A STUDY OF THE ECONOMIC FEASIBILITY OF IRRIGATION OF CORN IN THE MARAIS DES CYGNES VALLEY, KANSAS

by

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INTRODUCTION

Water is a limited resource, and is becoming increasingly important as a factor in agricultural production in the United States. The arid and semi-arid regions of the West have long been aware of the necessity of irrigation for successful crop production. The rapid extension of supplemental irrigation eastward into more humid areas is the result of extended drought and improvement or irrigation technology. Irrigation provides supplemental water during periods of inadequate precipitation too meet crop moisture requirements. The development of irrigation provides a more stable agricultural production and a more dependable source of income.

The 1954 Census of Agriculture reveals that irrigation increased from 25,787,455 acres in 1949 to 29,552,155 acres in 1954 in the United States.[1] Recent estimates of irrigation specialists in land grant colleges in collaboration with 1954 Census data show a national expansion of 5 million irrigated acres between 1950 and 1955, an increase of 19 percent.[2] The 17 western irrigation states accounted for a 3½ million acre increase, while the remaining mideastern and eastern states showed a significant 1½ million acre gain or 30 percent of the total increase. Even though these states have relatively high annual rainfall to sustain normal

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[1]U.S. Bureau of Census, Statistical Abstract of the United States: 1957, p. 607.

[2]Irrigation Engineering and Maintenance, Vol. VI, No. 9, August, 1956.

crop production, the frequency and distribution of rainfall are the determining factors affecting crop yields.

A similar pattern of irrigation development was taking place in Kansas. Low annual rainfall, plentiful ground water reserves, and favorable soils and terrain have stimulated irrigation expansion in western Kansas. The Garden City Experiment Station reported some 350 thousand acres in western Kansas under irrigation in 1955.[1] The reports of county agents estimated the irrigated acreage for the state of Kansas at 500,000 acres for 1956.[2] The Census Bureau data reveals that the acreage of irrigated land in Kansas increased from 138,686 acres in 1950 to 331,551 acres in 1955, an increase of 139 percent. Census data also shows the number of irrigation enterprises in Kansas expanded from 1,166 irrigated farms in 1950 to 2,736 irrigated farms in 1955, an increase of 134 percent.[3] The increase in the amount of land under irrigation and the number of irrigation enterprises indicate the influence of several years of below normal rainfall throughout the state.

In periods of extended statewide drought, as experienced from 1952 through 1956, irrigation moved eastward on a supplemental basis. The normal annual rainfall in eastern Kansas of 35 to 40

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[1]Andrew B. Erhart, Walter B. Meyer, Ben L. Grover, Irrigation in Western Kansas, Kansas Agricultural Experiment Station Cir. 324, p. 5.

[2]Warren L. Trock, Leasing Arrangements for Farms with Irrigation Enterprises, p. 3. Unpublished master's thesis, Kansas State College, 1957.

[3]U.S. Census of Agriculture 1954, Vol. I, pt. 13, p. 2.

inches is generally sufficient to meet normal crop consumptive use, but supplemental moisture is needed when seasonal or annual deficiencies occur. Several irrigation studies have been conducted in western and southcentral Kansas.[1] However, no formal irrigation economics study has been done in eastern Kansas. There is a need for research in this area as a basis for determining the economic feasibility of irrigation in eastern Kansas. The State Water Resources Board has the responsibility of working out a state plan of water resources development for each watershed in Kansas. The state has been divided into 12 units to facilitate an organized approach to the study of the availability and use of water and related resources. An adequate water supply is of prime importance to farming as well as any other type of business venture. Water for domestic, stock, and irrigation uses must be given careful consideration in regions where water supplies are limited in allocating for agricultural uses.[2]

The Water Resources Board and others are interested in learning what amount farmers could pay for water for irrigation in the Marais des Cygnes Valley. The purpose of this thesis is to present information which will be helpful in answering such questions as: Can farmers afford to irrigate in this area? How much can farmers afford to pay for water in certain months? How much water can

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[1]Merton L. Otto, Wilfred H. Pine, Sprinkler Irrigation, Kansas Agricultural Experiment Station Bul. 381, August 1956. Publications listed in footnotes 1 and 2 on page 2.

[2]State Water Resources Board, Availability, Use, and Control of the Water Resources of Kansas, Marais des Cygnes Unit, Planning Report No. 1, p. 44.

farmers afford to apply under certain price-cost relationships?

The Problem

The extension of irrigation into eastern Kansas has created problems for farmers irrigating and for those considering the feasibility of irrigation. The decision of whether to establish irrigation rests primarily on determining the economic soundness of maintaining the fixed costs in years when the system is not in use.

The problem confronting those farmers who have made a positive decision to irrigate or are now irrigating becomes threefold. (1) To determine the response of crop yields (in this study corn) to additional water, (2) to determine the amount which could be paid for water and (3) the quantity of water which should be applied to maximize the net return.

A production function which yields a reliable estimate of the increase in corn yields from each additional inch of water must be derived. Consideration must also be given to the effects of fertilizer on corn yields under irrigation. Irrigation costs must be established; fixed costs for interest on land leveling, structures, and equipment must be determined on a per acre basis, while the other variable costs must be determined on a per acre-inch basis. The excess of the value of the additional returns above the increased costs of irrigation is the net increase in returns. Farmers could pay up to the point where the cost of the water applied equated the net returns above other costs. However, to maximize the net return they would extend water application to where the marginal cost of water is equal to the marginal return of the corn increment. The amount which should be applied would be dependent upon the physical production and the price-cost relationships.

The Objectives

The prime objective of the study was to determine the net gains which might have been obtained under irrigation from 1925 to 1954 in Franklin County under assumed prices for corn and water. This would indicate the maximum amount which could have been paid in those years for irrigation water and the optimum amount of water which should have been applied to maximize net returns.

The amount which farmers could pay for water in the future may be estimated on the basis of past records. The determination of the quantity of water which should be applied is dependent upon price-cost ratios, and can be determined by application of production economic theory.

Scope of Study

The investigation of the economics of irrigation in the Marais des Cygnes Valley was limited to Franklin County (Fig. 1). It was selected as a county representative of the area in soils, topography, cropping patterns, rainfall, and crop yields. The study was conducted on a representative county basis within the area to facilitate gathering of data and to limit the analysis. Inferences and implications drawn from Franklin County would have general application for the Marais des Cygnes Unit as a whole.

Corn was selected as the crop to be considered in the study,

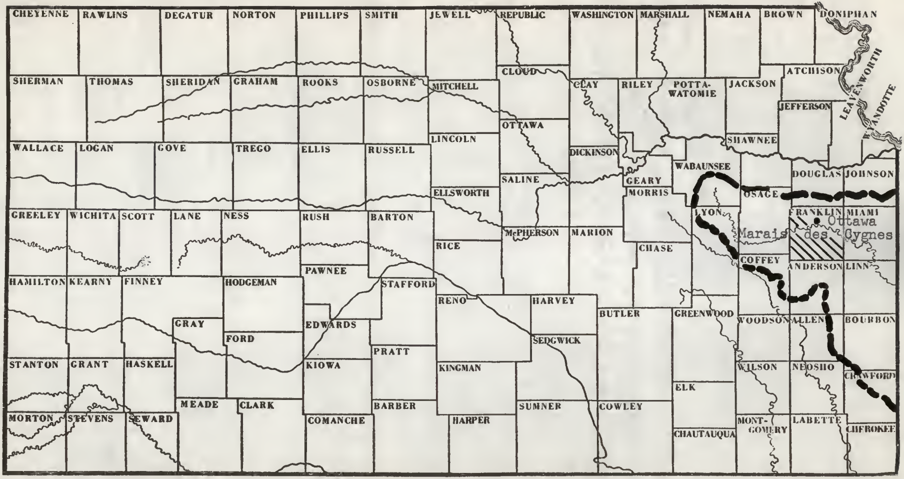

Fig. 1. Location of Franklin County in relation to the Marais des Cygnes Unit as developed by the State Water Resources Board.

due to its historical importance in the area. During the early part of the period corn was planted on about one half of the cropland. The past few years it has represented about one fourth of the cropland. Corn planted during the period since 1928 has represented 34 percent of the total cropland.[1] Widespread adoption of irrigation in the area would probably increase corn acreage in the irrigable bottomlands, due to its response to water. Careful study should be given to other major crops and analysis of detailed soil surveys before making recommendations.

A thirty-year period of time, from 1925 through 1954, was chosen. A time period of this length was desirable for purposes of correlation, as it would include a wide range of climatic conditions in relation to variation in corn yields.

The average yield per acre of corn harvested for Franklin County was adjusted to obtain an estimate of bottomland corn yields for Franklin County. A bottomland yield was considered more meaningful, as most irrigation in the area would be conducted on bottomland.

Monthly precipitation records at Ottawa in Franklin County, Kansas, were obtained from the Climatological Data of the United States Weather Bureau. Seasonally weekly rainfall and daily temperatures were obtained from the punched card library of the Kansas State College Weather Station.

Irrigation cost data for water and applying the water were not

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[1] From data compiled by the Federal-State Crop Reporting Service, Topeka, Kansas.

available for the eastern Kansas area. Similar costs incurred on irrigation development farms in other areas of Kansas were used as a basis for estimating fixed and variable costs.[1] Three assumed costs for water were used, and four assumed prices for corn.

For the purposes of this study, the following basic assumptions were made: (1) Surface irrigation would be the method of application; (2) a supply of irrigable water is available; (3) the effects of irrigation water and rainfall are the same; and (4) water would be applied in 3-inch increments.

The limited ground water resources of the Marais des Cygnes Valley coupled with the potential of impounding tne normally high runoff associated with a mean annual rainfall of 35 to 40 inches lend logical support to assumptions (1) and (2). The surface irrigation method would consist of water from surface reservoirs being delivered by a system of canals to the individual farms. The water would then be distributed by ditches throughout the irrigable area of the farm unit, and applied to the particular crop by the siphon tube method. To substantiate assumption (3), it was felt that the greater evaporation losses encountered under irrigation would tend to be offset by the possibility of greater runoff because of the inability to control the amount of intensity of rainfall. The general compact composition of soils in the Marais des Cygnes Valley would limit the quantity of a particular application (assumption 4).

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[1]Irrigation Development Farms, Kansas, 1957, Annual Report, Extension Service, Kansas State College, p. 82.

REVIEW OF ECONOMIC THEORY

The basic principles of economics must be given careful consideration in solving economic phases of an irrigation study. Water is a limited resource and must therefore be allocated among alternative uses. This study was concerned only with water used for irrigation purposes. Efficient use of this resource at various price-cost relationships is the problem of irrigation economics.

Economic efficiency may be affected by governmental policies, customs and institutions, or other developments which change production possibilities, cost structures, and resource management.[1] Irrigation affects production possibilities and cost structures, and generally demands a greater degree of managerial ability than dryland farming. Economic theory provides a basis for allocating irrigation water to its optimum use and distribution of the costs.

Goal of Irrigators

It was assumed that the goal of farm irrigators is the maximization of net returns from the irrigation enterprise. This goal would be realized when the farmer extended irrigation to a point where the value of the marginal returns equals the marginal cost of water. Economic efficiency is denoted when resources are used in a manner to maximize the particular objective or end quantity which is relevant to the economic unit under consideration.[2]

Once the initial outlay for irrigation equipment has been made,

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[1]Earl O. Heady, Economics of Agricultural Production and Resource Use, p. 115.

[2]Ibid., p. 98.

the annual interest on the investment and the depreciation become annual fixed costs to the farm business. These fixed costs are incurred even though irrigation might not be used in years of abundant rainfall. Therefore, once the decision has been reached to establish irrigation, the variable costs become the only determining factor in irrigation in any year. Variable costs such as labor, fertilizer, maintenance and repairs, and harvesting and marketing costs can be avoided in years when irrigation equipment is not used, and must be covered by the value of the additional yield if irrigation is to be profitable in the short-run. The cost of the irrigation water may be considered as a variable cost, but in an irrigation district a minimum assessment for a given quantity of water may have to be paid each year and would be a fixed cost. Production economic theory provides a tool for choosing the level at which the variable factors should be applied to the fixed factors for profit maximization. Heady states the following law or necessary condition: The factor-product price ratio must equal the marginal productivity of the resource.[1]

When resource limitation makes it physically impossible to extend water application to the optimum level, it should then be distributed among the enterprises to equalize marginal returns. This would be the case during an extended drought of several years duration, when water supplies are inadequate to meet the demands of the irrigators.

However, for the purposes of this study it was assumed that

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[1] Ibid., p. 99.

a sufficient supply of irrigable water was available to apply the optimum amount for realization of maximum profits.

Even with the possibility of a shortage of water ruled out by the basic assumption, farmers do not always extend water resource use to a point where the factor/product price ratio and the marginal physical product of a resource unit are equal. There are several reasons which might explain the apparent inability of farmers to equate marginal value products with marginal costs of resources. Heady lists three: (1) lack of knowledge of the relevant input-output relationships and cost structures, (2) the uncertainty of future prices and yields, and (3) the existence of severe capital limitations.[1]

Risk and Uncertainty

The time involved in agricultural production creates uncertainty. The farmer is faced with many possible outcomes due to risk and uncertainty which affect his plans for use of resources. Farmers have commonly associated all outcomes which lead to losses as risks. It is not the purpose of this paper to make an exhaustive study of risk and uncertainty, but it is necessary to distinguish between the two.

Risk refers to variability or outcomes which are measurable in an empirical or quantitative manner.[2] Risk relating to variability phenomena can be incorporated into the cost schedule. Uncertainty refers to future events where the parameters of the

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[1]Earl O. Heady, op. cit., p. 115.

[2]Ibid., p. 440.

probability distribution cannot be determined empirically.[1]

Due to the risk and uncertainty of establishing or operating an agricultural enterprise, such as irrigation, farmers might not extend operations to where the marginal costs equal the marginal returns. Therefore, economic theory would suggest inclusion of a risk factor in the cost structure, and thus affect managerial decisions in areas where variability and risk are prevalent.

HYPOTHESES

Three hypotheses were tested. (1) Significant increases in corn yield can be obtained from additional water during critical periods during the growing season in Franklin County, Kansas. Subhypotheses under (1) are: (a) Significant increases can be obtained from additional water in June; (b) significant increases can be obtained from additional water in July; and (c) significant increases can be obtained from additional water in August. (2) Irrigation of corn would be profitable for the average farmer in the Marais des Cygnes Valley with corn $1.00 or more per bushel and water $0.50 or less per acre inch. (3) In three-fourths of the years from 1925 to 1954, farmers could have profitably applied 6 or more inches of water in July.

TESTING AND ANALYSIS OF HYPOTHESES

Bottomland Corn Yields under Irrigation

The first step of the analysis was to derive a procedure to obtain annual bottomland yields of corn in Franklin County. The

[1] Ibid., p. 443.

average county yields for corn were adjusted upward for bottomland yields based on a similar adjustment made in a Kansas River study.[1] This method included the effects of seasonal (June, July, and August) and pre-seasonal (to the prior October 1) rainfall on the relationship between county yields and bottomland yields. The method was derived on the basis that a normal seasonal and pre-seasonal rainfall would result in a 40 percent increase in the average county yield to arrive at the bottomland yield. As the seasonal and pre-seasonal rainfall decreased, it was felt that there would be a greater differential between bottomland and upland corn, and the percentage change was increased. For wetter years, the percentage increase used was below 40 percent, as the bottomland yields were assumed to be only a little greater than the upland yields. The percentages in Table 1 were used in making the adjustment.

This method of adjustment was applied to the average county yield for each individual year and the results are shown in Table 2, and graphically in Figure 2 in relation to July rainfall. The adjusted bottomland corn yields ranged from 5 bushels per acre in 1936 to 43 bushels per acre in 1928 and 1950. The average bottomland yield was 29 bushels per acre compared with an average county yield of 21 bushels per acre, with a sample standard deviation of 10.8 bushels per acre.

A brief summary of previous correlation studies of rainfall

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[1] A Study of Land Uses, Crop Yields, Costs of Production, Replanting Possibilities, and Effects of Sedimentation and Scouring of the Agricultural Land in Kansas River Flood Plain, Kansas State College Agricultural Experiment Station, October 1956.

Table 1. Adjustment of average county yields to average bottomland yields in Franklin County, Kansas.[1]

Seasonal precipitation	Pre-seasonal precipitation	Percentage above average county yield
Below normal[2]	Above normal[5]	60
	Normal[6]	70
	Below normal[7]	80
Normal[3]	Above normal	30
	Normal	40
	Below normal	50
Above normal[4]	Above normal	10
	Normal	15
	Below normal	20

[1]Discussed with O. W. Bidwell and Floyd Smith, Experiment Station Agronomists, Kansas State College.
[2]Less than 11.5 inches.
[3]11.5 to 14.5 inches.
[4]Above 14.5 inches.
[5]Less than 18 inches.
[6]18 to 23 inches.
[7]Above 23 inches.

and corn yields suggested the next step in the study. Previous studies in Kansas indicated a closer relationship between corn yield and rainfall than between corn yield and temperature for the state as a whole. Considering the partial correlation coefficients, the relationships between yield and temperature and between yield and rainfall are closer for July, followed by August and June, respectively.[1]

Hodges found that rainfall and temperature account for a large proportion of the variation in corn yield when these are averaged

[1]J. A. Hodges, "The Effect of Rainfall and Temperature on Corn Yields in Kansas," Journal of Farm Economics, Vol. XIII, No. 2, April, 1931, p. 307.

Table 2. Comparison of average county yields and adjusted bottomland yields, seasonal, pre-seasonal, and June, July, and August rainfall[1] in Franklin County, Kansas.

Year	Average county yield[2]	Adjusted bottomland yield[3]	Seasonal rainfall, inches	Pre-seasonal precipitation, inches	June rainfall, inches	July rainfall, inches	August rainfall, inches
1925	23	41	9.6	14.8	5.16	3.38	1.04
1926	19	34	7.6	13.6	1.90	3.45	2.30
1927	33	38	16.9	22.3	5.06	5.58	6.24
1928	29	43	12.9	15.4	5.70	3.26	3.90
1929	19	30	11.4	27.7	4.80	3.95	2.68
1930	7	12	8.8	18.8	4.41	1.38	2.02
1931	18	24	12.0	18.3	5.59	3.62	2.82
1932	23	30	14.4	23.5	7.11	4.19	3.05
1933	16	27	11.2	19.7	0.28	3.76	7.14
1934	5	8	5.4	12.6	2.52	1.92	0.91
1935	16	21	13.2	23.0	6.05	1.68	5.50
1936	3	5	1.0	19.2	0.26	--	0.77
1937	14	24	6.2	15.3	3.06	1.66	1.51
1938	26	33	12.5	23.3	7.37	2.77	2.35
1939	10	15	11.7	12.0	4.77	2.26	4.66
1940	20	33	10.1	18.2	4.48	0.21	5.40
1941	30	39	14.4	23.0	4.32	3.88	6.24
1942	32	41	14.1	25.2	4.08	1.78	8.26
1943	25	29	14.8	20.7	10.09	1.89	2.87
1944	32	35	14.7	25.5	5.08	3.12	6.52
1945	20	22	15.0	33.1	8.31	5.65	1.07
1946	22	31	11.5	20.3	2.87	1.35	7.27
1947	17	22	14.5	28.3	10.56	2.80	1.13
1948	35	40	15.6	20.1	4.90	8.63	2.09
1949	34	39	19.6	22.9	6.13	10.38	3.11
1950	36	43	20.5	17.0	4.95	9.07	6.47
1951	17	20	31.0	16.5	10.90	13.78	6.64
1952	27	31	14.8	18.8	1.26	5.76	7.75
1953	22	40	5.7	16.6	1.01	2.98	1.70
1954	9	11	16.8	17.5	4.07	2.00	10.78

1. State Board of Agriculture, Climate of Kansas, Vol. I, No. 285, p. 75.
2. From data compiled by the Federal-State Crop Reporting Service, Topeka, Kansas.
3. Adjustment made by using Table 1.

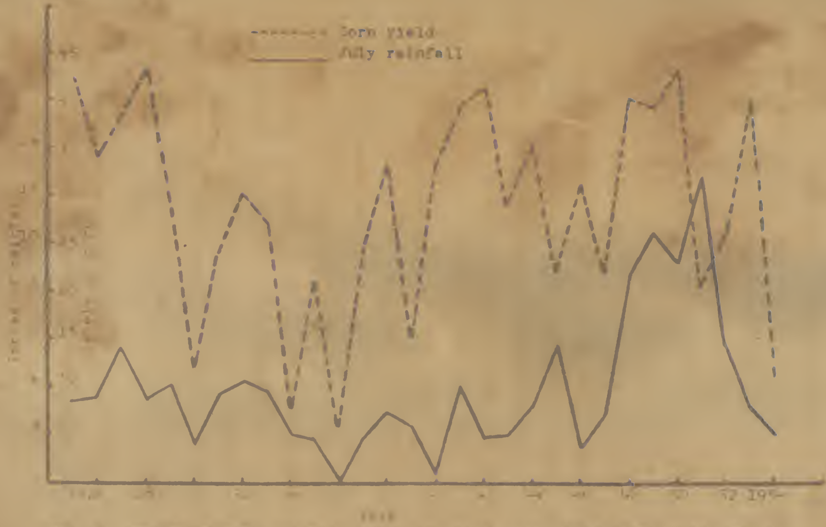

Fig. 2. Graph of July rainfall and [illegible] corn yield in Franklin County, Kansas, from [illegible] to [illegible] (see Table [illegible] for source).

for the state as a whole, or by type of farming areas. On a particular field, the yield is also influenced by other factors. The type of soil, the methods of culture, variety of corn used, and insects and diseases encountered are a few of the factors which might be mentioned. In a large area these tend to be offsetting.[1]

The coefficients of determination in Hodges' study show the tendency toward the greater importance of rainfall in the eastern portion and temperature in the western portion of the state.[2] On the basis of the findings of these previous studies, it was decided to use only June, July, and August rainfall as factors influencing corn yields most in eastern Kansas.

A linear regression of the combined seasonal rainfall of June, July, and August to the bottomland yield (Fig. 3) resulted in a relatively low correlation of 0.37. This included data for each year, 1925 through 1954, exclusive of the flood year 1951, which was excluded from the study at this point because of abnormally high rainfall and low yield. The high degree of variability may be partially accounted for by the variability in the frequency and distribution of rainfall during the growing season. This suggested that a shorter period of time should be considered. Each of the three months was then considered individually to determine the extent of the influence of rainfall in a given month upon corn production.

Three methods of statistical analysis were applied to the data to find a suitable method of determining the effects of water

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[1] Ibid., pp. 312-313.
[2] Ibid., p. 311.

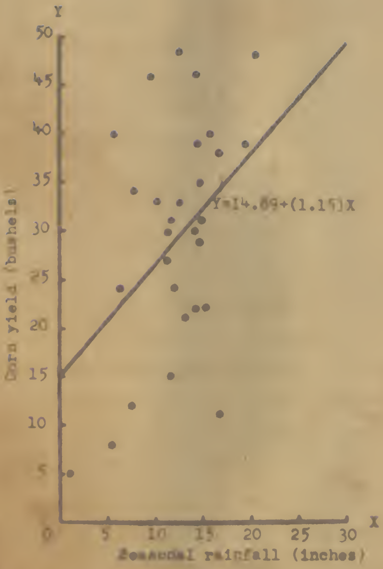

Fig. 3. Relation between seasonal rainfall (June, July, and August) and bottomland corn yield in Franklin County, Kansas, from 1925 to 1954.

upon corn yields during the three most important months of the growing season, June, July, and August.

The linear regression method was first applied, relating the precipitation in each of the individual months of June, July, and August to the annual bottomland yield (Figs. 4, 5, 6). The correlation coefficient for July was the highest at 0.51, August was 0.39, and June was 0.11. None of these resulted in a high degree of closeness of fit due to the frequency and distribution of rainfall during the month and to other factors.

The extent of the variation in rainfall was determined for each month. June rainfall ranged from 0.26 inch in 1936 to 10.56 in 1947, with a mean rainfall of 4.69. Sample standard deviation was 2.53 inches. July rainfall ranged from 0.00 in 1936 to 10.38 inches in 1949. The average precipitation in July amounted to 3.53 inches, with a standard deviation of 2.40 inches. August precipitation ranged from 0.77 inch in 1936 to 10.78 inches in 1954. The mean rainfall was 3.81 inches and the sample standard deviation was 2.31 inches.

An illustration of how two similar amounts of precipitation resulted in such wide yield differences points to the need of extending research to even shorter periods of time, such as a week. Rainfall of 1.92 inches in July 1934 resulted in an 8-bushel yield, while 1.78 inches in July 1942 resulted in a 42-bushel yield. Much of this variation can be explained by examining the weekly precipitation and daily temperatures for the last three weeks in July in each of these years. In 1934, 17 of the last 21 days in July, temperatures of 100 degrees or above were recorded, while precipitation amounted to only 0.68 of an inch. The same period of July 1942 showed only two days when the temperature was 100 degrees or above, and precipitation was 1.69 inches.

Examination of rainfall records for shorter segments of time relative to yields produced in a given year indicates that the timing of rainfall during the critical physiologic growth stages of corn has more influence than the total precipitation of a given period. A study at the Irrigation Experiment Station in Prosser, Washington,[1] concluded that soil moisture depletion to the wilting percentage by field corn at certain physiologic growth stages markedly depressed grain yields. Such deficits for periods of one to two days during the tasseling or pollination period resulted in as much as a 22 percent yield reduction and periods of six to eight days gave a yield reduction of about 50 percent. Observation of the results of their study emphasizes the importance of careful timing and management to obtain optimum results in irrigation.

This substantiates the argument for irrigation in humid regions, and offers at least a partial explanation of the high variability in yields with similar precipitation amounts in a given period. The frequency and distribution of rainfall, temperature, and the various other influencing factors contribute towards limiting the degree of correlation which can be obtained.

The hypothesis that significant increases in corn yields result from additional water in June or in August is rejected. The

[1]C. E. Domingo and J. S. Robins, "Some Effects of Severe Soil Moisture Deficits at Specific Growth Stages in Corn," Agronomy Journal, Vol. 45, 1953, p. 621.

Table 3. Yield of corn from segregated plot portions,[1] Prosser, Washington.[1]

Treatment	Yield of corn, bushels per acre at 15.5% moisture
Wilted 6-8 days at tassel, one subsequent irrigation	66.7
Wilted 1-2 days at tassel, one subsequent irrigation	117.9
Wilted 6-8 days at tassel, two subsequent irrigations	79.1
Wilted 1-2 days at tassel, two subsequent irrigations	132.9
Wilted 1-2 days at pollen-shed, one subsequent irrigation	106.5
Wilted 1-2 days at pollen-shed, two subsequent irrigations	106.9

[1]C. E. Domingo and J. S. Robins, "Some Effects of Severe Soil Moisture Deficits at Specific Growth Stages in Corn," Agronomy Journal, Vol. 45, Table 2, p. 619.

hypothesis that a significant increase in corn yield results from additional water in July is accepted at the 1 percent level of probability by use of the "t" test of significance. Therefore, it was accepted that there is a significant increase in bottomland corn yields with each additional inch of water in July. The regression coefficient indicates that corn production increased 2.25 bushels with each added inch of precipitation in July. At this point, imputing expected returns from the linear production function would seem illogical. The implications of a linear production function showing constant returns would be to apply all the available water. If the farmer could afford to irrigate at all, each added inch would continue to result in an increase of 2.25 bushels of corn. If the irrigator could afford to apply one inch

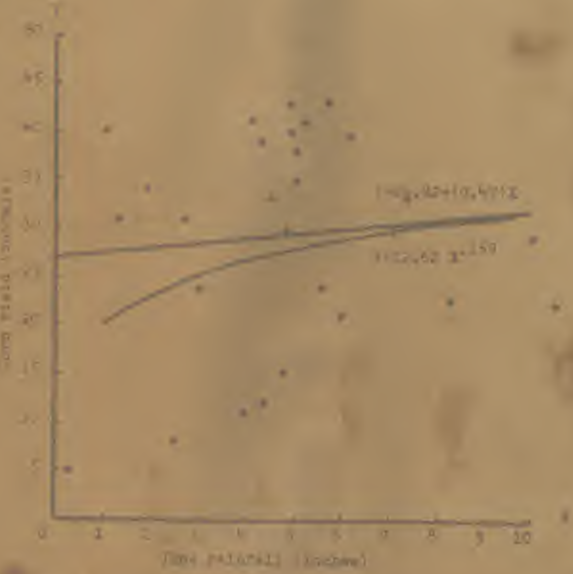

Fig. 4. Relation between June rainfall and bottomland corn yield in Franklin County, Kansas, from 1925 to 1954.

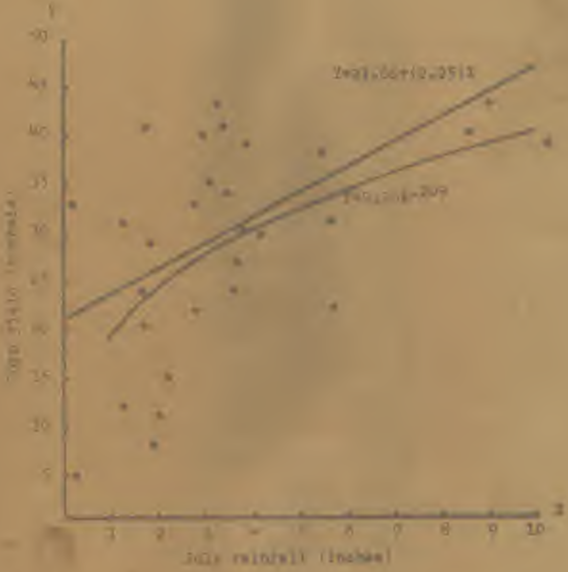

Fig. 5. Relation between July rainfall and bottomland corn yield in Franklin County, Kansas, from 1925 to 1954.

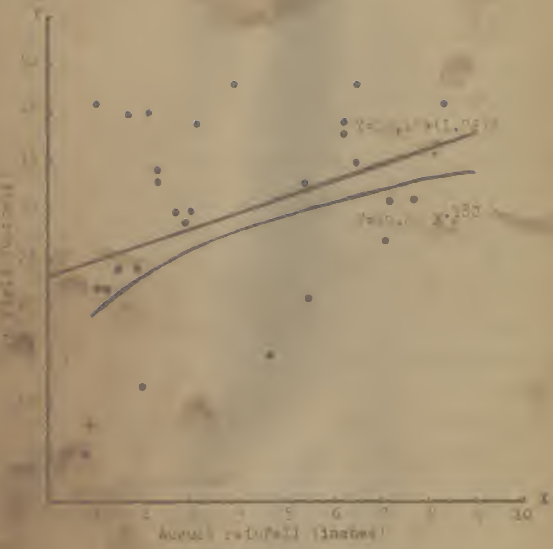

Fig. [illegible]. Relation between August rainfall and bottomland corn yield in [illegible] County, Kansas, from [illegible] to 1959.

of water, under these conditions, it would pay him to apply 100 inches or more.

Wallace[1] has shown that the relationship between corn yield and weather factors is not always linear. Temperatures or rainfall, both below and above the optimum for a given time, in a specific area may result in a decreased yield. The more logical approach would necessitate the use of a curvilinear function which would show diminishing returns.

Three Cobb-Douglas production functions of the form $Y = aX^b$ were used, relating June, July, and August rainfall independently to annual corn yield (Figs. 4, 5, 6). This function allows diminishing productivity, but holds elasticity of production constant. The correlation coefficients increased for June and July over the linear regression, while August was just slightly less.

The comparison of correlation coefficients obtained from linear regression and Cobb-Douglas functions given below shows a better overall fit of the Cobb-Douglas function to the data.

Month	Linear Regression "r"	Cobb-Douglas "r"
June	0.11	0.34
July	0.51	0.58
August	0.39	0.37

However, it was felt that a multiple regression might give a higher degree of fit. A multiple correlation taking into account the effects of rainfall in each of the three units while holding

[1] H. A. Wallace, "Mathematical Inquiry into the Effect of Weather on Corn Yields in the Eight Corn Belt States," Monthly Weather Review, Vol. 48, No. 8, pp. 439-446

the other two constant resulted in a correlation coefficient (R) of rainfall in June, July, and August to corn yield of 0.66. The coefficient of total determination (R^2) was considered as the percentage of the variation in corn yield accounted for by the three factors included. An (R^2) of 0.43 indicated that 43 percent of the variation in corn yield in Franklin County can be attributed to rainfall in June, July, and August.

The results of the "t" tests of the partial correlations are as follows:

June $t = 0.8172$, 27 degrees of freedom, $P > .40$

July $t = 2.808$, 27 degrees of freedom, $P < .01$

August $t = 1.529$, 27 degrees of freedom, $P > .10$

The hypothesis that the regression coefficient for June rainfall was different from zero was rejected. The hypothesis that the regression coefficient for August rainfall was different from zero was also rejected. The regression coefficient for July rainfall was the only one found to be significantly different from zero. At a probability level of 1 percent, therefore, the hypothesis was accepted.

The implication for irrigation from this analysis was that, of the three factors considered, July rainfall is the most important determinant affecting the yield of corn in Franklin County. This is substantiated by Hodges' study,[1] which points out that July rainfall is the most important for the state as a whole and for Type of Farming Area 4 (northeastern Kansas), and is important in

[1] J. A. Hodges, op. cit., p. 312.

all areas. This would imply that irrigation water applied in July would have more influence on corn yields than in June or August, and on this basis farmers could afford to pay more for water in July.

Optimum Water Application

The next step in the study was to determine the optimum amount of water which should be applied under certain assumed prices for water and corn, during the critical period of July only. To determine the effects of each inch of water, the Cobb-Douglas function relating yield to July rainfall, independent of June and August rainfall, was used. It was satisfactory for imputing these returns, as its coefficient of correlation was not significantly different than the July partial correlation of the multiple correlation (Fig. 5).

The amount of nitrogen which should be applied with corn priced at four assumed prices was determined by having the value of the marginal product equal to or greater than the marginal cost of the fertilizer. A nitrogen cost of 15 cents per pound applied to the corn was used.[1] The amount of nitrogen which should be used was determined on the basis of a fertilizer response curve developed by Orazem and Smith from experimental data of the Pomona farm located in Franklin County. The equation for the curve was $Y = 69.38 + 0.311946\ N - 0.001379\ N^2$, Y representing the predicted

[1]Burton L. French, "Functional Relationships for Irrigated Corn Response to Nitrogen," Journal of Farm Economics, Vol. 38, August, 1956, p. 742.

Table 4. Estimated and predicted yield and increment in yield of corn associated with each additional 10 pounds of nitrogen applied per acre on Verdigris-like soil using a response curve of the type $y = a + b_1 N + b_2 N^2$.[1]

Applications of nitrogen, pounds per acre	Response curve: Yield per acre, bushels	Response curve: Increment on yield, bushels
0	69.38	--
10	72.36	2.98
20	75.06	2.70
30	77.48	2.42
40	79.63	2.15
50	81.50	1.87
60	83.10	1.60
70	84.42	1.32
80	85.47	1.05
90	86.24	0.77
100	86.73	0.49
110	86.95	0.22
120	86.89	-0.06

[1] Frank Orazem and Floyd W. Smith, op. cit., Table 5, Columns 1, 6, 7, p. 11.

yield of corn, and N representing Nitrogen.[1] (Table 4) These amounts were as follows:

Pounds of Nitrogen	Corn per Bushel
40	$0.75
60	1.00
70	1.25
80	1.50

[1] Frank Orazem and Floyd W. Smith, An Economic Approach to the Use of Fertilizer Including an Economic Interpretation of a Corn-Fertilizer Experiment on Verdigris-Like Soil in 1956, Agricultural Experiment Station Technical Bulletin 94, May 1958, p. 9.

The limited experimental data in eastern Kansas has not shown the corn response to nitrogen to be any greater under above normal rainfall conditions. Therefore, it was assumed that the response of corn to fertilizer with varying amounts of water would be the same. Since the amount of nitrogen was held constant at each price level and did not vary with the quantity of water, it was not included in the marginal cost analysis.

The physical increments from each additional inch of water in July as derived from the Cobb-Douglas production function used in the study are given in Table ~~7~~. 5

The four values of the marginal product were computed by multiplying the four assumed prices per bushel of corn, $0.75, $1.00, $1.25, and $1.50, respectively, times the physical increments for each additional inch of water. (Tables 11, 12, 13, 14, column 3, in the Appendix)

The fixed and variable costs used in this study were derived primarily from costs incurred in growing corn on the irrigation development farm in Republic County in the Kansas-Bostwick Irrigation District.[1]

The annual fixed costs per acre consisted of these four items:

Land grading	$2.42
Structures	.41
Irrigation equipment	1.12
Increase in real estate taxes	1.00
Total fixed cost	$4.95

Land grading and leveling averaged $48.50 per acre, the inter-

[1] Irrigation Development Farms, Kansas, 1957, Kansas-Bostwick Farm, Table VII, p. 82.

Table 5. Predicted corn yield and increment per inch of water in July in Franklin County, Kansas.

Inches of water	Predicted yield,[1] bushels per acre	Physical increment, bushels per acre
0	12.3	---
1	19.2	6.9
2	24.0	4.8
3	27.3	3.3
4	29.9	2.6
5	32.1	2.2
6	34.0	1.9
7	35.8	1.8
8	37.3	1.5
9	38.8	1.4
10	40.2	1.4

[1]Without the effects of fertilizer.

est on the investment being computed at 5 percent. Structures included division boxes, check-drops, and culverts, costing an average of $3.11 per acre. Interest on investment was also 5 percent, depreciation 5 percent, and repairs 3 percent. Irrigation equipment was comprised of check dams and siphon tubes valued at $234, a ditcher at $170, and land plane at $720. Interest on all of these items was computed at 7 percent. Depreciation was 20 percent on check dams and siphon tubes and 10 percent on the ditcher and land plane. Repairs were also computed at 3 percent. An additional cost was added for the increase in real property taxes attributed to the increase in land value from irrigation. It was estimated that eventually assessed valuation would rise approximately $25 per acre and an average levy of 40 mills would result in the $1.00 per acre increase in taxes.

The variable cost figure consisted of three components: (1) cost of application, (2) cost of water, and (3) additional costs incurred under irrigation. The cost of applying water was comprised of labor for irrigation, land planing, and maintenance of ditches, plus tractor expense. Labor was calculated at $1.00 per hour, and tractor costs at $0.18 per gallon of fuel used. The cost of $0.95 per 3-inch application was computed from the Kansas-Bostwick figures by dividing the cost by the number of acres irrigated to obtain cost per acre, and then dividing by 3, assuming this would be the average number of applications in the Marais des Cygnes Unit.

Three prices were assumed for water, $0.31, $0.50, and $1.00 per acre inch. A charge of $0.31 per acre inch was paid by farmers in the Kansas-Bostwick District for water in 1957. They will be charged $8.85 for 18 inches of water in 1958, or $0.49 per acre inch.[1] It was expected that water would cost approximately $0.50 per acre inch in the Marais des Cygnes, and could conceivably be higher, depending upon the portion of the cost which the government would pay. Therefore, $0.50 and $1.00 were used also as planning costs.

Additional costs are incurred through irrigation from handling

[1]Reported by members of the Soil Conservation Service in a meeting in Manhattan, May 5, 1958.

larger yields. These were estimated on a per inch basis, in relation to the size of the physical increment. It was assumed that irrigation would create the need for an additional cultivation. This cost was estimated at $1.00 per acre,[1] when distributed among 6 inches of irrigation, as the average rainfall is 3.5 inches in July; this amounts to $0.16 per inch. Additional harvesting and hauling costs were computed at $0.05 per bushel for each bushel of increment. Combining these two amounts gives the figure shown in column 4 of Table 6.

Table 6 shows the development of the total variable cost structure and cumulative variable cost with irrigation water costing $0.50 per acre inch. Only the cumulative variable costs are shown with water $0.31 and $1.00 per acre inch, as this cost would be computed in the same way with the exception of the different amount to be paid for water.

Tables 11, 12, 13, 14 (Appendix) show the gain available to be applied to the fixed costs with corn prices at the four given amounts per bushel, and water at the three given costs. The difference between the cumulative value of the increments and the cumulative variable costs gives the gain from irrigation. With rainfall a given amount, the effects of adding a certain amount of irrigation water can be determined.

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[1]C. F. Bortfeld, M. J. Friesen, J. A. Hodges, 1952-53 Custom Rates for Farm Operations in Eastern Kansas, Kansas State Agricultural Economics Report No. 58, p. 20.

Table 6. Variable costs for irrigation with water costing $0.31, $0.50, and $1.00 per acre inch applied in 3-inch increments for the Marais des Cygnes Valley, Kansas.

Water, inches	Variable costs: Cost of applying	Variable costs: Water per acre	Variable costs: Additional harv., cul., haul. costs	Water $0.50: Total variable	Water $0.50: Cumulative variable	Water $0.31: Cumulative variable	Water $1.00: Cumulative variable
1	.95	.50	.50	1.95	1.95	1.76	2.45
2		.50	.40	.90	2.85	2.47	3.85
3		.50	.32	.82	3.67	3.10	5.17
4	.95	.50	.29	1.74	5.41	4.65	7.41
5		.50	.27	.77	6.18	5.23	8.68
6		.50	.26	.76	6.94	5.80	9.94
7	.95	.50	.25	1.70	8.64	7.31	12.14
8		.50	.24	.74	9.38	7.86	13.38
9		.50	.23	.73	10.11	8.40	14.61
10	.95	.50	.23	1.68	11.79	9.89	16.79

Net Returns from Irrigating Corn During the 30 Year Period

The actual rainfall received in each of the 30 years of the period was examined, the amount of additional water needed in each of these years to maximize returns was determined, and the gains in each year were compiled in Tables 15 through 20, Columns 6, 7, and 8 in the Appendix. Examples will be cited to illustrate how these gains were derived, when different amounts of rainfall were received in July. The rainfall amounts were rounded to the nearest inch. For illustrative purposes, \$1.00 per bushel for corn and \$0.50 per acre inch for water will be used (Table 12, Column 9, and Table 16, Column 7), but the same principles were applied to all of the price combinations.

When no rainfall was received, as in July 1936, the irrigator would apply 9 inches of water, and the net gain of \$16.29 was read directly from Table 12, Column 9, Line 9. When 9 or more inches of rainfall was received, irrigation would not be profitable.

When the amount of rainfall received was an even increment of 3 or 6 inches the net gain would be obtained by subtracting the amount of gain at the even increment from the greatest net gain of additional even increments. For example, 3 inches of rainfall in July 1925 would have given a net gain of \$11.33 per acre. It would have been most profitable to add 6 or more inches of water, the corn would have received 9 inches of water altogether, or a gain of \$16.29. However, the actual net gain from irrigation to be applied against fixed costs would be the difference in the two amounts, or \$4.96 (Table 16, Column 7, Line 1).

When rainfall was not on one of the even increment amounts, additional steps were necessary for calculation. To illustrate: July rainfall in 1929 was 4 inches; 6 inches would remain the optimum amount to apply. However, the net gain can no longer be computed by subtracting the respective gains, due to the 3-inch increment cost changes. The net gain can be determined by subtracting the cumulative value of $17.60 at 4 inches from the cumulative value of $27.80 for 10 inches, amounting to $10.20. The cumulative variable costs must be recomputed by use of Variable Cost, Table 6. Beginning at the particular rainfall amount, 4 inches in this case, the cumulative variable cost of $5.41 for 4 inches was deducted from $11.79, the variable cost of 10 inches, giving the cost of adding 6 inches of water of $6.38. The difference between $10.20 and $6.38 of $3.82 appears as the net gain to be applied against fixed costs in Table 16, Column 7, Line 5. The 30 year total gave the gain per acre for the period. A net gain from irrigation was determined by subtracting the total fixed costs from total gains for the period 1925 to 1954. The difference was divided by 30 years to obtain the average net gain per acre per year.

A summary of the net gains (or losses) per acre per year which might be anticipated from irrigation of corn at each of the given prices is given in Table 7.

It would be necessary for corn to be priced at $1.00 per bushel or more, and irrigation water $0.50 per acre inch or less before irrigation would be considered profitable on the basis of marginal analysis. The net gain would be so near the margin at $1.00 per bushel that the average farmer probably would not consider irrigation in the area unless his long run price expectations for corn were around $1.25 per bushel, or unless water charges were anticipated to be appreciably less than $0.50 per acre inch. With corn priced at $1.25 per bushel and water costing $0.50 per acre inch, farmers could expect an average net gain of $3.23 per acre. With corn priced at $1.50 per bushel, irrigators could pay $1.00 per acre inch for water and still anticipate an average net return of $3.20 per acre.

Table 7. Summary of net gain (or loss) per acre per year from irrigation of corn in Franklin County, Kansas.[1]

Price of corn	Net gain under irrigation with water		
	$0.31 per A./in.	$0.50 per A./in.	$1.00 per A./in.
$0.75	-1.30	-2.24	-3.85
1.00	1.53	.53	-1.87
1.25	4.24	3.23	.58
1.50	6.95	5.94	3.20

[1]Tables 15, 16, 17, 18, Columns 6, 7, 8, Line 35.

Risk Consideration

Many farm operators are aware of uncertainty of prices and yields due to many uncontrollable factors. As mentioned in the review of economic theory, a risk factor may be included in the costs to make the marginal analysis more realistic. It was assumed that a 25 percent risk factor, taken as a reduction in the value of the marginal product at a given price, could account for price or yield uncertainty. The 25 percent figure was arbitrarily selected, as the exact figure to use is unknown, but the fact that farmers discount future returns is recognized. The summary in Table 8 shows the net gains or losses from irrigation after the risk factor has been deducted.

Table 8. Summary of net gain (or loss) per acre per year less risk from irrigation of corn in Franklin County, Kansas.[1]

	Net gain less risk with water		
Price of corn	$0.31 per A./in.	$0.50 per A./in.	$1.00 per A./in.
$1.00	-1.30	-2.24	-3.85
1.25	1.02	.28	-2.55
1.50	2.98	1.47	- .91

[1]Tables 16, 19, 20, Columns 6, 7, 8, Line 35.

With risk taken into consideration it would be necessary for corn to be priced at $1.25 per bushel or more and irrigation water not much more than $0.50 per acre inch, to realize a gain. With corn at $1.50 per bushel and water $0.50 per acre inch, a net gain of $1.47 per acre would be realized.

These results might be expected by the average farmer in the Marais des Cygnes Valley. The above-average farmer would adopt various methods and techniques which would reduce costs or increase yields and might eliminate some of the risk and thus obtain an even higher level of net gains. The good irrigation manager would soon learn the proper techniques, amounts, and timing of water application. A few years of irrigating experience in the area would result in selection of crops most responsive to water, proper rotations, and proper fertilizer application. Full utilization of the 180 day growing season with possible double cropping and off season irrigation would express good management. Combinations of these possibilities would enhance the chances of the farmer profitably operating above the designated levels for average farmers.

Optimum Water Application During the 30 Year Period

A summary of the amounts of water which would be applied from the third, fourth, and fifth columns of Tables 15, 16, 17, 18 is given in Table 9. The third major hypothesis was tested by examination of this summary. In 23 of the 30 years, or 77 percent of the time, irrigators could have profitably applied 6 or more inches of water, within the range of prices for corn and water, with the exception of $0.75 a bushel for corn and $1.00 per acre inch of water. The optimum amounts for the period, with the one exception mentioned above, show that to maximize returns during the 30 years the average farmer would have applied no water in 4 years, 3 inches in each of 3 years, 6 inches in each of 19 years, and 9 inches in each of 4 years, with all the remaining combinations of prices.

When the risk factor was deducted from the gain from irrigation, the only basic differences in the amounts of application were when water costs were $1.00 per acre inch, and corn $1.00 or $1.25 per bushel (Table 10). In these cases, farmers maximizing returns would have applied no water in 7 years, 3 inches in 19 years, and 6 inches in 4 years. With water at $0.31 and $0.50 per acre inch and corn $1.00, $1.25, or $1.50 per bushel, irrigators could have profitably applied 6 or more inches of water in 23 out of 30 years.

Table 9. Number of years specified amounts of water would have been applied.

Price of corn per bushel	Cost of water per acre inch	Inches			
		0	3	6	9
.75	.31	4	3	19	4
.75	.50	4	3	19	4
.75	1.00	7	19	4	0
1.00	.31	4	3	19	4
1.00	.50	4	3	19	4
1.00	1.00	4	3	19	4
1.25	.31	4	3	19	4
1.25	.50	4	3	19	4
1.25	1.00	4	3	19	4
1.50	.31	4	3	19	4
1.50	.50	4	3	19	4
1.50	1.00	4	3	19	4

Table 10. Number of years specified amounts of water would have been applied (risk considered).

Price of corn per bushel	Cost of water per acre inch	Inches 0	3	6	9
1.00	.31	4	3	19	4
1.00	.50	4	3	19	4
1.00	1.00	7	19	4	0
1.25	.31	4	3	20	3
1.25	.50	4	3	20	3
1.25	1.00	7	20	3	0
1.50	.31	4	3	19	4
1.50	.50	4	3	19	4
1.50	1.00	4	3	19	4

SUMMARY AND CONCLUSIONS

More empirical research is needed in the Marais des Cygnes Valley, particularly in: (1) actual data of crop response to irrigation water and fertilizer, and (2) costs of establishing and operating an irrigation enterprise in the region.

This research should not be limited to corn alone, but should include major and possible special crops adapted to the area, which are significantly responsive to water. This study showed that additional water in August and in June had relatively less influence than July rainfall or irrigation water on corn. Further research might reveal that certain other crops, such as alfalfa, would benefit equally well throughout the growing season, and thus farmers with proper management and rotations could effectively utilize water throughout the season at a given price.

Individual farmers combining their experience with recommended irrigation procedures might expect to reach higher levels of production than shown in this study. The importance of this study was not based on determining the amounts of corn which might be produced per acre under irrigation, but rather deriving a method to determine what given amounts of additional water would mean in additional bushels of corn. Higher yields of corn probably would not appreciably increase the amount of the increments. The marginal analysis tables of net gains from irrigation and net gains with risk deducted can serve the farmer as a planning guide, and aid in managerial decisions relative to irrigation. Flexibility of corn and water prices will enable the farmer to select the prices which will most nearly fit his individual situation.

If the farm operator has made the decision to establish irrigation, or this decision has been made for him by society through a compulsory irrigation district, the problem then becomes one of following basic irrigation economic principles. This study has shown the net returns which might be expected from the irrigation of corn. The allocation of the irrigation water in an efficient manner in order to equalize the marginal returns of the various competing crops should be the economic goal of the irrigation farmer.

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A P P E N D I X

Table 11. Net gain per acre from irrigation with corn $0.75 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas.

Water (inches)	Physical increments, bushels	Value of increments, dollars	Cumulative value of increments, dollars	Cumulative variable cost with water at $0.31	$0.50	$1.00	Net gain[1] with water at $0.31	$0.50	$1.00
1	6.9	$5.18	$5.18	$1.76	$1.95	$2.45	$3.42	$3.23	$2.73
2	4.8	3.60	8.78	2.47	2.85	3.85	6.31	5.93	4.93
3	3.3	2.48	11.26	3.10	3.67	5.17	8.16	7.59	6.09
4	2.6	1.95	13.21	4.65	5.41	7.41	8.56	7.80	5.80
5	2.2	1.65	14.86	5.23	6.18	8.68	9.63	8.68	6.18
6	1.9	1.42	16.28	5.80	6.94	9.94	10.48	9.34	6.34
7	1.8	1.35	17.63	7.31	8.64	12.14	10.32	8.99	5.49
8	1.5	1.12	18.75	7.86	9.38	13.38	10.89	9.37	5.37
9	1.4	1.05	19.80	8.40	10.11	14.61	11.40	9.69	5.19
10	1.4	1.05	20.85	9.89	11.79	16.79	10.96	9.06	4.06
			Net Gain Less Risk[2]						
1	6.9	3.88	3.88	1.76	1.95	2.45	2.12	1.93	1.43
2	4.8	2.70	6.58	2.47	2.85	3.85	4.11	3.73	2.73
3	3.3	1.86	8.44	3.10	3.67	5.17	5.34	4.77	3.27
4	2.6	1.46	9.90	4.65	5.41	7.41	5.25	4.49	2.49
5	2.2	1.24	11.14	5.23	6.18	8.68	5.91	4.96	2.46
6	1.9	1.06	12.20	5.80	6.94	9.94	6.40	5.26	2.26
7	1.8	1.01	13.21	7.31	8.64	12.14	5.90	4.57	1.07
8	1.5	.84	14.05	7.86	9.38	13.38	6.19	4.67	.67
9	1.4	.79	14.84	8.40	10.11	14.61	6.44	4.73	.23
10	1.4	.79	15.65	9.89	11.79	16.79	5.76	3.86	-.14

[1]Above variable costs.

[2]The values of the increments were reduced by 25 percent.

Table 12. Net gain per acre from irrigation with corn $1.00 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas.

Water (inches)	Physical increments, bushels	Value of increments, dollars	Cumulative value of increments, dollars	Cumulative variable cost with water at $0.31	$0.50	$1.00	Net gain[1] with water at $0.31	$0.50	$1.00
1	6.9	$6.90	$ 6.90	$1.76	$1.95	$2.45	$5.14	$4.95	$4.45
2	4.8	4.80	11.70	2.47	2.85	3.85	9.23	8.85	7.85
3	3.3	3.30	15.00	3.10	3.67	5.17	11.90	11.33	9.83
4	2.6	2.60	17.60	4.65	5.41	7.41	12.95	12.19	10.19
5	2.2	2.20	19.80	5.23	6.18	8.68	14.57	13.62	11.12
6	1.9	1.90	21.70	5.80	6.94	9.94	15.90	14.76	11.76
7	1.8	1.80	23.50	7.31	8.64	12.14	16.19	14.86	11.36
8	1.5	1.50	25.00	7.86	9.38	13.38	17.14	15.62	11.62
9	1.4	1.40	26.40	8.40	10.11	14.61	18.00	16.29	11.79
10	1.4	1.40	27.80	9.89	11.79	16.79	17.91	16.01	11.01
			Net Gain Less Risk[2]						
1	6.9	5.18	5.18	1.76	1.95	2.45	3.42	3.23	2.73
2	4.8	3.60	8.78	2.47	2.85	3.85	6.31	5.93	5.43
3	3.3	2.48	11.26	3.10	3.67	5.17	8.16	7.59	6.09
4	2.6	1.95	13.21	4.65	5.41	7.41	8.56	7.80	5.80
5	2.2	1.65	14.86	5.23	6.18	8.68	9.63	8.68	6.18
6	1.9	1.42	16.28	5.80	6.94	9.94	10.48	9.34	6.34
7	1.8	1.35	17.63	7.31	8.64	12.14	10.32	8.99	5.49
8	1.5	1.12	18.75	7.86	9.38	13.38	10.89	9.37	5.37
9	1.4	1.05	19.80	8.40	10.11	14.61	11.40	9.69	5.19
10	1.4	1.05	20.85	9.89	11.79	16.79	10.96	9.06	4.06

[1] Above variable costs.

[2] The values of the increments were reduced by 25 percent.

Table 13. Net gain per acre from irrigation with corn $1.25 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas.

Water (inches)	Physical increments, bushels	Value of increments, dollars	Cumulative value of increments, dollars	Cumulative variable cost with water at $0.31	$0.50	$1.00	Net gain[1] with water at $0.31	$0.50	$1.00
1	6.9	$8.62	$ 8.62	$1.76	$1.95	$2.45	$ 6.86	$6.67	$6.17
2	4.8	6.00	14.62	2.47	2.85	3.85	12.15	11.77	10.77
3	3.3	4.12	18.74	3.10	3.67	5.17	15.64	15.07	13.57
4	2.6	3.25	21.99	4.65	5.41	7.41	17.34	16.58	14.58
5	2.2	2.75	24.74	5.23	6.18	8.68	19.51	18.56	16.06
6	1.9	2.38	27.12	5.80	6.94	9.94	21.32	20.18	17.18
7	1.8	2.25	29.37	7.31	8.64	12.14	22.06	20.73	17.23
8	1.5	1.88	31.25	7.86	9.38	13.38	23.39	21.87	17.87
9	1.4	1.75	33.00	8.40	10.11	14.61	24.60	22.89	18.39
10	1.4	1.75	34.75	9.89	11.79	16.79	24.86	22.96	17.96
			Net Gain Less Risk[2]						
1	6.9	6.46	6.46	1.76	1.95	2.45	4.70	4.51	4.01
2	4.8	4.50	10.96	2.47	2.85	3.85	8.49	8.11	7.11
3	3.3	3.09	14.05	3.10	3.67	5.17	10.95	10.38	8.88
4	2.6	2.44	16.49	4.65	5.41	7.41	11.84	11.08	9.08
5	2.2	2.06	18.55	5.23	6.18	8.68	13.32	12.37	9.87
6	1.9	1.78	20.33	5.80	6.94	9.94	14.53	13.39	10.39
7	1.8	1.69	22.02	7.31	8.64	12.14	14.71	13.38	9.88
8	1.5	1.41	23.43	7.86	9.38	13.38	15.57	14.05	10.05
9	1.4	1.31	24.74	8.40	10.11	14.61	16.34	14.63	10.13
10	1.4	1.31	26.05	9.89	11.79	16.79	16.16	14.26	9.26

[1]Above variable costs.

[2]The values of the increments were reduced by 25 percent.

Table 14. Net gain per acre from irrigation with corn $1.50 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas

Water (inches)	Physical increments, bushels	Value of increments, dollars	Cumulative value of increments, dollars	Cumulative variable cost with water at $0.31	Cumulative variable cost with water at $0.50	Cumulative variable cost with water at $1.00	Net gain[1] with water at $0.31	Net gain[1] with water at $0.50	Net gain[1] with water at $1.00
1	6.9	$10.35	$10.35	$1.76	$1.95	$2.45	$ 8.59	$8.40	$7.90
2	4.8	7.20	17.55	2.47	2.85	3.85	15.08	14.70	13.70
3	3.3	4.95	22.50	3.10	3.67	5.17	19.40	18.83	17.33
4	2.6	3.90	26.40	4.65	5.41	7.41	21.75	20.99	18.99
5	2.2	3.30	29.70	5.23	6.18	8.68	24.47	23.52	21.02
6	1.9	2.85	32.55	5.80	6.94	9.94	26.75	25.61	22.61
7	1.8	2.70	35.25	7.31	8.64	12.14	27.94	26.61	23.11
8	1.5	2.25	37.50	7.86	9.38	13.38	29.64	28.12	24.12
9	1.4	2.10	39.60	8.40	10.11	14.61	31.20	29.49	24.99
10	1.4	2.10	41.70	9.89	11.79	16.79	31.81	28.91	24.91
			Net Gain Less Risk[2]						
1	6.9	7.76	7.76	1.76	1.95	2.45	6.00	5.81	5.31
2	4.8	5.40	13.16	2.47	2.85	3.85	10.69	10.31	9.31
3	3.3	3.71	16.87	3.10	3.67	5.17	13.77	13.20	11.70
4	2.6	2.92	19.79	4.65	5.41	7.41	15.14	14.38	12.38
5	2.2	2.48	22.27	5.23	6.18	8.68	17.04	16.09	13.59
6	1.9	2.14	24.41	5.80	6.94	9.94	18.61	17.47	14.47
7	1.8	2.02	26.43	7.31	8.64	12.14	19.12	17.79	14.29
8	1.5	1.69	28.12	7.86	9.38	13.38	20.26	18.74	14.74
9	1.4	1.58	29.70	8.40	10.11	14.61	21.30	19.59	15.09
10	1.4	1.58	31.28	9.89	11.79	16.79	21.39	19.49	14.49

[1]Above variable costs.

[2]The values of the increments were reduced by 25 percent.

Table 15. Net gain per acre from irrigation with corn $0.75 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas.[1]

Year	July rainfall, inches	Inches of water to be applied with water at: $0.31	$0.50	$1.00	Gain to be applied against fixed costs with water at: $0.31	$0.50	$1.00
1925	3	6	6	3	$3.24	$2.10	$0.25
1926	3	6	6	3	3.24	2.10	0.25
1927	6	3	3	0	0.48	0.35	--
1928	3	6	6	3	3.24	2.10	0.25
1929	4	6	6	3	2.40	1.34	0.24
1930	1	9	9	6	9.32	7.61	4.64
1931	4	6	6	3	2.40	1.34	0.24
1932	4	6	6	3	2.40	1.34	0.24
1933	4	6	6	3	2.40	1.34	0.24
1934	2	6	6	3	4.58	3.44	1.15
1935	2	6	6	3	4.58	3.44	1.15
1936	0	9	9	6	11.40	9.69	6.34
1937	2	6	6	3	4.58	3.44	1.15
1938	3	6	6	3	3.24	2.10	0.25
1939	2	6	6	3	4.58	3.44	1.15
1940	0	9	9	6	11.40	9.69	6.34
1941	4	6	6	3	2.40	1.34	0.24
1942	2	6	6	3	4.58	3.44	1.15
1943	2	6	6	3	4.58	3.44	1.15
1944	3	6	6	3	3.24	2.10	0.25
1945	6	3	3	0	0.48	0.35	--
1946	1	9	9	6	9.32	7.61	4.64
1947	2	6	6	3	3.24	2.10	0.25
1948	9	0	0	0	--	--	--
1949	10	0	0	0	--	--	--
1950	9	0	0	0	--	--	--
1951	14	0	0	0	--	--	--
1952	6	3	3	0	0.48	0.35	--
1953	3	6	6	3	3.24	2.10	0.25
1954	2	6	6	3	4.58	3.44	1.15
Totals		159	159	81	109.62	81.13	32.96
Fixed costs					148.50	148.50	148.50
Net gain per acre for period					-38.88	-67.37	-115.54
Average net gain per acre per year					-1.30	-2.24	-3.85

[1]This table would be applicable with corn $1.00 per bushel, less the 25 percent reduction for risk.

Table 16. Net gain per acre from irrigation with corn $1.00 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas, annually from 1925 to 1954.

Year	July rainfall, inches	Inches of water to be applied with water at: $0.31	$0.50	$1.00	Gain to be applied against fixed costs with water at: $0.31	$0.50	$1.00
1925	3	6	6	6	$6.10	$4.96	$1.96
1926	3	6	6	6	6.10	4.96	1.96
1927	6	3	3	3	2.10	1.53	0.03
1928	3	6	6	6	6.10	4.96	1.96
1929	4	6	6	6	4.96	3.82	2.32
1930	1	9	9	9	14.65	12.94	8.44
1931	4	6	6	6	4.96	3.82	2.32
1932	4	6	6	6	4.96	3.82	2.32
1933	4	6	6	6	4.96	3.82	2.32
1934	2	6	6	6	7.92	6.78	3.78
1935	2	6	6	6	7.92	6.78	3.78
1936	0	9	9	9	18.00	16.29	11.79
1937	2	6	6	6	7.92	6.78	3.78
1938	3	6	6	6	6.10	4.96	1.96
1939	2	6	6	6	7.92	6.78	3.78
1940	0	9	9	9	18.00	16.29	11.79
1941	4	6	6	6	4.96	3.82	2.32
1942	2	6	6	6	7.92	6.78	3.78
1943	2	6	6	6	7.92	6.78	3.78
1944	3	6	6	6	6.10	4.96	1.96
1945	6	3	3	3	2.10	1.53	0.03
1946	1	9	9	9	14.65	12.94	8.44
1947	3	6	6	6	6.10	4.96	1.96
1948	9	0	0	0	--	--	--
1949	10	0	0	0	--	--	--
1950	9	0	0	0	--	--	--
1951	14	0	0	0	--	--	--
1952	6	3	3	3	2.10	1.53	0.03
1953	3	6	6	6	6.10	4.96	1.96
1954	2	6	6	6	7.92	6.78	3.78
Totals		159	159	159	194.54	164.33	92.33
Fixed costs					148.50	148.50	148.50
Net gain per acre for period					46.04	15.83	-56.17
Average net gain per acre per year					1.53	0.53	-1.87

Table 17. Net gain per acre from irrigation with corn $1.25 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas, annually from 1925 to 1954.

Year	July rainfall, inches	Inches of water to be applied with water at			Gain to be applied against fixed costs with water at		
		$0.31	$0.50	$1.00	$0.31	$0.50	$1.00
1925	3	6	6	6	$8.96	$7.82	$4.82
1926	3	6	6	6	8.96	7.82	4.82
1927	6	3	3	3	3.28	2.71	1.21
1928	3	6	6	6	8.96	7.82	4.82
1929	4	6	6	6	7.52	6.38	3.38
1930	1	9	9	9	18.31	16.60	12.10
1931	4	6	6	6	7.52	6.38	3.38
1932	4	6	6	6	7.52	6.38	3.38
1933	4	6	6	6	7.52	6.38	3.38
1934	2	6	6	6	11.39	10.25	7.25
1935	2	6	6	6	11.39	10.25	7.25
1936	0	9	9	9	24.60	22.89	18.39
1937	2	6	6	6	11.39	10.25	7.25
1938	3	6	6	6	8.96	7.82	4.82
1939	2	6	6	6	11.39	10.25	7.25
1940	0	9	9	9	24.60	22.89	18.39
1941	4	6	6	6	7.52	6.38	3.38
1942	2	6	6	6	11.39	10.25	7.25
1943	2	6	6	6	11.39	10.25	7.25
1944	3	6	6	6	8.96	7.82	4.82
1945	6	3	3	3	3.38	2.71	1.21
1946	1	9	9	9	18.31	16.60	12.10
1947	3	6	6	6	8.96	7.82	4.82
1948	9	0	0	0	--	--	--
1949	10	0	0	0	--	--	--
1950	9	0	0	0	--	--	--
1951	14	0	0	0	--	--	--
1952	6	3	3	3	3.28	2.71	1.21
1953	3	6	6	6	8.96	7.82	4.82
1954	2	6	6	6	11.39	10.25	7.25
Totals	117	159	159	159	275.71	245.50	166.00
Fixed costs					148.50	148.50	148.50
Net gaim per acre for period					127.21	97.00	17.50
Average net gain per acre per year					4.24	3.23	0.58

Table 18. Net gain per acre from irrigation with corn $1.50 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas, annually from 1925 to 1954.

Year	July rainfall, inches	Inches of water to be applied with water at $0.31	$0.50	$1.00	Gain to be applied against fixed costs with water at $0.31	$0.50	$1.00
1925	3	6	6	6	$11.80	$10.66	$7.26
1926	3	6	6	6	11.80	10.66	7.26
1927	6	3	3	3	4.45	3.88	2.38
1928	3	6	6	6	11.80	10.66	7.26
1929	4	6	6	6	10.06	8.92	5.92
1930	1	9	9	9	23.22	21.51	17.01
1931	4	6	6	6	10.06	8.92	5.92
1932	4	6	6	6	10.06	8.92	5.92
1933	4	6	6	6	10.06	8.92	5.92
1934	2	6	6	6	14.56	13.42	10.42
1935	2	6	6	6	14.56	13.42	10.42
1936	0	9	9	9	31.20	29.49	24.99
1937	2	6	6	6	14.56	13.42	10.42
1938	3	6	6	6	11.80	10.66	7.26
1939	2	6	6	6	14.56	13.42	10.42
1940	0	9	9	9	31.20	29.49	24.99
1941	4	6	6	6	10.06	8.92	5.92
1942	2	6	6	6	14.56	13.42	10.42
1943	2	6	6	6	14.56	13.42	10.42
1944	3	6	6	6	11.80	10.66	7.26
1945	6	3	3	3	4.45	3.88	2.38
1946	1	9	9	9	23.22	21.51	17.01
1947	3	6	6	6	11.80	10.66	7.26
1948	9	0	0	0	---	---	--
1949	10	0	0	0	---	---	--
1950	9	0	0	0	---	---	--
1951	14	0	0	0	---	---	--
1952	6	3	3	3	4.45	3.88	2.38
1953	3	6	6	6	11.80	10.66	7.26
1954	2	6	6	6	14.56	13.42	10.42
Totals		159	159	159	357.01	326.80	244.50
Fixed costs					148.50	148.50	148.50
Net gain per acre for period					208.51	178.30	96.00
Average net gain per acre per year					6.95	5.94	3.20

Table 19. Net gain per acre from irrigation with corn $1.25 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas, annually from 1925 to 1954 less risk.

Year	July rainfall, inches	Inches of water to be applied with water at $0.31	$0.50	$1.00	Gain to be applied against fixed costs with water at $0.31	$0.50	$1.00
1925	3	6	6	3	$5.39	$4.25	$1.51
1926	3	6	6	3	5.39	4.25	1.51
1927	6	3	3	0	3.58	3.01	--
1928	4	6	6	3	5.39	4.25	1.51
1929	4	6	6	3	4.32	3.18	0.70
1930	1	9	9	6	13.34	12.20	8.97
1931	4	6	6	3	4.32	3.18	0.70
1932	4	6	6	3	4.32	3.18	0.70
1933	4	6	6	3	4.35	3.18	0.70
1934	2	6	6	3	7.08	6.94	2.76
1935	2	6	6	3	7.08	6.94	2.76
1936	0	9	9	6	16.34	14.63	10.39
1937	2	6	6	3	7.08	6.94	2.76
1938	3	6	6	3	5.39	4.25	1.51
1939	2	6	6	3	7.08	6.94	2.76
1940	0	9	9	6	16.34	14.63	10.39
1941	4	6	6	3	4.35	3.18	0.70
1942	2	6	6	3	7.08	6.94	2.76
1943	2	6	6	3	7.08	6.94	2.76
1944	3	6	6	3	5.39	4.25	1.51
1945	6	3	3	0	3.58	3.01	--
1946	1	6	6	3	13.34	12.20	8.97
1947	3	6	6	3	5.39	4.25	1.51
1948	9	0	0	0	--	--	--
1949	10	0	0	0	--	--	--
1950	9	0	0	0	--	--	--
1951	14	0	0	0	--	--	--
1952	6	3	3	0	3.58	3.01	--
1953	3	6	6	3	5.39	4.25	1.51
1954	2	6	6	3	7.08	6.94	2.76
Totals	117	156	156	78	179.05	156.92	72.11
Fixed costs					148.50	148.50	148.50
Net gain per acre for period					30.55	8.42	-76.39
Average net gain per acre per year					1.02	0.28	-2.55

Table 20. Net gain per acre from irrigation with corn $1.50 per bushel and water $0.31, $0.50, and $1.00 per acre inch in Franklin County, Kansas, annually from 1925 to 1954 less risk.

Year	July rainfall, inches	Inches of water to be applied with water at $0.31	$0.50	$1.00	Gain to be applied against fixed costs with water at $0.31	$0.50	$1.00
1925	3	6	6	6	$8.53	$6.39	$3.39
1926	3	6	6	6	8.53	6.39	3.39
1927	6	3	3	3	2.69	2.12	0.62
1928	3	6	6	6	8.53	6.39	3.39
1929	4	6	6	6	5.93	4.79	1.79
1930	1	9	9	9	15.38	13.69	9.17
1931	4	6	6	6	5.93	4.79	1.79
1932	4	6	6	6	5.93	4.79	1.79
1933	4	6	6	6	5.93	4.79	1.79
1934	2	6	6	6	9.57	8.43	5.43
1935	2	6	6	6	9.57	8.43	5.43
1936	0	9	9	9	21.30	19.59	15.09
1937	2	6	6	6	9.57	8.43	5.43
1938	3	6	6	6	8.53	6.39	3.39
1939	2	6	6	6	9.57	8.43	5.43
1940	0	9	9	9	21.30	19.59	15.09
1941	4	6	6	6	5.93	4.79	1.79
1942	2	6	6	6	9.57	8.43	5.43
1943	2	6	6	6	9.57	8.43	5.43
1944	3	6	6	6	8.53	6.39	3.39
1945	6	3	3	3	2.69	2.12	0.62
1946	1	9	9	9	15.38	13.67	9.17
1947	3	6	6	6	8.53	6.39	3.39
1948	9	0	0	0	--	--	--
1949	10	0	0	0	--	--	--
1950	9	0	0	0	--	--	--
1951	14	0	0	0	--	--	--
1952	6	3	3	3	2.69	2.12	0.62
1953	3	6	6	6	8.53	6.39	3.39
1954	2	6	6	6	9.57	8.43	5.43
Totals	117	159	159	159	237.78	192.57	121.07
Fixed costs					148.50	148.50	148.50
Net gain per acre for period					89.28	44.07	-27.43
Average net gain per acre per year					2.98	1.47	-0.91

A STUDY OF THE ECONOMIC FEASIBILITY OF IRRIGATION OF CORN IN THE MARAIS DES CYGNES VALLEY, KANSAS

by

JACK DEAN EDWARDS

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The purpose of this thesis was to examine the economic feasibility of establishing and operating irrigation enterprises for corn in the Marais des Cygnes Valley of eastern Kansas. Two basic problems had to be considered before prospective irrigators would have information to aid their decision making. This required: (1) the determination of the quantity of water (precipitation or irrigation) which maximizes net returns and (2) the determination of the quantity of irrigation water which would be applied during a historical period of years and the resulting net returns from irrigation.

Franklin County was used to represent the Marais des Cygnes Valley. Precipitation and average county yield data were gathered for a 30 year period, 1925 through 1954. Average county yields were adjusted upwards to obtain average bottomland yields, as irrigation in this area was assumed to be on the bottomland.

Linear and curvilinear production functions correlating June, July, and August rainfall and yield data showed that only in July differences in precipitation had significant effects on corn yields. Consequently, the main concern of the study was to determine the economic feasibility of irrigation in July. The Cobb-Douglas production function showing diminishing returns was used for imputing the increments which would result with each additional inch of water. The values of the marginal products were obtained by multiplying the physical increments by the price for corn.

A schedule of fixed and variable costs and tables giving the net returns at the various price-cost combinations were developed. The amount of additional water needed to maximize returns in each of the years 1925 to 1954 was determined on the basis of actual rainfall received. The net gain above variable costs from irrigation in each of the years of the period was compiled, total fixed costs were deducted, and the average net gain per acre year was determined. Four prices were assumed for corn: $0.75, $1.00, $1.25, and $1.50 per bushel, and three prices for water delivered to the farm: $0.31, $0.50, and $1.00 per acre inch. The prices of other items were not varied.

This study found that it would be necessary for corn to be priced at $1.00 or more per bushel and irrigation water at $0.50 or less per acre inch before irrigation would be profitable for the average farmer in the Marais des Cygnes Valley on the basis of marginal analysis. The net gain would be so near the margin at $1.00 per bushel that the average farmer probably would not consider irrigation unless his expectations were for a higher corn price or a lower water cost. With an amount deducted for risk, it would be necessary for corn to be priced at $1.25 or more per bushel and water not much more than $0.50 per acre inch to realize a gain.

The 30 year analysis also showed that in 23 of the years the irrigators could have profitably applied 6 or more inches of water in July at all ranges of prices for corn and water, with one exception. With corn at $0.75 a bushel and water at $1.00 per acre inch, only 3 inches would be applied.

The extension of irrigation into the more humid regions of Kansas and the United States suggests the need for continued research in all phases of irrigation economics. This thesis suggests the need for gathering further empirical data in three areas: (1) actual corn response to irrigation water and fertilizer, (2) fixed and variable costs encountered, and (3) consideration of other major crop responses and profitableness under irrigation.