24	4.62	4.09
95	7.98	6.55	5.59	4.82	4.32
100	8.33	6.90	5.88	5.13	4.54
105	8.75	7.24	6.18	5.64	4.77
110	9.58	7.59	6.47	5.90	5.00

costs associated with private irrigation development where the water source is a well. Various break-even yields and break-even prices needed at different levels of production costs were determined for silage (Table 20). A farmer having production costs of $90.00 per acre and a yield of 17.0 tons per acre must receive $5.24 per ton for corn silage to break even. At costs of $80.00 per acre, and if he receives $7.00 per ton, the farmer must produce 11.4 tons to break even. The costs presented in the crop budgets charges the current rates for all of the resources used in producing the crops.

Corn Grain

The corn raised for grain budget applies to an area south of highway I-94 and east of the Missouri River. Corn grain was profitable on both dryland and irrigation in this area. The return to management for dryland farming was $22.74 per acre and increased under irrigation to $26.96 per acre for farmers using center pivot systems and $29.37 per acre for all irrigation systems (Table 21).

TABLE 21. CORN GRAIN: PER ACRE AND PER BUSHEL COSTS AND RETURNS FOR DRYLAND AND IRRIGATION

		Sprinkler Systems			All
Expected Returns	Dryland	Center Pivot	Boom	Hand-Move	Irrigation Systems
Yield Per Acre (Bushels)	75	120	120	120	120
Value Per Bushel	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00
Total Value Per Acre	$75.00	$120.00	$120.00	$120.00	$120.00
Expected Costs					
Seed	$ 4.80	$ 5.80	$ 5.80	$ 5.80	$ 5.80
Fertilizer	13.15	21.60	21.60	21.60	21.60
Weed & Insect Control	6.00	6.00	6.00	6.00	6.00
Crop Insurance	2.03	3.24	3.24	3.24	3.24
Machinery Variable Cost	6.12	7.04	7.04	7.04	7.04
Irrigation Variable Cost		6.15	9.65	7.74	7.78
Labor[a]	4.24	4.72	4.72	4.72	4.72
Interest on Operating Capital (7½%)	1.36	2.05	2.18	2.11	2.11
Total Operating Cost	$37.70	$ 56.60	$ 60.23	$ 58.25	$ 58.29
Machinery Fixed Cost	$ 6.70	$ 7.96	$ 7.96	$ 7.96	$ 7.96
Irrigation Fixed Cost		23.56	17.43	17.38	19.46
Real Estate Tax	1.00	1.00	1.00	1.00	1.00
Land Charge	6.86	6.86	6.86	6.86	6.86
Total Fixed Cost	$14.56	$ 36.44	$ 30.31	$ 30.26	$ 32.34
Total Production Cost	$52.26	$ 93.04	$ 90.54	$ 88.51	$ 90.63
Return to Management	$22.74	$ 26.96	$ 29.46	$ 31.49	$ 29.37
Production Cost Per Bushel	$ 0.70	$ 0.78	$ 0.75	$ 0.74	$ 0.76

[a]Charge for labor to irrigate is included in the irrigation variable cost.

The farmer irrigating with a center pivot system needed an additional 40.8 bushels of corn at $1.00 per bushel to break even (Table 22). Break-even yields and prices at various costs of production, yields, and prices are shown in Table 22.

TABLE 22. CORN GRAIN: INCREASED COST OF IRRIGATION AND YIELD INCREASE AND PRICE REQUIRED TO BREAK EVEN

	Added Operating Costs and Added Yields to Break Even at $1.00 Per Bushel				
	Cost		Yield (Bushels)		
System	Operating	Fixed	Operating	Fixed	Total
Center Pivot	$18.90	$21.88	18.9	21.9	40.8
Boom	22.53	15.75	22.5	15.8	38.3
Hand-Move	20.55	15.70	20.6	15.7	36.3
All Systems	20.59	17.78	20.6	17.8	38.4

Break-Even Yields for Corn Grain (Bushels)

	Price Per Bushel				
Cost Per Acre	$0.95	$1.05	$1.15	$1.25	$1.35
$ 55	57.9	52.4	47.8	44.0	40.7
60	63.2	57.1	52.2	48.0	44.4
65	68.4	61.9	56.5	52.0	48.1
70	73.7	66.7	60.9	56.0	51.9
75	79.0	71.4	65.2	60.0	55.6
80	84.2	76.2	69.6	64.0	59.3
85	89.5	81.0	73.9	68.0	63.0
90	94.7	85.7	78.3	72.0	66.7
95	100.0	90.5	82.6	76.0	70.4
100	105.3	95.2	87.0	80.0	74.1

Break-Even Prices Per Bushel for Corn Grain

	Yield Per Acre (Bushels)					
Cost Per Acre	65	75	85	95	105	115
$ 55	$0.85	$0.73	$0.65	$0.59	$0.52	$0.47
65	1.00	0.87	0.76	0.68	0.62	0.57
75	1.15	1.00	0.88	0.79	0.71	0.65
85	1.31	1.13	1.00	0.89	0.81	0.74
95	1.46	1.27	1.12	1.00	0.90	0.83
105	1.62	1.40	1.24	1.11	1.00	0.91

Alfalfa

Alfalfa raised under irrigated conditions must have a yield of 4.4 tons to be as profitable as a 2.0-ton yield under dryland at a price of $18.00 per ton (Table 23). The return to management was $9.39 per acre from dryland

TABLE 23. ALFALFA: PER ACRE AND PER TON COSTS AND RETURNS FOR DRYLAND AND IRRIGATION

Expected Returns	Dryland	Sprinkler Irrigation Systems				All Irrigation Systems
		Center Pivot	Boom	Tow-Line	Hand-Move	
Yield Per Acre (Tons)	2.00	5.14	5.14	5.14	5.14	5.14
Value Per Ton	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00
Total Value Per Acre	$36.00	$92.52	$92.52	$92.52	$92.52	$92.52
Expected Costs						
Establishment Costs--4 Years	$ 1.95	$ 2.53	$ 2.53	$ 2.53	$ 2.53	$ 2.53
Machinery Variable Cost	3.15	6.29	6.29	6.29	6.29	6.29
Irrigation Variable Cost		6.93	7.23	7.84	7.78	7.45
Fertilizer	4.40	10.60	10.60	10.60	10.60	10.60
Weed & Insect Control	.50	1.00	1.00	1.00	1.00	1.00
Labor	4.26	9.08	9.08	9.08	9.08	9.08
Interest on Operating Capital (7½%)	.53	1.37	1.38	1.40	1.40	1.39
Total Operating Cost	$14.79	$37.80	$38.11	$38.74	$38.68	$38.34
Irrigation Fixed Cost		$23.56	$17.43	$18.07	$17.38	$19.11
Machinery Fixed Cost	$ 3.96	4.73	4.73	4.73	4.73	4.73
Real Estate Tax	1.00	1.00	1.00	1.00	1.00	1.00
Land Charge	6.86	6.86	6.86	6.86	6.86	6.86
Total Fixed Cost	$11.82	$36.15	$30.02	$30.66	$29.97	$31.70
Total Production Cost	$26.61	$73.95	$68.13	$69.40	$68.65	$70.04
Return to Management	$ 9.39	$18.57	$24.39	$23.12	$23.87	$22.48
Production Cost Per Ton	$13.30	$14.39	$13.25	$13.50	$13.36	$13.63

and $22.48 per acre when all irrigation systems were combined. The highest return with irrigated alfalfa was $24.39 per acre using a boom system. Farmers using the center pivot system realized returns of $18.57 per acre for their management.

Because the same stand of alfalfa can be used for a number of years, an establishment cost representing the seed and planting cost was determined separately. Four years was assumed to be the productive life of alfalfa and the total planting cost was divided by four to obtain an annual cost.

The added yields needed to pay for additional irrigation costs and break-even yields and prices are shown in Table 24.

TABLE 24. ALFALFA: INCREASED COST OF IRRIGATION AND YIELD INCREASE AND PRICE REQUIRED TO BREAK EVEN

	Added Operating Costs and Added Yields to Break Even at $18.00 Per Ton				
	Cost		Yield (Tons)		
System	Operating	Fixed	Operating	Fixed	Total
Center Pivot	$23.01	$24.33	1.28	1.35	2.63
Boom	23.32	18.20	1.30	1.01	2.31
Tow-Line	23.95	18.84	1.33	1.05	2.38
Hand-Move	23.89	18.15	1.33	1.01	2.34
All Systems	23.55	19.88	1.31	1.10	2.41

Break-Even Yields for Alfalfa Hay (Tons/Acre)

Cost	Price Per Ton				
Per Acre	$15.00	$17.50	$20.00	$22.50	$25.00
$50	3.3	2.9	2.5	2.2	2.0
55	3.7	3.1	2.8	2.4	2.2
60	4.0	3.4	3.0	2.7	2.4
65	4.3	3.7	3.2	2.9	2.6
70	4.7	4.0	3.5	3.1	2.8
75	5.0	4.3	3.8	3.3	3.0
80	5.3	4.6	4.0	3.6	3.2

Break-Even Prices Per Ton for Alfalfa Hay

	Yield (Tons/Acre)							
Cost Per Acre	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
$50	$25.00	$20.00	$16.67	$14.29	$12.50	$11.11	$10.00	$ 9.09
60	30.00	24.00	20.00	17.14	15.00	13.45	12.00	10.91
70	35.00	28.00	23.33	20.00	17.50	15.69	14.00	12.73
80	40.00	32.00	26.67	22.86	20.00	17.95	16.00	14.55

Wheat

Wheat was used to represent the small grains in the cost and return analysis. Small grains were unprofitable under irrigation as shown in Table 25. Wheat raised under dryland continuous cropping conditions returned $5.21 per acre to management, whereas wheat raised under irrigation had a negative return to management with all of the individual sprinkler groups (Table 25). Wheat certificate payments were not included in the analysis.

TABLE 25. WHEAT: PER ACRE AND PER BUSHEL COSTS AND RETURNS FOR DRYLAND AND IRRIGATION

Expected Returns	Dryland	Sprinkler System: Center Pivot	Sprinkler System: Boom	All Irrigation Systems
Yield Per Acre (Bushels)	26	40	40	40
Price Per Bushel	$ 1.40	$ 1.40	$ 1.40	$ 1.40
Total Value Per Acre	$36.40	$56.00	$56.00	$56.00
Expected Costs				
Seed	$ 2.50	$ 2.50	$ 2.50	$ 2.50
Fertilizer	4.68	5.62	5.62	5.62
Weed and Insect Control	2.60	2.60	2.60	2.60
Crop Insurance	1.39	2.14	2.14	2.14
Machinery Variable Cost	3.52	3.77	3.77	3.77
Irrigation Variable Cost		6.61	7.67	7.14
Labor[a]	3.36	3.46	3.46	3.46
Interest on Operating Capital (7½%)	.68	1.00	1.04	1.02
Total Operating Cost	$18.73	$27.70	$28.80	$28.25
Machinery Fixed Cost	$ 4.60	$ 4.60	$ 4.60	$ 4.60
Irrigation Fixed Cost		23.56	17.43	20.50
Real Estate Tax	1.00	1.00	1.00	1.00
Land Charge	6.86	6.86	6.86	6.86
Total Fixed Cost	$12.46	$36.02	$29.89	$32.96
Total Production Cost	$31.19	$63.72	$58.69	$61.21
Return to Management	$ 5.21	$-7.72	$-2.69	$-5.21
Production Cost Per Bushel	$ 1.20	$ 1.59	$ 1.47	$ 1.53

[a]Labor cost for irrigating is included in the irrigation variable cost.

The cost of production per bushel was higher for the irrigated wheat budgets than for the dryland budget. The additional yield needed, as shown in Table 26, was higher than the yield increase shown in Table 25 between

TABLE 26. WHEAT: INCREASED COST OF IRRIGATION AND YIELD INCREASE AND PRICE REQUIRED TO BREAK EVEN

System	Added Operating Costs and Added Yields to Break Even at $1.40 Per Bushel				
	Cost		Yield (Bushels)		
	Operating	Fixed	Operating	Fixed	Total
Center Pivot	$ 8.97	$23.56	6.4	16.8	23.2
Boom	10.07	17.43	7.2	12.5	19.7
All Systems	9.52	20.50	6.8	14.6	21.4

Break-Even Yields for Wheat (Bushels)

Cost Per Acre	Price Per Bushel							
	$1.20	$1.25	$1.30	$1.35	$1.40	$1.45	$1.50	$1.55
$40	33.3	32.0	30.8	29.6	28.6	27.6	26.7	25.8
45	37.5	36.0	34.6	33.3	32.1	31.0	30.0	29.0
50	41.7	40.0	38.4	37.0	35.7	34.5	33.3	32.3
55	45.8	44.0	42.3	40.7	39.3	37.9	36.7	35.5
60	50.0	48.0	46.1	44.4	42.9	41.4	40.0	38.7
65	54.1	52.0	50.0	48.1	46.4	44.8	43.3	41.9
70	38.3	56.0	53.8	51.9	50.0	48.3	46.7	45.2

Break-Even Prices Per Bushel for Wheat

Cost Per Acre	Yield Per Acre (Bushels)			
	20	30	40	50
$40	$2.00	$1.33	$1.00	$0.80
45	2.25	1.50	1.13	0.90
50	2.50	1.67	1.25	1.00
55	2.75	1.83	1.38	1.10
60	3.00	2.00	1.50	1.20
65	3.25	2.17	1.63	1.30
70	3.50	2.33	1.75	1.40

the dryland and irrigation budgets. Losses were incurred as wheat raised with a center pivot system required 23.2 additional bushels per acre to pay the added cost, but increased only 14.0 bushels per acre over dryland farming. The break-even yield, with production costs per acre of $60.00 and a price received of $1.40 per bushel, was 42.9 bushels per acre. The farmer must receive $1.50 per bushel to break even with production costs of $60.00 per acre and a yield of 40 bushels per acre.

The primary data used in this study are subject to some limitations. The data were secured from a small number of farmers particularly those having boom, hand-move, and tow-line systems. In some instances not every one of the

farmers surveyed provided full data for every item of investment and cost. Therefore, some of the investment and cost items are averages per farm reporting rather than averages per farm. The data are based on a single year's operation where a number of years would give more representative data on costs. Many of the farmers in the sample have been irrigating only one or two years and had to estimate what some of the costs might be. Even though the data are subject to limitations, they can be used for a preliminary estimate of how irrigation might fit into a particular farm situation. The cost and return data used are subject to change and will vary from year to year.

LIST OF TABLES

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