

TECHNICAL INFORMATION SERIES  
August 1976 Number 5

# IRRIGATION IN IOWA

Part I: The Question of Water Availability

by

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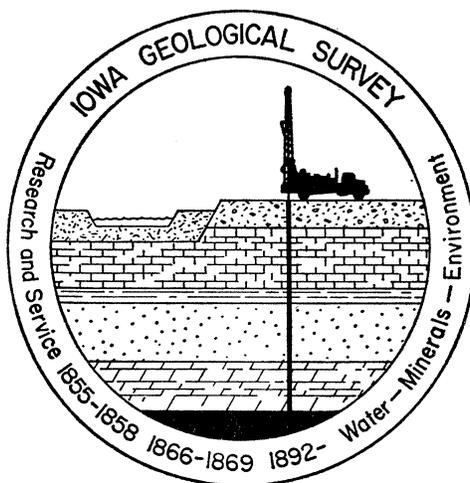
and

PAUL J. HORICK

Part II: An Overview of the Needs,  
the Costs, the Problems

Compiled by

GEORGE R. HALLBERG



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IRRIGATION IN IOWA  
PART I: THE QUESTION OF  
WATER AVAILABILITY

BY  
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AND  
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## THE QUESTION OF WATER AVAILABILITY

Although irrigation presently does not significantly affect Iowa's total agricultural base or total water use, the potential impact of expanded irrigation on the economy and on the water budget is high, at least at the local level. The increase in the number of acres irrigated since 1949, along with the consumptive use of water, and a projection to the year 2000 is as follows:

<u>Year</u>	<u>Authorized number of permits</u>	<u>Acres irrigated</u>	<u>Acre-feet of water used or authorized</u>
1949		7,500	
1956		27,000	
1969	649	93,200	99,300
1976	837	131,300	146,000
1977	1,150?	185,000?	225,000?
2000	7,000?	1,300,000?	1,425,000?

The figures projected for 1977 may be too low, and the figures for the year 2000 may be too high. Much will depend upon 1976 crop yields and demonstration of the economic feasibility of irrigation, now and over the next several years. The projected figures may be realistic if irrigation is relied upon as a method to reduce year-to-year variations in crop yields.

Historically, by far the greatest use of water for irrigation has been in western Iowa, especially on the bottomlands of the Missouri River. During the last three years, applications for

irrigation permits received by the Iowa Natural Resources Council for upland sites in west-central and northwestern Iowa have increased markedly. More recently, permits have been approved for sites in north-central Iowa, and permit authorization is pending at a few sites as far east as Winneshiek County.

Authorized withdrawal of water for irrigation during the 1976 growing season amounts to only about 4% of Iowa's total water use. In reality, a large volume of this water is unused. Actual consumption often is less than authorized withdrawals, and many farmers who are considering irrigation have obtained water permits for later beneficial use.

Nevertheless, the present consumption for irrigation does present potential conflicts in water use. The overriding element here is the question of water availability. Few problems are anticipated for the Missouri bottomlands region where tremendous volumes of water are available from thick alluvial sand and gravel aquifers. Even some reaches of Iowa's interior streams contain highly productive sand and gravel aquifers that will support at least moderate withdrawals for irrigation. It is the upland areas, distant from alluvial aquifer sources, that present the greatest number of problems which require resolution. Are adequate ground-water resources readily available in these areas to provide for multiple beneficial use that includes large withdrawals for irrigation? The answer is an unequivocal no for some of these areas, such as much of south-central, southwestern, and northwestern Iowa where it often is difficult to develop water supplies that are sufficient for domestic and livestock

use, much less for irrigation supplies. Where irrigation permits have been issued for upland sites, extant data usually is inadequate to predict the long term effects of mining ground water, especially from some artesian aquifers where recharge to the ground-water system is exceedingly slow. Interference problems between wells are likely to result from overpumping.

As part of the Iowa Water Resources Framework Study for development of a comprehensive State Water Plan, the task force on water resources availability is compiling information on water availability and water quality. The report of this task force also will include a discussion of future development alternatives for management of the state's water resources. Although the report will be extremely comprehensive, it can include only the best possible summary of what presently is known about the state's aquifers. Pertinent questions that can be answered only through geohydrologic research in critical areas include:

1. What water yields can be developed at specific sites?
2. What are the finite characteristics of the aquifer(s) in question?
3. How much can the hydraulic pressure(s) be lowered without seriously affecting sustained yields?
4. What is the natural rate of recharge to the aquifers?
5. How much ground-water mining can take place, or can be permitted before management regulations must be imposed?
6. What parameters of water quality might adversely affect soil conditions or plant growth?

Drought prone northwestern Iowa is one area where all of the above questions are applicable. Some stream irrigators have not renewed their irrigation permits because the protected flow of

streams does not allow them to take water from streams during droughts, which is precisely the period they most need the water. Many irrigators are turning to wells, or a combination of wells and streams to obtain the large quantities of water needed. How much water is available from wells completed in the alluvial aquifers of northwestern Iowa? Sustained yields of 100 to 500 gallons per minute (gpm) have been developed from alluvial aquifers in the lower reaches of major streams. Yields of 100 gpm or less are typical of alluvial aquifers in the upper reaches. There are local exceptions where, because of unusually favorable conditions and specially designed wells, several hundred gallons per minute can be obtained in the upper reaches. For example, the town of Sheldon has a horizontal collector well that has yielded 300 gpm, while vertical gravel-pack wells have produced 200 gpm or more at Hawarden and Rock Valley in the Big Sioux and Rock River systems respectively; at Merville, Correctionville, and Spencer in the Little Sioux River system; at Battle Creek and Ida Grove in the Maple River system; and at Denison and Wall Lake in the Boyer River system. Additional geohydrological data must be obtained to assess the impact of increased withdrawals for irrigation.

The Dakota Sandstone is the only other potential aquifer of northwestern Iowa for developing irrigation supplies, at least at comparatively shallow depths. But less substantive information is available for this aquifer than for any other aquifer in Iowa. The stratigraphy is poorly understood and hydrologic data is insufficient for predicting either the short or long term effects of heavy pumping. The Dakota Sandstone has yielded as much as 200 to 750 gpm to a few municipal wells in Osceola, O'Brien,

Sioux and Cherokee Counties. The sandstone is fine grained and poorly cemented which can result in sand-pumping problems when wells are pumped at high rates. In addition, water from the Dakota aquifer in parts of northwestern Iowa has such a high concentration of dissolved solids it may be objectionable for its effects on crops and soils.

This brief overview of water resources and associated problems has been limited intentionally to northwestern Iowa. This is where the question of water availability is most intense, and where geohydrologic research efforts must be concentrated first. The Iowa and U.S. Geological Surveys have developed preliminary plans to investigate the availability of water from the alluvial aquifers in northwestern Iowa. This study will include an inventory of present water withdrawals for municipal, irrigation, and domestic use, geophysical exploration for thick alluvial sand and gravel deposits, and drilling and aquifer testing. The first study area is along the Floyd River between Hinton and LeMars. Contingent upon the allocation of funds, the Dakota Sandstone aquifer is the next target for geohydrologic research.

The pattern of drought in recent years, higher crop and land prices, and improved technology in automatic sprinkler systems have exerted strong pressures for expansion of irrigation in Iowa. Questions on climatic trends, climatic predictions, costs and benefits of irrigation, ground water contamination, soil erosion, and energy demands are addressed in Part II.



IRRIGATION IN IOWA

PART II: AN OVERVIEW OF THE NEEDS,  
THE COSTS, THE PROBLEMS

COMPILED BY

GEORGE R. HALLBERG



NOTE

Shortly after the completion of the main portion of this report some additional pertinent data became available. This material will help to further illustrate some of the issues discussed, and has been added as an addendum. The contents are shown below.

	Page
VIII. ADDENDUM. . . . .	51
II.B.-Add. <u>Microclimate--Soils</u> . . . . .	51
III.A.-Add. <u>Yield Data</u> . . . . .	51

Table

6. Harvested corn yields in Burt County, Nebraska, 1970-1974. . . . .	54
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Figure

11. Percentage of "coarse" textured soils of low water-holding capacity by county. . . . .	52
12. Irrigated and unirrigated yield trends from central Iowa, 1956-1961; for portions of Nebraska, 1970-1974. . . . .	53
13. Corn yield trends; added costs and added profits or losses from irrigation. . . . .	55



## Table of Contents

	Page
LIST OF TABLES . . . . .	ii
LIST OF FIGURES . . . . .	ii
Preface . . . . .	iv
I. INTRODUCTION . . . . .	1
II. THE NEED FOR IRRIGATION? . . . . .	3
A. <u>Climatic Trends</u> . . . . .	3
B. <u>Macroclimate in Iowa</u> . . . . .	6
C. <u>Microclimate--Soils</u> . . . . .	8
D. <u>Climatic Predictions?</u> . . . . .	10
III. COSTS AND BENEFITS? . . . . .	14
A. <u>Yield Data</u> . . . . .	14
B. <u>Economics</u> . . . . .	19
IV. PROBLEMS? . . . . .	26
A. <u>Water Use--Aquifer Depletion?</u> . . . . .	26
B. <u>Ground Water Contamination</u> . . . . .	30
C. <u>Soil Erosion</u> . . . . .	37
D. <u>Energy Demands</u> . . . . .	38
E. <u>Federal Policy vs. State Resources</u> . . . . .	38
V. RESEARCH NEEDS . . . . .	41
VI. SUMMARY AND CONCLUSIONS . . . . .	43
VII. REFERENCES CITED . . . . .	49

## LIST OF TABLES

Table	Page
1. Contributors to Review of Irrigation in Iowa.	v
2. State Average Corn Yields.	18
3. Initial Costs and Annual Fixed Costs for Various Irrigation Distribution Systems (from Eisenhauer and Fischbach, 1976).	20
4. Estimated Operating Costs and Total Costs per Acre for Irrigation with Various Systems (from Eisenhauer and Fischbach, 1976).	21
5. Yield increase (in bu/ac) necessary to pay for costs of irrigation for corn at \$2.50 and \$3.00/bu.	24

## LIST OF FIGURES

Figure	Page
1. Drought periods in Nebraska plotted against double sunspot cycle (after Thompson, 1973).	4
2. Temperature cycle plotted against double sunspot cycle (after Thompson, 1973).	4
3. Corn Belt corn yields 1891-1973 plotted against double sunspot cycle (data from L. M. Thompson and R. H. Shaw).	4
4. Normal annual precipitation (after Waite, 1969).	7
5. Normal crop season precipitation, April through September (after Waite, 1969).	7
6. Corn Belt corn yields 1891-1973 (modified from Thompson, 1975).	11
7. Maximum irrigated and nonirrigated corn yields on Colo silty clay loam, Ames, Iowa (after Beer, et al., 1967).	15

8. A. Relationships between the amount of water required and supplied and maximum corn yields obtained on Colo silty clay loam, Ames, Iowa (after Beer, et al., 1967). B. Shows added data on temperature and yield differences. 17
9. Average nitrate-nitrogen concentration and distribution in 6.1-m soil profiles of watershed 2, Treynor, Iowa (after Schuman, et al., 1975). 34
10. Average nitrate-nitrogen concentration and distribution in 6.1m soil profiles of watershed 1, Treynor, Iowa (after Schuman, et al., 1975). 35

## Preface

In the following discussion of irrigation in Iowa, I have attempted to summarize facts, figures, and opinions presented to I.G.S. by various experts. Most of these persons attended a meeting on the Iowa State University campus on 22 April 1976 to discuss these issues. Many have also aided with subsequent meetings and discussions, and by providing pertinent data. Although I have acted to compile this report, its substance is derived from all the contributing individuals named in Table 1. I have tried to faithfully represent their inputs and I thank them for their time and efforts in this task.

Respectfully submitted,  
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Table 1. Contributors to Review of Irrigation

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## I. INTRODUCTION

At the present time irrigation does not comprise a very significant part of Iowa's agricultural base or total water use. Figures compiled by Paul J. Horick from Iowa Natural Resources Council (I.N.R.C.) data show that as of early 1976 837 irrigation permits were in effect. This amounts to a total of 131,364 acres being irrigated--about 0.4% of the state. There is a total quantity of water permitted of about 146,000 acre-feet/year or 47.5 billion gallons/year. This only amounts to about 3.7% of Iowa's total water withdrawals per year. Considerably less than this amount is actually used.

Irrigation requests are grouped in three categories:

1. General Farm Crops--seed and feed corn, soybeans, wheat, alfalfa, milo, or sorghum	% of Permits 75
2. Specialty Crops--sugar beets, potatoes, onions, orchards, etc.	15
3. Golf Courses	10

Wells were listed as the source of supply for 60% of the water permitted, streams for 18%, reservoirs for 5.5%, and combinations of wells, reservoirs, and streams for 16.1% of the projects.

Beginning in late 1974 irrigation permit applications began being submitted at an ever-increasing rate. As of this time about 100 applications have been filed at I.N.R.C. that remain to be acted upon. It is estimated that perhaps as many as 250 permits will be applied for in 1976. This would amount approximately to 50,000 acres of land and about 65,000 acre-feet of

water per year. This is about 45% of the total previously allocated--an enormous increase for one year.

This sudden shift to the utilization of irrigation raises several pertinent questions: What is the real need for irrigation in Iowa? What are the long-term costs and benefits? What are the problems associated with irrigation? Is there water available? This report deals with the issues other than water availability. Iowa has not had much experience with irrigation, and much research conducted in other areas is not always pertinent to the Iowa situation. Consequently, there are more questions than available answers, and considerable research in Iowa will be necessary to answer these questions adequately.

However, to put the problem into perspective some comparisons can be made. If we extrapolate that irrigation will expand in Iowa at the present 1976-rate of 50,000 acres per year, by the year 2000, Iowans would be irrigating about 1.3 million acres of land. Even though it does not seem likely that this rate of expansion will continue, this still only amounts to about 3.5% of Iowa's land. For comparison, in 1976, Nebraska had about 1.3 million acres being irrigated by center-pivot systems alone (Splinter, 1976), with total irrigation in the realms of 5.0 to 5.5 million acres, with irrigation systems expanding by 1,000 to 2,000 units per year.

However, many states, like Nebraska, are experiencing serious problems because of irrigation. Hopefully, Iowa can learn from these experiences and work to avoid or cure these problems as irrigation expands.

## II. NEED FOR IRRIGATION?

The recent interest in irrigation in Iowa has been generated in part by the dry growing seasons of 1974 and 1975. These recent climatic factors, however, have been complicated by changes in our National Foreign Trade Policy. This policy has promoted a national agricultural policy aimed at putting all available land into its full production potential. Accompanying this policy change was the removal of certain soil conservation programs. These actions coupled with market and economic pressures and the decline of cattle populations in parts of Iowa, forced or at least pressured many acres of low productive droughty soils to be converted from hay crop or pastureland into row-crop production. High and rising production costs have made the maintenance of high yields imperative on all soils. These changes, coupled with the dry weather, enhanced the interest in irrigation potential.

### A. Climatic Trends

Discussion of the dry years of 1974-75 brings up the aspect of climatic trends. Much discussion has been devoted to the "20-year drought cycle," and the fact that the dry years of the 1970's were predicted by many people.

Figure 1 shows the relationship between sunspots and drought. The coincidence between these 20-22 year cyclic phenomena is striking. Figure 2 shows July-August temperature variability for this century plotted against the double sunspot cycle. The correlation is again remarkable. Warming trends occur after the peak of a minor cycle (below the zero sunspot line) until the peak of a major cycle (above the zero sunspot

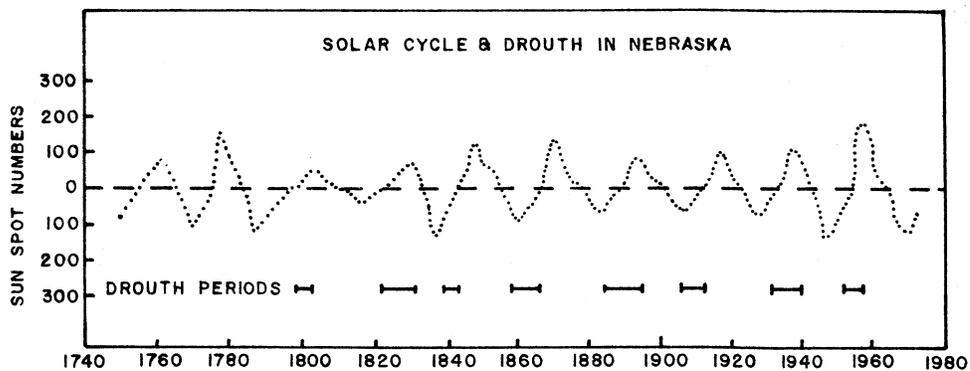


Figure 1. Drought periods in Nebraska plotted against double sunspot cycle (after Thompson, 1973).

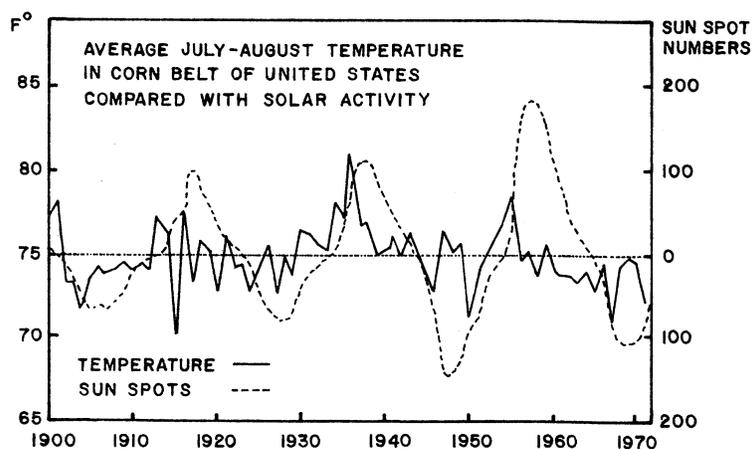


Figure 2. Temperature cycle plotted against double sunspot cycle (after Thompson, 1973).

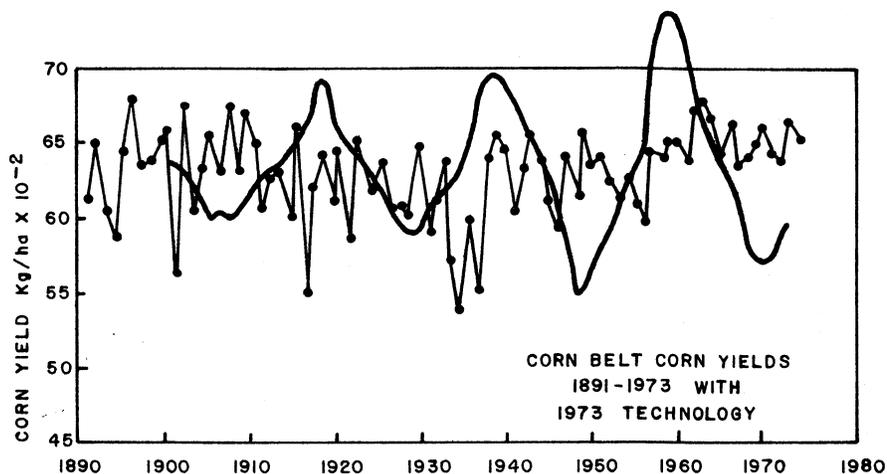


Figure 3. Corn Belt corn yields 1891-1973 plotted against double sunspot cycle (data from L. M. Thompson and R. H. Shaw).

line). Cooling trends occur after the peak of a major cycle until the peak of a minor cycle. Although the question of irrigation tends to focus on water, in comparing figures 1 and 2 one sees that hot July-August temperatures are coincident with the periods of severe and prolonged drought.

The correspondence between these weather and sunspot cycles may be coincidental. However, there is a growing feeling among scientists that there must be a causal relationship. Unfortunately, it is not possible to predict when a severe drought year will occur, because superimposed on these 20-year trends are year-to-year variability. There appears to be a 2-year cycle superimposed on the 20-year cycle (Thompson, 1973). Even though the trend is toward warmer summers, the next summer could be cooler than the previous one, and vice-versa. This is apparent in figure 2. Even with the year-to-year variability there is a definite long-term trend, lasting about ten years, and then reversing itself which is evident in figure 2.

Figure 3 gets to the heart of the issue, showing Corn Belt corn yields from 1891 to 1973, statistically standardized to 1973 level technology. Again, a relationship is evident, but in this case the curves have an inverse relation. In the portions of the sunspot curve where July-August temperatures rise (and where droughts occur) Corn Belt corn yields are reduced--often severely as in the 1930's. In the parts of the sunspot curve where July-August temperatures are reduced yields increase such as in the yield record setting years of the 1960's and early '70's.

This points out an important fact--that yields are dependent upon temperature as well as moisture. Work by Dr. Louis M. Thompson at Iowa State University has pointed out that optimal corn yields are associated with average June temperatures and below-average July and August temperatures. Average precipitation from September through June appear optimum for corn, but the highest yields are correlated with above-average rainfall in July (Thompson, 1969). Soybeans follow a similar pattern (Thompson, 1970). Temperature and precipitation combine with plant use and evapotranspiration to deplete or enrich the available soil moisture. These effects are somewhat independent, i.e., even with adequate rainfall, hot July and August temperatures will cause reductions in yield. When temperatures rise too high the plants are not physiologically capable to use the available moisture to its full capacity. Obviously, when hot and dry conditions occur together the effects are much more severe.

The timing of hot and dry weather is also critical. When these conditions occur at particular stages of plant development, such as at silking, the effects are more pronounced. This, in particular, is where supplemental irrigation can play an important role by maintaining sufficient soil moisture during critical periods.

#### B. Macroclimate in Iowa

Annual precipitation in Iowa varies from northwest to southeast, with a particularly strong gradient in northwest Iowa (fig. 4). The average crop season precipitation (fig. 5)

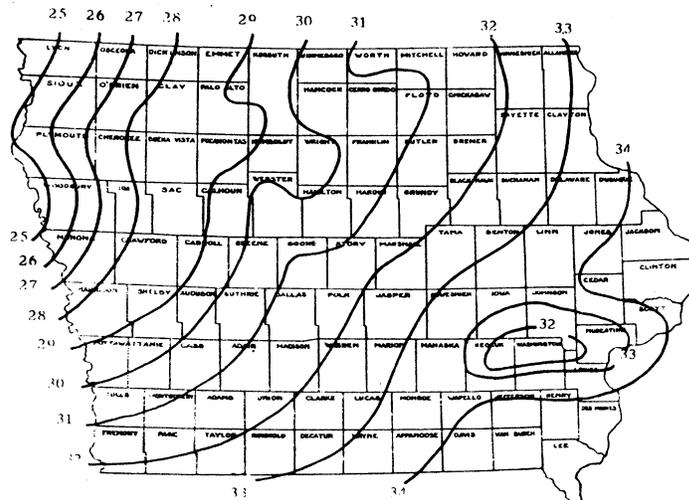


Figure 4. Normal annual precipitation (after Waite, 1969).

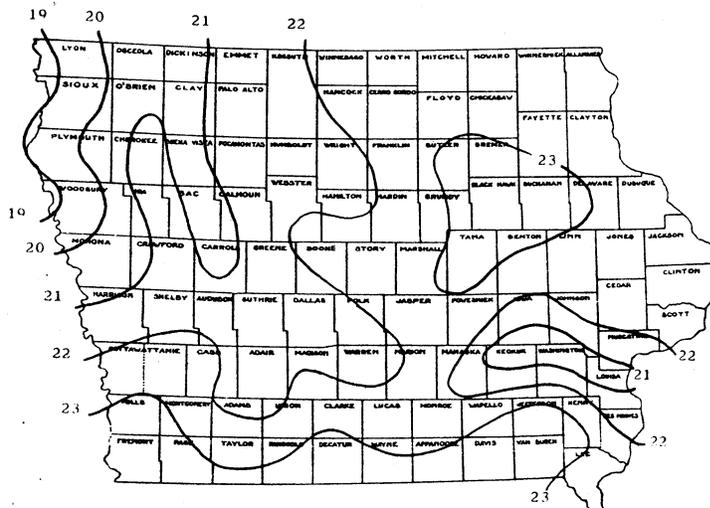


Figure 5. Normal crop season precipitation, April through September (after Waite, 1969).

also increases from 19 inches in the northwest to 23 inches in the south and east. These average figures demonstrate why the greatest interest and demand for irrigation is in the west and northwest areas of the state. For example, the eight western border counties hold about 50% of the total irrigation permits, and over 60% of the total water permitted for irrigation.

However, the average figures don't reveal the year-to-year variability. Especially during these dry years in the weather cycle, the effects can be scattered. For example, in 1975 there were isolated large areas in eastern Iowa that had severe drought. In 1974, the drought problems were essentially confined to western Iowa.

Again, over the long term, western and northwestern Iowa have the most persistent shortage of rainfall, and are the areas most likely to suffer from dry and hot weather.

#### C. Microclimate--Soils

In times of severe drought, crop yields on almost any soil will show some response to irrigation. Considering the long-term mix of favorable and unfavorable climatic conditions, soils of low water-holding capacity will show the best response to irrigation. Some of these light-textured soils, with sandy or even gravelly subsoils would show yield increases even in the better climatic years. Sandy and gravelly soils comprise about 6.5% of Iowa soils.

The west-to-east macroclimatic trend shows up in this aspect as well. In far western Iowa about 92% of the irrigation permits are for general crops with only 8% used for specialty

crops and golf courses. In the four counties in eastern Iowa with the greatest number of permits, about 24% are for general crops with 76% going for specialty crops and golf courses.

In western Iowa, especially on the Missouri Bottomland, even fine-textured, poorly drained soils with high water-holding capacities are being irrigated. In eastern Iowa many more general farm crop irrigation permits are being requested and most are for areas of soils with low water-holding capacity. Requests to irrigate these types of soils have increased all over the state as well.

The recent interest in irrigating these droughty soils is not just in response to the recent dry weather. These soils are generally of low natural productivity, and in the past were often used for hay and pasture, which perhaps, is a more suitable use for these soils. The changes in agricultural policy and economics has pressured these soils (as well as other soils prone to severe soil erosion) into row-crop production. These light-textured soils of low water-holding capacity also have a high permeability. This has promoted the very real concern that irrigation may cause percolation of nitrates and other ag-chemicals into our ground water aquifers.

There are other limiting factors on what soils can be irrigated. It is now mechanically possible to irrigate on slopes of up to 15%. About 87% of Iowa's land is between 0 and 14% slope. However, irrigating soils in the 9-14% and even the 5-9% slope category may be inviting soil erosion problems. These soils comprise about 27% of Iowa's land. This leaves about 60% of

Iowa land in the 0-5% slope range, which might be considered quite suitable for irrigation from this standpoint.

Other limiting factors might be the type of soil conservation practices in use. Certain types of land-treatment may preclude certain methods of irrigation. However, many permanent soil conservation measures are also designed for water retention.

Questions have also been raised about the necessity of now irrigating soils where drainage tile had been installed in the past. In Iowa's particular climatic regime these practices are certainly compatible. Depending on the soil type, it may be necessary to drain the soil in the wet spring months to allow tillage and planting. It may also be beneficial to irrigate this same field in the dry summer growing season. In soils with high water-holding capacity, tiling (as well as surface drainage) may be necessary to avoid problems of excessive wetness created by adverse combinations of rainfall and irrigation.

At the present time an irrigation manual for Iowa soils is in preparation by the U.S.D.A.--Soil Conservation Service in Des Moines. This manual will help in proper engineering and management of irrigation systems for Iowa soils. It should be ready by early 1977.

#### D. Climatic Predictions?

The question of the necessity for irrigation could readily be answered if the climate for the future could be predicted. Based on the climatic data and cyclic trends discussed (see figs. 1 to 3), certain pertinent points can be made.

Figure 2 shows the sunspot curve and July-August temperatures. The peak in temperatures and drought conditions generally occurs at or shortly after the "quiet year," which is the zero point on the sunspot number curve. Quiet years were 1934 and 1954 with peak drought years being 1936 in the Corn Belt and 1955 and 1956 in Iowa. The quiet year of the present cycle appears to have been 1974-75. The question remains whether the peak of hot-dry weather was 1974; is it 1976, or will it be 1977 or 1978? At this time the peak appears to be 1976, and if so, the present dry cycle may be relatively easy on

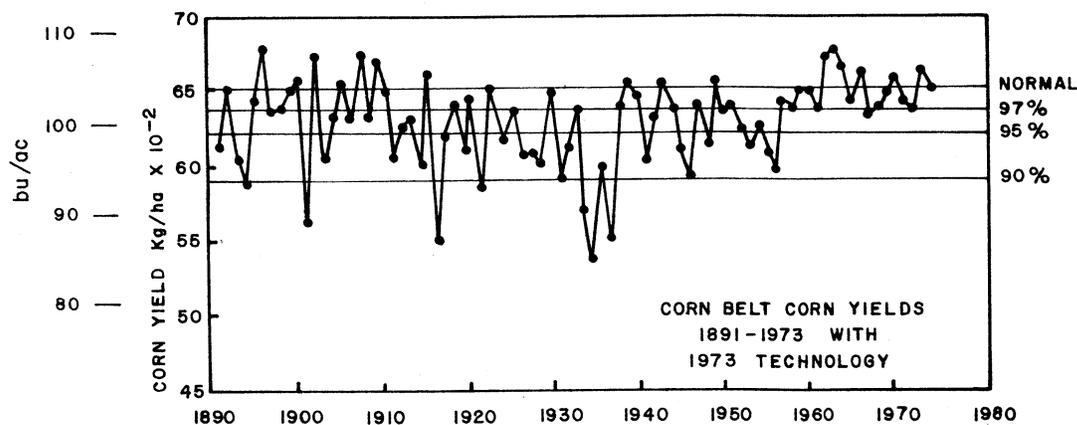


Figure 6. Corn Belt corn yields 1891-1973; "normal" line shows yield with "normal" weather. 90-95-97% show percent of normal yield (modified from Thompson, 1975).

Iowa. The only possible prediction at this point is that the remainder of the 1970's will probably have warmer and drier than "normal" summer weather.

The 1980's should be the next period of favorable weather, with hot and dry conditions recurring in the mid-1990's. If in a few years favorable weather conditions will return,

is there any need to be concerned with irrigation in Iowa? There was considerable interest in irrigation in the mid-50's drought years. This soon quieted down with the generally favorable weather of the 1960's.

Figure 6 will provide some perspective on the 1960's era. Figure 6 shows 1973 technology Corn Belt corn yields for 1891-1973. The "normal" line is the yield calculated for normal weather. As discussed previously, "normal" weather is associated with better than average yields. Corn Belt yields for "normal" weather and above occurred in only 25% of the 83 years shown in figure 6. The 90-95-97% lines are percent of normal yields. Although 90% of normal sounds fairly good, a 10% decrease in yield averaged across the whole Corn Belt is a very serious reduction in yield. This is obvious in viewing figure 6.

The 97% of normal line is nearly the median yield; about 50% of the yields occur above and below this line. One conspicuous feature stands out. The period from 1956 to 1973 lies entirely on or above this line. These 18 years comprise only 22% of the 83 years shown but they account for about 40% of the yields above 97% "normal", and 43% of the years with above "normal" yields. These years have been unusually and consistently good years climatically for agriculture.

Figure 6 shows other periods of favorable climate and yields, but not for such a consistently long period of time. If we considered the weather pattern to be random and that there would be an equal chance of falling above or below the 97% line, the odds against 17 or 18 years in a row with yields above this line are astronomical (less than one chance in 100,000). However, the

cyclic trends in weather and long duration periods such as this cast doubt on treating weather as random.

A direct result of this long period of exceptional weather and yields was the development of a National Foreign Trade policy which in essence did away with the U.S. grain reserve and which is promoting and utilizing surplus grain production as a powerful tool in foreign trade markets. Although drought in the mid-1970's has been severe in many parts of the world, it has not been too severe in the Midwestern U.S. A drought in the Corn Belt in the remainder of the 1970's or in the 1990's as severe as in the 1930's could be devastating to the U.S. and to the world without some type of grain reserve.

Based on the extrapolation of these 20-year cycles, the 1980's should be favorable for agriculture. But will they be as good as the 1960's? Again, the 17 years from 1957-1973 in Iowa were exceptionally good. Based on the records from 1891 to 1973, the only plausible prediction is that weather will probably be more variable once again. This infers that the 1980's may be favorable in general but they probably will not be as consistently good as the 1960's-early 1970's. This may enhance the potential to use irrigation to maintain yields.

These exceptionally good climatic years present a further problem. Much of our modern agricultural research was conducted during this period. Irrigation studies conducted during this time may or may not be indicative of the costs and/or benefits that might be derived.

### III. COSTS AND BENEFITS?

The relationship of climatic factors and corn yields raises the question: "What improvement in yields can irrigation produce over natural climatic conditions?" In many areas the answer is obvious--corn could not be grown successfully without irrigation. In Iowa the question is more difficult to answer. There is not enough data pertinent to Iowa's situation to provide a dependable base for an analysis of the economics of irrigation in Iowa. More long-term research in Iowa is needed on this issue.

#### A. Yield Data

Only two irrigation studies have been conducted in Iowa--during 1951-1955 (Schwab, et al., 1958) and 1956-1961 (Beer, et al., 1967) respectively. Figure 7 shows the maximum corn yields which were recorded in the 1956-1961 study, on poorly drained soils with high water holding capacity. These yields were not always the result of equivalent stand size, fertility, or irrigation levels in all years. However, they do provide some measure for evaluating the yields that a good manager could expect with and without irrigation.

Without irrigation, the highest yields for the six-year period averaged 108 bushels per acre, ranging from 33 to 147 bu/ac. With irrigation, the high yields averaged 131 bu/ac, but only ranged from 109-149 bu/ac. Thus, without irrigation over the six-year period there was a range in yields of 114 bu/ac, but under irrigation, yields only varied by 38 bu/ac.

Over the six-year period the irrigated acreage averaged 23 bu/ac higher yields than the high-management unirrigated corn.

The year-to-year differences ranged from only 1 bu/ac (1961) to 76 bu/ac (1957). Irrigation did not remove the year-to-year variations in yields, but it did reduce the total variation by 76 bu/ac (fig. 7).

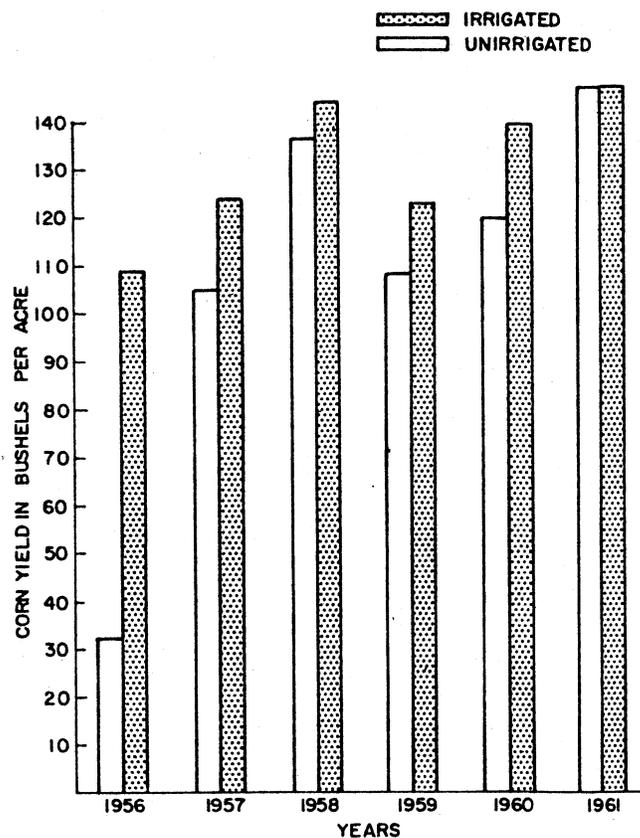
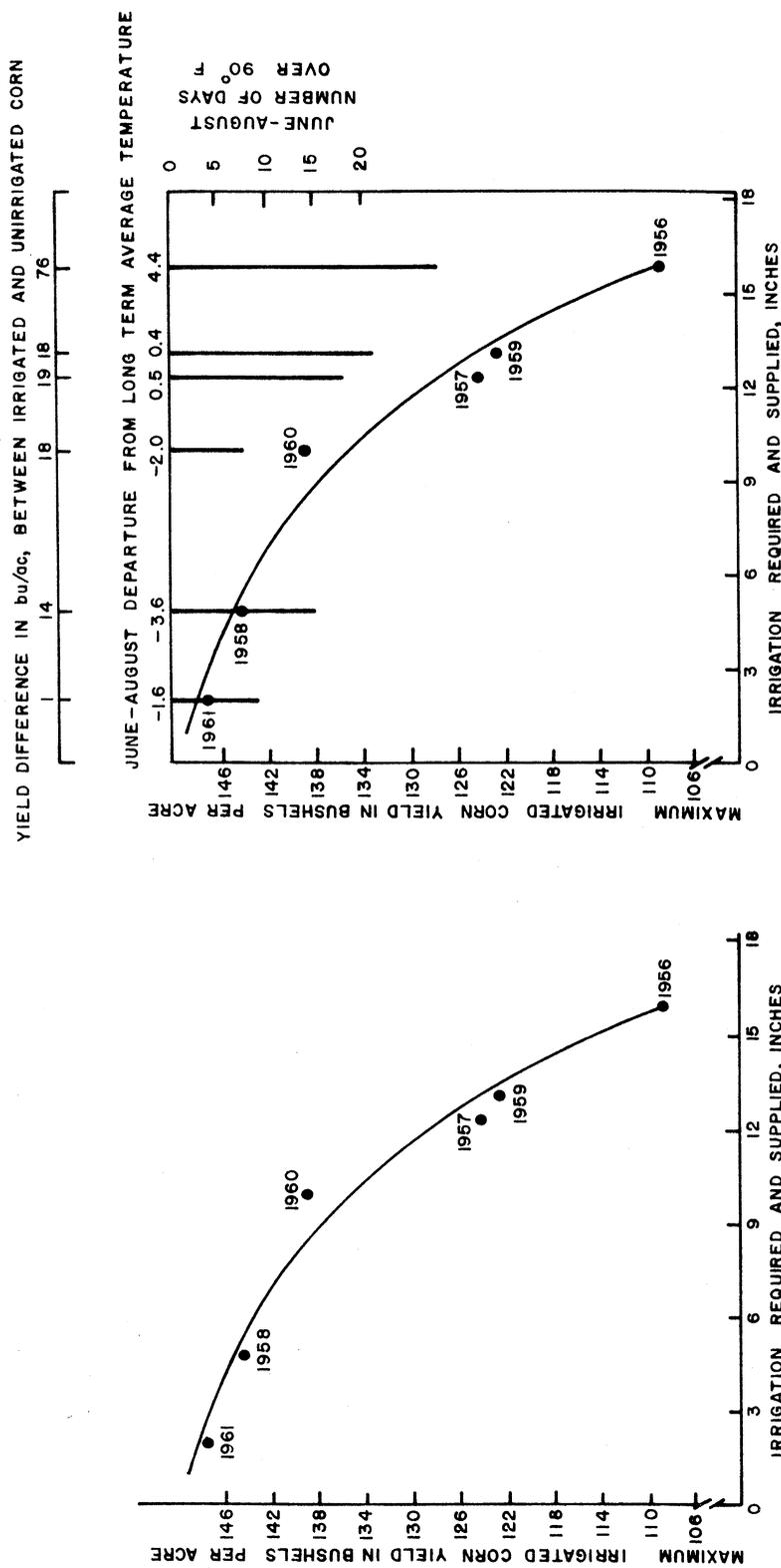


Figure 7. Maximum irrigated and nonirrigated corn yields on Colo silty clay loam, Ames, Iowa (after Beer, et al., 1967).

Much of this variation can be explained by climatic variability in spite of irrigation. Figure 8a shows the maximum irrigated yields plotted against the amount of irrigation water required and supplied to maintain 60% available moisture. Thus, the amount of irrigation water supplied is also a measure of the lack of rainfall. The interesting point of figure 8a is that as irrigation water supplied goes up, yields go down. This again points to climatic effects on yields that cannot be removed completely by irrigation. Figure 8b shows this same curve with added data on temperature during June through August. The decline in yields roughly parallels the number of days over 90 degrees, despite maintenance of soil moisture by irrigation. The average temperature data help to explain some of the variance from this trend.

Again, when hot and dry conditions occur together as in 1956 (fig. 8) the maximum response to irrigation will be recorded, but irrigation cannot totally overcome the stress created by excess temperatures.

This can also be seen in statewide yield figures for Nebraska. Table 2 shows state average yields for Iowa and Nebraska for 1971-1975. There is a decline in yields from 1972-1974. Part of this decline may be accounted for by the increased acreages of less productive land that was put into row crops during this time. The very sharp reduction in yields in Nebraska in 1974 (68 bu/ac) reflects climatic conditions again. In parts of central Nebraska during this year an essential crop failure occurred--in spite of irrigation. This happened because of numerous days with temperatures in excess of 100 degrees.



A.

B.

Figure 8. A. Relationships between the amount of water required and supplied to maintain soil moisture above 60 percent of the available water-holding capacity and maximum corn yields obtained on Colo silty clay loam, Ames, Iowa (after Beer, et al., 1967).

B. Shows added data on temperature and yield differences.

Table 2. State Average Corn Yields

	Year/Yield (bu/ac)				
	1971	1972	1973	1974	1975
Iowa	102	116	107	80	90
Nebraska	85	104	94	68	85

Daily irrigation cannot overcome the stress created by these excessive temperatures.

The 1951-55 studies in Iowa (Schwab, et al., 1958) showed similar results. This study was conducted in two different areas. In one area on a well-drained "sandy" soil of low water-holding capacity the average maximum-yield increase for the five-year period was 34.3 bu/ac. The results for 1951 are questionable because it was a climatically problematical year. The average yield increase for 1952-1955, which were warm and dry years, was 45 bu/ac.

In 1954 and 1955 experiments were also conducted on a somewhat poorly drained soil of high water-holding capacity. The average maximum-yield increase with irrigation was 21 bu/ac. For this same two-year period the yield increase on the "sandy" soil was about 48 bu/ac, or about a 2.3 times greater response than on the high water-holding capacity soil.

In summary, the data available from studies in Iowa show that year-to-year yield variations because of climatic differences cannot be removed by irrigation, but they can be reduced. In climatically favorable years on soils of high water-holding capacity there may not be any significant response

to irrigation (1961--one bu/ac difference). Over a longer term (1956-1961) the response on these soils has averaged about 23 bu/ac (Beer, et al., 1967). On soils of low water-holding capacity a much greater response can be anticipated, averaging about 45 bu/ac for 1952-1955, and showing a greater than two-fold increase in yield over high water-holding capacity soils for equivalent years. Technology has improved considerably since the 1950's and early 60's. It seems likely that the maximum response from irrigation in bu/ac might be increased somewhat by these technological improvements.

#### B. Economics

This is not intended to be a detailed economic analysis--only a review of some pertinent points. The economics and feasibility of irrigation will generally have to be determined by the farm operators in question, as long as the water is available to him to make the decision.

Tables 3 and 4 present some basic economic figures for traveling gun and center-pivot irrigation systems. The data are the latest figures compiled from studies in Nebraska. Only the traveling gun and center-pivot systems are included because most attention in Iowa is directed toward these sprinkler-type systems. Although they are more expensive than gated-pipe or skid-tow systems, they are the most versatile and the most mechanized.

Table 3 shows the total fixed investment costs amortized over the life of the system, and adjusted to a per-acre per-year cost. These fixed costs alone are \$40 to \$50 per acre per year.

Table 3. Initial Costs and Annual Fixed Costs for Various Irrigation Distribution Systems

Item	Expected Life	Traveling Gun	Center Pivot
Well--150 feet	25 years	\$3,300	\$3,300
Pump	18	4,900	4,700
Diesel Power Unit	12	7,000	6,500
Gearhead	12	1,250	1,250
Fuel Tank	20	375	375
Pipe	15	2,595	---
Distribution System <u>1/</u>	15	10,000	30,000
Reuse System	<u>15</u>	<u>---</u>	<u>---</u>
Total Initial Cost	--	29,420	46,125
Acres Irrigated	--	100	130
Initial Cost Per Acre	--	294	355
Amortised Fixed Costs per Acre per year Including Taxes and Insurance based on 9% interest note		\$41.15	\$47.61

1/ Does not include land leveling

(From Eisenhauer and Fischbach, 1976.)

Table 4. Estimated Operating Costs and Total Costs per Acre for Irrigation with Various Systems

	Traveling Gun	Center Pivot
Inches of Water Applied per Year	13	12
Fuel--35¢gallon	\$23.87	\$15.52
Oil	2.83	1.84
Maintenance and Repairs	4.11	3.70
Labor--\$3.00/hour	5.70	1.50
Total Operating Costs per acre per Year	36.51	22.56
Total Irrigation Costs per acre per Year (operating costs plus fixed costs from Table 3.)	77.66	70.17

(From Eisenhower and Fischbach, 1976.)

Table 4 presents estimates for annual operating costs for these systems for an application of 12 and 13 inches of water. This application rate may be reasonable to use for Iowa. In the three "average" years in the 1956-61 irrigation study (Beer, et al., 1967) previously cited, an average of 11.9 inches of water was applied. If the amount of irrigation water applied was reduced, fuel costs would be reduced, but many yearly maintenance costs would be the same at 6 or 12 inches.

The total operating costs per year are about \$23 to \$37 per acre, giving a total-irrigation cost of about \$70 to \$80 per acre per year. If we cut the application rate to six inches, operating costs might reduce to \$14-\$22, which places total costs in the \$60-\$65 per-acre per-year range.

If we make a basic assumption that crop production costs per acre will remain about the same with irrigation as they were without irrigation, then we can evaluate the yield increases necessary to make irrigation economical. Table 5 shows figures based on corn prices of \$2.50 and \$3.00 per bushel. At these prices it will take an average yearly increase of 13 to 20 bu/ac just to cover the fixed costs of the irrigation system. More importantly for total irrigation operating costs of \$60 to \$80 per acre per year, it will necessitate an average yearly increase in yields of over 25 to 32 bu/ac over the 15-year life expectancy of the system to make it economical.

Recent costs for deep irrigation wells in upland areas of northwest Iowa are running four to five times higher than the average 150-foot well figures from Nebraska--shown in table 3. This will necessitate another 6 to 10 bu/ac average yearly

increase to break even. It will also increase fuel costs for operation.

The assumption that other production costs will remain the same may not be valid. Depending upon the soil type in question, plant populations would be increased under irrigation, which would increase seed, chemical and fertilizer costs. If increased yields resulted, the cost of grain handling would also be increased. This might necessitate a higher yield increase to cover expenditures.

These figures are based on 100- and 130-acre operations (see table 3). Obviously if the acreage to be irrigated was increased, and the same equipment was used to irrigate these other fields, the costs per acre would be reduced. For a 390-acre irrigation operation, costs might be reduced to require only a 15 to 20 bu/ac average yearly increase.

Comparing these figures with the yield data discussed previously, presents some perspective on this matter. In the 1956 to 1961 irrigation study (Beer, et al., 1967) the average yield increase for the six years was about 23 bu/ac per year. At this average yield increase irrigation would not be economical. Even if the price of corn went to \$3.50 a bushel, it would be very marginal.

If we assume that climate in the next 20 years will be more variable than the past years, we might speculate on this further. The 1956 to 1961 data showed one climatically poor year with a yield difference (between irrigated and unirrigated corn) of 76 bu/ac. This period showed one exceptionally good year with a difference of only 1 bu/ac, and four rather "normal" years

Table 5. Yield increase (in bu/ac) necessary to pay for costs of irrigation for corn at \$2.50 and \$3.00/bu.

Costs/acre/year	Corn Price/bu	
	\$2.50	\$3.00
Fixed Costs		
\$40	16	13
\$50	20	17
Total Costs		
\$60	24	20
\$80	32	27

averaging a 17 bu/ac increase. If we assume more variability (and figure on): two bad years out of six (at a 76 bu/ac increase), three average years (at 17 bu/ac) and one good year (at one bu/ac), this would still only result with an average yearly increase of 34 bu/ac. Depending upon costs, this appears to be marginally economical for irrigation on high water-holding capacity soils. Technological advancements since these studies were conducted might improve the average yearly increases somewhat, which might make these figures look more economically attractive.

The data from 1951 to 1955 on low water-holding capacity soils looks more attractive, as would be expected. The average yield increase for 1952 to 1955 was 45 bu/ac. The data and yield increases on this study would very likely be improved by modern technology.

Although these few (and possibly out-of-date) figures appear to indicate that irrigation on soils of high water-holding capacity is marginally economic, more research on this needs to be done in Iowa. Also, there are other economic pressures which may make irrigation more feasible. The high (and rising) cost of land and equipment, and other production costs may provide another incentive for irrigation. With inflated operating costs and extended credit the sharp economic "valleys" of a bad year cannot be absorbed as readily as in the past. Even, if in the long term, irrigation might be marginally economic or even result in minor losses, the reduction in sharp year-to-year yield variations could produce a more uniform cash flow from year to year. This could produce a more stable economic base for farm operations.

## IV. PROBLEMS?

As with any of man's uses of natural resources, irrigation poses significant problems. Any policy considerations from the costs and benefits of irrigation should evaluate these problems as part of the long term social costs. Particular problems for irrigation are the potential for ground water depletion and contamination, soil erosion, and energy consumption.

A. Water Use--Aquifer Depletion?

One major problem with the burgeoning number of requests for irrigation permits in western Iowa is the location of an adequate supply of water. The new sprinkler irrigation systems require a minimum pumping rate of about 550-600 gallons per minute (gpm) and for efficient use should be supplied with 900 to 1,000 gpm. As discussed in Part I. of this report (Water Availability), well yields of this magnitude are difficult to obtain other than on the Missouri Bottomland.

As pointed out previously, wells supply about 60% of irrigation water; streams about 18%; reservoirs 5.5%; and combinations of these about 16%.

Under the provisions of Iowa's water rights law, minimum flows in streams are protected from withdrawals for consumptive uses such as irrigation. Consequently, many stream irrigators have had to discontinue irrigating because the protected flows do not allow water withdrawal from the streams during droughts when the irrigation water is most needed.

In the upland areas multiple well systems could possibly be used to provide adequate yields but the cost of these systems is often prohibitive. Also, dependent upon the well spacing and aquifer characteristics, interference between wells might soon reduce these yields.

If irrigation is going to develop in some of these areas, there will have to be an increased reliance upon combination well, reservoir, and/or stream water supply systems. The cost of this may also be prohibitive unless cost-shared between operators. There is no federal assistance available within rural watershed development programs at this time.

There have been reports of farmers buying irrigation equipment before they know if water is actually available. Adequate water is not available everywhere and this should be thoroughly checked before investments are made. Many people feel that because they have a good farm well they can irrigate. However, many excellent rural wells only pump at a rate of 5 to 15 gpm, which is far removed from the 550 to 1,000 gpm needed for irrigation.

Another potential problem for water use for irrigation occurs in northwest Iowa. In parts of this area (see Part I: Water Availability) the Dakota aquifer has high concentrations of dissolved solids. Although it is not particularly high in sodium concentration, which is objectionable for irrigation, it is very high in sulphates, in places measuring over 1,500 mg/l. Research needs to be done on the quality of this water and its possible adverse effects upon crops and soils.

The potential problem which has created the greatest controversy over developing irrigation is possible aquifer depletion--the lowering of water levels by large withdrawals for irrigation wells. This is a very real and justifiable concern. For the past several years news stories have reported on the declining water levels in irrigation areas of Nebraska, Kansas, and Texas.

A center-pivot sprinkler system for a 160-acre field (130-138 acres irrigated) when operating and pumping even at a minimal rate (about 560 gpm) withdraws as much water per day as a town of about 10,000 people (about .8 mgd). When pumping at preferred efficient rates of 900-1200 gpm, it may withdraw 1.5 to 2 times the amount of water withdrawn by this same town.

Irrigation systems only operate seasonally so their total withdrawal is not this high. At permitted levels of withdrawal in the realms of 1 to 1.5 acre-feet of water/yr, yearly withdrawals would be in the realms of 45-60 mg/yr (million gallons/year) or 130-200 acre-feet/yr for a 160-acre tract. Past figures have shown that generally less than one-half of Iowa's irrigators actually operate during any year, and the average application is about 0.5 acre-feet/ac/yr (Gieseke, 1969). However, these figures were compiled in the 1960's during very favorable weather and may not be appropriate for the conditions of the 1970's.

Even at this rate, one center-pivot system would withdraw water at the same yearly rate of a town of 1,000 to 3,000 people, depending on the total application. Worse yet is the fact that sprinkler irrigation consumes nearly 100% of the water it withdraws. Smaller urban areas only consume about

10-12% of what they withdraw. The remainder is returned to streams or other parts of the hydrologic system as treated water.

Consequently, a single 160-acre center-pivot operation may only withdraw as much water yearly as a town of 1 to 3,000, but its water consumption may equal that of a town of 10-12,000 people. Obviously there is good reason for concern over the depletion of aquifers by expanding irrigation.

Even where recharge to an aquifer is more than adequate to sustain total withdrawals from the aquifer, localized stress situations have and will continue to occur as more competition for water use increases.

For example, in an area where the Dakota sandstone can supply enough water for one irrigation system, can it also supply water to ten irrigation systems in a localized area without detrimental effects upon rural and municipal water supplies or other irrigation wells? These questions cannot be answered without detailed research to determine to what extent an aquifer can be developed without depleting aquifer storage. Aquifer data and models must be developed to attempt to answer how withdrawals from alluvial aquifers will affect or deplete the protected flow of streams. Water-use conflicts of this type undoubtedly will arise and good answers must be sought. Problems of this type have already started to occur in western Iowa.

In Nebraska, where significant problems of water level decline are occurring, measures of water allocation, ground water rotation, restrictive well spacing, etc. are being implemented under the auspices of Nebraska's Natural Resources Districts and their Ground Water Management Act. If needed,

these measures could be implemented under Iowa's present permitting procedure. As irrigation expands in an area it may also be necessary to require more detailed testing as part of the permitting procedure, to ascertain the necessity of these conservation measures.

By the end of 1976 about 0.5% of Iowa's land may be permitted for irrigation. This will amount to permitted water withdrawal totaling about 5% of Iowa's total water withdrawal. In an earlier section the present rate of increase in irrigation was extrapolated to the year 2000, and would equal about 1.3 million acres of land or still only about 3% of the state. However, if we extrapolate the permitted water withdrawal at the same rate, this would equal about 1.7 million acre-feet per year, or about 43% of the total present state water withdrawal.

After the initial enthusiasm for irrigation passes, and with the probable return of more favorable weather in the 1980's, the rate of increase in irrigation will likely decline. Even if irrigation only increases at a third of its present rate, it will impose an increasingly significant role in management of Iowa's water resources. The future rate of increase will depend upon the economic feasibility demonstrated by present irrigators, and will certainly be limited by problems of water availability.

#### B. Ground Water Contamination

Another area of very real concern is the issue of ground water contamination from irrigation. The controversy focuses primarily on nitrate contamination. Nitrates are considered to be a health hazard to human infants under one year of age. Digestion of high nitrate water by infants can cause or contribute

to methemoglobinemia or cyanosis (blue babies). Safe drinking water standards for humans have been set at 10 mg/l  $\text{NO}_3\text{-N}$  (45 mg/l  $\text{NO}_3$ ).

High nitrate water has also been blamed for various livestock problems. Fear has been expressed that irrigation will increase the nitrate levels of shallow wells and farm ponds used for livestock water, creating a health hazard for livestock. However, this fear may be unfounded. Research in South Dakota on poultry (Adams, et al., 1966), swine, sheep (Seerley, et al., 1965), and cattle (R. J. Emerick, pers. commun.), indicates that water with treatments of nitrate up to 1000 mg/l  $\text{NO}_3\text{-N}$  (4,400 mg/l  $\text{NO}_3$ ) had very little affect on performance of the animals. In general their results showed that 300 mg/l  $\text{NO}_3\text{-N}$  (1,320 mg/l  $\text{NO}_3$ ) is a safe level for livestock, presuming a low nitrate diet. The highest  $\text{NO}_3$  level reported in Iowa is about 730 mg/l  $\text{NO}_3\text{-N}$  (3,200 mg/l  $\text{NO}_3$ ), and it is very rare to record as much as 300 mg/l  $\text{NO}_3\text{-N}$  (1,320 mg/l  $\text{NO}_3$ ) (Morris and Johnson, 1969). Nitrates in excessive amounts in Iowa are generally the result of poor well placement, design, or construction.

The research in South Dakota suggests that livestock problems attributed to drinking water are more likely caused by total salt content or bacteria or viruses. High bacteria and sulphate levels are often associated with high nitrate levels in Iowa and these are more likely the cause of livestock problems from water supplies.

Recent experience from Nebraska has shown reason for concern, however. In one area studied over the past eighteen years, irrigation has expanded from just an occasional operation to full irrigation in the area. The area is characterized by rather permeable sediments and shallow aquifers--ideal for

contamination. In this 18-year period nitrate levels went from 2 to 22 mg/l. In areas of Nebraska where only scattered irrigation takes place (such as in Iowa), no nitrate contamination can be documented. Where deep aquifers are tapped for irrigation this is not a realistic concern either.

In Iowa the water quality records for the towns of Whiting, Monona County, and Modale, Harrison County, have been analyzed. These towns draw their water from the basal sand and gravel of the Missouri River. They are also surrounded by irrigation systems. For Modale the earliest analysis is 1934 and the latest 1971. The  $\text{NO}_3$  level ranges from less than .02 mg/l  $\text{NO}_3\text{-N}$  (.1 mg/l  $\text{NO}_3$ ) to .51 mg/l  $\text{NO}_3$  (2.2 mg/l  $\text{NO}_3$ ). The .51 mg/l was in 1957, after which the  $\text{NO}_3$  content went down. For Whiting the earliest analysis is 1935 and the latest 1973. The  $\text{NO}_3$  level ranges from a recorded zero in 1950 to .81 mg/l  $\text{NO}_3\text{-N}$  (3.5 mg/l  $\text{NO}_3$ ) in 1973. The bulk of the analyses are less than .23 mg/l  $\text{NO}_3\text{-N}$  (1 mg/l  $\text{NO}_3$ ). There is no significant change in  $\text{NO}_3$  levels recorded during the period when irrigation has developed. Further research, including long-term monitoring of observation wells, should be conducted.

In essence, the potential for nitrate contamination is only of concern where highly permeable soils are irrigated over shallow aquifers. In Iowa where irrigation is only used to supplement soil moisture the problem of overwatering with subsequent chemical leaching is very minimal. As irrigation is practiced in Iowa the nitrate problem is really a question of farm management.

Experimentation on the Treynor, Castana, Moody, and Galva-Primghar experimental farms show that under recommended amounts of N fertilization very little N loss occurs. Figures 9 and 10 show the results over three years at the Treynor farm. These results show that under the recommended N fertilization rates, no consistent increase in N occurred below the corn root zone (fig. 9). Only slight leaching to ground water and streams may have occurred. In another watershed which was "overfertilized" at 2.5 times the recommended rate, significant N was leached below the root zone (fig. 10), and reached the water table.

Optimal recommended N application rates are determined to maximize yields and profits. At these optimal levels plant use is greatest and the least amount of N will be lost (in comparison to higher levels of application). At higher levels more N is wasted and lost to the subsoil and potentially to ground water. If N is wasted, profits decrease also, so proper N rates are economic incentives as well. A good farm manager would try to operate at these optimal levels.

Depending upon the soils in question and the plant population, optimal N rates for corn are in the range of 130 to 170 lbs/acre. Research indicates that over about 150 lbs/acre will promote leaching of nitrate out of the root zone. In the irrigation permit a maximum level of N application should be set to minimize the problem of nitrate leaching.

Irrigation may actually reduce the nitrate leaching problem. Deep percolation of soil water (and nitrates) only occurs significantly during ground water recharge periods

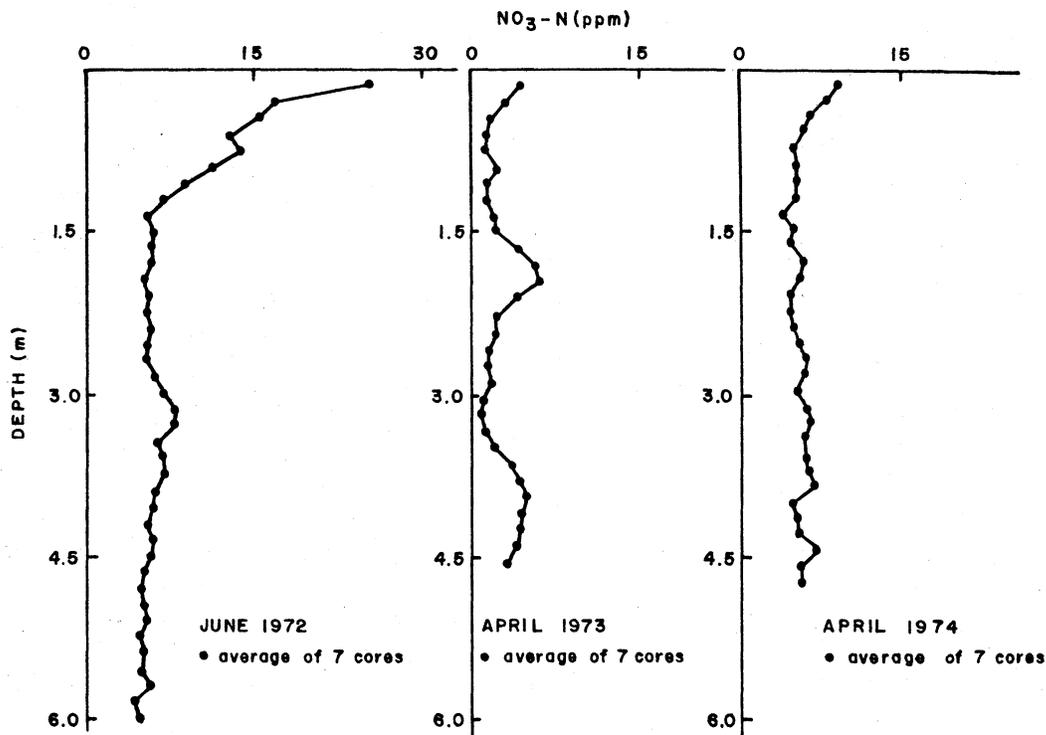


Figure 9. Average nitrate-nitrogen concentration (dry soil basis) and distribution in 6.1-m soil profiles of watershed 2 (fertilized at recommended rate of 168 kg N/ha per yr; 150 lbs N/ac per year) at three sampling dates, Treynor, Iowa (after Schuman, et al., 1975).

during the fall through spring. Most nitrate leaching will occur when excess N residues remain in the fall, or when deep percolation occurs after N application in the spring. There is little significant movement of water below the root zone during the dry summer months in Iowa. In a climatically bad year, without irrigation, seriously reduced yields will leave a large excess of N residue in the fall. Improved yields from irrigation would utilize more of the N, thereby reducing N residue.

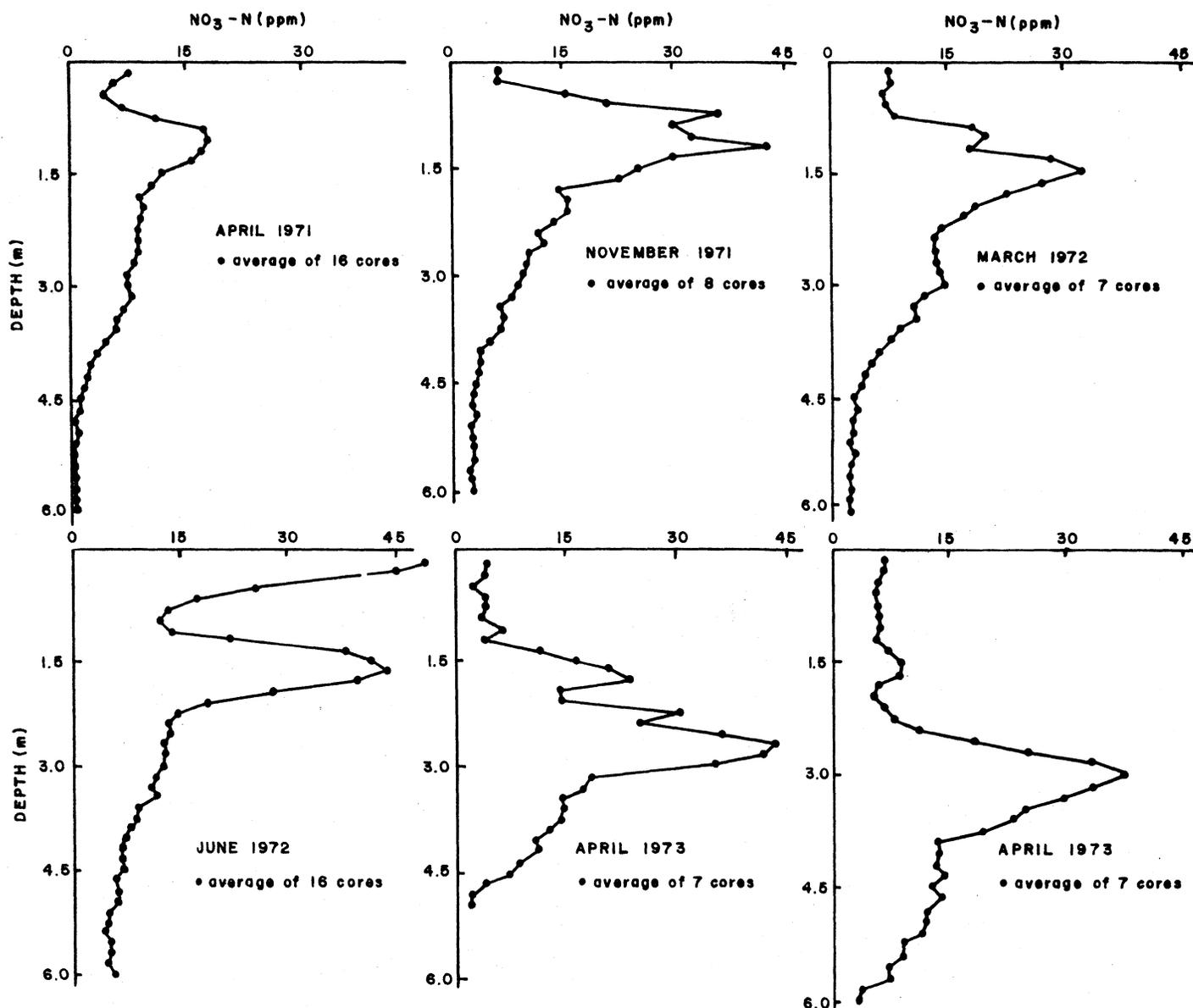


Figure 10. Average nitrate-nitrogen concentration (dry soil basis) and distribution in 6.1m soil profiles of watershed 1 (fertilized at 448 kg N/ha per year; 400 lbs N/ac per year; or 2.5 x recommended rate) at six sampling dates, Treynor, Iowa (after Schuman, et al., 1975).

Under normal practices N is applied all at once, by spreading or side dressing in the spring or fall. With heavy spring rains after application, deep percolation may remove N below the root zone. With sprinkler irrigation side dressing can be minimized. N can be applied through the sprinkler systems at critical periods during plant development when N will be used most effectively.

Research in Nebraska (Fischbach and Mulliner, 1975) has also shown that the  $\text{NO}_3\text{-N}$  in ground water used in irrigation can be used as part of the N fertilizer requirement. Thus, from water quality analyses, the N fertilizer rate can be reduced by the amount of N in the water. For example:

1.  $4.4 \text{ mg/l NO}_3 = 1.0 \text{ mg/l NO}_3\text{-N}$ .
2.  $1.0 \text{ mg/l NO}_3\text{-N} = 0.23 \text{ lbs-N/acre-inch water}$ .
3. For a water analysis of  $44 \text{ mg/l NO}_3$  ( $10 \text{ mg/l NO}_3\text{-N}$ ) and 12 inches of water applied for irrigation, the N fertilizer applied can be reduced by about 27 lbs N/acre.

With supplemental sprinkler irrigation in Iowa, over-irrigation and leaching of nitrates should not be a significant problem. No yield increases are gained by keeping soil moisture above 60% available moisture content (Beer, et al., 1967). Significant leaching cannot take place at this moisture content and this level can be maintained by monitoring rainfall and knowing the approximate water-holding capacity of the soil. Deficiencies can then be made up by irrigating. Water-holding capacity data are available from the S.C.S. and Extension Service, and further information will be available in the S.C.S. irrigation handbook for Iowa. Commercial monitoring services are also available to provide actual on-site measurements of available moisture. A

good farm manager should not over irrigate because nothing is gained for the costs involved.

Adverse combinations of irrigation and rainfall undoubtedly will occur and cause some deep percolation of water and nitrates during some summers. However, this is probably not very significant compared to the leaching that can occur during the recharge periods. A greater problem under these adverse conditions may be increased soil erosion, which would deliver increased sediment and ag-chemicals into surface water. Hopefully, this problem can also be minimized by proper conservation treatment prior to irrigation.

In summary, proper management is the key to controlling the potential for nitrate contamination of ground water supplies.

#### C. Soil Erosion

Developing irrigation on upland areas with slopes in the 5 to 15% range may seriously increase the potential for severe soil erosion problems. Problems of this nature have developed in Nebraska. Potential soil erosion should be controlled before it becomes a problem. When upland soils that are prone to erosion are considered for irrigation, perhaps the permitting procedure should include a review of or implementation of soil conservation measures by the Soil Conservation District to ensure adequate protection of the land involved and to ensure compliance with the soil loss limit regulations established by Iowa's 100 Soil Conservation Districts.

#### D. Energy Demands

Another consideration of developing irrigation systems is the demand on energy. Studies in Nebraska have shown that 43% of the energy devoted to agriculture in Nebraska is consumed in pumping water for irrigation. A more important figure for consideration in Iowa is that a typical center-pivot irrigation system uses about 50 gallons of diesel fuel per acre per year in applying 22 inches of water. According to Nebraska figures, this is about ten times the fuel needed to till, plant, cultivate, and harvest a corn crop (Splinter, 1976). A recent survey of some Iowa irrigators showed an average fuel use of 2.5 to 3 gallons of diesel fuel per acre inch of water applied. If we cut the amount of irrigation water to 6 to 12 inches, which is a reasonable figure for Iowa, irrigation will demand about a 4- to 8-fold increase in energy use per irrigated acre. Some permitted irrigators in Iowa have discontinued irrigating because of the high energy costs for their operations.

Most systems at present are powered by diesel fuel; some by natural gas and electric motors. This growing energy demand will likely focus on diesel fuel because electric generating capacity probably can not be expected to expand to meet a heavy peak load for irrigation for a short period in the summer, which would not be matched during the rest of the year.

#### E. Federal Policy vs. State Resources

Another issue that must be addressed is the problem of complying with national policy at the expense of depletion of

Iowa's natural resources. National Foreign Trade Policy has effected a National Agricultural Policy of "fence-row to fence-row" row-crop production. The varied economic pressures resulting from these policies have brought much land into row-crop production that was used for less intensive purposes in the past. Much of this land is prone to severe soil erosion, and some of these soils require irrigation to support row crops or to maintain high production. At the same time, federal soil conservation programs have been terminated or cut back. No federal assistance is currently available to aid in irrigation development. If water for irrigation were to be included in rural watershed development programs, funded in part by the S.C.S., then this portion of the project would have to be paid for solely by local funds.

At the same time that the Iowa Department of Soil Conservation and Soil Conservation Districts, and agencies such as D.E.Q. and E.P.A. are trying to implement measures to control soil erosion and non-point source pollution, full production agriculture, without adequate soil and water conservation practices, is acting to increase this type of pollution.

In other words, to comply with full agricultural production, the State and people of Iowa are bearing the burden of serious resource depletion, in terms of: 1. Soil erosion and concurrent increases of sediment and chemical pollutants to surface waters; 2. Possible ground water depletion from irrigation; 3. Possible ground water contamination; and 4. Energy resource depletion from irrigation. This trend can be seen in Iowa with the establishment of the \$4 million-dollar State-funded soil conservation cost-sharing program.

National agricultural policy of maximum production and the issues of soil, water, and energy conservation must be brought together, both philosophically and fiscally, as concurrent goals. We cannot afford maximum short-term production at the expense of our long-term productivity and the depletion of Iowa's soil and water resources.

## V. RESEARCH NEEDS

On the preceding pages many questions have been looked at--but few answered adequately. There is a great deal of research necessary to answer these questions for Iowa. These items have been mentioned in the text and are outlined below:

### A. Hydrogeologic Research

1. Detailed hydrogeologic investigations of the Dakota, alluvial, and Pleistocene aquifers of western Iowa. If ground water depletion is to be avoided, and if we are going to be able to better predict water availability, we must have a better understanding of the ground water aquifers.
2. Monitoring of aquifer response (depletion) to irrigation.
3. Long-term monitoring of ground water quality in irrigated areas.

### B. Agronomic Research

1. Short-term statistical analysis to analyze the costs or benefits irrigation might have had over the past 50 to 75 years in Iowa. This would provide a much better base for evaluation of the real economic potential of irrigation.
2. Long-term experimental irrigation studies to determine actual field tested yield data and economics. If a Missouri Bottoms experimental farm is set up, it should certainly incorporate irrigation experiments.
3. Development of an adequate monitoring and management system that farm operators can utilize to avoid over irrigation.
4. Research on the effects of high-dissolved solids Dakota aquifer water on crops and soils.

### C. Soil and Water Conservation

1. Evaluation of possible soil conservation measures suitable for use with irrigation.

2. Monitoring of possible soil erosion and non-point source pollution in areas of upland irrigation.

## VI. SUMMARY AND CONCLUSIONS

During the early 1970's several concurrent events took place:

1. A National Foreign Trade Policy developed which promoted the use of the U.S. surplus grain production as a tool in foreign trade.
2. This in turn created a national agricultural policy promoting a full production agricultural economy.
3. These policy changes, coupled with cutbacks in various ag-support programs, created economic pressures, which coupled with declining cattle prices and populations, pressured many new, marginal acres of land into row-crop production.
4. Just as numerous acres of low water-holding capacity soils came into production, and as these economic pressures made high production imperative, the climatic regime of Iowa and the Corn Belt shifted from the unusually favorable weather of the 1960's and early 70's to the hot droughty weather of the mid-1970's.

All of these concurrent events have stimulated a renewed interest in irrigation in Iowa. Applications for irrigation permits have accelerated to five or six times their usual rate.

This has raised serious questions about the feasibility of widespread irrigation in Iowa. Unfortunately, the data is not available to conclusively answer all of the pertinent questions. Much research in other states is not pertinent to Iowa's particular situation. Limited research conducted in Iowa is 15 to 20 years old and the effects of time are unclear. Added research in Iowa is a necessity.

Long-term climatic trends can be correlated with the 20-22 year double sunspot cycle. Above average temperatures and drought conditions have occurred in the Corn Belt in the 1890's, 1920's, 1930's, 1950's, and now the mid-1970's. Although it is

difficult to predict what will happen in any given year, some long-term predictions can be made. The hot and dry conditions of the mid-1970's were predicted by many people.

The Corn Belt was "spoiled" by the consistently high yields produced during the very unusual consecutive number of climatically favorable years from 1957 to 1973. These 18 years resulted in record yields for agriculture, accounting for 43% of all the above-normal yields for the past 83 years. It was this consistent high level of production that promoted the decline of the U.S. grain reserve and the concurrent use of grain in the National Foreign Trade Policy. With these changes, if the predictable drought of the 1970's became as severe as the 1930's, the effect could be disastrous.

Extrapolating into the future from these long-term trends it is likely that the remainder of the 1970's will be marked by above-average summer temperatures. With the quiet year in the sunspot cycle occurring in the 1974-1975 season, 1976 may be the peak of the present hot and dry conditions in Iowa. The 1980's should mark a return of more favorable climate. From the long-term climatic data it is likely that this period will be more variable than the 1960's. This may make irrigation more attractive in the 1980's than it was in the 1960's.

During periods of dry weather like the mid-1970's, irrigation is indeed attractive. Irrigation cannot, however, offset the yield reduction problem caused by excess temperature, but it will reduce the year-to-year yield variations from climatic fluctuations.

The greatest response to irrigation can be achieved on coarse textured soils of low water-holding capacity. These soils

comprise about 6.5% of Iowa. Mechanically it is possible to irrigate on slopes up to 15%. About 87% of Iowa's land is between 0-14% slope. However, irrigating soils in the 5-14% slope category may be inviting soil erosion problems. These soils make up about 27% of Iowa's land. This leaves about 60% in the 0-5% slope range, which might be considered suitable for irrigation from this standpoint.

The costs for a sprinkler irrigation system, based on a 130-acre tract, is in the range of \$60 to \$80 per acre per year. In an oversimplified example, this will require an average yearly increase of 25 to 35 bu/ac corn to break even. One six year study using irrigation in Iowa on soils of high water-holding capacity showed only an average yearly increase of 23 bu/ac corn. In one climatically bad year the study showed a 76 bu/ac increase over unirrigated corn, but in a climatically good year irrigation only increased the yield by 1 bu/ac.

In the long term, considering the mix of favorable and unfavorable climatic conditions, irrigation may be very marginally economic on soils of high water-holding capacity, based on the data for sprinkler irrigation on 130-acre tracts. Soils of low water-holding capacity will show a better economic response. Even if the long-term economics of irrigation are marginal, it may be attractive to reduce year-to-year yield variations, providing a more uniform cash flow and reducing the impact of sharp "economic valleys" of bad years.

The greatest increase in irrigation will be in western and northwestern Iowa. However, in much of this area it may be difficult to produce wells which will yield sufficient quantities

of water for efficient operation of sprinkler irrigation systems. In these areas, if irrigation is to be implemented, it may be necessary to use combinations of wells, reservoirs, and streams for water supplies. This will present additional problems and expense to developing irrigation.

There are many problems associated with irrigation, which may present long-term costs to society, which must be evaluated. These problems are principally ground water depletion and contamination, soil erosion, and energy consumption. The most serious potential problem is depletion of our water resources.

One center-pivot system applying one acre-foot of water to a 160-acre tract (about 133 acres irrigated) will consume as much water as a town of 10,000-12,000 people per year. Obviously, this issue is of serious magnitude and conflicts in water use will arise. The expansion of irrigation must be carefully managed to avoid serious depletion of water resources.

The problems of ground water contamination and soil erosion (and non-point source pollution) are primarily a problem of good farm and land management. With optimal recommended fertilization and chemical application rates, proper irrigation application rates, and proper land treatment these potential problems can be minimized.

Depending on the amount of water applied, irrigation may require a 3- to 10-fold increase in the amount of diesel fuel used per acre to produce a crop. In Nebraska irrigation consumes ten times the amount of fuel needed to till, plant, cultivate, and harvest a corn crop.

By the end of 1976 permitted irrigation may amount to about 5% of Iowa's total yearly water withdrawals, while only being applied to 0.5% of Iowa's land. If irrigation were to continue to expand at the 1976 rate until the year 2000 it would still only apply to 3% of Iowa's land but would amount to 43% of current water withdrawals. It is very doubtful that this rate of increase will continue. After the initial enthusiasm about irrigation is past, and with the predictable return to more favorable climate in the 1980's, the rate of expansion of irrigation will likely decrease.

The climate of the 1980's will probably be more favorable than the mid-1970's, but is likely to be more variable than the unusually good weather of the 1960's-early 1970's. This, plus the high cost of agricultural production, will probably promote the expansion of irrigation at a rate higher than the 1960's, but lower than at present. Irrigation will pose serious problems and questions in the management of Iowa's water resources.

To answer these questions, much research will be needed, especially in the area of ground water development and depletion, and agricultural economics and management.

To deal with the attendant problems of expanding irrigation the permitting procedure may have to include:

1. Restrictions on maximum or optimal N-fertilization rates to protect water quality.
2. Review of upland sites by the Soil Conservation District where soil erosion may be a problem, to ensure compliance with the Iowa Conservancy District Law (Iowa Sediment Control Law), and to prevent accelerated non-point source pollution.
3. Requirements for detailed testing and/or long-term monitoring of aquifer depletion, to avoid serious water depletion or water-use conflicts.

National agricultural policy has pushed for full agricultural production, which has created economic pressures, which in turn has brought many acres of land into row-crop production which are prone to severe soil erosion or which require irrigation to sustain high yields. At the same time, federal soil conservation programs have been cut back and no federal funds are available in rural watershed programs for irrigation. In essence, as Iowa complies with a policy of full production the state is also asked to bear the problems and expense of resource depletion. Concurrently, the Iowa Department of Soil Conservation, Department of Environmental Quality, and the U.S. Environmental Protection Agency, etc. are attempting to control soil erosion and non-point source pollution, which are being accelerated by full production.

National agricultural policy for maximum production and the issues of soil, water, and energy conservation must be brought together, both philosophically and fiscally, as concurrent goals. We cannot afford maximum short-term production at the expense of our long-term productivity and the depletion of Iowa's soil and water resources.

Irrigation will continue to expand in Iowa. The rate will be determined by the economic feasibility demonstrated by present irrigation over the next several years, but will undoubtedly be limited by the availability of water.

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## VIII. ADDENDUM

II.B.-Add. Microclimate--Soils

As previously stated, about 6.5% of Iowa's soils are coarse textured (sandy and/or gravelly) and would have low water-holding capacity. These are the soils which would show the most favorable response to irrigation. Figure 11 shows the distribution of these soils by county in Iowa.

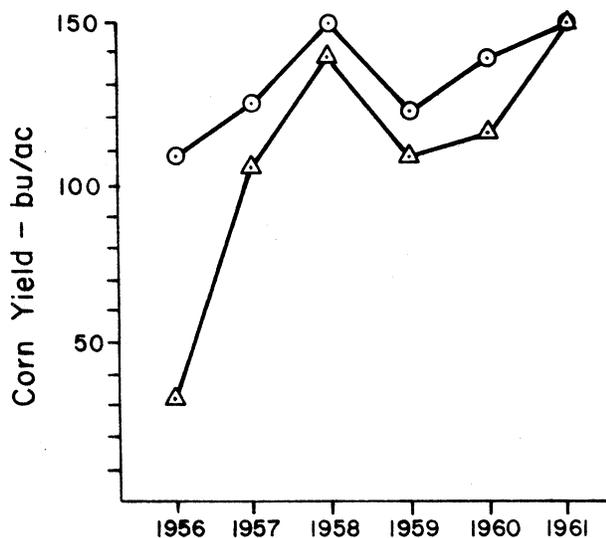
Although the expansion of irrigation is concentrated in western and northwestern Iowa, the highest concentrations of low water-holding capacity soils is in a belt from north-northeastern through east-central Iowa. Water would generally be more readily available in this area, than in northwestern Iowa. Moderate to high well yields would also be easier to produce, at least in the southeastern 2/3 of this belt. However, municipal and industrial water use is also much higher in this area than in northwest Iowa.

III.A.-Add. Yield Data

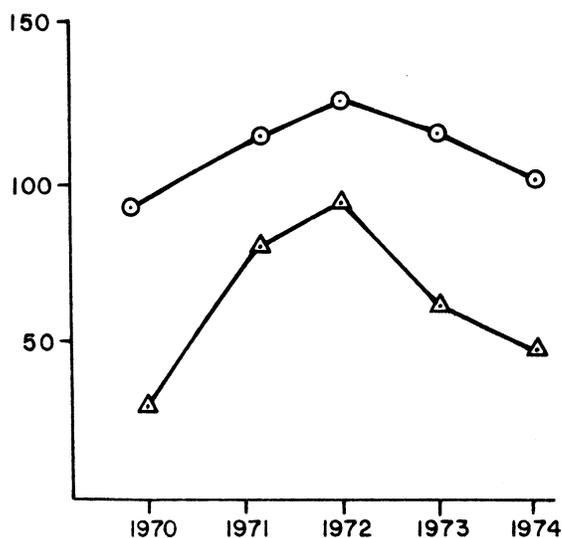
Figure 12 shows irrigated and unirrigated corn yield data from various portions of northeastern Nebraska for 1970 through 1974. This data has all been plotted graphically to reemphasize that as a general rule the trends in irrigated yields parallel those of unirrigated yields, i.e., as unirrigated yields go down, so do irrigated yields. Irrigation is not a guarantee of consistently high yields.

Burt County, Nebraska, is immediately adjacent to Monona County, Iowa. Consequently, this recent data from Burt County should be applicable to northwest Iowa. Table 6 shows the yield

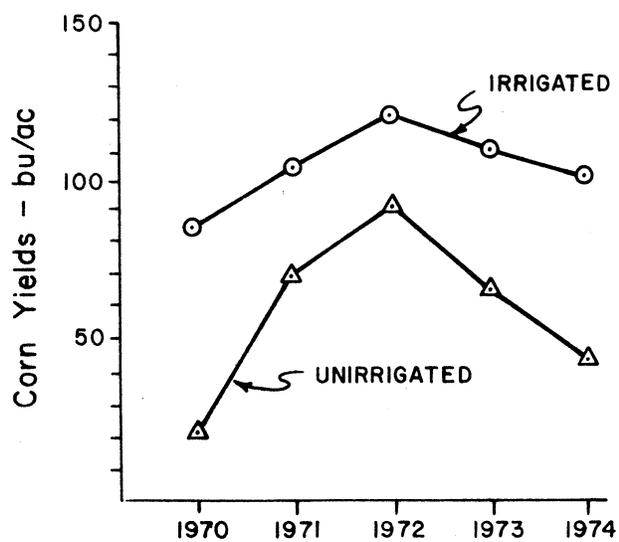




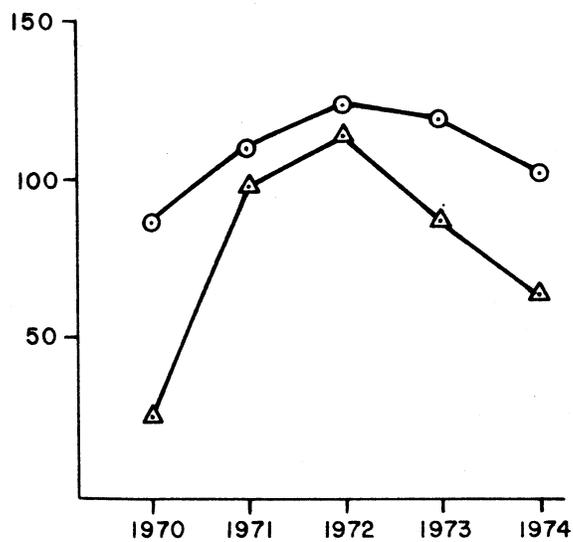
Central Iowa  
(Beer, et al., 1967).



"Northeast" Nebraska



Wayne County, Nebr.



Burt County, Nebr.

FIGURE 12. IRRIGATED AND UNIRRIGATED CORN YIELD TRENDS FROM CENTRAL IOWA, 1956-1961 (BEER, ET AL., 1967); FOR PORTIONS OF NEBRASKA, 1970-1974 (HENDERSON, PERS. COMMUN.).

data for Burt County. Irrigation did not remove variability, irrigated yields ranged from 84 to 121 bu/ac. However, irrigation did lessen the severity of this variability. For the 5-year period the average yearly yield increase with irrigation was 30.6 bu/ac. This data, which was compiled by Philip A. Henderson, University of Nebraska, also showed that the average annual cost of an irrigation system was \$76-\$77/ac. The average

Table 6. Harvested Corn Yields (bu/ac) in Burt County, Nebraska, 1970-1974.

	Irrigated	Unirrigated	Yield Increase
1974	84	25	59
1973	109	95	14
1972	121	113	8
1971	117	84	33
1970	99	60	39
5-yr Average	106	75.4	30.6

(From P. A. Henderson, pers. commun.)

annual "extra" costs for seed, fertilizer, grain handling, etc. was \$25-\$30/ac, which brings total annual costs to about \$100-\$107/ac. This would require an average annual yield increase of 33 to 50 bu/ac (for corn prices from \$3-\$2/bu) to break even. For this 5-year period irrigation would show a loss of from 2 to 19 bu/ac. The 1975 and 1976 seasons will certainly make this economic picture look better, but this data does reemphasize the point that in the long term, irrigation may only be marginally economical in this area.

Figure 13 shows this material graphically. It shows the actual yield trends for central Iowa (1956-1961) and for Burt County, Nebraska (1970-1974), that were shown in fig. 12.

Two other lines are shown on these figures which represent the bu/ac yield increase needed to break even for corn at \$2 and \$3/bu. These lines were simply added to the unirrigated yields using the \$100 added cost/acre figure cited above. The difference between these lines and the irrigated yield lines represent the

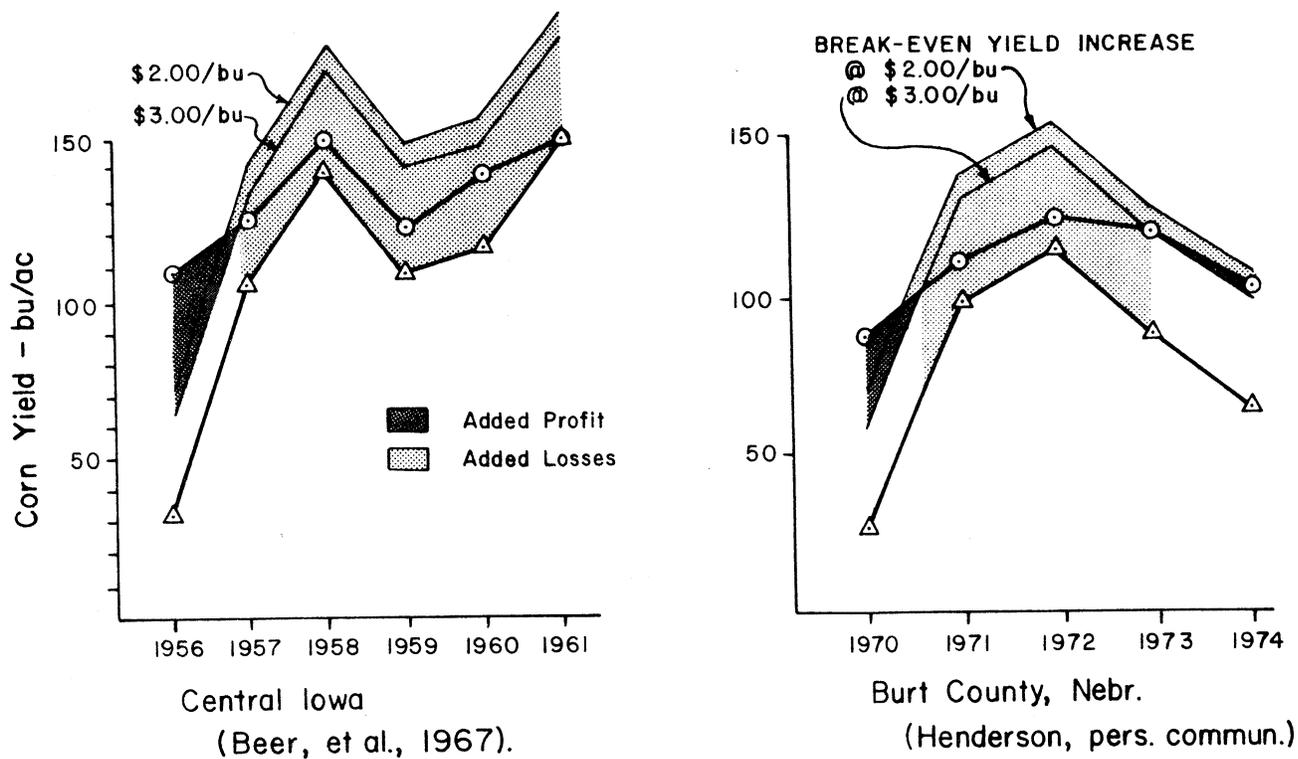


Figure 13. Corn yield trends (from fig. 12); added costs and added profits or losses from irrigation for corn at \$2.00 and \$3.00 per bushel.

added loss or added profits resulting from irrigation. The large areas of added losses should point out the need for some detailed long-term analysis before a farm operator invests in irrigation.

