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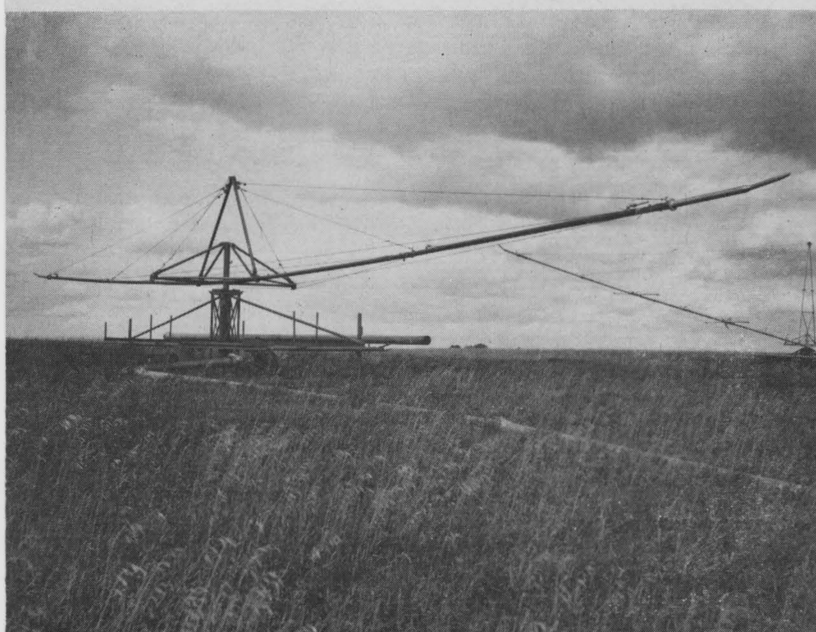
Economics of Supplemental Irrigation in Central Minnesota



ROGER B. LONG
PHILIP M. RAUP

University of Minnesota

AGRICULTURAL EXPERIMENT STATION

Summary

Water becomes an increasingly limiting factor in agricultural production as land use is intensified through better seeds, more fertilizer, improved cultivation, and wider use of agricultural chemicals. Heavier cash outlays per acre also increase the potential loss from drought or fluctuating rainfall. Supplemental irrigation, although still very limited in use in Minnesota agriculture, is one possible means by which water can be brought under managerial control.

Forty irrigators in three central Minnesota counties were interviewed in 1962 to determine irrigation investments, practices, costs and returns, and personal characteristics associated with decisions to adopt or expand irrigation.

Irrigated farms were much larger than nonirrigated farms in the study area; they were primarily devoted to production of field crops. Potatoes and corn were the principal crops irrigated, accounting for 82 percent of all irrigated land in 1961. Sprinkler irrigation was almost universal, with frequent use of large booms of 200 feet or more.

Rates of water application varied from ½ to 2 inches per hour, with rates of ½ and 1 inch most common. Total water use per acre in 1961 averaged 5.08 inches on corn and 7.06 inches on potatoes.

Under irrigation, yields per acre were 254 hundredweight (cwt.) for potatoes and 78 bushels for corn. Without irrigation, yields per acre on the same soils were estimated at 94 cwt. for potatoes and 31 bushels for corn. Fertilizer costs per acre on irrigated land averaged $52 for potatoes and $17 for corn. Costs of providing water averaged $30 per acre for potatoes and $19 for corn.

Total investments in irrigation equipment averaged $21,150 for potato irrigators and $7,200 for corn growers. To add another irrigated acre would cost corn growers an estimated $64 in additional investment in equipment. For potato growers the comparable equipment cost would be $186 for an additional acre.

For tracts under 40 acres, costs of corn irrigation per acre increased sharply with decreasing size. Above 80 acres the decrease in per acre costs for corn was small as acre-size expanded. For potatoes, average costs per acre declined slowly as acreage expanded from 40 to 280 acres but were quite variable. Four of the six potato irrigators with lowest costs per acre had less than 100 acres under irrigation.

Irrigation paid for the 40 irrigators studied, but net returns per acre were much greater for potato growers than for corn producers. This fact was reflected in estimates of land value increases which were marked on potato farms and quite modest on farms where corn was the principal irrigated crop.

Distinct differences existed in the personal characteristics of irrigators and nonirrigators in the study area and between those irrigating potatoes and those irrigating corn.

Irrigators were younger than nonirrigating farm operators, had completed more years of formal schooling, and had an average of 29 years

of farming experience. Potato growers tended to seek increased profits as their goal in irrigation, had more than 10 years of irrigation experience, and estimated the maximum acreage of land manageable under irrigation at well over 120 acres.

Corn irrigators were primarily interested in drought avoidance, had less than 10 years of irrigation experience, and estimated the maximum acreage of land manageable under irrigation at less than 120 acres.

Corn irrigators appeared more concerned with survival of the firm; potato irrigators were risk takers and stressed profit maximization.

Irrigation reduced resource mobility on irrigated farms in the study area; it also held some low-valued land in agricultural production. Future expansion of irrigation may be expected on lighter soils in marginal farming areas where drought is a constant hazard. Corn growers seemed more likely than potato growers to expand irrigation in the face of a decline in profit margins.

In this publication, you will find:

Economics of Supplemental Irrigation in Central Minnesota

Roger B. Long and Philip M. Raup

The Problem

Water and Minnesota are intimately related. More than 10,000 lakes, Indian legend, popular song, and aggressive advertising attest to Minnesota's wealth in water. But, this wealth is limited—and Minnesota has known drought. Although Minnesota is classed as a humid state, water is not evenly distributed among its agricultural regions.

With advancing agricultural technology, these facts assume new importance. High quality seeds, heavy fertilizer applications, weed and insect sprays, and intensive land use increasingly lift agricultural productivity to levels where water is a limiting factor. Heavier investments per acre also increase the potential loss from drought or fluctuating rainfall.

These trends explain the growing interest of farmers in humid areas concerning a reliable water supply during the growing season. Evidence of this interest can be found in irrigation statistics. For Minnesota the U. S. Census of Agriculture showed a doubling in acres irrigated between 1950-54 and a further 50-percent increase in 1954-59. By comparison with western states, the 15,000 acres irrigated in Minnesota in 1959 were quite small. In terms of water supply and soil suitability, the potential increase in Minnesota is great.

The 31 states east of the 97th meridian of longitude comprise the "humid" region of the United States. Irrigation in this area differs fundamentally from irrigation practiced in the more arid western states. In the arid region, water is usually applied to the land by flooding or ditching, with consequent heavy investments in ground leveling.

In Minnesota and the humid region generally, water is typically applied by sprinkler systems; little or no ground leveling is required. Since rainfall remains the primary source of moisture for crop production, such irrigation is called "supplemental irrigation." In most cases, it need not be used every year. Although techniques of applying water

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Roger B. Long was formerly a research assistant, Department of Agricultural Economics, University of Minnesota. He is now assistant professor, Department of Agricultural Economics, New Mexico State University. Philip M. Raup is a professor, Department of Agricultural Economics, University of Minnesota.

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by sprinkler are not difficult, successful operation requires knowledge of soil conditions, crop characteristics, and the agronomic and economic variables concerned.

Even though ground leveling is not involved, supplemental irrigation requires a comparatively large capital investment per acre. Before deciding to make this investment, the farm operator must consider the physical characteristics of his farm; his potential water supply, financial position, age, and family labor supply; and a host of related questions.

He must also consider the rapid increase in competing demands for available water generated by municipal, industrial, and recreational users. The Twin Cities and certain municipalities upstream currently conflict regarding maintenance of water levels behind Mississippi dams. In southwestern Minnesota, conflicts exist between agricultural and municipal users of water; industrial expansion in some communities is hampered by water shortages.

Therefore, in addition to farm management considerations on individual farms, information is needed on potential future expansion of agricultural water use in the light of conflicts among local, state, regional, and national users. Since important agricultural areas of Minnesota drain northward into Canada, international considerations also cannot be ignored.

These facts form the background for the present study, which had the following principal objectives:

Objectives

1. To describe the nature of supplemental irrigation in a typical Minnesota area with respect to physical aspects of crops, soils, and water supplies.

2. To report investments, operating costs, and returns from supplemental irrigation in a manner that is useful to farm operators contemplating irrigation.

3. To study personal characteristics and motivations of farmers in the study area who adopted irrigation in order to derive a better basis for estimating potential future expansion in irrigation.

4. To survey existing irrigation practices in the study area in order to gain a better basis for estimating future demands for agricultural water in relation to Minnesota's total water supply.

Source of Data

Two sources of information were available concerning the number of irrigators in Minnesota: the U. S. Census of Agriculture for 1959 and records maintained by the Division of Waters, Minnesota Department of Conservation. The Census of Agriculture reported 387 farmers irrigating 14,991 acres in Minnesota in 1959. Records of the Division of Waters listed 341 irrigators holding valid irrigation permits in 1960.

Although the Bureau of Census apparently could provide the most complete list of irrigators, names and addresses were confidential. Because permits to appropriate water are required under Minnesota Statutes, Chapter 105.41, and because names and addresses of irrigators were available from the Division, this source was used.

After the population was identified, a segment of it was selected. For this purpose, use was made of *Water Use for Irrigation in Minnesota,* Bulletin No. 17, Division of Waters, Minnesota Department of Conservation, April 1962. The bulletin stated that "the area of greatest water use for irrigation, with about 50 percent of the total water use, was in Central Minnesota, primarily on truck farms in Sherburne, Stearns, and Todd Counties." Because this area used "about 50 percent" of the irrigation water in Minnesota in 1960, it was selected as the study area.

The study area was not selected to represent the entire state. It was chosen because it was an area of relatively intensive irrigation that would yield the most reliable data on range of practices and time span covered. Counties involved and number of respondents in each county are shown in figure 1.

Forty irrigators were interviewed in the three counties in summer, 1962. The data obtained formed the basis for the analysis in this report.

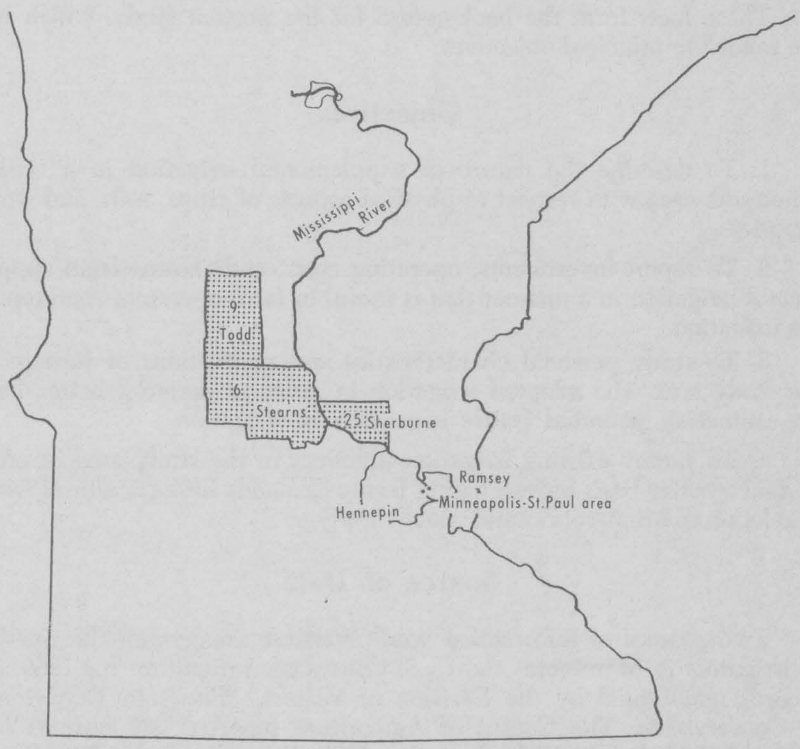

Figure 1. Minnesota irrigation study area. Number in county indicates number of respondents.

Minnesota's Water Supply

Water Sources

Precipitation—Rain and snow are the principal sources of water in Minnesota. The average annual rainfall for Minnesota is 25.5 inches; its uneven distribution is apparent from figure 2. Average annual rainfall varies from 32 inches in the southeast corner of the state to only 20 inches in the northwest. The gradient in rainfall from southeast to northwest is generally quite gradual.

Runoff estimates based on stream flow data are presented in figure 3. Runoff is defined as that part of precipitation which flows over the land into lakes and streams after deducting the water lost through evaporation, transpiration, and seepage. A sizable portion of the state's potential water supply is exported in this manner. Approximately 37 trillion gallons of water fall in the state each year in the form of precipitation. About one-fifth of this amount, 7.4 trillion gallons, flows to neighboring states and Canada. But little surface water flows into Minnesota.

Surface and Ground Water—Minnesota, according to Division of Waters' estimates, has at least 14,000 lakes. These lakes have important recreational uses in addition to their agricultural, industrial, and municipal value. Although ground water is also abundant in many areas, accessible ground water deposits are not uniformly distributed throughout the state. Figure 4 shows the location of the study area relative to the four principal ground water regions. Based on the ease with which ground water may be obtained, Region I is most favorable and Region IV is most difficult.

Region I is an area of medium to high precipitation, low to medium evaporation, good infiltration, and ground water storage provided by sandstones, dolomites, and limestones. It is the most favorable section of the state for developing large ground water supplies. However, these large supplies are likely to be deep and may be too costly to develop.

Region II has medium precipitation, medium evaporation, and medium infiltration from sandy glacial drift. It can yield large quantities of water to wells.

Region III has the lowest precipitation in the state, medium to high evaporation, and low infiltration because of clayey glacial drift and Cretaceous strata. Large aquifers are available in some places but extensive test drilling is required to locate them.

Region IV has medium to high precipitation, low evaporation, and low infiltration due to crystalline rocks and thin patches of glacial drift. This region is not favorable for developing extensive ground water supplies.

Minnesota, statewide, has an average net moisture deficiency of 4 inches of precipitation each year.[1] This figure is derived by subtracting

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[1] *Water Resource Activities in the United States,* Select Committee on National Water Resources, U. S. Senate, Comm. Print No. 13, Dec. 1959, pp. 26-27.

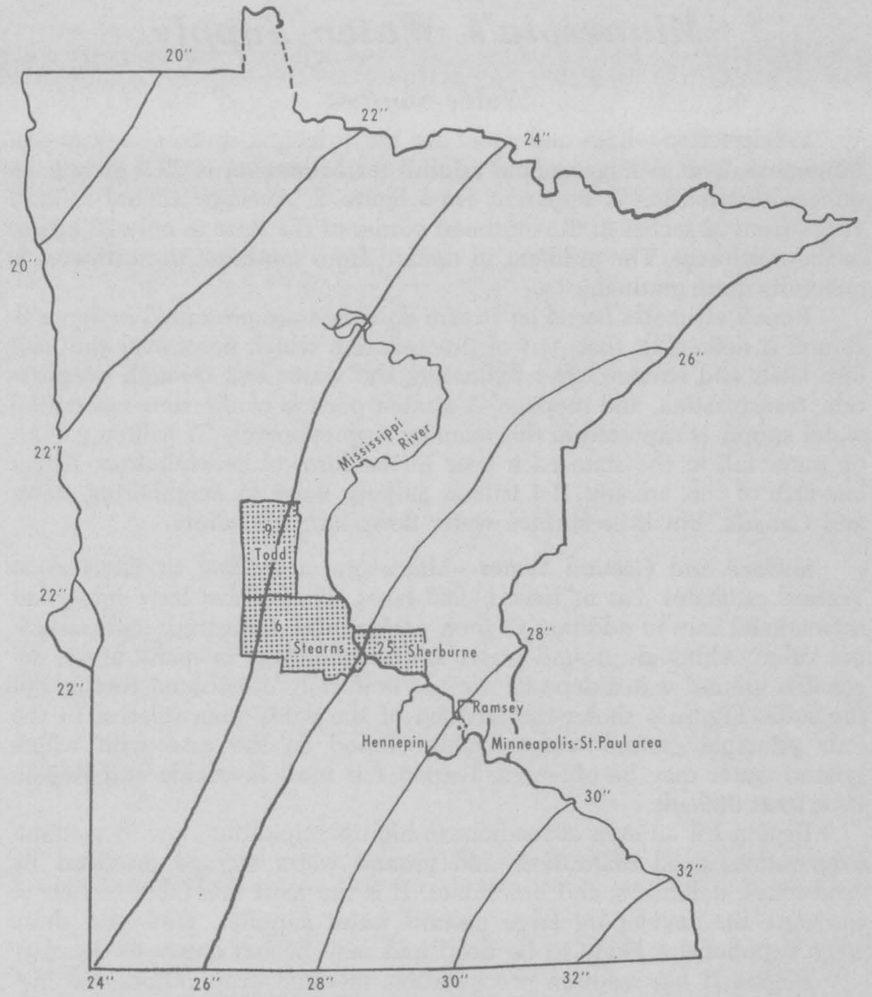

Figure 2. Minnesota lines of equal annual precipitation. Number in county indicates number of respondents. Source: *Hydrologic Atlas of Minnesota.*

annual runoff (5 inches) and potential evapotranspiration (24 inches) from average annual precipitation (25 inches). Counties in the study area receive from 24 to 26 inches of rainfall annually, are in an area where runoff is below average for the state, and lie predominantly in ground water region II—an area of medium to large ground water supplies.

Water Law

During 1934-36, Minnesota suffered a relatively severe and prolonged drought. Mainly as a result of this drought, the Minnesota Legislature enacted a statute, effective July 1, 1937, making it illegal to use Minnesota waters, with some important exceptions, without first obtaining written permission from the Commissioner of Conservation.[2] This law's objective, as stated in Minnesota Statutes, Chapter 105.38, is "to conserve and utilize the water resources of the state in the best interests of the people of the state and for the purpose of promoting the public health, safety and welfare."

Generally, water permits must be obtained by industrial, municipal, and agricultural users of water; however, three types of exemptions exist.

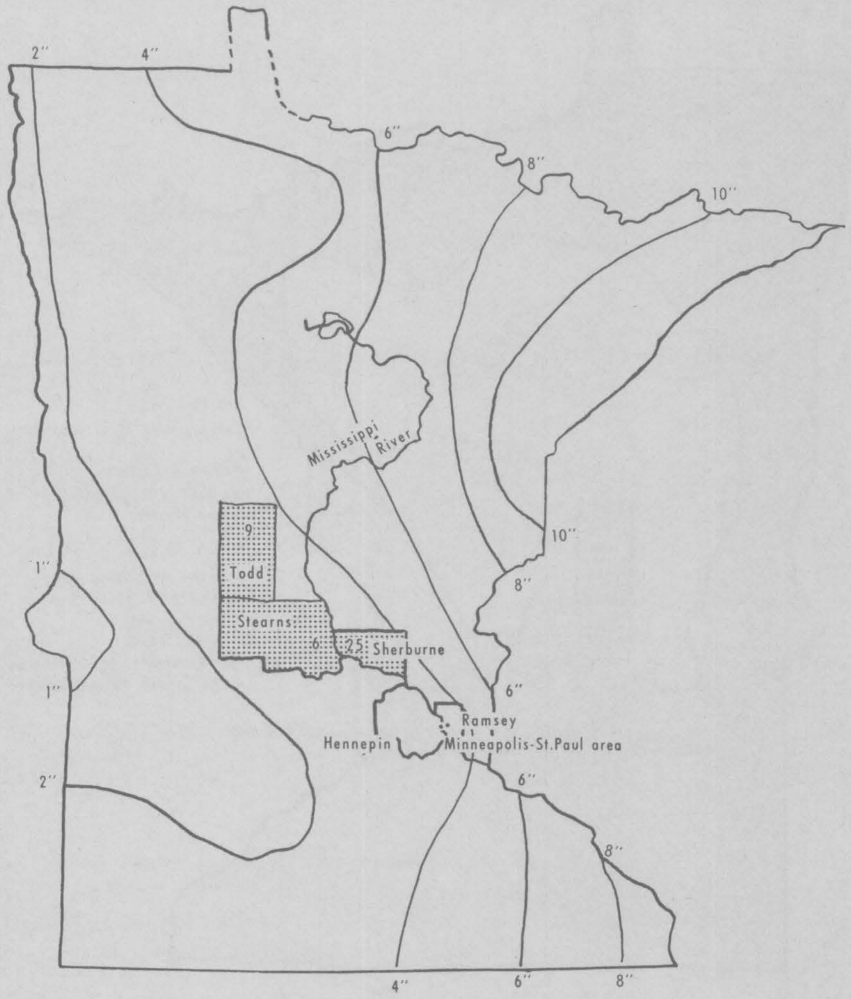

Figure 3. Minnesota lines of equal annual runoff to streams. Number in county indicates number of respondents. Source: *Hydrologic Atlas of Minnesota.*

[2] C. O. Nohre and P. M. Raup, *Regulation of Water Use in Minnesota Agriculture,* Univ. of Minn. Agr. Exp. Sta. Bull. 453, Mar. 1961, pp. 3-22.

In terms of number of users involved, the first and most important is that permits are not required for domestic uses. A "domestic use" is one that serves at any time less than 25 persons. In practice, irrigation of 5 acres or less has been regarded as a "domestic use"; a permit is not required.

Second, the law was not retroactive. Therefore, all beneficial uses and rights in existence on July 1, 1937 outside the geographical limits of any municipality are exempt.

Third, any beneficial uses and rights in existence on July 1, 1959 inside the geographical limits of any municipality are exempt.[3]

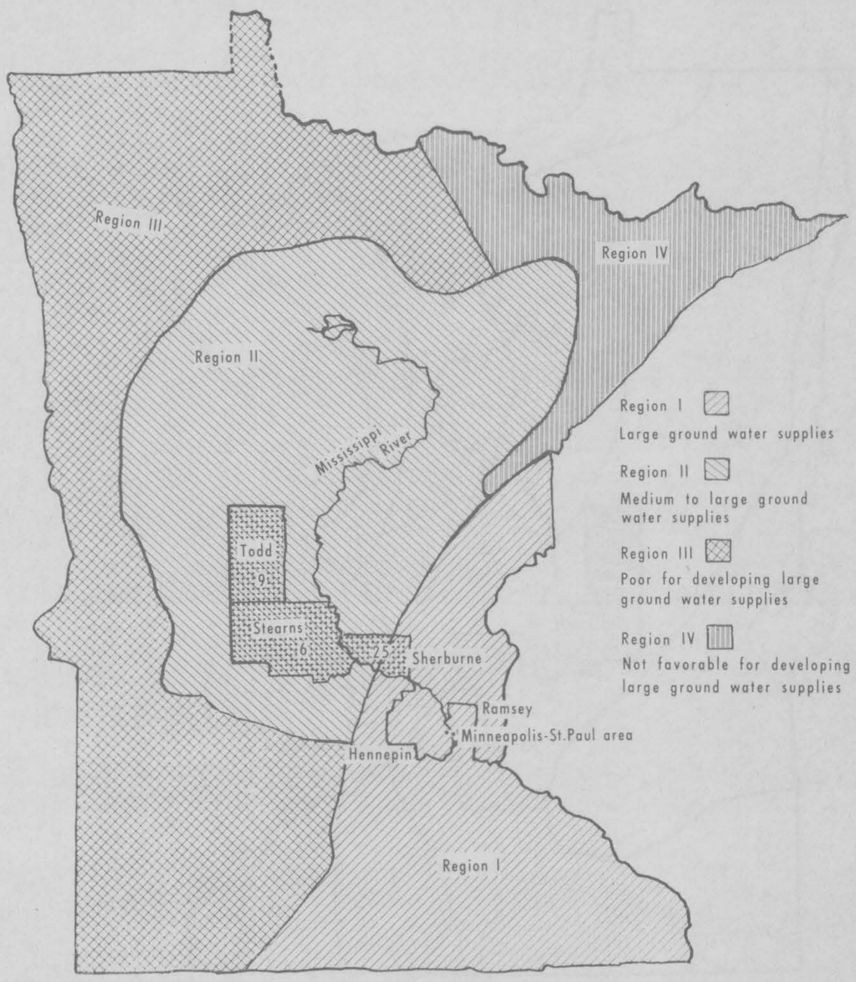

Figure 4. Minnesota ground water regions. Number in county indicates number of respondents. Source: *Hydrologic Atlas of Minnesota.*

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[3] Users within boundaries of municipalities were exempt from the permit requirement in the original 1937 legislation. This exemption was withdrawn in 1959 but the act was not retroactive. For a more detailed explanation see: Nohre and Raup, op. cit.

Applications for water permits are made to the Division of Waters, Minnesota Department of Conservation, St. Paul. An irrigator granted a permit must keep continuous pumping records of his operation and can use only that amount of water allotted to him. The Division's policy allows up to 6 inches (one-half an acre foot) per year for each acre irrigated. How this water is allocated is up to the farmer.

An important distinction exists between surface and ground water sources. If the source of water is a well, a farmer may be granted a permit to irrigate any land he wishes. If the source of water is a lake or stream, the farmer is granted a permit to irrigate only in units of 40 acre tracts, or government lots, that are abutting (riparian to) the source.

Enforcement of the law regarding water permits is primarily achieved through annual pumping reports that show the amount of water used. If an irrigator fails to comply with this procedure, the Division may cancel his water permit. Violation of any provision of the permit system is by law a gross misdemeanor.

The amount of water used for irrigation purposes is small compared to all other uses. The Division of Waters estimated this use to consume about 2 percent of all Minnesota water in 1950. Relative to other uses, water use for irrigation should not expand greatly in the near future.

Precipitation in 1961

Farmers interviewed in this study were asked questions primarily about irrigation practices in 1961—a year in which rainfall was not always adequate. One weather summary described the situation: ". . . . the lack of precipitation was not aggravated by high daily temperatures. This was one of the reasons that the near-drought condition where it existed was not as severe as it was in 1934 and 1936."[4] This same source summarized the weather through the growing season in terms listed in table 1.

Although precipitation in Minnesota during 1961 was far from optimal, timely rains fell in most areas when they were needed. Drought severity varied greatly, depending on soil conditions and crops grown.

Table 1. Minnesota precipitation conditions, 1961

Time period	Precipitation situation
January through March	"Slightly above" average
April through May 14	"Below" average
May 14 through June 29	"Much below" average
June 30	General rains
July	"Much above" average
August	"Below" normal
September	"Much above" normal

[4] *Minnesota Agricultural Statistics, 1962,* Minn. Dept. of Agr. and U. S. Dept. of Agr., Mar. 1962, p. 39.

Characteristics of Irrigated Farms

Irrigated farms in the study area had distinctive patterns of land use and cultural practices that differed from typical farm practices on unirrigated farms in these counties.

Land Tenure, Land Uses, and Sources of Income

The 40 irrigated farms were relatively large for the area, averaging 324 acres in size. The 1959 Census of Agriculture data for the three counties showed about 187 acres as the average size of all farms. Census data also revealed that two-thirds of all farms in the three counties were under 259 acres in 1959. Nearly three-fourths of the irrigated farms were larger than 259 acres.

Irrigators owned an average of 260 of their 324 acres and rented an additional 66 acres. Of this total, they leased out an average of 2 acres. Sixteen irrigators rented land while only 2 leased it out. Of the 18 irrigators involved in leasing arrangements, 83 percent used cash rent leases —an unusually high percentage.

Of all farmers in the three counties who leased some land in 1959, 43 percent reported some cash renting. For Minnesota as a whole, cash rent was paid for only 4 percent of the commercial farms operated by full tenants. So cash rent is more frequently associated with part ownership than with full tenancy. It was the dominant form of renting irrigated land in the study area.

Eighty percent of the respondents owned some land or were buying

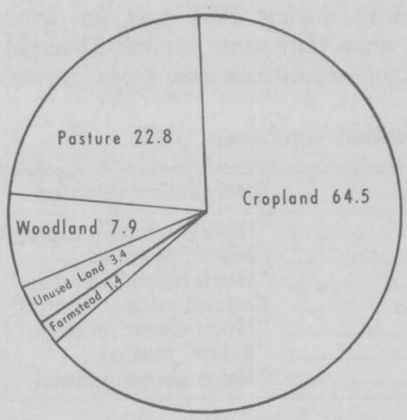

Figure 5. Land use in percent, 40 irrigated farms, central Minnesota, 1961.

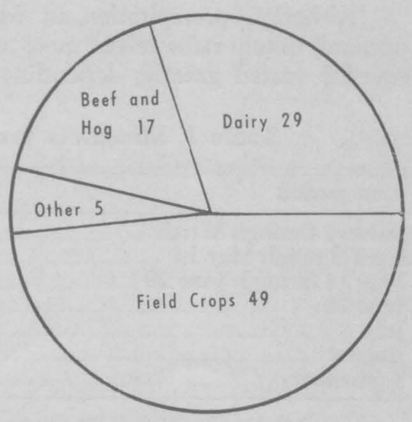

Figure 6. Sources of income in percent, 40 irrigated farms, central Minnesota, 1961.

their farms; 8 percent were involved in family partnerships. One farm was incorporated. Ten percent of the irrigators were full tenants. Percentages for ownership and tenancy were similar to those reported in the 1959 Census for all farms in the three counties.

The 40 irrigators operated 12,963 acres. Of this total area, 8,356 acres were cropland; 2,951 acres, pasture; 1,026 acres, woodland; and 630 acres, wasteland or farmstead (see figure 5). These farmers produced milk, beef, hogs, and various field and truck crops. When these sources of income were aggregated for the 40 farms, it was found that 49 percent of all income came from field crops (including potatoes); 29 percent, dairying; 9 percent, beef; 8 percent, hogs; and 5 percent, truck crops and miscellaneous crops (see figure 6).

Area Irrigated, Crops Irrigated, Type of Irrigation, and Water Use

Respondents estimated that they could irrigate 4,831 acres in total—about 121 acres per farm. Approximately 70 percent of this capacity was utilized in 1961 when 3,411 acres were irrigated—an average of about 85 acres per farm. According to Division of Waters' permit records, these same farmers were authorized to irrigate 4,322 acres. Capital and labor limitations and water restrictions were given as reasons why more land was not irrigated.

Potatoes were the most important single crop under irrigation, occupying 1,776 acres or over half of the total. Corn was second, accounting for 1,034 acres; hay and alfalfa were third with 376 acres. Other crops included 91 acres of soybeans, 69 acres of oats, 10 acres of pasture, and 55 acres of strawberries and truck crops. The most frequently named factors influencing choice of crops to be irrigated were: returns, soil conditions, animal feed requirements, and irrigation costs.

Sprinkler irrigation was found on 39 of the 40 farms studied. In the driest year, farmers reported using an average of 6.8 inches of water per acre. In 1961 the average use of water was reported as 5.5 inches per acre. Application rates ranged from 0 to 11 inches of water per acre.

Ninety percent of all irrigators had not encountered problems in obtaining water permits, and only 25 percent indicated that community concern existed about irrigation uses of water. Such community concern was primarily about irrigation effects on ground water levels.

Water Supply, Soil Types, and Irrigation Practices

Irrigators used both surface and ground water sources. In total, 24 farms had wells and 19 farmers used ponds, lakes, and rivers. Several farmers used more than one source. Well points and ditches were also used. Potato farmers tended to use deep wells, while corn and other grain farmers were more likely to use shallow wells and rivers.

Soils on these farms tended to be sandy (see figure 7). The predominant soils irrigated, as indicated by each operator, were: 45 percent

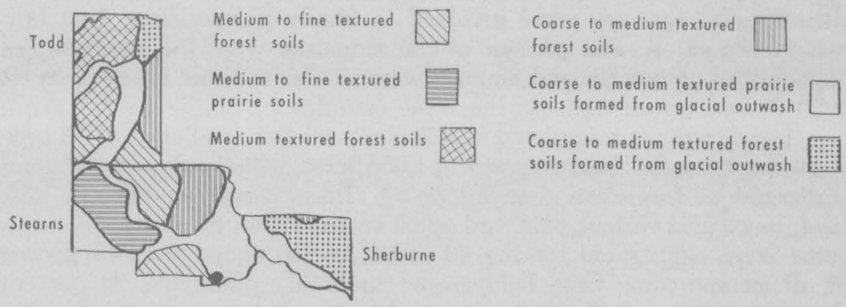

Figure 7. Generalized soil types of study area. Source: H. F. Arneman, *Soils of Minnesota*, Univ. of Minn. Ext. Bull. 278, June 1963.

irrigated sand, 50 percent sandy-loam, and 5 percent clay and silt. Slopes of irrigated fields fell into three equally divided classes: level, slightly rolling, and rolling. Maximum slopes for irrigated land were estimated to be about 3 percent. One-fourth of the irrigators had erosion problems, mostly from wind. Only 10 percent reported drainage problems.

Water application rates varied from ½ to 2 inches per hour; rates of ½ and 1 inch were most frequently named. Although irrigators used their systems from 1 to 20 weeks per year, 80 percent of the respondents indicated use of 4 to 10 weeks per year. The total amount of water applied per application ranged from 1 to 4 inches with three-fourths of the irrigators using 2 inches or less (see table 2).

During the survey year, 1962, summer rains were well distributed. Of the total respondents, 40 percent had not irrigated at all during the year; 60 percent had. Generally speaking, potato farmers irrigated more than did corn farmers during 1962.

Fifty-five percent of the irrigators depended upon soil conditions to indicate when they should apply water. The others used plant conditions

Table 2. Water utilization for irrigation on 40 farms, central Minnesota, 1961

Water utilization	Number of irrigators reporting
Water application rates (inches per hour):	
0.50-0.67	15
0.75-1.00	23
1.25-2.00	2
Average number of weeks per year in which irrigation was used:	
1-4	8
5-8	21
Over 8	11
Inches of water applied per irrigation:	
0-1	12
1.5-2	19
2.5-4	9

and the period of time since the last rain as their indicators. Apparently, irrigators regarded soil moisture as the key indicator.

Labor Needs

Farmers were asked specific questions about their labor requirements for irrigation purposes. Forty-two percent of the irrigators reported that the installation of irrigation equipment caused them to hire more labor. One to seven persons were hired for this purpose, averaging two per farm for those farms hiring labor. Hired labor was used primarily to move equipment. Potato farmers were the principal employers. Many farmers irrigating corn did not find it necessary to hire extra help.

Shifts in Cropping Under Irrigation

When adopted, irrigation caused certain shifts in cropping practices. More than one-third of all irrigators reported reduction or elimination of truck crops, certain grains, corn, and dairying in order to achieve increased specialization.

Irrigation Equipment

A narrow range of highly specific equipment was characteristic of irrigators in the area (see table 3). Forty centrifugal pumps were in use in combination with surface water, shallow wells, and well points. The 14 turbine pumps encountered were associated with deep wells (up to 430 feet) on potato farms. These pumps had capacities ranging from 110 to 1,300 gallons per minute. Gas, diesel, electric, and liquefied petroleum gas (LPG) engines were all in use, in that order of frequency. Engine

Table 3. Water sources and irrigation equipment in use on 40 irrigated farms, central Minnesota, 1961

Sources and equipment	Number
Water sources:	
Ground water (wells)	24
Surface water (streams and lakes)	19
Type of water pumps:	
Centrifugal	40
Turbine	14
Type of engines:	
Gas (including three tractors)	27
Diesel	19
Electric	6
LPG	2
Type of sprinklers	
Booms	41
Rotary head sprayers	653

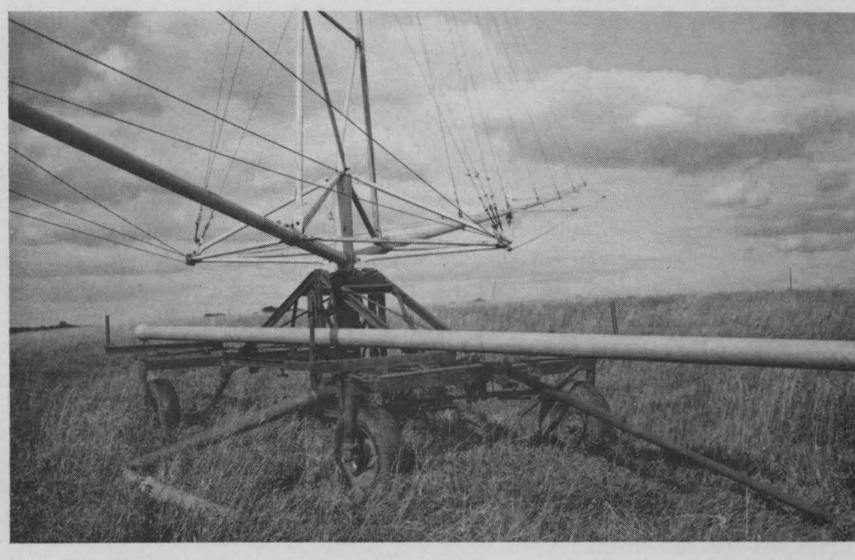

Figure 8. Boom sprinkler and trailer.

sizes ranged from 3 to 180 horsepower. Aluminum pipe was in universal use, varying in diameter from 3 to 8 inches. Amounts of pipe owned varied from 1,500 to 16,000 feet. Some steel pipe was also used.

Boom sprinklers, a recent innovation, were popular. Of the 40 irrigators, 28 owned 41 boom sprinklers. Some 653 smaller rotary sprinklers were also in use. Of the booms, 29 were the 200-foot size and six each were the 140- and 250-foot sizes. Boom sprinklers are quite large, varying from 140 to 260 feet in length (see cover and figure 8). One large boom sprinkler can irrigate up to 4½ acres at a setting. Chief advantages of owning a boom sprinkler are reduced labor requirements and reduced crop damage.

Although several rotary sprinklers are required to irrigate 1 acre of land, they were widely used in the study area. All but 1 of the 40 irrigators owned some rotary sprinklers—the average was 16 sprinklers per farm. Large quantities of pipe are also associated with rotary sprinklers, requiring substantial labor each time they are moved.

Labor and fuel costs were highly variable, depending on the system used. For a handmove rotary sprinkler system, labor costs were about 1 man-hour per irrigation per acre. For a boom system, the labor requirement was only a fraction of a man-hour per irrigation per acre. Some farmers estimated that two men could move a boom, that could irrigate 4 acres, in about 20-30 minutes. Fuel costs averaged about 56 cents per acre-inch for all irrigators. Only one-fourth of the farmers moved their equipment without a tractor drawn trailer.

Increases in personal property taxes due to irrigation equipment were reported by 82 percent of the owners.

Production Practices and Crop Yields

Information was gathered on cultural practices for potatoes and corn used in 1961. Information on other crops was scant. With irrigation, potato growers used an average of 1,200 pounds of seed per acre; corn growers averaged 16,500 plants per acre. Potato growers reported the use of from $25.64 to $79.57 of fertilizer per acre; they averaged $52.26. Corn growers used less but still large quantities of fertilizer. Their fertilizer investments ranged from $2.90 to $26.96 per acre; they averaged $16.96.

Without irrigation, farmers indicated fertilizer inputs for both crops would have been cut in half. Potato yields reported by irrigators averaged 254 cwt. per acre, compared to the three-county average of 150 cwt. per acre. Average irrigated corn yields were also high at 78.4 bushels per acre, compared to the three-county average of 50 bushels per acre.

Irrigators were asked to compare their actual yields in 1961 with yields they would have expected on the same soils without irrigation (see table 4). Differences between average yields with irrigation and expected yields without irrigation were much greater than differences between yields under irrigation and average yields for all producers in the three-county study area. This indicated the below-average productivity of the soils in question under normal conditions of rainfall agriculture.

Irrigators were also asked if they had obtained any of a list of five possible benefits from irrigation. Their answers are summarized in table 5.

Table 4. Reported yields per acre with irrigation and expected yields without irrigation, 40 irrigators, three counties, central Minnesota, 1961

		Irrigators		
Crop	Unit	Reported yields with irrigation	Expected yields without irrigation	Average, all producers, three-county study area
Potatoes	cwt.	254	94	150
Corn	bu.	78	31	50
Soybeans	bu.	24	14	18
Oats	bu.	75	30	39
Alfalfa	tons	3.5	1.2	1.7*

* All hay, including alfalfa.

Table 5. Percent of irrigators reporting specified benefits from irrigation, 40 irrigators, central Minnesota, 1961

Possible benefit	Percent of irrigators
Increased production	100 0
Drought insurance	92.5
Improved crop quality	90 0
Earlier maturity	52 5
Frost protection	15.0

Operator Characteristics

As a group, the 40 irrigators were substantially younger and had completed more years of formal schooling than the average farm operator in the three-county study area. Ages ranged from 23 to 72 and averaged 43. The average age for all farm operators in the study area was 48, as reported in the 1959 Census of Agriculture.

Irrigators averaged 10.6 years of formal schooling and 28.7 years of farming experience. Almost three-fourths of the irrigators had been farming for 20 years or more. In the three-county area as a whole in 1960, over 70 percent of the farm population age 25 and over had not gone beyond the eighth grade in school. Among irrigators, 60 percent had some high school training and 20 percent reported some college. Although half of the irrigators had been irrigating for 5 years or less, almost one-third had more than 10 years of irrigation experience (see tables 6 and 7).

Table 6. Selected personal characteristics of 40 irrigators, 1962, and of all farm operators, three counties, central Minnesota, 1959

	40 irrigators, three counties, 1962		All farm operators, three counties, 1959*	
Personal characteristics	Number	Percent	Number	Percent
Age distribution:†				
Under 35	8	20	1,413	17.7
35-44	16	40	1,919	24.1
45-54	8	20	2,087	26.2
55-64	4	10	1,722	21.6
65 and over	4	10	826	10.4
Education level (years of school completed):				
8 or less	16	40	11,881	70.5
9-12	16	40	4,001	23.7
Some college	8	20	983	5.8

* U. S. Census of Agriculture, 1959. Data for educational level refer to all persons 25 and over in the three counties in 1960.

† Estimated distribution from decennial size classes.

Table 7. Farming and irrigating experience, 40 irrigators, three counties, central Minnesota, 1962

	Irrigators	
Years of experience	Number	Percent
Farming experience:		
0-10	5	12.5
11-20	6	15.0
21-30	14	35.0
Over 30	15	37.5
Irrigation experience:		
0-5	20	50.0
6-10	7	17.5
11-20	7	17.5
Over 20	6	15.0

Reasons for Choosing Irrigation and Sources of Information

"Drought avoidance" to reduce losses and ultimately increase profits was the most frequent answer of irrigators asked why they started irrigating. Seventy percent of the respondents gave this reply. One-fourth gave "increased yields" or "profits" as their most important reason and 5 percent cited other reasons.

For technical information, irrigators relied at first on commercial firms, university literature and extension services, observation of other farms, and personal experience, in that order of importance. Thirty-eight percent had experimented with irrigation on a small scale before further adoption. Fifty percent had observed irrigation practices in areas where it was well established before undertaking it on their own.

Future Plans of Irrigators

Sixty percent of the irrigators desired to expand irrigation operations, primarily on corn, potatoes, and alfalfa. Irrigators also reported an average of six neighbors each who had serious interest in this practice. In terms of flexibility of farm operations, 52 percent felt that their choice of crop alternatives was less limited because of irrigation, 35 percent felt more limitations, and 13 percent indicated no change. The majority (72 percent) also felt more committed to farming because of the investment in irrigation; 28 percent felt no added commitment.

Capital Sources and Land Values

Bank loans, private funds, Production Credit Associations (PCA's), finance companies, the Federal Land Bank, and equipment dealers were sources of funds for buying irrigation equipment, in that order of frequency. Eighty percent of the irrigators used bank loans or private funds.

Investment in irrigation equipment ranged from $300 to $70,000 and averaged $12,420 per farm. Gross sales of irrigators were also spread over a wide range. For 17.5 percent of the irrigators, gross sales were less than $10,000 in 1961; an equal number sold more than $40,000 worth of farm products. The remaining 65 percent fell in the $10,000-$40,000 gross sales category.

Over two-thirds of all irrigators felt that irrigation had increased their land's value; the others felt that it had not. Owners in Stearns and Todd Counties were less likely to indicate land value increases than were those in Sherburne County. This undoubtedly reflected the prevalence of light sandy soils in Sherburne County, often of low value unless irrigated.

Farmers' Reasons for Irrigating and Their Personal Characteristics

A principal objective of this study was to learn about the relationships between personal characteristics of individuals who adopted irrigation and their reasons for so doing.[5]

Three aspects of the operator's decision to adopt irrigation were determined:

What was his primary goal (typically drought avoidance or increased profits)?

Had he experimented with irrigation on a small scale before adoption?

Had he observed other irrigation operations before making his decision?

These three dimensions of the decision to irrigate were compared with 10 personal characteristics, expressed opinions, or choices of each operator:

1. Age of operator.
2. Years of school completed.
3. Length of farming experience.
4. Length of irrigation experience.
5. Length of time irrigation was considered before adoption.
6. Opinion as to operator's need for more training.
7. Opinion as to whether irrigation would expand or contract in the future.
8. Estimate of the maximum irrigated acreage one operator can manage.
9. Estimate of length of time required for the system to pay for itself.
10. Choice of crops irrigated.

These characteristics were divided into two groups based on response. If replies were positive or negative they were so classified; if quantities, they were divided by their arithmetic mean.[6]

[5] To accomplish this purpose chi-square analysis was used with two-by-two contingency tables for independence. Observations were generally not adequate for forming conclusive judgments about the potential population. Instead, they point the way for formulation of hypotheses for a more conclusive study. Partenheimer and Bell used similar tests to suggest hypotheses for future investigations (see Glenn L. Johnson et al., *Managerial Processes of Midwestern Farmers,* Iowa State Univ. Press, 1961, p. 90).

[6] The 0.025 level of significance was chosen for these tests, although many were significant at even smaller levels. Variables were judged to be either independent or dependent. The majority of tests revealed no dependent relationships.

Certain characteristics of farmers were found associated with the increased profit motive and others with the drought avoidance motive. Desire for increased profit as the dominant motive for irrigation was found associated with farmers who had more than 10 years' irrigation experience, who estimated the maximum acreage of land manageable under irrigation at greater than 120 acres, and who raised potatoes as a major crop.

Drought avoidance as the primary motive for beginning irrigation was found associated with farmers who had less than 10 years' irrigation experience, who estimated the maximum acreage of land that could be managed under irrigation at less than 120 acres, and who raised corn.

Significant associations were also found concerning prior experimentation with irrigation on a small scale. Farmers who had first experimented with irrigation on a small scale were typically those who had at least 10 years' irrigation experience and who raised potatoes as a major crop. Farmers who had not experimented were most frequently those with less than 10 years' irrigation experience and grew corn as their major crop.

The prior observation of irrigation in areas where it was well established was not associated with any characteristic or opinion of irrigators.

This analysis, coupled with data on scale and intensity of operation, suggests some basic differences between corn and potato growers. Motivational differences between those who chose irrigation to avoid drought and those who sought increased profits now come into focus. A search for increased returns by potato growers implies reasoning based on the profit maximization goal, as assumed by most economists.

The desire for drought avoidance by corn growers, on the other hand, may imply motivational logic focused on a desire to insure survival of the farm firm. Where this is the case, farmers might be expected to irrigate even in the absence of greatly increased returns due to the additional security provided. Further research in this area is needed and may yield significant results in projecting possible future trends in supplemental irrigation.

Associations between motivation and choice of crops were also coupled with sharply different levels of capital investment, scale, and intensity of operations. Potato growers had an average investment in irrigation equipment of $21,150. The investment of corn growers averaged only $7,200. Potato growers averaged 111 acres under irrigation in 1961; corn growers averaged 44.9 acres. With regard to irrigation experience, potato growers averaged 14.4 years and corn growers 7 years.

The approximate average total cost of irrigating potatoes was $30 per acre; for corn, about $19 per acre. Potato farmers hired more labor than did corn farmers. Average intensities of water use were also greater on potato farms. The average number of inches applied per acre in 1961 was 5.08 inches on corn farms and 7.06 inches on potato farms. These data on water and fertilizer usage (see page 17) indicate clearly that potato farming is far more intensive than corn farming in the area studied.

Investments, Costs, and Returns

Investments

Each irrigator estimated his total investment in irrigation equipment. Their figures agreed closely with a synthetic estimation of this investment based on an inventory of the equipment owned, valued at current list prices. When correlation analysis was used to compare these two estimates, synthetic estimates were associated with 89 percent of the variation in estimates supplied by farmers.

Investments estimated in this section were based on current list prices and may be slightly higher than those paid by an astute purchaser. One irrigation equipment dealer estimated that list prices could be decreased by 10-20 percent, depending upon the amount of equipment purchased and the time of year.

Simple regression analysis was used to relate total irrigation investment and total acres of corn irrigated (see table 8). Twenty-three corn irrigators had an average investment of about $7,200 in equipment. About 45 percent of the variation in total investment among farms was associated with variations in total acres irrigated. Since only two corn producers irrigated over 100 acres, estimation beyond the 100-acre point was hazardous with this regression equation (see figure 9).

This same procedure was used to estimate total investments necessary to irrigate potatoes. Figure 10 presents the estimating regression

Table 8. Estimated total investment in equipment necessary to irrigate corn in relation to number of acres under irrigation*

Acres irrigated	Estimated investment at 1962 prices
40	$ 5,237
80	7,803
120	10,368
160	12,933

* Investments are estimated with the regression equation: $Y = 2{,}672.19 + 64.13X$. The value for r^2 is 0.45; $N = 23$; $\bar{X} = 70.74$; and $\bar{Y} = 7{,}208.69$.

Table 9. Estimated total investment in equipment necessary to irrigate potatoes in relation to number of acres under irrigation*

Acres irrigated	Estimated investment at 1962 prices
50	$ 6,777
100	16,117
150	25,457
200	34,797
250	44,137

* Levels of investment are estimated with the regression equation: $Y = -2{,}563.00 + 186.60X$. The value for r^2 is 0.58; $N = 16$; $\bar{X} = 126.81$; and $\bar{Y} = 21{,}125.00$.

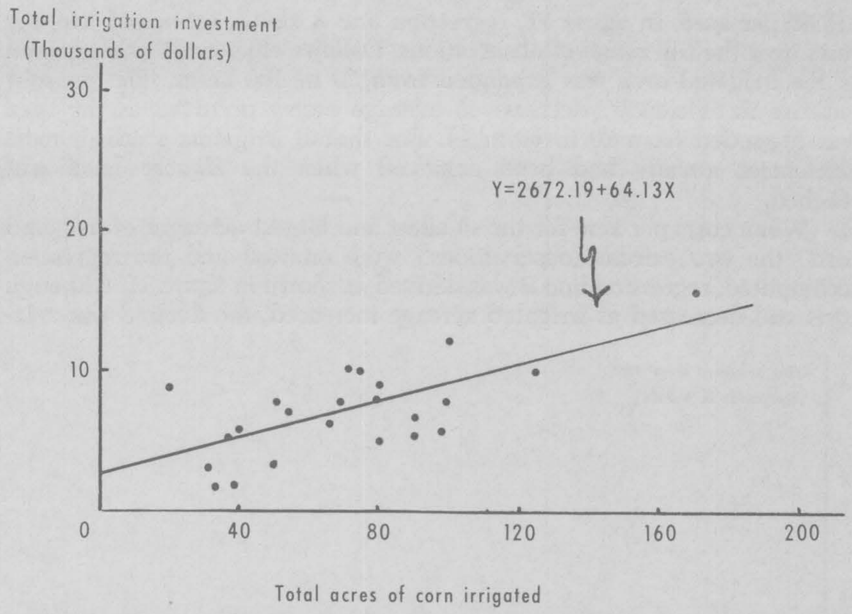

Figure 9. Investment in irrigation equipment on corn farms in relation to area irrigated, three counties, central Minnesota, 1961.

line. Figures 9 and 10 illustrate the differences in additional cost required for potato and corn irrigators to bring another acre under irrigation—about $64 for a corn farmer and about $186 for a potato farmer. Observations for potatoes were plotted over a greater range of total acres than were corn observations. The average investment of potato growers was estimated at about $21,000; the average area under irrigation was 127 acres.

Table 9 presents estimated investments in equipment for selected areas of irrigated potatoes, over the range of observations.

Fifty-eight percent of the variation in equipment investment for potato irrigation was explained by changes in the number of acres irrigated, compared to 45 percent of the variation with corn.

Average Costs

Average total irrigation costs (excluding land costs) were also estimated for corn and potato growers. These costs included estimates for: depreciation over 15 years, interest at 6 percent, taxes, insurance, fuel, lubrication, repairs, and labor. While all irrigators did not take all costs fully into account, they were included in these calculations as the costs of opportunities foregone in other investments.

The average total cost for irrigating corn, for all respondents, was

$18.86 per acre. In figure 11, regression line A shows estimated average costs over the full range of observations. Definite efficiencies were gained as the irrigated area was expanded from 20 to 100 acres. The greatest increase in efficiency (decrease in average costs) occurred as the area was expanded from 20 to 60 acres. For the 40 irrigators studied, most efficiencies already had been achieved when the 80-acre level was reached.

When costs per acre for the smallest and largest acreages of irrigated corn (the two extreme observations) were omitted and the regression recomputed, regression line B was derived as shown in figure 11. Although costs still decreased as irrigated acreage increased, the decline was rela-

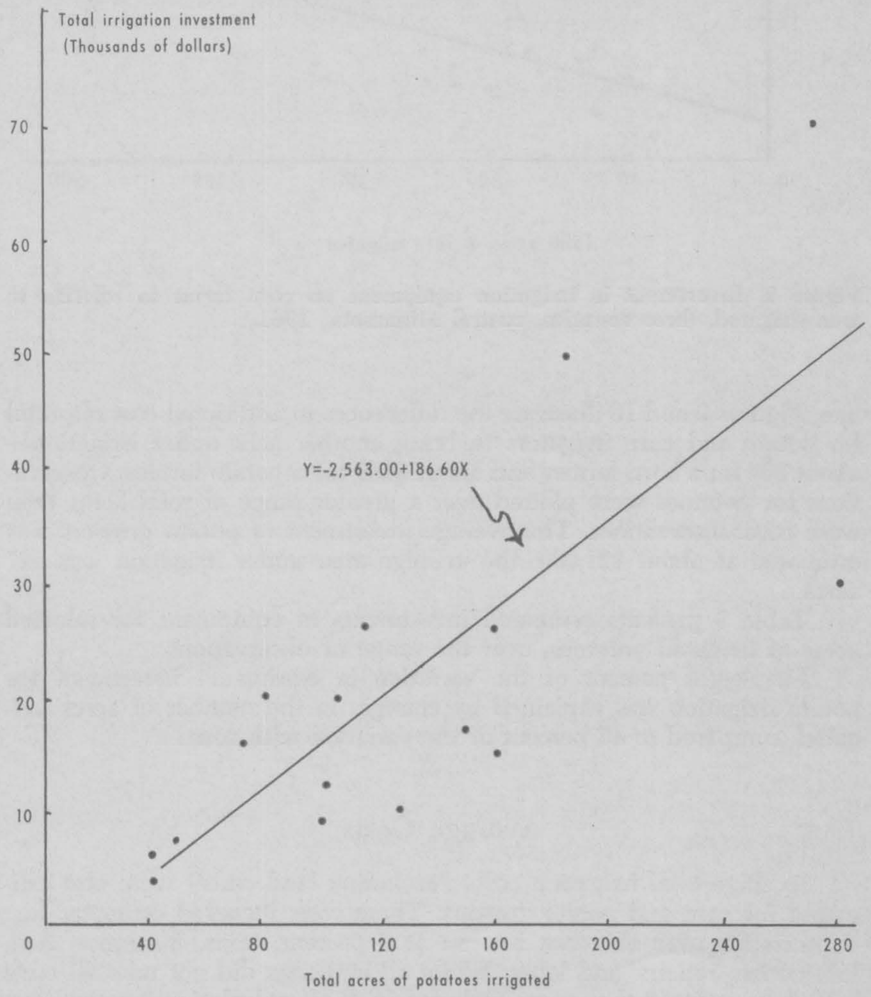

Figure 10. Investment in irrigation equipment on potato farms in relation to area irrigated, three counties, central Minnesota, 1961.

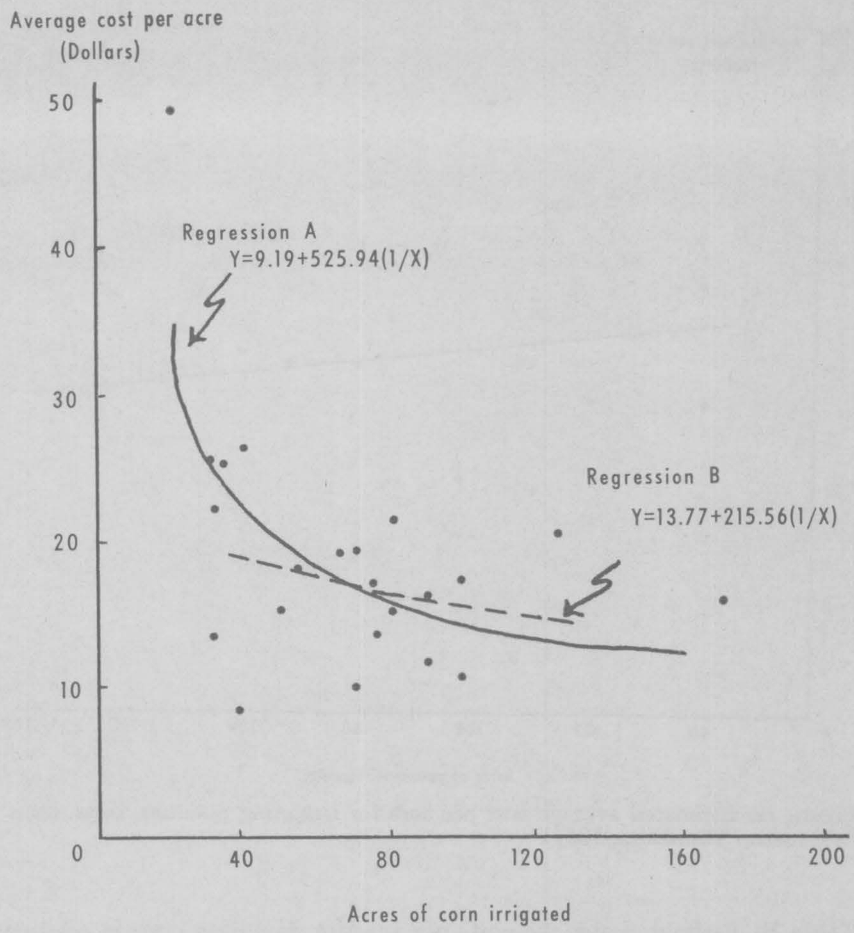

Figure 11. Estimated average cost per acre for irrigating corn, three counties, central Minnesota, 1961.

tively modest. Costs per acre for 40 irrigated acres of corn averaged only about 16 percent higher than costs per acre for 80 irrigated acres. Table 10 presents the estimated average total costs for corn irrigation at selected levels of operation.

Average total costs on potato farms were extremely variable; no significant relationships existed between costs per acre and acres irrigated. Figure 12 presents average cost data for potato growers and a simple regression line of estimation. Table 11 shows cost estimates at two extreme levels to illustrate the small change in cost per acre according to this regression line as the irrigated area is expanded.

But what caused this variation in the reported average costs of irrigating different acreages of potatoes? Closer examination of cost factors revealed three extremely variable components in total costs:

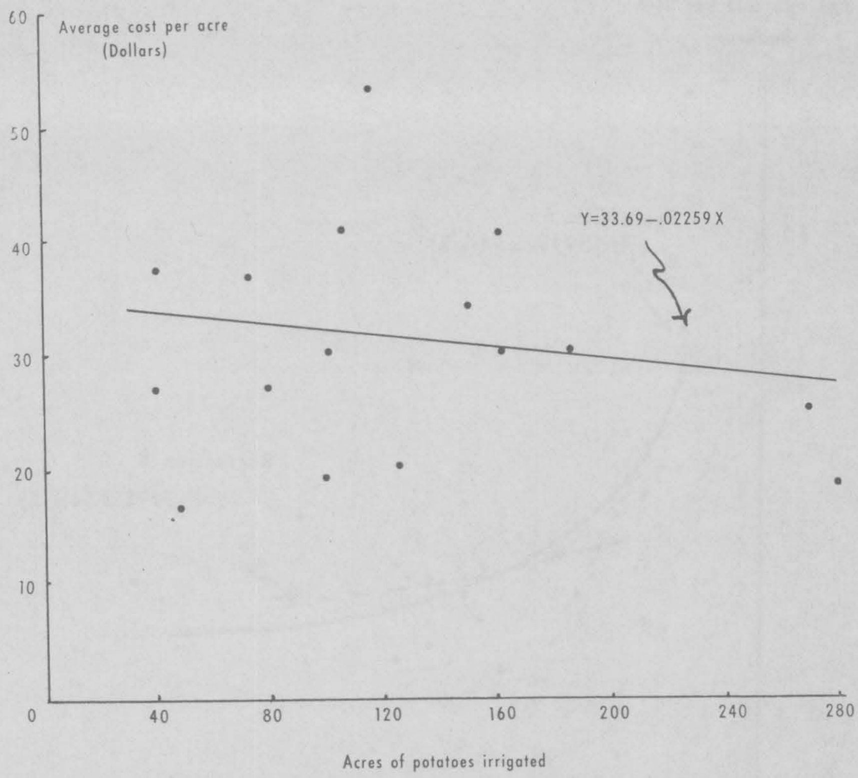

Figure 12. Estimated average cost per acre for irrigating potatoes, three counties, central Minnesota, 1961.

Table 10. Estimated average costs per acre for irrigating corn in relation to number of acres irrigated*

Acres irrigated	Estimated average costs per acre: All corn irrigators	Estimated average costs per acre: Excluding two most extreme observations
20	$35.49	....
40	22.34	$19.16
60	17.95	17.36
80	15.76	16.46
100	14.44	15.93
120	13.57	15.57
160	12.48	....

* Costs are estimated with the regression equation: $Y = 9.19 + 525.94 \left[\frac{1}{X}\right]$. The value for r^2 is 0.46; $N = 23$; and $\overline{Y} = 18.86$. Omitting the two extreme observations, the equation becomes $Y = 13.77 + 215.56 \left[\frac{1}{X}\right]$. The value for r^2 becomes 0.30; $N = 21$; and $\overline{Y} = 17.53$.

Table 11. Estimated average cost per acre for irrigating potatoes in relation to number of acres irrigated*

Acres irrigated	Estimated average cost per acre
40	$32.79
280	27.37

* Costs are estimated with the regression equation: $Y = 33.69 - 0.02259X$. The value for r^2 is 0.041; $N = 16$; $\overline{X} = 126.8$; and $\overline{Y} = 30.83$.

1. Both boom type and the smaller rotary type sprinklers were used so labor costs varied extremely, depending on the predominant type on the farm.

2. Two sources of water were commonly used, one a relatively cheap source and the other quite expensive. Where river water was extracted by centrifugal pumps, costs were far lower than for deep well water extracted by turbine pumps.

3. The size of the farm family obviously influenced the amount of money spent on hired labor. Although both family and outside labor were considered in calculating total costs, outside labor required to replace a family member was often higher cost labor than was necessary for the job.

Corn farmers were a more homogeneous group than were potato farmers. Generally, they used boom sprayers, relied on surface water sources or shallow wells, and incurred little if any outside labor cost. For these reasons, study data relating costs per acre to number of corn acres irrigated were comparatively reliable over the range from 40 to 100 irrigated acres; labor and water inputs of similar unit cost and quality were evaluated.

Data for potatoes should not be interpreted to mean that no decreases in costs per acre occurred as the number of irrigated acres increased. But costs per acre in potato irrigation were heavily affected by sprinkler type, water supply, and availability of family labor. These cost elements increased in significance for potato irrigation because of the greater investments required and higher rates of fertilizer and water use.

Returns

Yields estimated by the 40 irrigators for potatoes and corn produced under irrigation were well above 1961 state averages for these crops. One conclusion of this study is that irrigation and its allied cultural practices produces above-average crops on below-average farmland.

Returns from irrigation are most meaningful when compared with yields expected by these same farmers without irrigation. The average corn yield among irrigators was 78 bushels per acre; yields expected by these farmers on the same lands without irrigation averaged 31 bushels per acre.

For potato growers the average actual yield was 254 cwt. per acre with irrigation; the anticipated yield was 94 cwt. per acre without irrigation (see table 4). On the basis of these expectations, differences in returns with and without irrigation would more than cover irrigation costs.

Returns and costs under irrigation can be compared in terms of averages. For instance, the average potato grower received $190.40 more gross income per acre because he irrigated. This figure was determined by subtracting expected from actual yields and valuing the difference at the 1961 price of potatoes: (254-94) ($1.19) = $190.40. The average cost of water and its application per acre was $30.83; the average fertilizer investment was $52.26 per acre.

Some idea of the intensity of fertilizer use is provided by the fact that fertilizer investments in the Red River Valley for potatoes without irrigation are about $10 per acre. In terms of these averages, an $83.09 input in irrigation and fertilizer returned $190.40. This left $107.31 per acre to cover costs of additional seed, spraying, and family farm labor made necessary by irrigation.

Average returns from corn were also examined. At $1 per bushel the average corn irrigator raised his gross income by $47.10 per acre. Average fertilizer and irrigation costs were $35.82. So the average corn operator had $11.28 per acre to cover additional seed, labor, and other miscellaneous costs incurred because of irrigation.

Obviously, analysis based on averages cannot be applied to all farms. For example, it would be wrong to draw inferences from these cost and return data regarding profitability of supplemental irrigation on naturally productive soils. Nevertheless, irrigation apparently paid the 40 farmers interviewed, especially for potatoes. Additional benefits, such as the security of having a crop each year, are important but are less easily evaluated.

Returns from soybeans, oats, and alfalfa were not analyzed because adequate information was not available.

Some Impacts of Irrigation

Water Use and Water Law

In evaluating the significance of water use in irrigation, one comparison to make is with requirements for household consumption. Water requirements for an individual residential consumer were estimated by the Division of Waters, Minnesota Department of Conservation, to be 150 gallons per day or about 54,750 gallons per year.[7] Using these figures as a base, the average irrigator in central Minnesota in 1961 used enough water to supply 286 persons for a year. All 40 irrigators used enough water to supply the residential requirements for a community of 11,440.

Most of the annual precipitation that falls each year is a "flow" and not a "fund" type of resource. This statement emphasizes the managerial aspects of water since the extent to which water can be accumulated and stored is limited. Extremely small portions of the total water resources of Minnesota are used today. If the 3.5 million persons in Minnesota used 150 gallons of water per day, they would consume about 192 billion gallons per year. This quantity is large yet amounts to only ½ of 1 percent of total annual precipitation. The resource is great and supply problems are less a matter of scarcity than of proper storage and distribution.

Water use by irrigators, based on 1961 rates, also appears infinitesimal when compared to total supply. The average irrigator used about 15 million gallons in 1961; the largest single water user among the 40 studied consumed about 40 million gallons. If each farmer in Minnesota used an annual average of 15 million gallons of water for irrigation, it would amount to about 6 percent of the precipitation. If each of Minnesota's 145,000 farmers used 40 million gallons annually, they would consume less water than is lost from runoff each year.

These data illustrate the importance of distribution of water supplies. The above statements are valid for Minnesota as a whole, but they can be misleading if applied to areas within the state.

Potato growers indicated concern about the state regulation limiting their use of water to 6 inches per acre. As a group, their most pointed criticism rested on the fact that many other businesses and industries are exempt from control. They wondered why potato growers were singled out for regulation.

The information in this survey stresses the importance of the type of irrigation that may be expanded in the future. Potato irrigators used nearly 50 percent more water per acre in 1961 than did corn irrigators. In 1962, when rainfall was well distributed throughout the summer, potato growers continued to irrigate while about 50 percent of the corn growers did not irrigate at all. These two types of irrigators are distinctly different in the economic structure of their businesses and in the intensity and duration of their water demands.

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[7] *Hydrologic Atlas of Minnesota,* Division of Waters, Minn. Dept. of Conservation Bull. 10 Apr. 1959, p. 1.

Table 12. Land values per acre for irrigated farms, 1962, and for all farms, three counties, central Minnesota, 1959-61

County	Average sale price per acre, all farms, 1959-61*	Average estimated value per acre, irrigated farms, 1962†
	dollars per acre	
Sherburne	82	182
Stearns	124	116
Todd	89	86

* *The Minnesota Farm Real Estate Market in 1962*, Univ. of Minn. Dept. of Agr. Econ. Rept. 524, Feb. 1963, p. 29.
† Estimated by owners.

Water Use and Land Values

Nearly two-thirds of the irrigators felt that their land's value had increased because they irrigated. Soil types on these farms were of low productivity without irrigation. Prices reported for irrigated land were relatively high when compared to average prices in the same area. Irrigation farmers in the three counties estimated the average value of their land at about $158 per acre—$2 per acre above the state average in 1961.[8] Evidently, an adequate water supply, in proximity to a soil type that is responsive to additional fertilizer and irrigation, can significantly increase the value of relatively low quality farmland.

Irrigators did not indicate uniform land price increases in all three counties. Table 12 presents a comparison of irrigated land values in 1962, as estimated by owners, and average prices received in farmland sales in the three counties in 1959-61.

The extent that land values increased on irrigated farms was closely related to the irrigation of potatoes and to differences in soil quality. Sherburne County contained 15 of the 16 potato farmers in the study group. This county is characterized by the prevalence of large areas of light sandy soils. Corn farming predominated in Stearns and Todd Counties, and the effect of irrigation on land values was much less pronounced.

Public Interest in Irrigation

The extent of the public interest in water is relevant to this discussion. Individual states have the power, within constitutional limits, to govern the use of surface and ground water within their jurisdiction. Most states are involved in water-resource development, pollution control, regulation of municipal water supplies, control of ground water withdrawal, flood control measures, and drainage projects. In other words, the state holds in trust those rights in water shared by the general public. It is appropriate in this setting to ask whether irrigation is converting any public investment or public interest in water into private gain.

[8] *The Minnesota Farm Real Estate Market in 1961*, Univ. of Minn. Dept. of Agr. Econ. Rept. 521, Jan. 1962.

The appearance of comparatively high land values for poor land under irrigation might lead to the conclusion that some public interest is being "captured" by irrigators. In view of the investment, labor, and additional fertilizer necessary to complement the water supply in irrigation farming, this conclusion is difficult to evaluate. The portion of the total water supply consumed in this use is small. Withdrawal of water for irrigation to date has not been prominent where there have been major public water improvement projects. It is doubtful that any significant amount of public investment in water is being "captured" for private gain at the present scale of irrigation.

Principles of economic analysis argue that the allocation of water should be to its highest use—the use in which it earns the greatest marginal return. Industrial and municipal uses may yield greater returns from water, but this has not been clearly demonstrated in all areas. Water conveyance costs from some areas may be greater than returns from water in nonfarm uses. Where this is the case, the water available on many farms may be put to its best use, in terms of realistic alternatives, when pumped for irrigation.

These questions of water use and public interests in water are extremely complex. Further studies into the economic issues involved and the policies that should be established are needed.

Study Conclusions and Resource Mobility

The subject of both human and capital resource mobility on farms is also importantly connected with irrigation and agricultural policy today. Recent shifts in the agricultural labor force have been great and further changes are expected.

In any evaluation of irrigation or other resource development programs, one major policy issue concerns the effect on resource mobility. Do managers gain greater flexibility in their farm operations? Or, are their choices limited to fewer alternatives? These are pertinent questions in view of the large investments in durable capital equipment required for successful irrigation farming.

In terms of their ability to shift from one crop to another, 65 percent of the respondents thought irrigation had not altered their flexibility or limited their alternatives. Thirty-five percent of all respondents felt irrigation made their crop alternatives more limited. Reasons for these replies were not associated with any particular type of farming. The most frequently mentioned reason for believing that crop alternatives were more limited was that specialization in one crop was necessary in order to increase scale of operations and reduce costs.

Almost three-fourths of the irrigators (72 percent) felt that they were more committed to farming because they had invested in irrigation equipment. Investment size was the most frequently given reason for this reply. Others felt more committed because they had acquired added security in their expectation of a crop each year.

The typical irrigator had farmed most of his life and intended to continue. Where corn growers gave drought avoidance as the major motivation for beginning irrigation, it suggests strongly that the investment was made in order to remain in farming. This reasoning was typical of corn farmers but not of potato growers.

This analysis supports the conclusion that irrigation decreased resource mobility in agriculture on the 40 farms studied. The increased investment in equipment and the relatively high ratios of fixed costs to variable costs give weight to this conclusion, especially for corn farmers. For example, in northern Todd County—an extremely sandy area— irrigators admitted that they could not be sure of an adequate feed supply for their milk cows without irrigation. Many neighboring farms were in the soil bank.

Although capital investments were larger on potato farms and variable costs were higher, there was less evidence that these operators had undertaken irrigation in order to stay in farming. For them, irrigation of potatoes involved a highly specialized cash crop operation unrelated to any livestock enterprises. Potato production is sharply different from the conventional combination of grains, hay, and dairying that characterized past agriculture of the study area. Irrigation enabled corn farmers to intensify and stabilize an established pattern of technology and land use. But for potato farmers, irrigation required mastery of a new technology.

Supplemental irrigation in the three counties studied held some marginal or near marginal land areas in agricultural production. For corn growers, the motivation centered on greater stability. For potato producers, the search for greater profits was a primary goal.

Any future expansion of irrigation by potato growers probably will be governed by straightforward considerations of costs, returns, and profits. Projections of future rates of expansion in irrigated corn production involve more complex considerations.

Returns per acre from irrigated corn were modest, as reflected in the comparatively small increases in estimated land values in areas where irrigated corn predominated. These data suggest that expansion of the practice of irrigating corn may depend less on prospects of high profit and more on the search for stability.

It is consistent with this hypothesis to expect the future expansion of supplemental irrigation in Minnesota to take place primarily on lighter soils in marginal farming areas where drought is a constant hazard. Soils and water supplies permitting, it would also be consistent with the analysis presented to expect the expansion of supplemental irrigation of corn, even if profit margins in corn production declined. In that situation, the significance of stability in yield expectations would grow in importance.

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