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Irrigation

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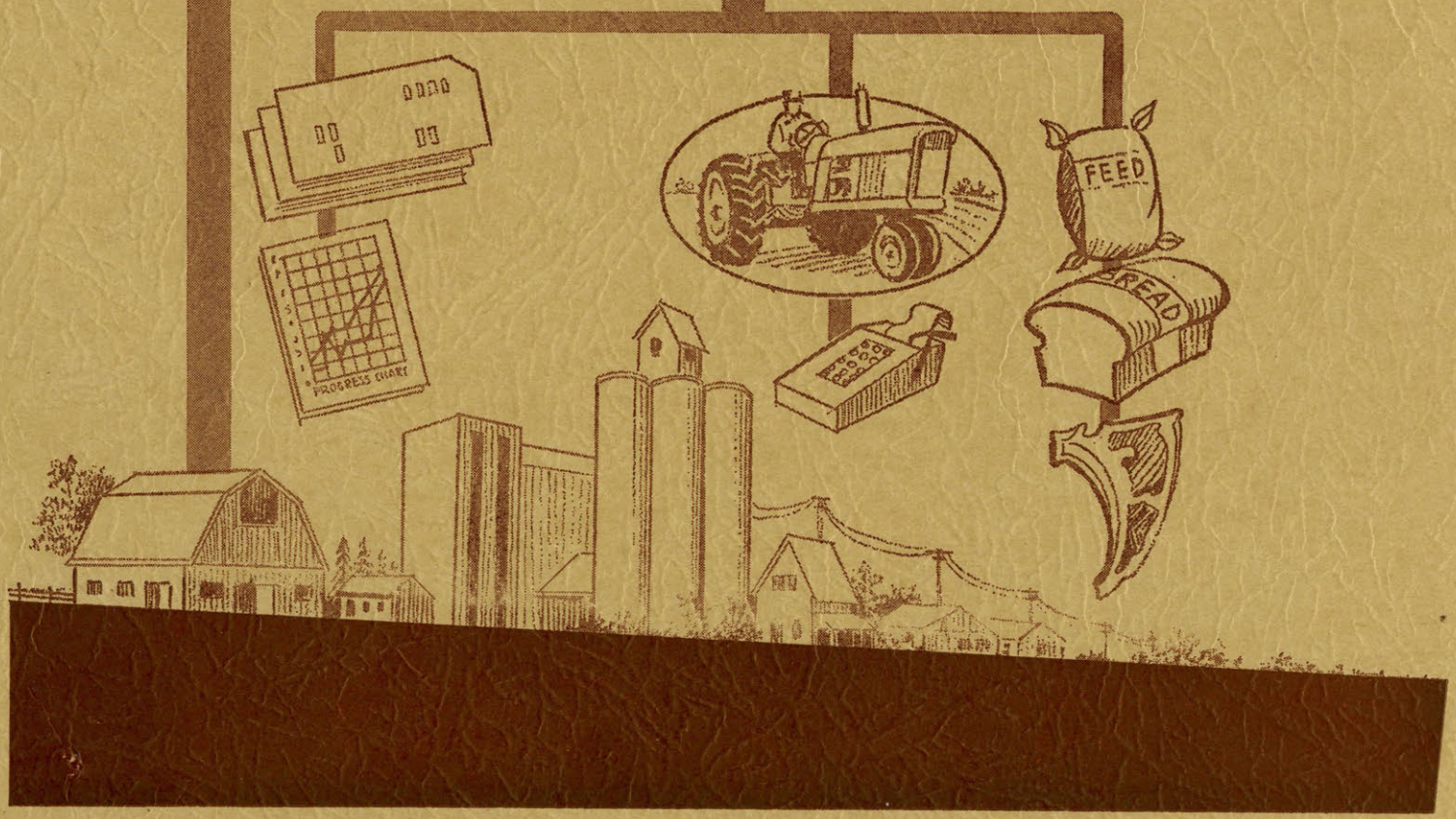
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THE IMPACT OF CENTER PIVOT
IRRIGATION IN SOUTHWEST NEBRASKA

By

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THE IMPACT OF CENTER PIVOT IRRIGATION IN SOUTHWEST NEBRASKA

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I. The Development of Center Pivot Irrigation

The development of center-pivot, self-propelled irrigation systems has made it possible to irrigate hundreds of thousands of acres of land of uneven topography and sandy or sandy loam soils previously considered unsuited to irrigation. The term center pivot irrigation refers to that type of irrigation system in which one end of the pipe is attached to a swivel connection at the center of the field and the pipe, mounted on wheels or skids, is propelled around this pivot point like a giant clock hand. Most systems utilize overhead revolving sprinkler heads which are placed along the length of sprinkler pipe and either the size of the sprinkler head orifices is varied or the spacing between sprinklers is varied to compensate for the difference in the speed of travel over the surface from one end of the pipe to the other so as to obtain a sufficiently uniform distribution of water.

The first center pivot irrigation system was developed by Mr. Frank Zybach, a farmer near Strasburg, Colorado. He applied for a patent on his irrigation system June 27, 1949 and the patent was granted July 22, 1952. Later in 1952 he joined with Mr. A. E. Trowbridge from Columbus, Nebraska who helped redesign the system so it could be utilized to irrigate taller-growing crops such as corn, since Mr. Zybach's first prototype system was built with the pipeline suspended only 2-3 feet above the ground. In September, 1954, Mr. Zybach and Mr. Trowbridge sold the manufacturing rights under a royalty agreement for the manufacture and sale of center pivot irrigation systems to Valley Manufacturing Company (now Valmont Industries, Inc.) at Valley, Nebraska.¹

¹Valmont Industries, Inc., Valley, Nebraska, Unpublished paper titled "The History of the Valley Self Propelled Irrigation System", January, 1970.

While Valmont Industries is the oldest and largest manufacturer of center pivot irrigation systems, a recent survey indicated there are at least 25 firms engaged in the making and selling of these type systems in the United States. These different makes of systems utilize various means of propelling the system around the circle; including (1) water which is exhausted through hydraulic cylinders; (2) electric motors at each tower; (3) oil hydraulic drive units at each tower; and (4) compressed air drive units at each tower. Valmont Industries, Inc. now has three different sprinkler systems on the market, the standard water-driven unit, an oil hydraulic-driven unit; and an electric motor-driven unit which uses a truss support instead of towers and suspension cables. Some of the other manufacturers of center pivot systems also offer a choice of method of propulsion to meet the needs or preferences of the buyers. For most systems, the water pressures required varies from 55 to 90 psi at the pivot point depending upon the system's design and length and the method of propulsion used.

Like many new technological developments, these new center-pivot, self-propelled irrigation systems were not accepted overnight by irrigation farmers or the professional and financial institutions connected with the irrigation industry. After a few years of product development and refinement by the manufacturer, in the mid-1950's a few foresighted individuals installed some of the systems on low cost land (\$40-50 per acre) in Holt County, Nebraska on sandy loam soils with a shallow soil profile and highly permeable subsoil. By all the traditional and then accepted rules of irrigation, these type soils were classified as non-irrigable because of their porosity and low water holding capacity.

However, unlike gravity type irrigation which requires a heavier application of water, generally 2-4 inches at a time, applied usually from two to four times during the growing season; the center pivot system can be set to apply from less than .3 inch to over 2 inches per application and with the labor input minimized,

a system can make 15-20 or more revolutions during the irrigation season. Thus, the center pivot system can apply water as the crop needs it without the necessity of ditching or furrows or borders commonly used for gravity irrigation which relies on the filling of the soil profile (preferably of the silt or clay loam types) to its moisture holding capacity which in turn provides water for the crop until the next irrigation or rainfall.

Among the first to demonstrate the economic feasibility of these new systems on sandy shallow profile soils were Mr. A. E. Trowbridge (associated with Mr. Zybach in the early stages of development of center pivot systems) and Mr. William Curry both from Columbus, Nebraska. Their partnership development of center pivot irrigation systems in Holt County proved that it was possible to convert low livestock carrying capacity grassland to highly productive irrigated cropland with resulting yields of corn in the 125-150 bushels per acre range. Their success, coupled with similar experiences by other early users of these systems, paved the way for rapid irrigation expansion in the 1960's using center pivot irrigation systems.²

II. Survey of Center Pivot Irrigation in Southwest Nebraska

A. Survey Procedures

The spread of center pivot irrigation systems to other areas of Nebraska and to many other states and even foreign countries which occurred in the 1960's aroused increasing interest in this new concept of irrigation. The general trend prevalent in all of agriculture whereby farmers have continued to mechanize their farming operations as labor costs increased, and available labor continued to decline, was a key factor in wider acceptance of the new method of irrigation.

The author had observed the rapid increase in this type of irrigation development which occurred in the late 1960's in Southwest Nebraska. This observation and

²Based on telephone conversations with Neil Dawes, former County Extension Agent in Holt County and John Burbank, Holt County Extension Agent. July, 1970.

interest lead to a 3-month survey conducted by the author from October 1 through December 31, 1969 in a 9-county area which included Lincoln, Keith, Perkins, Chase, Dundy, Hayes, Hitchcock, Red Willow and Frontier Counties. During that time, the author, with the assistance of county extension agents and Soil and Water Conservation District personnel in the area, contacted the owners and/or operators of every center pivot irrigation system in these nine counties.

Information obtained in the survey included: the number and location of each system; the date of installation; make of the system; acres covered; crops produced including yields for the years 1967, 1968 and 1969 along with crop plans for 1970; information about the owner or operator's size and type of farming or ranching enterprise, including years of farming and irrigation experience; irrigation well and motor data; and data on other types of irrigation being used by center pivot system operators. The survey form developed for this survey contained 93 data collection blanks to help pinpoint as accurately as possible how these center pivot systems are being utilized.

The data obtained from the survey was processed by computer to enable the author to retrieve various combinations of data and specific information for the individual counties as well as for the 9-county area surveyed.

B. Survey Results Revealed 190 Operators With 349 Center Pivot Systems

It was found that, including center pivot systems installed late in 1969 for use in 1970 or systems definitely committed for installation and use in 1970, there were 190 different operators of 349 center pivot irrigation systems in the 9-county area. Chase County with 72 operators and 156 systems accounted for 44.7% of all center pivot systems in the 9-county area. Perkins County with 40 operators and 72 systems accounted for another 20.6% of the total systems while Dundy County with 31 operators and 53 systems accounted for 15.2% of the total center pivot system. Keith County had 19 operators with 27 systems or 7.7%; Lincoln County

had 15 operators and 19 systems or 5.4%; Hayes County had 8 operators and 14 systems or 4.0% of the total systems in the area. Hitchcock County with 4 operators using 4 systems had 1.2% of the total and Red Willow County with 2 operators and 4 systems made up the remaining 1.2% of the systems in the area. Only one county out of the nine counties surveyed, Frontier County, had no center pivot irrigation systems installed or definitely planned for installation at the time of the survey.

C. Investment Costs for Center Pivot Irrigation

While the cost of center pivot installations varies depending upon such factors as: (1) depth and size of irrigation well and pump; (2) size and type of motor; and (3) length and type center pivot system used; a fairly standard rule of thumb is \$10,000 for installation of the well, pump and motor and from \$15,000 to \$20,000 for a quarter-section size center pivot irrigation system, depending upon type of propulsion, optional features such as end gun, type of controls, etc. The 160-acre size system will irrigate approximately 130-135 acres since there are normally 25-30 acres in the four corners which are not irrigated by the system while it revolves. Using an average figure of \$25,000 per center pivot installation (not including the land cost), the 349 systems in the 9-county area represent an investment of \$8,725,000. Using the \$30,000 per installation as an average, the total added investment due to irrigation development by center pivot would be \$10,470,000. It probably would be safe to assume that the total added investment resulting from center pivot irrigation development in the 9-county area of Southwest Nebraska as of December 31, 1969 would be in the \$9-10 million range.

D. First Center Pivot System in Area Installed in 1953 -- Growth Rapid in Late 1960's

It is interesting to note that the survey revealed that there were only 14 systems in use in 1965 in the 9-county area. Two of these systems were among the first systems sold by Valley Mfg. Company; the second unit built by them was a small size unit installed in April, 1953 by Vic Kiolbasa west of Grant; and another

small size unit installed in 1954 on a farm owned by Rector Searle west of Ogallala. The rapid growth of center pivot irrigation in the 9-county area in the late 1960's is revealed in Table 1.

TABLE 1. Growth In Center Pivot Irrigation In 9-County Area of Southwest Nebraska

Year of Installation or First Year of Use*	Center Pivot Irrigation Systems	
	No.	%
1965 & before	14	4.0
1966	15	4.3
1967	42	12.0
1968	90	25.8
1969	135	38.7
1970**	53	15.2
TOTALS	349	100.0

* Systems installed after October 1 are included with following year's data since in most cases little irrigation occurs after that date.

**Includes only those systems already installed at the time of the survey or definitely planned for installation in 1970. (Survey dates: Oct. 1-Dec. 31, 1969)

As can be noted from the above table, nearly 80% of the total center pivot systems in the 9-county area were installed in the last two years included in the survey.

Table 1-A shows the number of center pivot systems by counties by years of installation in the 9-county area surveyed.

E. Number of Center Pivot Systems Per County and Acres Irrigated

Table 2 shows the number of systems per county and the acres irrigated by center pivot, average acres per system and the per cent of total irrigated acreage in each county and for the 9-county area which is irrigated by center pivot systems. The 349 center pivot systems found in the survey cover 46,141 acres plus the 3,965 acres covered on 2nd and 3rd pivot points (one system towed to different fields) or a total of 50,106 acres. The average center pivot system in the 9-county area covers 132.2 acres and 13.0% of the 385,600 acres under irrigation in the 9-county area (Nebraska 1969 Preliminary County Estimates issued by State-Federal Division of Agricultural Statistics) is irrigated by center pivot systems. For individual

TABLE 1-A

SURVEY OF CENTER PIVOT SELF PROPELLED IRRIGATION SYSTEMS IN SOUTHWEST NEBRASKA
 Nine County Area by Year of Installation of First Use
 Based on a Survey Conducted by Leslie F. Sheffield, Supt.
 University of Nebraska North Platte Station
 October 1 -- December 31, 1969

Year of Installation*	Chase		Perkins		Dundy		Keith		Lincoln		Hayes		Hitchcock		Red Willow		Frontier		TOTALS	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1965 and before	3	1.9	4	5.5	1	1.9	5	18.5	0	0	1	7.1	0	0	0	0	0	0	14	4.0
1966	7	4.5	2	2.8	4	7.5	2	7.4	0	0	0	0	0	0	0	0	0	0	15	4.3
1967	19	12.2	15	20.8	6	11.3	1	3.7	1	5.2	0	0	0	0	0	0	0	0	42	12.0
1968	44	28.2	21	29.2	11	20.8	3	11.1	5	26.3	3	21.5	1	25.0	2	50.0	0	0	90	25.8
1969	54	34.6	20	27.8	29	54.7	14	51.9	9	47.4	5	35.7	3	75.0	1	25.0	0	0	135	38.7
1970	29	18.6	10	13.9	2	3.3	2	7.4	4	21.1	5	35.7	0	0	1	25.0	0	0	53	15.2
TOTALS	156	100.0	72	100.0	53	100.0	27	100.0	19	100.0	14	100.0	4	100.0	4	100.0	0	0	349	100.0
% of systems in 9-county area		44.7		20.6		15.2		7.7		5.4		4.0		1.2		1.2		0		100.0

*Systems installed after October 1 are included in data for following year since irrigation season is normally concluded by that date.

counties, the range in the percentage of total irrigated acreage in 1969 irrigated by center pivot systems is from a low of 0.9% for Red Willow County to a high of 54.4% for Perkins County.³

TABLE 2: Center Pivot Systems: Number of Systems, Acres Irrigated, and Percent of Total Irrigated Acreage by Counties and for Area, Southwest Nebraska. (Based on Survey Conducted October 1 to December 31, 1969)

County	No. of Systems	A. Irr. by 1st Pivot*	A. Irr. by 2nd & 3rd Pivots	Total A. Irr. by Pivot Systems	Total Irr. Acres	% Irr. by CP
Chase	156	20,541	(10) 1,270	21,811	64,700	33.7
Perkins	72	9,776	(7) 878	10,654	19,600	54.4
Dundy	53	7,195	(1) 130	7,325	27,400	26.7
Keith	27	3,633	(8) 860	4,493	50,100	9.0
Lincoln	19	2,313	(7) 461	2,774	96,000	2.9
Hayes	14	1,729	(3) 366	2,095	14,100	14.9
Hitchcock	4	504	----	504	40,300	1.2
Red Willow	4	450	----	450	49,400	0.9
Frontier	0	0	0	0	24,000	0.0
TOTALS	349	46,141	(36) 3,965	50,106	385,600	13.0

*The average acreage irrigated on the first pivot point by the 349 center pivot systems in the 9-county area is 132.2 acres.

F. Number of Center Pivot Systems Per Operator -- 90% have 1-3 systems

An important aspect of the impact of center pivot irrigation systems is the great reduction in labor required as compared with other types of sprinkler irrigation or gravity irrigation. This reduced labor requirement has resulted in the development of multiple installations of center pivot systems for a single owner or operator. Paul Fischbach, Extension Irrigation Engineer at the University of Nebraska, estimates that one man can successfully operate and service up to six center pivot systems during the irrigation season. Using this figure, one man operating six standard quarter section center pivot systems, each covering 135 acres, could irrigate a total of 810 acres of land during the irrigation season. For comparison with the traditional methods of gravity irrigation, Mr. Fischbach estimates that one man using siphon tubes and open ditch can irrigate 200 acres in a season, while

³State-Federal Division of Agricultural Statistics, Nebraska 1969 Preliminary County Estimates and State Agricultural Data, April, 1970.

with properly leveled land and length of run using gated pipe one man can irrigate up to 400 acres in a season.

One important finding in the survey concerned the number of center pivot systems per operator in the 9-county area. Table 3 shows that 62% of the operators in the 9-county area have one center pivot system while another 20% of the operators have two center pivot systems and 8% of the operators have three center pivot systems. Thus 90% of the center pivot operators at the time of the survey were operating or managing from 1-3 center pivot systems. The remaining 10% of the operators are operating or managing from 4-13 center pivot systems although those in this category are generally utilizing additional labor to look after the systems and maintain them. One operator in the area surveyed has 11 center pivot systems under single ownership while another operator has 13 center pivot systems under the same ownership and management.

G. Makes of Center Pivot Systems in Southwest Nebraska

Since the Valley Self-Propelled irrigation system was the first center pivot system marketed, as might be expected they have the largest share of the market in the area surveyed, accounting for 150 of the 349 systems or 43.0% of the total. There were 91 Higromatic systems accounting for 26.1% of the total. Next in order among those with 10 or more center pivot systems in the area surveyed were: BJM Crop Wheels with 22 or 6.3% of the total; Gifford-Hill-Western pivot systems with 18 or 5.1%; Olson Oil Hydraulic systems with 17 or 4.8% of the total; and Walking 7 pivot systems with 13 or 3.7% of the total. There were 13 different makes of center pivot systems in the 9-county area at the time of the survey. One mechanically adept young farmer in Perkins County, with the help of his landlord, built their own center pivot system with parts obtained from various sources. During its first year of operation in 1969 on a sandy loam soil, the 128 acres irrigated by the system yielded an average of 185 bushels of corn (corrected to 15.5% moisture).

Table 3: Number of Center Pivot Irrigation Systems per operator in 9-county area Southwest Nebraska based on survey conducted October 1-December 31, 1969.

No. of Systems per Operator	No. of Operators : No.	% :	No. of Pivot Systems in each Size Group : No.	% :
1	118	62.1	118	33.8
2	37	19.5	74	21.2
3	16	8.4	48	13.8
4	7	3.7	28	8.0
5	6	3.2	30	8.6
6	2	1.1	12	3.4
7	1	0.5	7	2.0
8	1	0.5	8	2.3
9	0	0.0	0	0.0
10	0	0.0	0	0.0
11	1	0.5	11	3.2
12	0	0.0	0	0.0
13	1	0.5	13	3.7
Totals	190	100.0	349	100.0

Table 4: Makes of Center Pivot Irrigation Systems in 9-county area of Southwest Nebraska, based on survey conducted October 1-December 31, 1969.

Make of Pivot System	No. Systems	% of the Total
1. Valley	150	43.0
2. Higromatic	91	26.1
3. BJM Crop Wheel	22	6.3
4. Gifford-Hill-Western	18	5.1
5. Olson	17	4.8
6. Walking 7#	13	3.7
7. Dowd (Now Farmhand)	8	2.3
8. Raincat	7	2.0
9. Rotosquirt	7	2.0
10. Kroy	2	0.6
11. Hydrocycle	1	0.3
12. Central Pivot*	1	0.3
13. Oasis*	1	0.3
14. Own (Home-made system)	1	0.3
15. Undecided (1970 installations)**	10	2.9
Totals	349	100.0

*Manufacturer has discontinued manufacture of center pivot systems.

**Owner had made definite plans to install center pivot system but had not decided upon the make of system to install at the time of the survey.

#Company making this system was purchased by Valmont Industries in February, 1970

One variety of corn grown under the system (there were more than one variety) averaged 205 bushels per acre on a 15.5% moisture basis.

Table 4 gives the data on makes of center pivot irrigation systems found in the survey in Southwest Nebraska.

H. Classification of Center Pivot System Operators with Respect to Land Ownership

One of the factors determined during the survey was the classification of the operators of center pivot systems with respect to the ownership of the land being irrigated by center pivot systems. For the 9-county area, the results showed that 73.3% of the land units (including 2nd and 3rd pivot points for a single pivot system) being irrigated by center pivot systems was owned by the operator. Only 15.6% of the total land units irrigated by center pivot were being rented by the operator. In 7.0% of the cases the operator was either a son or son-in-law of the land owner. A total of 1.3% of the land units were owned by either a brother or brother-in-law. A total of 5 of the land units (1.3%) irrigated by pivot systems were either all or partially leased by the owners to another operator, primarily for sugar beet production.

With the rapid growth and interest in center pivot irrigation systems, it was interesting to note that three center pivot systems covering five pivot points which were not operated in 1969, had not been operated during the past six years. Two different owner-operators were involved and in one case the land under the system was in the soilbank, while in the other case the operator said five years of records on adjacent pieces of land of the same soil type, one irrigated by two center pivot systems each towed to two pivot points, and the other land non-irrigated and cropped alternately to wheat and summer fallow for a 5-year period 1958-63 had convinced him he couldn't afford to operate his two pivot systems. It should be noted, however, that since 1963 the price of wheat has declined considerably in relation to the prices of other crops which respond best to irrigation.

In spite of the decline in wheat prices, this particular operator has left his two systems unoperated for the past six years and has produced wheat every other year with alternate summer fallow on this land.

Table 5 gives the data obtained on classification of operators of center pivot systems with respect to land ownership.

TABLE 5: Classification of operators of Center Pivot Systems with respect to Land Ownership in the 9-county area of Southwest Nebraska, Dec., 1969.

Operator Classification	Center Pivot Land Units*	
	No.	%
Land owned by the operator	282	73.3
Land rented by the operator	60	15.6
Operator is son or son-in-law of owner:	27	7.0
Operator is brother or brother-in-law :	5	1.3
Operator is father of land owner	1	0.2
All or Part of System Leased in 1969	5	1.3
Systems not operated in 1969	5	1.3
TOTALS	385	100.0

*Includes 2nd and 3rd Pivots irrigated by one center pivot system

I. Farming and Irrigation Experience of Center Pivot Operators

As can be seen from Table 6 over half (54.0%) of the operators of center pivot systems in the area surveyed had 21 or more years of farming experience at the time the survey was made. When the next highest category of those operators with 11-20 years of farming experience (32.4%), is included with the more experienced group, these two categories account for 86% of the operators of center pivot systems. However, irrigation development on a large scale outside of the valley areas in southwest Nebraska is a relatively recent phenomenon. The results from the data on years of irrigation experience of center pivot operators shows that 32.8% had less than 3 years of irrigation experience and another 15.7% had from 4-6 years of irrigation experience at the time of the survey. Consequently only slightly less than half of the operators (47.7%) had from 1-6 years of irrigation experience. Another 12% had from 7-10 years experience, but 35% of those with

center pivot systems had been irrigating for 11-20 years. Only 5% of the operators in the survey had 21 or more years of irrigation experience.

TABLE 6: Farming & Irrigation Experience of Operators of Center Pivot Systems in 9-county area of Southwest Nebraska, October 1-December 31, 1969.

Farming Experience			:	Irrigation Experience		
Years	No.	%	:	Years	No.	%
1-3	5	2.8	:	1-3	55	32.0
4-6	6	3.4	:	4-6	27	15.7
7-10	13	7.4	:	7-10	20	11.6
11-20	57	32.4	:	11-20	61	35.5
21 or more	95	54.0	:	21 or more	9	5.2
TOTALS	176	100.0	:	TOTALS	172	100.0

J. Crops Produced Under Center Pivot Irrigation in Southwest Nebraska

Data obtained from the survey on 1969 crop production under center pivot systems revealed that corn is by far the leading crop accounting for 57.8% of the total acreage grown under 202 systems or partial systems in cases where more than one crop is grown. The total acreage of corn grown under center pivot systems in the 9-county area in 1969 was 23,541 acres. Interest in irrigated pastures has been increasing rapidly in recent years and the survey disclosed that irrigated pastures was the number two crop under center pivot systems with 12.5% of the total acreage or 5,080 acres seeded under 42 systems or partial systems. Those operators contacted during the survey indicated that in 1970 they planned to seed irrigated pasture under an additional 39 complete or partial systems totaling an additional 4,597 acres. Thus, it appears that by the fall of 1970 there could be as much as 10,000 acres seeded to irrigated pasture under center pivot systems in Southwest Nebraska. The third-ranking crop under center pivot systems was alfalfa with 11.2% of the total acreage of 4,536 acres grown under 51 systems or partial systems. Fourth-ranked in terms of total acreage under center pivot systems in 1969 was sugar beets accounting for 4.9% of the total or 2,000 acres grown under 19 systems or partial systems. Surprisingly, native grass ranked 5th under center pivot irrigation

with 2.4% of the total acreage or 967 acres. However, in some cases this was only a temporary crop with some operators planning to interseed either cool season grasses or planning eventually to tear up the old native sod and seed with an irrigated pasture mixture.

Data on other crops produced under center pivot irrigation in 1969 in Southwest Nebraska is given in Table 7.

TABLE 7: 1969 Crops Produced under Center Pivot Systems in 9-county Area, Southwest Nebraska, based on Survey Data obtained Oct. 1-Dec. 31, 1969.
(In some cases more than one crop is grown under center pivot, in which cases the crop with the most acres is Crop 1; crop with second highest acreage is Crop 2; and third highest acreage crop is Crop 3 in the following table)

Crop	: Crop 1*		: Crop 2**		: Crop 3***		: Crop 1-3 Totals	
	:No.	Acres	:No.	Acres	:No.	Acres	Acres	%
1. Corn	:199	23,421	: 3		120: 0	0	:202 23,541	57.8
2. Irrigated Pasture	32	4,489	: 9		541: 1	50	: 42 5,080	12.5
3. Alfalfa	: 37	4,021	:11		423: 3	92	: 51 4,536	11.2
4. Sugar Beets	: 11	1,539	: 7		441: 1	20	: 19 2,000	4.9
5. Native Grass	: 7	877	: 2		65: 1	25	: 10 967	2.4
6. Oats	: 8	747	: 2		105: 1	33	: 11 885	2.2
7. Dry Beans	: 4	400	: 7		373: 1	27	: 12 800	2.0
8. Wheat	: 5	507	: 6		251: 1	25	: 12 783	1.9
9. Sudan or Sudex	: 4	457	: 3		133: 0	0	: 7 590	1.4
10. Cane	: 2	170	: 9		402: 1	12	: 12 584	1.4
11. Milo	:	:	:		:	:	:	
(Grain Sorghum)	: 5	370	: 1		25: 2	52	: 8 447	1.1
12. Millet	: 1	33	: 5		229: 2	41	: 8 303	0.7
13. Rye	: 1	105	: 0		0: 1	24	: 2 129	0.3
14. Summer Fallow	: 0	0	: 1		23: 2	44	: 3 67	0.2
TOTALS****	316	37,136	66		3,131:17	445	:399 40,712	100.0

*A total of 252 center pivot land units produced only one crop under the entire system

**A total of 51 center pivot land units were used to produce two crops under the system

***A total of 17 center pivot land units were used to produce three crops with 3 of these used to produce 4 crops under the system.

****Figures shown under totals include number of land units and acres irrigated on 2nd and 3rd pivot points by a single system.

Data on crop yields was obtained from center pivot operators wherever this information was available, but since some fields either were not yet harvested or in the process of being harvested when the survey was made in the fall of 1969,

the yield data for 1969 under center pivot systems is incomplete. However, in those cases where operators had picked some or all of their corn and calculated or estimated their yields, this data was obtained. The weighted average yield of corn on a No. 2 yellow corn basis (15.5% moisture) under center pivot irrigation in 1969 based on this data was 114 bushels per acre. The yield data for those center pivot operators who produced corn in 1968 under center pivot systems resulted in a weighted average yield of 105 bushels per acre. Similar data for 1967 showed an average yield of 100 bushels per acre for those who operated center pivot systems that year. Table 8 shows the number of systems producing corn, the total acreage, the yield and total production of corn under center pivot irrigation in Southwest Nebraska for the years 1967-1969.

TABLE 8: Number of Center Pivot Land Units used to produce corn, total acreage, average yield per acre and total production of corn in 9-county area in Southwest Nebraska for the years 1967, 1968 and 1969.

Year	: *No. System Land Units	: Total Acres	: Ave. Yield	: Total Production
1967	: 56	: 6,577	: 100 bu/A:	658,325 bu.
1968	: 115	: 14,001	: 105 bu/A:	1,469,394 bu.
1969	: 202	: 23,541	: 114 bu/A:	2,675,551 bu.

*Includes 2nd and 3rd pivot points where one system is used to irrigate more than one unit of land.

The above table demonstrates vividly the tremendous impact of center-pivot irrigation on the productivity of land which previous to development for irrigation was, for the most part, either planted to wheat with alternate years of summer fallow or in native grass sod with a very low livestock carrying capacity. If irrigation development utilizing center pivot type systems continues at a similar pace in the next decade, it is apparent that the agricultural production and level of economic activity which have been prevalent in Southwest Nebraska for the past 30-40 years will be changed drastically.

K. Irrigation Well Data in the 9-county Area

Data obtained in the survey showed a total of 326 irrigation wells were used to provide water for the 349 center pivot systems in the 9-county area of Southwest Nebraska. In 23 cases, one irrigation well was used to supply water for two center pivot systems by piping the water to the two pivot points. The average depth of the 326 irrigation wells was 291 feet, with the static water level averaging 78 feet. The average lift for the water from the 326 wells was 108 feet and the average gallons per minute being pumped through the 349 center pivot systems was 936 g.p.m.

Table 9 shows the data on irrigation wells for the 9 counties and the area obtained from the survey.

TABLE 9: Irrigation Well Data Obtained in Survey of Center Pivot Irrigation Systems in 9-county Area, Southwest Nebraska (Oct. 1 - Dec. 31, 1969)

	: No. : :Wells:	: Depth : ft. :	: Static : Water :	: Water : Lift :	: System Gallonage in g.p.m.
Chase	: 146 :	: 292 :	: 55 :	: 76 :	971
Perkins	: 62 :	: 369 :	: 127 :	: 154 :	956
Dundy	: 52 :	: 230 :	: 41 :	: 72 :	933
Keith	: 26 :	: 241 :	: 100 :	: 152 :	854
Lincoln	: 20 :	: 235 :	: 78 :	: 111 :	877
Hayes	: 13 :	: 367 :	: 171 :	: 222 :	877
Hitchcock	: 4 :	: 279 :	: 186 :	: 250 :	775
Red Willow	: 3 :	: 12 :	: 121 :	: 101 :	200
TOTALS (or Averages)	: 326 :	: 291 :	: 78 :	: 108 :	936

L. Types of Irrigation Motors Found in the Survey

Data obtained on the types of motors used on irrigation wells for center pivot systems in the 9-county area survey revealed that electric motors are the dominant type accounting for 55% or 174 out of the 318 for which data was available. Engines using natural gas were the second most popular type motor for irrigation wells in Southwest Nebraska accounting for 30% of the total or 97 out of 318. There were 8% in the category of motors using propane fuel while diesel engines made up 7% of the total.

TABLE 10: Type of Power Unit Used for Center Pivot Irrigation Systems in Southwest Nebraska Based on Survey Oct. 1 - Dec. 31, 1969

Type of Motor	No.	%
Electric	174	55
Natural Gas	97	30
Propane	25	8
Diesel	22	7
TOTALS	318	100

III. The Unanswered Questions

While many of the operators of center pivot systems contacted during the survey were enthusiastic about this new method of irrigation, some were either discouraged or disenchanted with them. Practically all of the operators contacted were much concerned about the continuing cost-price squeeze faced by farmers. The large amount of capital required for irrigation development coupled with the need to purchase additional high cost mechanized equipment to handle irrigated crops such as corn, sugar beets, dry beans, alfalfa, etc., must be weighed carefully against the returns realized from the added production resulting from irrigation. When farmers compare the prices received for their crops over the past 10 years with the ever increasing costs of all the inputs necessary for crop production, it is readily understandable why they are concerned. A frequently voiced question was what will Congress and the Administration do about farm programs and price supports for farm commodities in the years ahead?

Several of the operators stated they felt they had little choice about going into irrigation, and the labor-saving aspects of the center pivot systems were instrumental in their selection of the type of irrigation. The principal reasoning behind this rationale is that wheat had long been the dominant crop in Southwest Nebraska but because of tighter and tighter acreage restrictions on wheat coupled with the decline in wheat prices the past several years, about the only alternative that would substantially bolster their sagging incomes was to go into irrigation. Even so, a sizable number of operators were discouraged about the relatively low returns

to irrigation after all the added capital required and additional labor are taken into consideration. Because of the wet harvest season in the fall of 1969, moisture content of the corn remained high through most of the harvest season, and many farmers were netting only 80-85¢ per bushel on high moisture corn that they sold at harvest. The sugar beet growers in the area were worse off with muddy fields delaying harvest into late November and even early December. Their equipment took a severe beating and in some cases where beets were harvested after hard freezes, the beets deteriorated in the piles so badly they could not be processed.

Another frequently asked question concerned which crop would yield the highest return under center pivot irrigation? A sizable number of operators expressed interest in having facts and figures on the costs and returns from center pivot irrigation for different crops. There is a real need for much additional research of an economic nature on irrigation and center pivot irrigation in particular. The author is currently involved in an economic research study with 20 operators of center pivot systems to analyze the costs and returns for corn production in the 9-county area of Southwest Nebraska. Similar studies on other alternative crops are needed.

Of paramount interest to farmers going into high cost irrigation development is the question about how much more irrigation development can occur before the underground water supplies begin to diminish or are even exhausted? How soon and what kind of regulations or laws restricting irrigation development or limiting the amount of water used for agricultural production are likely to be enacted in Nebraska? Since most of the development of land for irrigation outside the valley areas of Southwest Nebraska has occurred within the last few years, there are no satisfactory answers to these questions. While Nebraska, including this southwest region, is indeed fortunate to have a large underground water reservoir that can be tapped for irrigation with some exceptions, few if any people in the area feel the

water supplies are inexhaustible. Many of the operators contacted are well aware of the concern about declining water tables in some of the intensive irrigated areas in the Texas panhandle, New Mexico, California, and even in some areas of Nebraska. Colorado recently established strict regulations affecting the drilling of irrigation wells in eastern Colorado, and many of the land owners and operators in Southwest Nebraska are well aware of the fact that Nebraska, which is now working on a State Water Plan, could establish restrictions or regulations affecting future irrigation development. There is no doubt that this concern has triggered a sizable proportion of this new irrigation development since it is highly possible that when and if water restrictions are applied, their water rights could be based on how long they have been irrigating, when their wells were registered, etc.

These are but a few of the many unanswered questions encountered during the survey. In conclusion, the author was tremendously impressed with the friendliness and willingness to cooperate in the survey shown by the owners and operators of center pivot systems. Not a single person contacted refused to provide information sought in the survey although they were given the opportunity to decline to provide any of the information requested. It also is worthy of note that those contacted were generous with their time in spite of the many difficulties they faced with adverse weather in trying to harvest their crops in the fall of 1969. It was a wet and muddy harvest season full of frustration and disappointment for many of the farmers in the area. Upon conclusion of the survey the author was more than ever convinced of the truth of the long-time observation to the effect that "those who till the soil are the salt of the earth."