DECISION INNOVATION SOLUTIONS

Prepared for:

Agriculture Commissioner
Doug Goehring

North Dakota Irrigation and Drainage Study

April 2026

Contents

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

List of Figures

List of Tables

Legal Disclaimer

Decision Innovation Solutions, LLC ("DIS") has prepared this analysis (the "Project") for review and use. The Project consists of a North Dakota Irrigation and Drainage Study.

While DIS has made every attempt to obtain the most accurate data and include the most critical factors in preparing the Project, DIS makes no representation as to the accuracy or completeness of the data and factors used or in the interpretation of such data and factors included in the Project. The responsibility for the decisions made by you based on the Project, and the risk resulting from such decisions remains solely with you; therefore, you should review and use the Project with that in mind.

While the Project does include certain estimates and possible explanations for the economic impacts that have occurred due to the failure to realize the irrigation potential in North Dakota and to assess the potential forward economic impacts that could be seen if that irrigation potential is realized, it cannot be ascertained with certainty the extent to which these estimates are entirely accurate. The following factors, among others, may prevent complete accuracy of the estimation of this project and explanations for the same:

- Inadvertent errors and omissions related to data collection, data summarization, and visual display of data.

Table 1. Acronyms

Acronym	Description
CDO	Climata Data Online
DIS	Decision Innovation Solutions, LLC
MT	Montana
NCEI	National Centers for Environmental Information
ND	North Dakota
NDSU	North Dakota State University
NOAA	National Oceanic and Atmospheric Administration
USACE	US Army Corp of Engineers
USDA	United States Department of Agriculture
USDA CDL	USDA Crop Data Layer
USDA-ERS	USDA Economic Research Service
USDA-FSA	USDA Farm Service Agency
USDA-NASS	USDA National Agricultural Statistics Service

1 Executive Summary

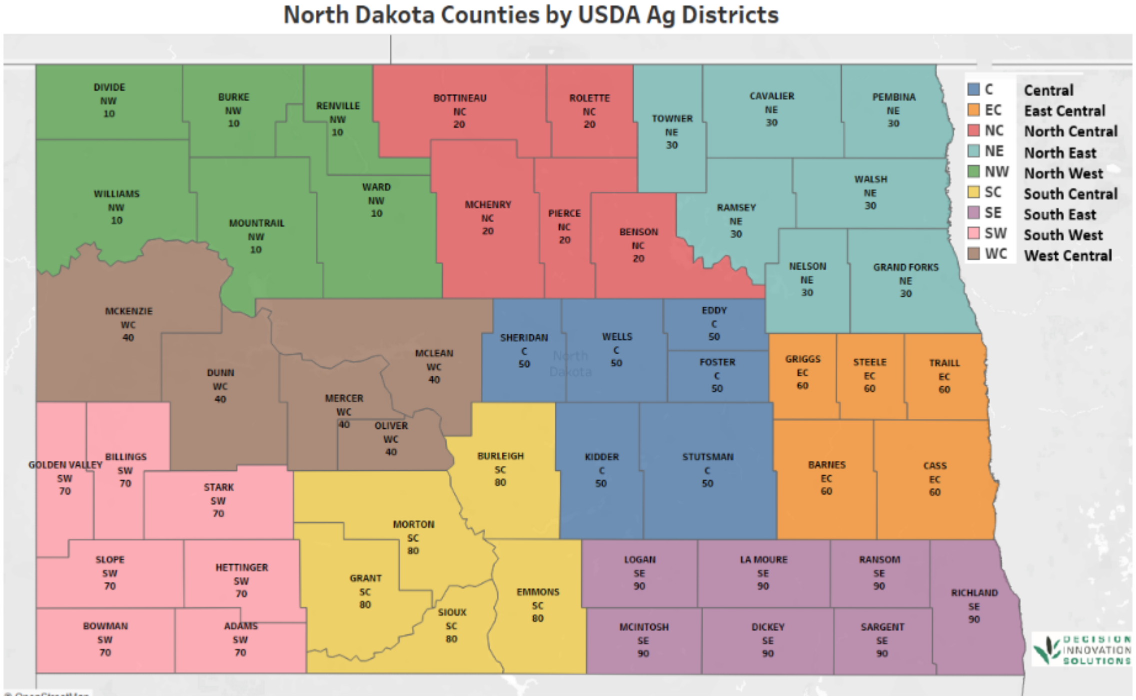
North Dakota agriculture benefits from development of its irrigation potential. To date, more than 250,000 acres of North Dakota are irrigated annually but this is only a fraction of its potential. A recent study, "North Dakota Statewide Irrigation Reconnaissance Study," reported that considering soil suitability and water availability, there are 1.26 to 1.52 million acres of cropland available for potential future irrigation development across the state. Of these lands, about half a million acres are within the 12 counties that border the Missouri River corridor for irrigation development and an additional 0.8 to 1.1 million acres may be developed for irrigation by using water from glaciofluvial aquifers across the state.

The potential for irrigation development was part of the original Pick-Sloan Plan of the 1940s, but fulfilling the full extent of irrigation potential as envisioned within the Pick-Sloan Plan has not yet occurred. This report examines how North Dakota agriculture has developed over the years since the Pick-Sloan Plan was developed and explores a counterfactual case of what North Dakota agricultural production might have looked like if irrigation had been fully developed in North Dakota by 1970.

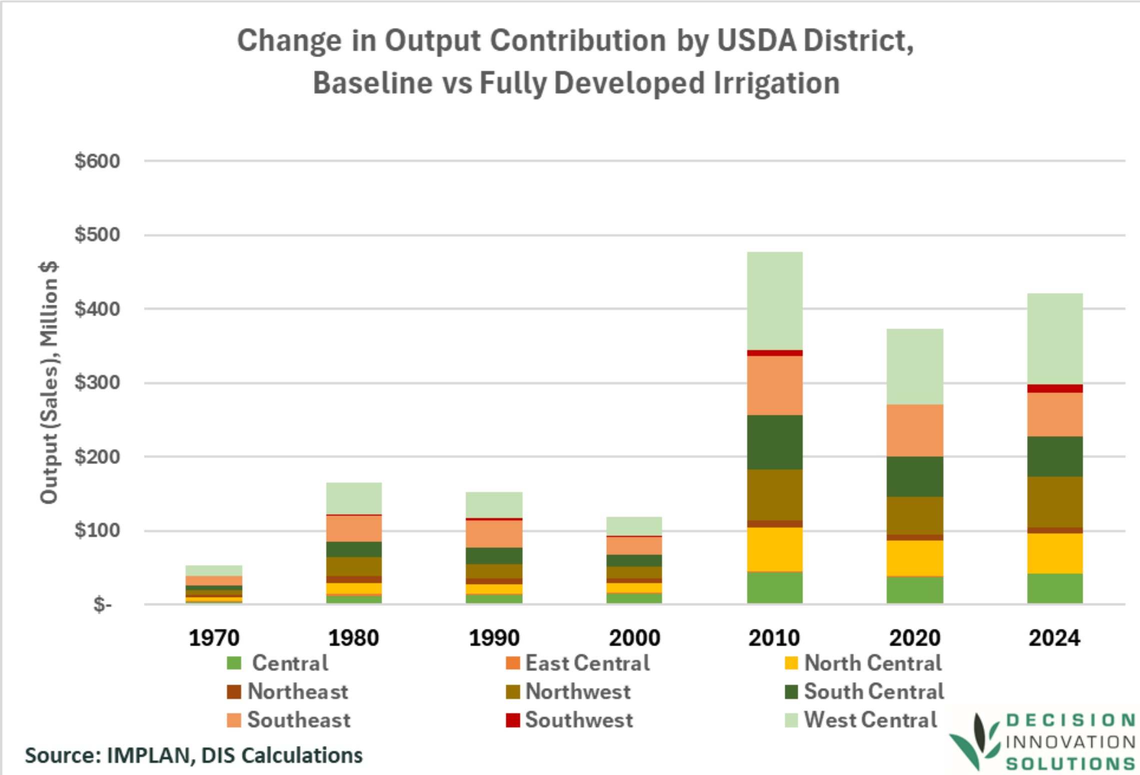
If the irrigation infrastructure had been fully developed in North Dakota, both the crop mix and the yields of crops in North Dakota would have been different than has occurred. This results in economic differentials between the baseline and the scenario. The aggregate difference between the baseline crop revenue and the crop revenue with full irrigation is $9.7 billion cumulatively from 1970 through 2024.

Note: USDA organizes statistical data for North Dakota into 9 ag reporting districts.

North Dakota Counties by USDA Ag Districts



11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com



Planted acres of irrigated crops with associated revenue and expenses for a fully developed irrigation scenario were developed and were used as inputs to estimate the total economic contribution of crop production under the baseline and fully developed irrigation scenario for the following years: 1970, 1980, 1990, 2000, 2010, 2020, and 2024. These total contribution values include impacts from farm input purchases (seed, fertilizer, equipment, etc.) and income spent by farmers within North Dakota in addition to direct economic activity at the farm level.

The figure above shows the increase in output contribution for the fully developed irrigation scenario relative to the baseline in each USDA Agricultural Statistics District which, when summed together, equal the state-level impact. The annual increase in output at the state level is $52.7 million in 1970, rises to $477.5 million in 2010, and reaches $421.9 million in 2024. The West Central district consistently shows the largest growth in output contribution from fully developed irrigation and has an estimated annual increased output of $124 million in 2024. The Northwest district is second ($70 million), followed by Southeast ($59 million), South Central ($54 million) and North Central ($54 million).

The economic impacts of irrigation flow beyond the gross and net revenue lines. Other economic impacts factors are also impacted by changes in irrigation status and the resultant changes in crop mix that occur due to increased availability of irrigation. Fixed costs, for example, tend to be higher for irrigated land than non-irrigated land, although the difference varies by crop. In aggregate, fixed expenses with fully developed irrigation would have been $2.24 billion more than the baseline for the years 1970 through 2024. Fertilizer expenses would have increased with the higher yields expected due to irrigation. The aggregate increased fertilizer expenditures for fully developed irrigation would have been $3.26 billion more than the baseline. Seed expenses vary by crop and can tend to be higher with irrigation due to higher planting populations for some crops with irrigation. The aggregate increase in seed cost with fully developed irrigation is $201 million. Interest expenses vary by crop and can be greater with increased usage of crop production inputs such as seed and fertilizer as well as increased fixed expenses. The aggregate increased interest expenses would have been $165 million.

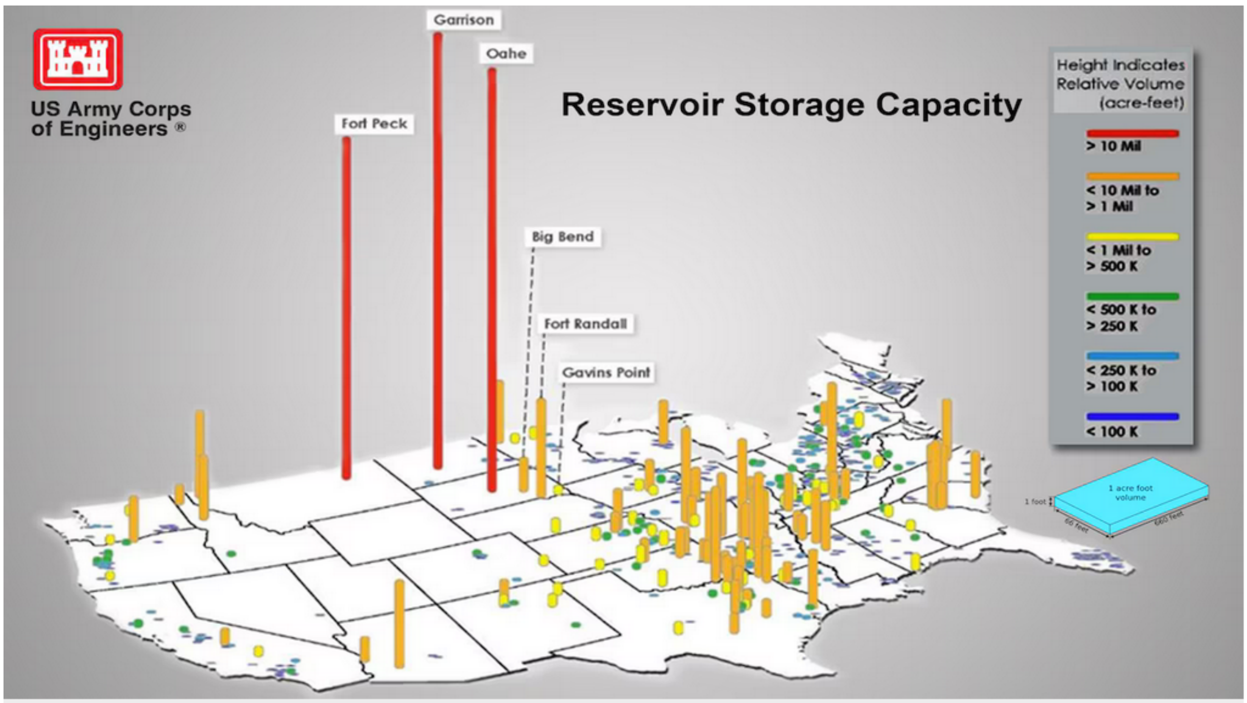
Value Added, a component of output, measures the total sales minus the costs of inputs. An industry's value added is equivalent to its contribution to GDP. The increase in value added under the fully developed irrigation scenario at the state level is $14.7 million in 1970, is between $40.0 and $60.0 million from 1980 to 2000, rises to $100.0 million in 2010, and is $185.7 million in 2024. The West Central district shows the largest increase in value added contribution in 2020 ($37.3 million) and 2024 ($48.9 million). The South Central district has the largest increase in 2010 of $20.3 million, and the Southeast district has the largest increase from 1970 ($5.3 million) to 2000 ($12.4 million). The increase in labor income for the fully developed irrigation scenario at the state level is $18.6 million in 1970, peaks at $97.2 million in 2020, and is $95.2 million in 2024.

To put this into context, if 1,000 acres of soybeans were converted from dryland to irrigated, that would result in a net increase of $139,814 in value added for those acres. Of that, $131,846 is realized at the farm level. The additional $7,968 would be gained elsewhere in the state due to indirect and induced impacts throughout the broader economy. Similarly, if 1,000 acres of corn were converted from dryland to irrigated, the net value added increase would be $111,614, of which $92,267 would be farm level impacts and $19,347 would be indirect or induced impacts. A specialty crop like potatoes has a larger impact. Converting 1,000 acres of potatoes results in a $2,484,107 impact, of which $1,613,274 are at the farm level and $870,833 are elsewhere.

In addition to irrigation, this study also looked at the economic contribution of public drainage infrastructure, legal drains, to the state. The estimated annual statewide economic contribution of additional crop production due to legal drains in North Dakota results in an additional direct revenue (output) to farmers of $65.8 million along with an increase of $41.8 million in value added, $23.0 million in labor income, and 149 jobs supported. After accounting for the additional crop inputs (seed, fertilizer, etc.) and spending of additional income earned through higher production, the total contribution of legal drains throughout the state is 260 jobs, $30.7 million in labor income, $54.0 million in value added, and $87.9 million in output.

2 Introduction & Background

The Pick-Sloan Plan was developed in the 1940s in response to significant flooding that was repeatedly occurring on the Missouri River. It called for the development of a series of dams and flood control features on the Missouri River. The chain of Missouri River reservoirs and dams from Montana to South Dakota is one of the nation's engineering marvels. Pick-Sloan reflected the prevailing certainty in large technological projects to sustain and support regional development in areas not always favored by climate and geography. The dams and reservoirs have only partially fulfilled their promise - hence the continuing discussion in the Missouri River basin regarding the fulfillment of the promises and visions that arose from the Pick-Sloan Plan. Figure 1 shows the location of the dams on the Missouri River as well as their relative reservoir storage capacity.



The water storage capacity of the six upper Missouri River dams

Figure 1. Water Storage Capacity of the Six Upper Missouri River Dams

The original Pick plan called for five dams on the Missouri River below Fort Peck, new and previously authorized but unbuilt reservoirs on tributaries, and 1,500 miles of levees on both sides of the river from Sioux City, Iowa, to the confluence with the Mississippi River where no federal levees had been built before. Essentially a flood control and navigation plan, Colonel Pick allowed for some hydroelectric power production at major dams. Pick maintained that his plan would provide for all uses of the river's water, "including irrigation, navigation, power, domestic and sanitary purposes, wildlife, and recreation." Sloan's plan emphasized irrigation and reclamation as well as hydroelectric power generation. He called for some seventeen power plants, ninety reservoirs-nearly four times as many as Pick's and the irrigation of nearly 5 million acres of the Great Plains.

Ultimately, the US Army Corp of Engineers (USACE) built, and continues to operate, six large and important dam and reservoir projects on the mainstem of the upper Missouri River. These dams, in combination with dams on the river's tributaries, reduce the risk of downstream flooding along the Missouri and Mississippi rivers. When not operating to reduce flood impacts, this "mainstem" system of dams is managed for hydropower generation, water supply, water quality, irrigation, fish and wildlife conservation, navigation, and recreation benefits. The Garrison dam located in western North Dakota forms Lake Sakakawea, the third largest man-made lake in the United States. The lake is 178 miles long, has over 1,500 miles of shoreline, and its maximum depth is about 175 feet. It has the largest reservoir capacity of all USACE managed reservoirs. Since its opening in 1960, Garrison Dam has provided hydropower and flood control potential envisioned by Colonel Pick and others who directed its development. But the irrigation potential of the Pick-Sloan plan has not been realized.

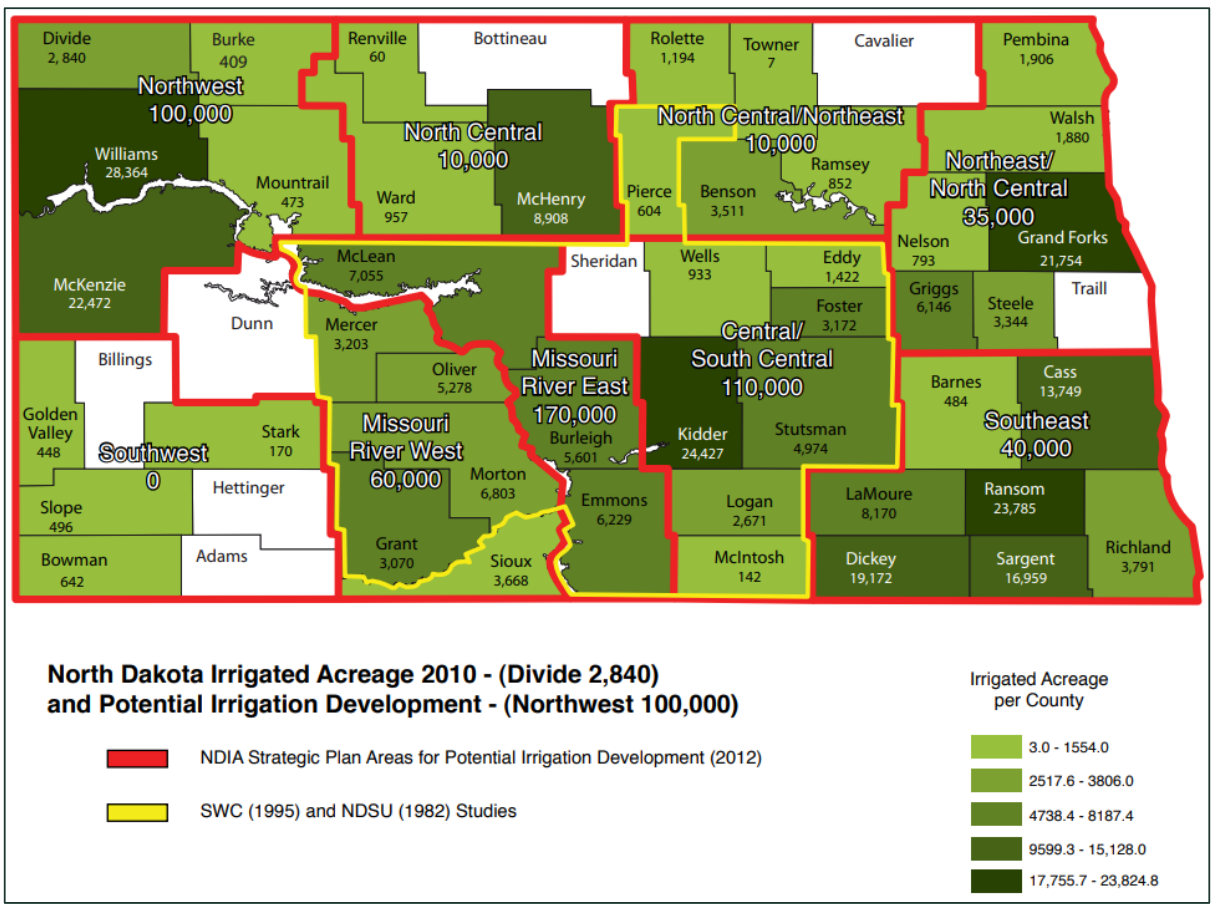


Figure 2. North Dakota Irrigated Acreage 2010 and potential Irrigation Development

In 2010 there were 272,988 irrigated acres in North Dakota (Figure 2 and Figure 3). Federally developed irrigation projects are not being served directly from the System reservoirs. The reservoirs, however, are being utilized by numerous private irrigators as well as federally financed projects that take water from the Missouri River. About 900 private irrigators pump directly from the reservoirs or river reaches[1].

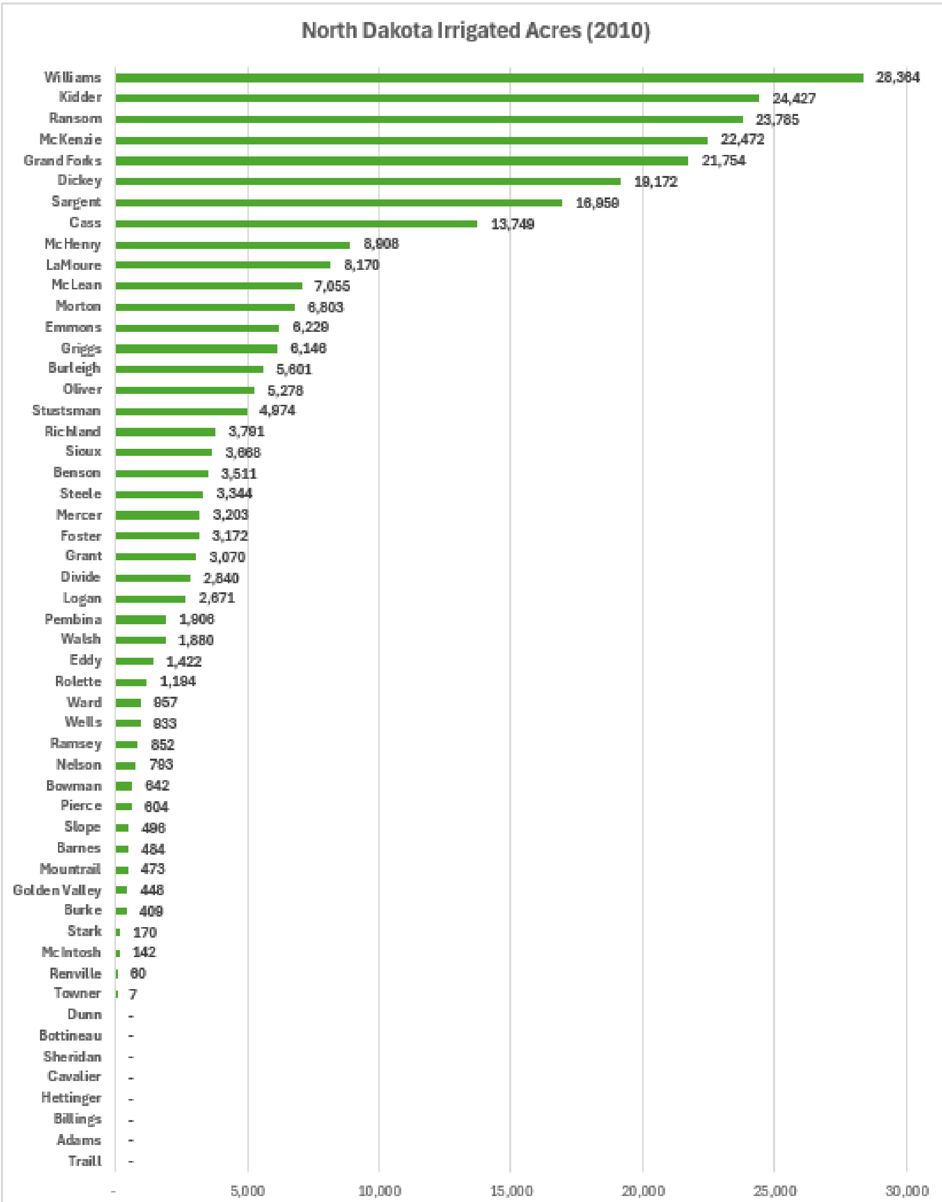


Figure 3. North Dakota Irrigated Acres (2010)

---

[1] Page 47, Missouri River Mainstem Reservoir System, Summary of Actual 2012 Regulations, USACE.

2.1 Irrigation Potential in North Dakota

The initial Pick-Sloan plan was extensive and included the building of a series of canals for irrigation from the middle of the state east to Devils Lake and then through natural waterways all the way to the eastern border (Figure 4). Due to a number of factors, including environmental concerns with Canada, only two of those canals were built (McClusky and New Rockford) and only one is currently being used (McClusky). Below is a map of the canals. You'll also note that there's an area in the south called the Oakes Test Area. The idea was that the canals would drop Missouri River water into the James River to deliver additional water for irrigation down there. Additionally, there were several areas along the river identified, the idea being there would be intakes right in the river. So, there were general areas identified but it was assumed that a lot of infrastructure would be used that was not built.

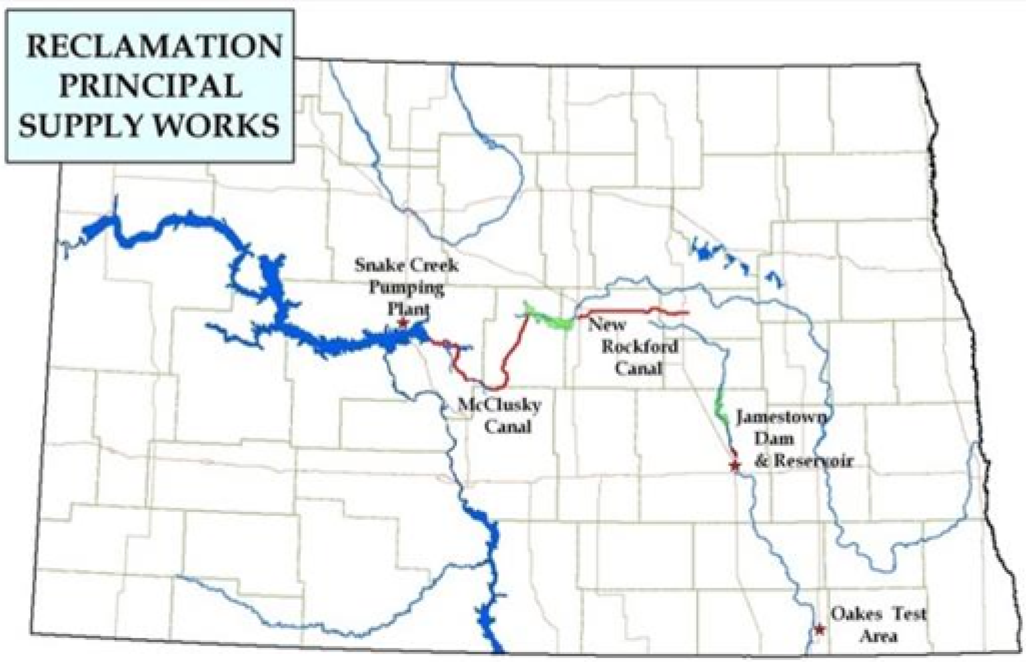


Figure 4. Map Showing the GDU's Principal Supply Facilities. The unlabeled green marker between McClusky Canal and New Rockford Canal shows where the Lonetree Dam Reservoir was supposed to connect them according to USBR. (Source: Figure 2 In Garrison Diversion Unit's Interim Cost Allocation, U.S. Department of the Interior)

The purpose of this study is to quantify the economic impacts that would have occurred if irrigation had been fully developed and to assess the potential forward economic impacts that could be seen if that irrigation potential is realized. Based on the map from the North Dakota Statewide Irrigation Reconnaissance Study (Figure 5), there are 1,258,200 acres in North Dakota with the potential to be irrigated. The listing by county of irrigation potential is shown in Figure 6.

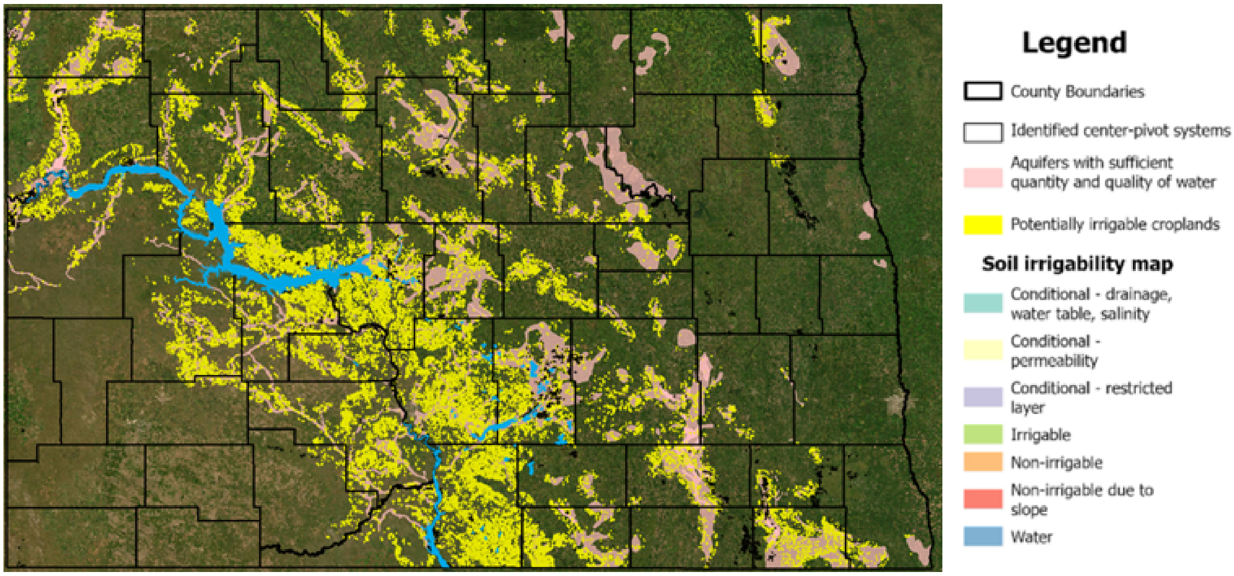


Figure 5. Map of Irrigation Potential in North Dakota[2]

[2]https://www.swc.nd.gov/pdfs/home_page/2025_north_dakota_statewide_irrigation_reconnaissance_study.pdf

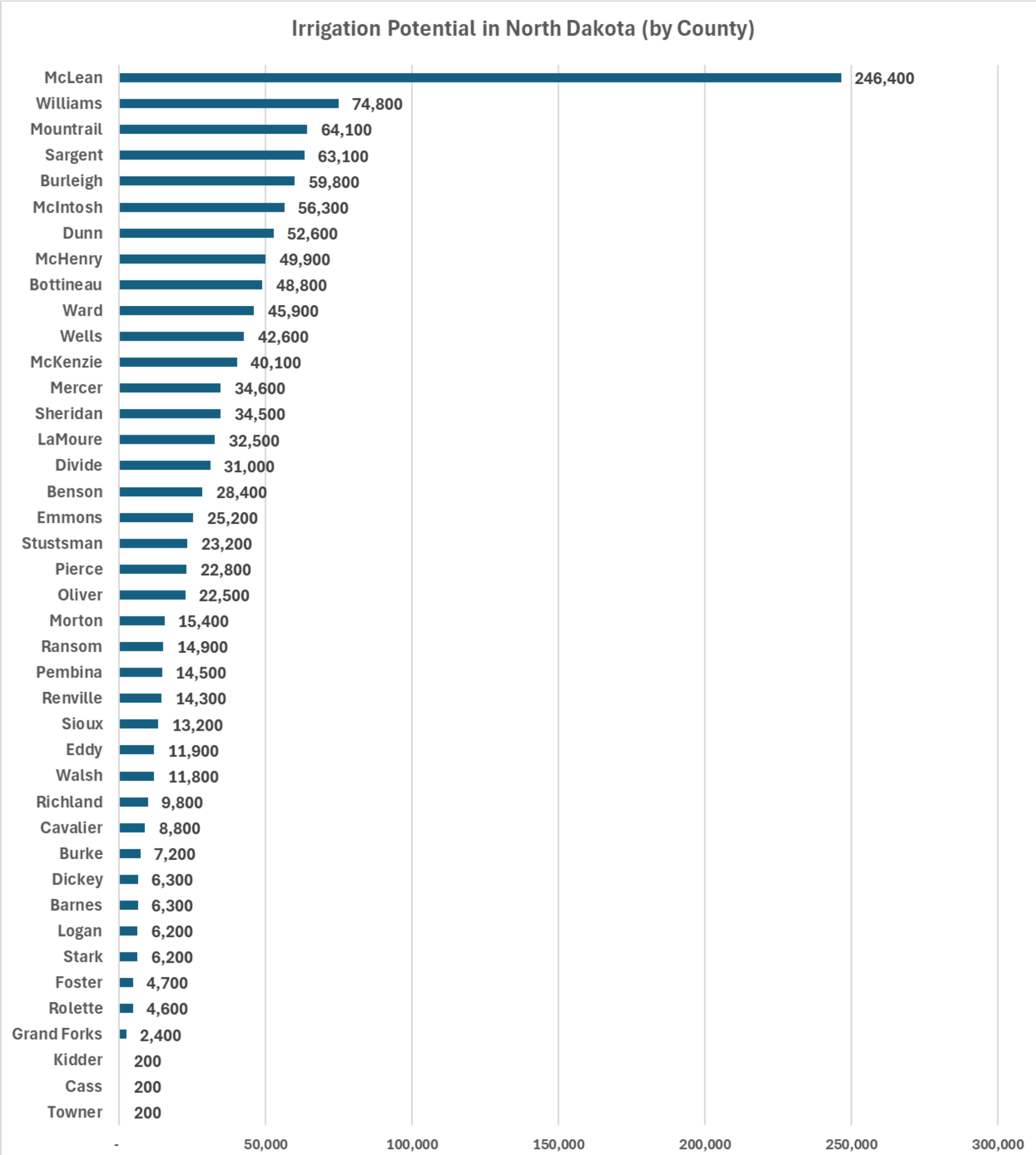


Figure 6. Irrigation Potential in North Dakota (by County)

2.2 Total Actual and Potential Irrigation in North Dakota (by County)

When currently irrigated land in North Dakota is combined with the land that has potential for irrigation in the state, there are 1.53 million acres that could be irrigated. The listing by county is in Figure 7.

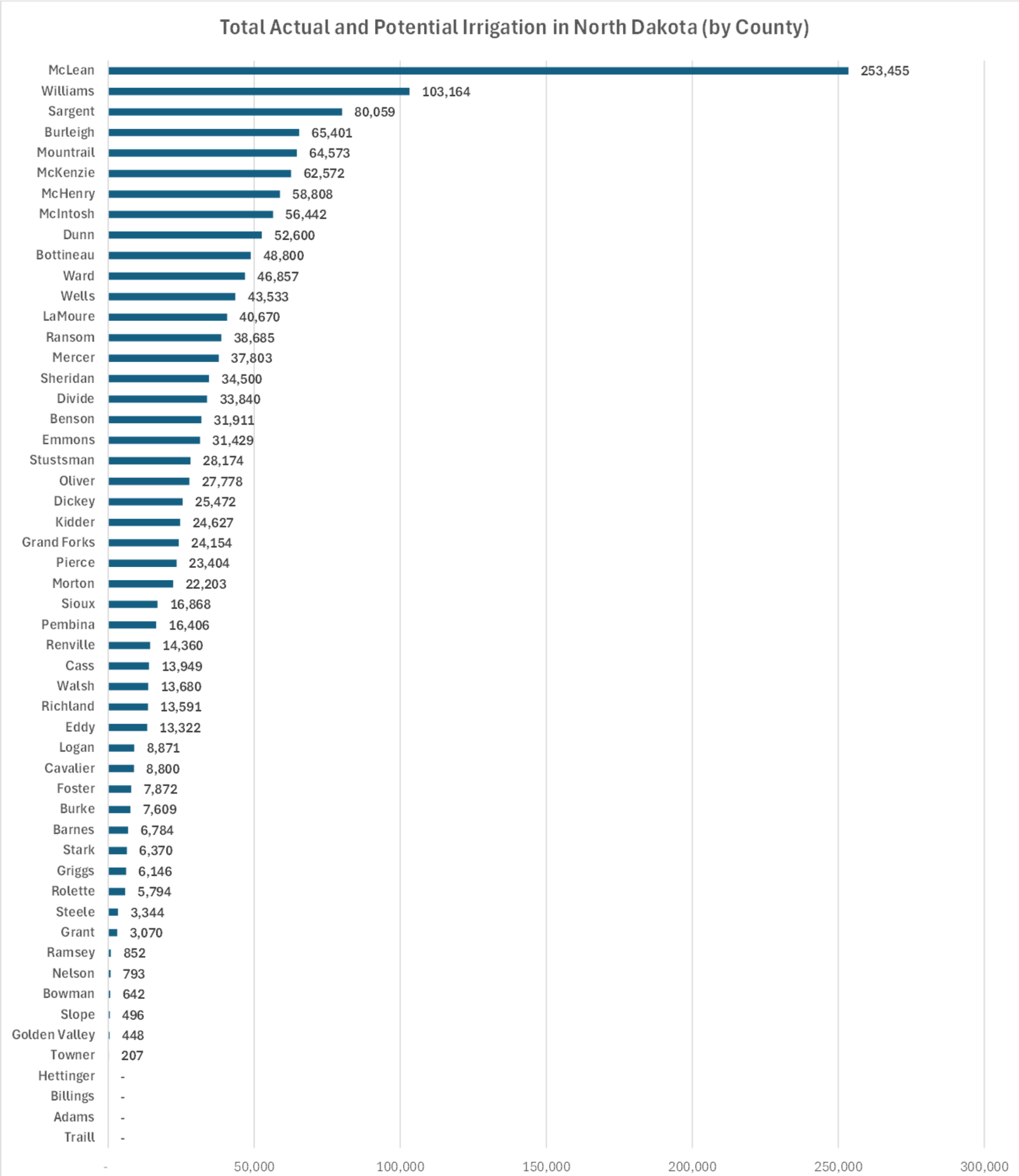


Figure 7. Total Actual and Potential Irrigation in North Dakota (by County)

Figure 8 shows actual and potential irrigated acres together in a stacked chart.

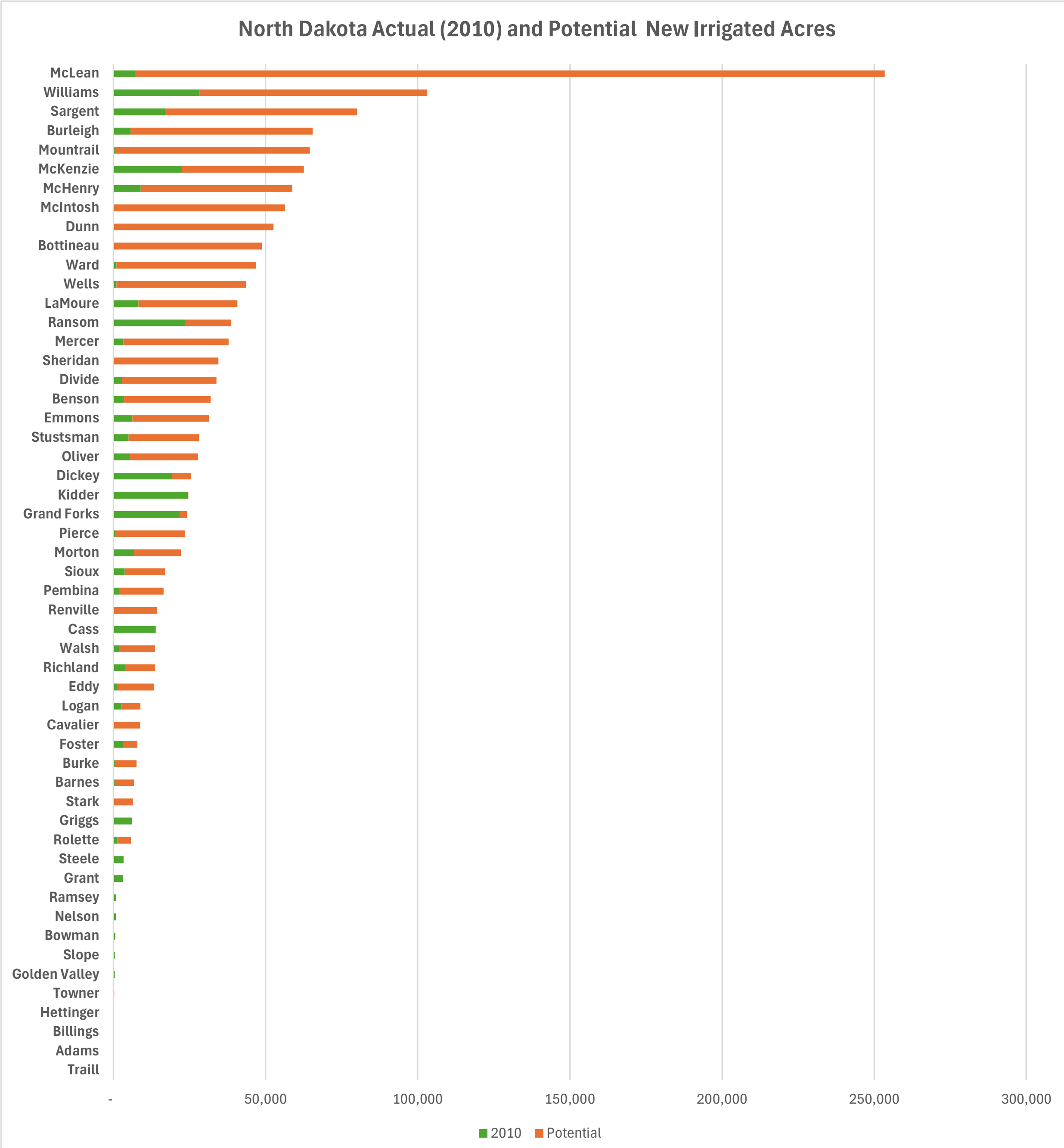


Figure 8. North Dakota Actual and Potential Irrigated Acres Stacked

A summary of the existing and potential irrigated acreage in North Dakota (by district) is presented in the following table.

Table 2. Summary of Actual and Potential Irrigated Acres in North Dakota by District

District	Sum of Irrigated Acres (2010)	Sum of Potential Irrigation Acres	Sum of Total Potential Irr Acres
Central	34,928	117,100	152,028
East Central	23,723	6,500	30,223
North Central	14,217	154,500	168,717
Northeast	27,192	37,700	64,892
Northwest	33,103	237,300	270,403
South Central	25,371	113,600	138,971
Southeast	74,690	189,100	263,790
Southwest	1,756	6,200	7,956
West Central	38,008	396,200	434,208
State Total	272,988	1,258,200	1,531,188

Source: North Dakota Department of Water Resources

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

3 Results

3.1 Crop Acreage

Crop acreage data indicates substantial changes in both the composition and total level of agricultural production in North Dakota from 1945-2022 (Figure 9). While total planted acreage fluctuates over time, the data reveals a clear structural transition from a wheat and small grain dominated system to a system dominated by corn, soybeans, and wheat.

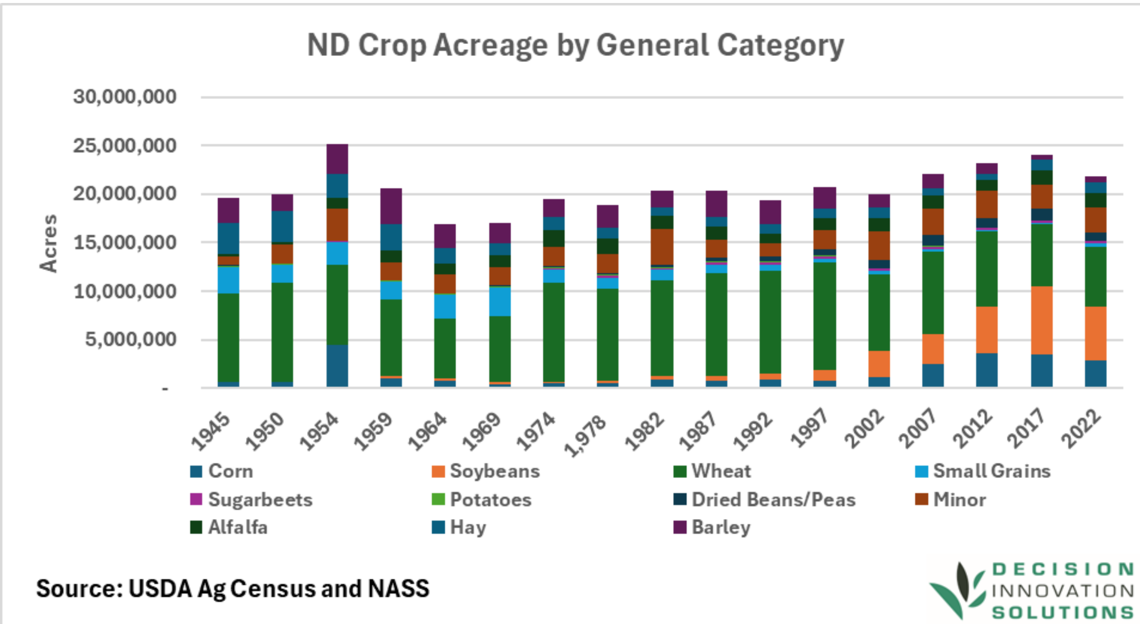


Figure 9. North Dakota Crop Acreage 1945-2022

From the 1940s through the 1960s, North Dakota agriculture was strongly dominated by wheat, with total wheat acreage accounting for on average around 8.1 million acres during this period. Barley was also a major crop, averaging 2.6 million acres. In contrast, corn and soybean acreage was negligible, with corn generally under 1 million acres and soybeans below 250,000 acres. This period reflects a highly concentrated, cereal-based production system.

During the 1970s and 1980s, total acreage became more variable and began to shift gradually. Wheat remained dominant, but barley and other small grains entered a long-term decline. At the same time, soybeans began to emerge as a viable crop, increasing from around 150,000 acres in the 1970s to nearly 500,000 acres by the end of the 1980s. Corn acreage grew as well, increasing from around 470,000 acres in 1974 to nearly 800,000 acres in 1987. This period represents the early stages of diversification, although traditional grains still dominated overall acreage.

A transition occurred in the 1990s, when soybean acreage expanded rapidly, rising from 632,000 acres in 1992 to over 1.1 million acres by 1997. Wheat acreage remained substantial but began to decline relative to total acreage, while barley, hay, and small grains continued downward trends. During this period, dry beans/peas and sugar beets showed steady increases, reflecting growing diversification into specialty crops.

The transformation accelerated significantly in the 2000s and 2010s. Soybean acreage increased dramatically, expanding from 2.6 million acres in 2002 to 7.1 million acres in 2017. Corn acreage also grew rapidly, rising from 1.2 million acres in 2002 to 3.5 million acres in 2017. These increases contributed to an overall rise in total planted acreage, exceeding 20 million acres by 2017. At the same time, traditional crops experienced sustained declines. Wheat acreage declined from the dominance of the 1940s-1960s but still accounted for a significant share of total acreage. Barley acreage fell sharply, dropping below 1 million acres after 2012. Small grains declined to minimal levels, and hay acreage decreased substantially.

3.1.1 Irrigated Acreage in North Dakota

Irrigated acreage in North Dakota was less than 100,000 acres in 1970. Since then, it has grown to more than 300,000 acres and in 2021 was at the highest reported level was just over 350,000 acres (Figure 10). Currently, corn is the dominant irrigated crop in North Dakota, accounting for more than 50% of irrigated acres in the state. Soybeans account for about one-fourth of irrigated acres, wheat 6%, dry beans 7%, potatoes 10%, and sugar beets less than 1%.

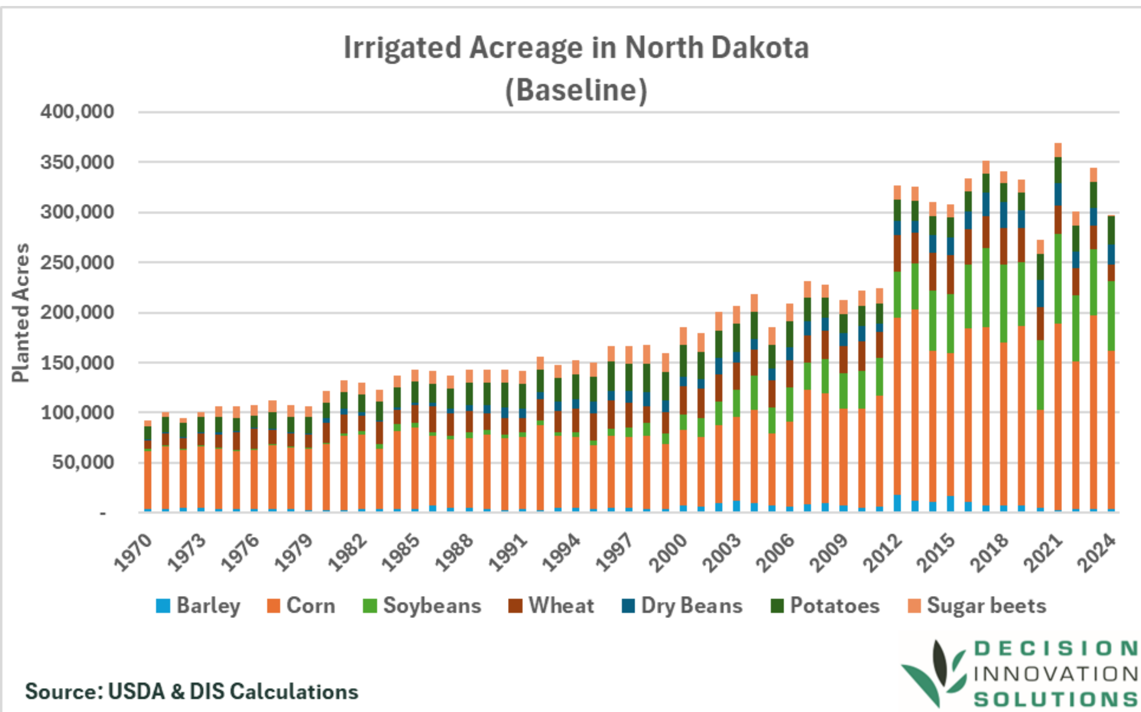


Figure 10. Irrigated Acreage in North Dakota (Baseline)

3.1.2 Fully Developed Irrigation Scenario

A counterfactual case was developed that modeled what acreage might have looked like in North Dakota if the irrigation potential had been fully developed as envisioned in the Pick-Sloan Plan. The crop mix on irrigated land is modeled on current uses of irrigated land in North Dakota and then adjusted for crop development over time such as the growth of soybeans in the overall crop mix and decline of wheat in the crop mix (Figure 11). In this model, corn accounts for 38% of irrigated acreage in North Dakota, soybeans 31%, wheat 27%, dry beans 2%, potatoes 2%, barley and sugar beets less than 1%.

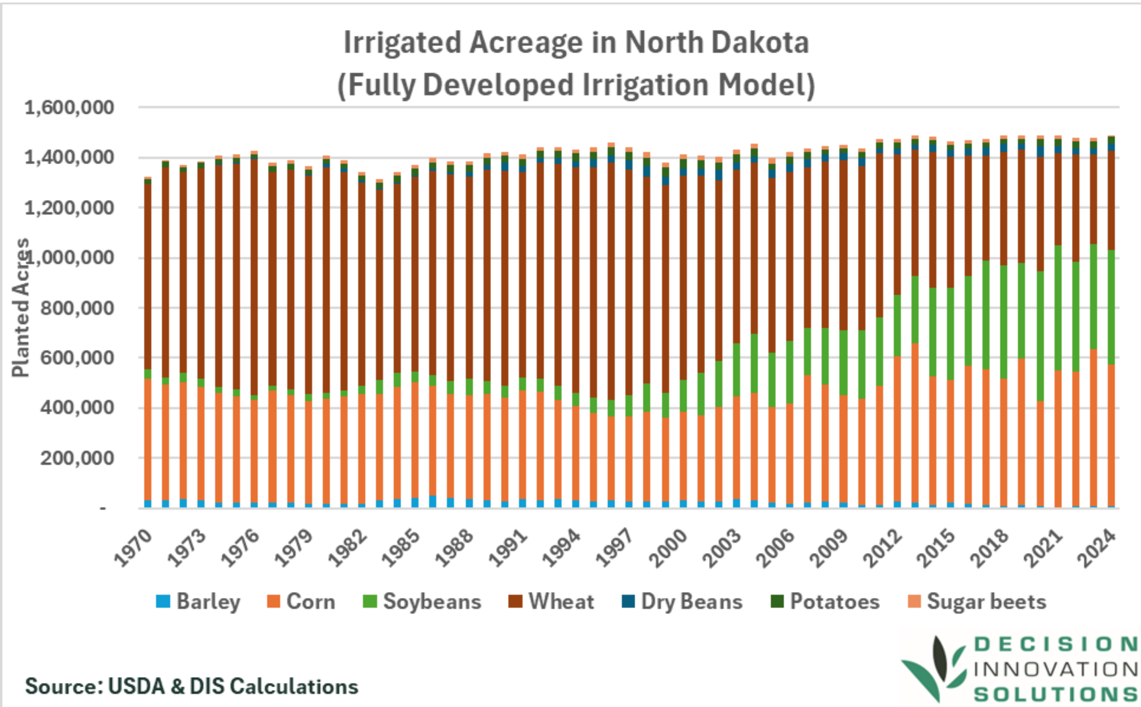
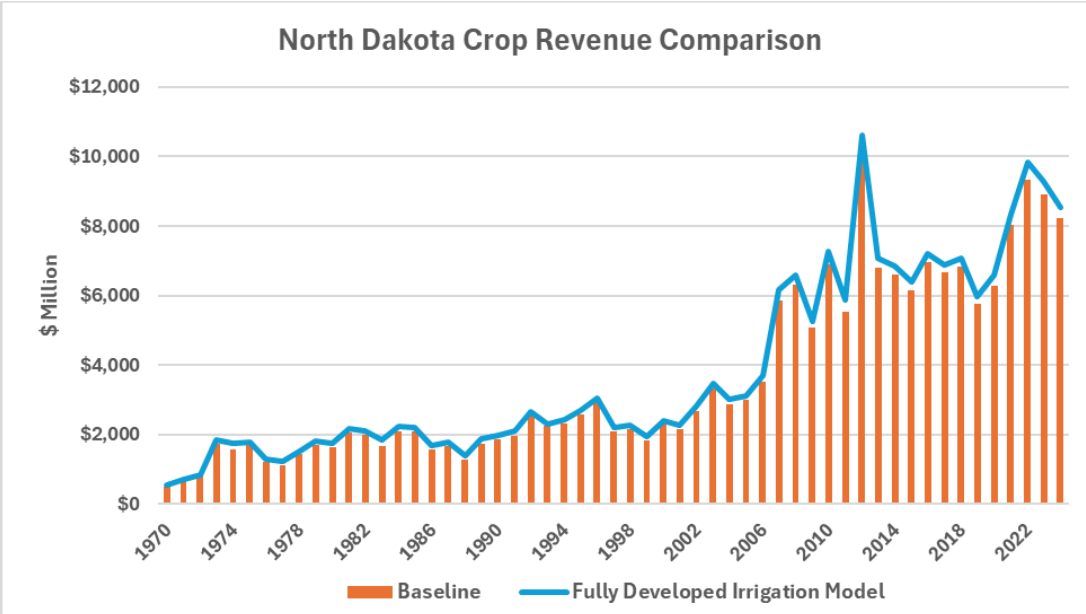


Figure 11. Irrigated Acreage in North Dakota (Fully Developed Irrigation Model)

3.2 Potential Economic Contribution of Additional Irrigation in North Dakota

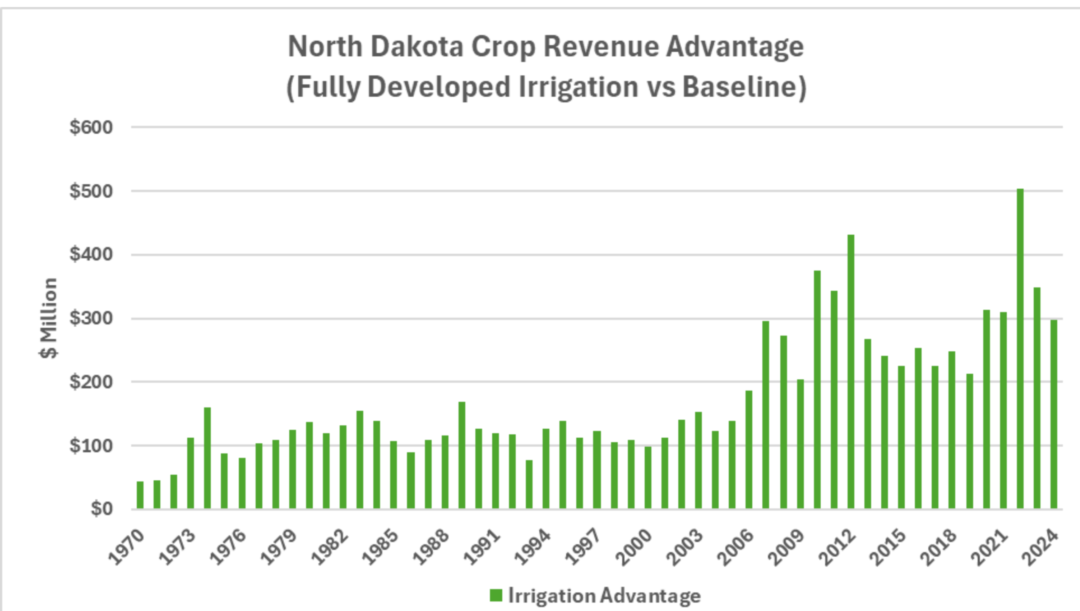
3.2.1 Revenue and Expenses Comparison

If the irrigation infrastructure had been fully developed in North Dakota, both the crop mix and the yields of crops in North Dakota would have been different than has occurred. This results in economic differentials between the baseline and the scenario. Figure 12 shows the crop revenue under the baseline and the scenario. The aggregate difference between the baseline crop revenue and the crop revenue with full irrigation is $9.7 billion from 1970 through 2024 with the average annual difference being $175 million more with full irrigation (Figure 13). On average, the fully developed irrigation scenario would have had 1.23 million acres more irrigated acres than the baseline situation and the average increased revenue for those additional irrigated acres would have been $145.60 per acre across the time period of 1970 through 2024 with a difference of $35.75 per acre in 1970 and $428.40 per acre in 2022, the year with the greatest difference (Figure 14).



Source: DIS Calculations based on USDA, NDSU, and Various Other Budgets
Notes: For Barley, Corn, Soybeans, Wheat, Dried Beans, Potatoes, Sugar beets, and Minor Crops

Figure 12. North Dakota Crop Revenue Comparison



Source: DIS Calculations based on USDA, NDSU, and Various Other Budgets
Notes: For Barley, Corn, Soybeans, Wheat, Dried Beans, Potatoes, Sugar beets, and Minor Crops. Aggregate revenue difference is $9.7 billion and annual average revenue difference is $175 million.

Figure 13. North Dakota Crop Revenue Advantage (Fully Developed Irrigation vs Baseline)

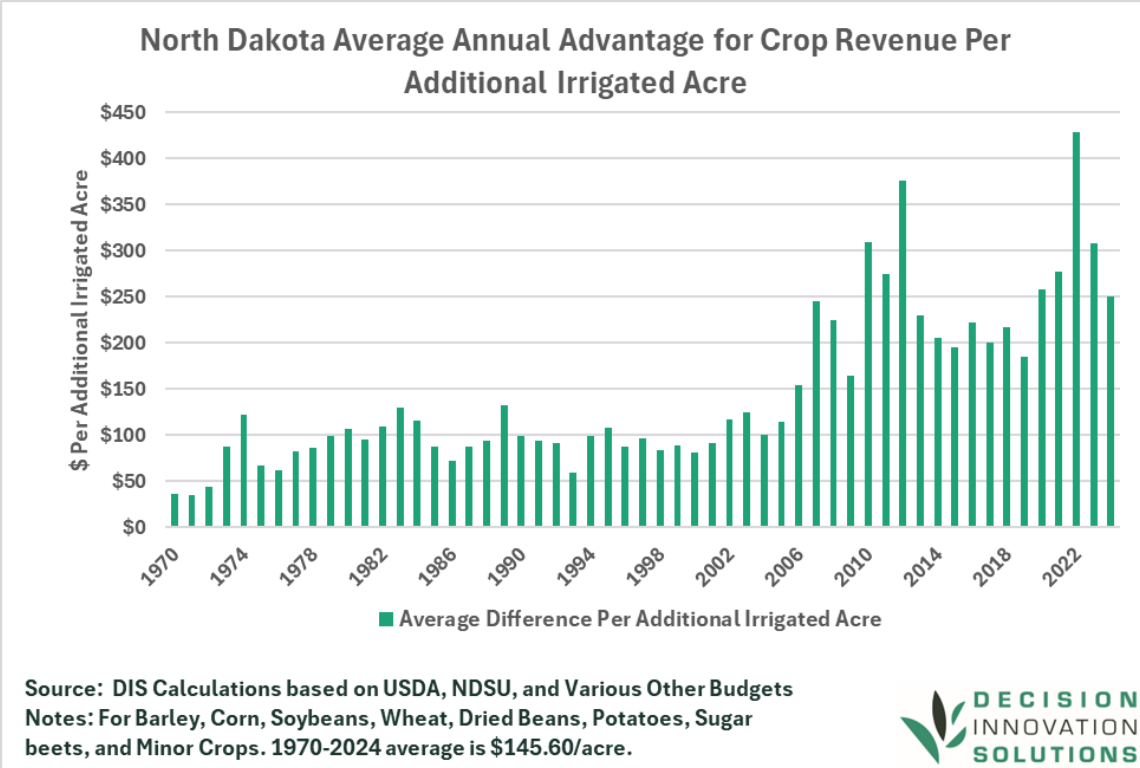
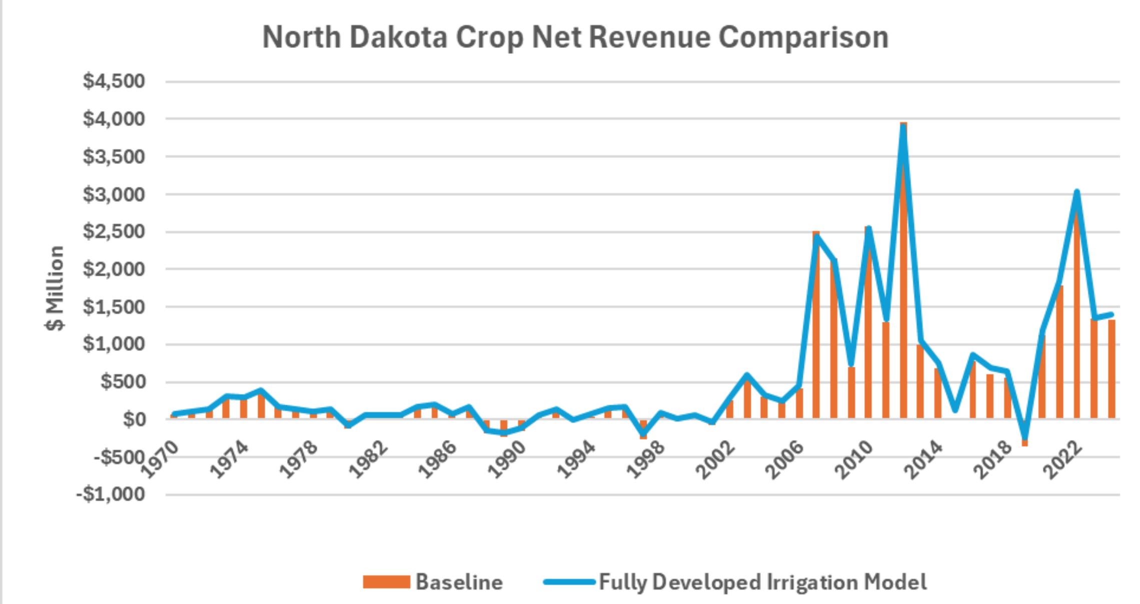


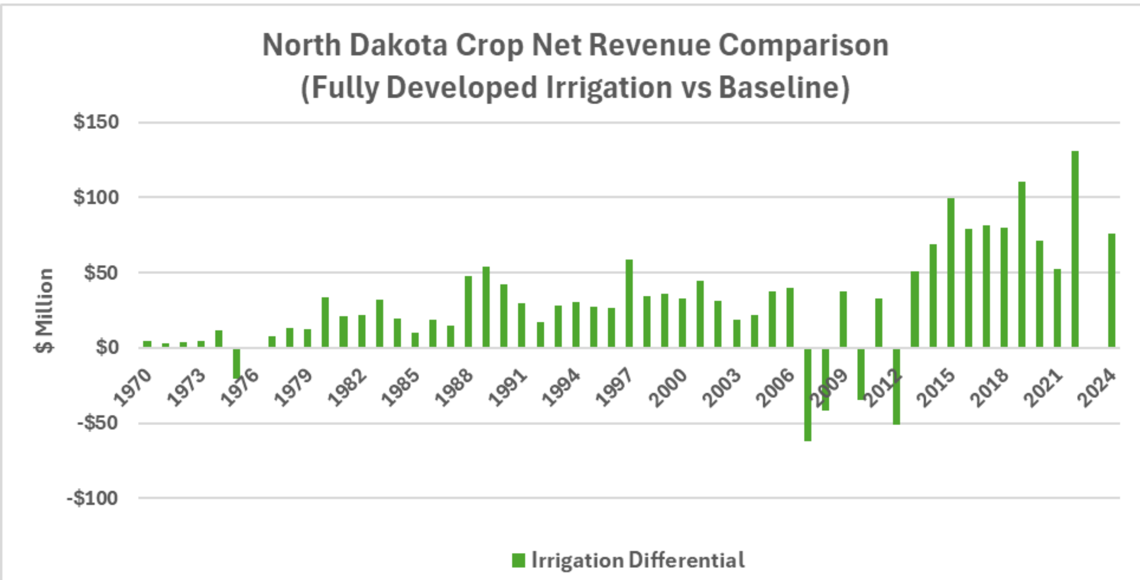
Figure 14. North Dakota Average Annual Advantage for Crop Revenue Per Additional Irrigated Acre

Net crop revenue is generally higher with more irrigated acres, but not always. Sometimes when there are extenuating circumstances such as very low prices or other weather related events net revenue may be less due to higher costs associated with irrigation (Figure 15 and Figure 16). In aggregate, net crop revenue would have been $1.65 billion greater with fully developed irrigation than has been seen under the baseline situation. The annual average premium of the irrigation scenario over the baseline is $30 million per year.



Source: DIS Calculations based on USDA, NDSU, and Various Other Budgets
Notes: For Barley, Corn, Soybeans, Wheat, Dried Beans, Potatoes, Sugar beets, and Minor Crops

Figure 15. North Dakota Crop Net Revenue Comparison



Source: DIS Calculations based on USDA, NDSU, and Various Other Budgets
Notes: For Barley, Corn, Soybeans, Wheat, Dried Beans, Potatoes, Sugar beets, and Minor Crops. Aggregate net revenue differential is $1.65 billion and average annual net revenue difference is $30 million.

Figure 16. North Dakota Crop Net Revenue Comparison (Fully Developed Irrigation vs Baseline

The economic impacts of irrigation flow beyond the gross and net revenue lines. Other economic impact factors are also affected by changes in irrigation status and the resultant changes in crop mix that occur due to increased availability of irrigation. Fixed costs, for example, tend to be higher for irrigated land than non-irrigated land, although the difference varies by crop. In aggregate, fixed expenses with fully developed irrigation would have been $2.24 billion more than the baseline with the annual average difference being $41 million (Figure 17 and Figure 18).

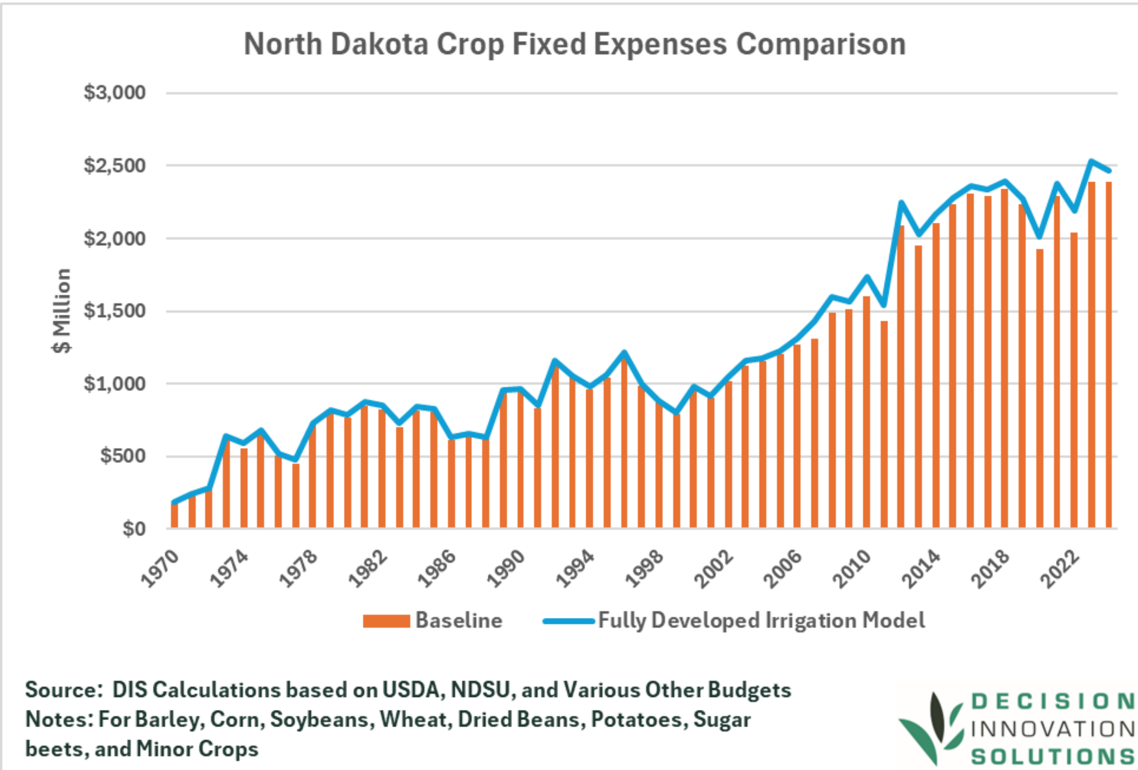


Figure 17. North Dakota Crop Fixed Expenses Comparison

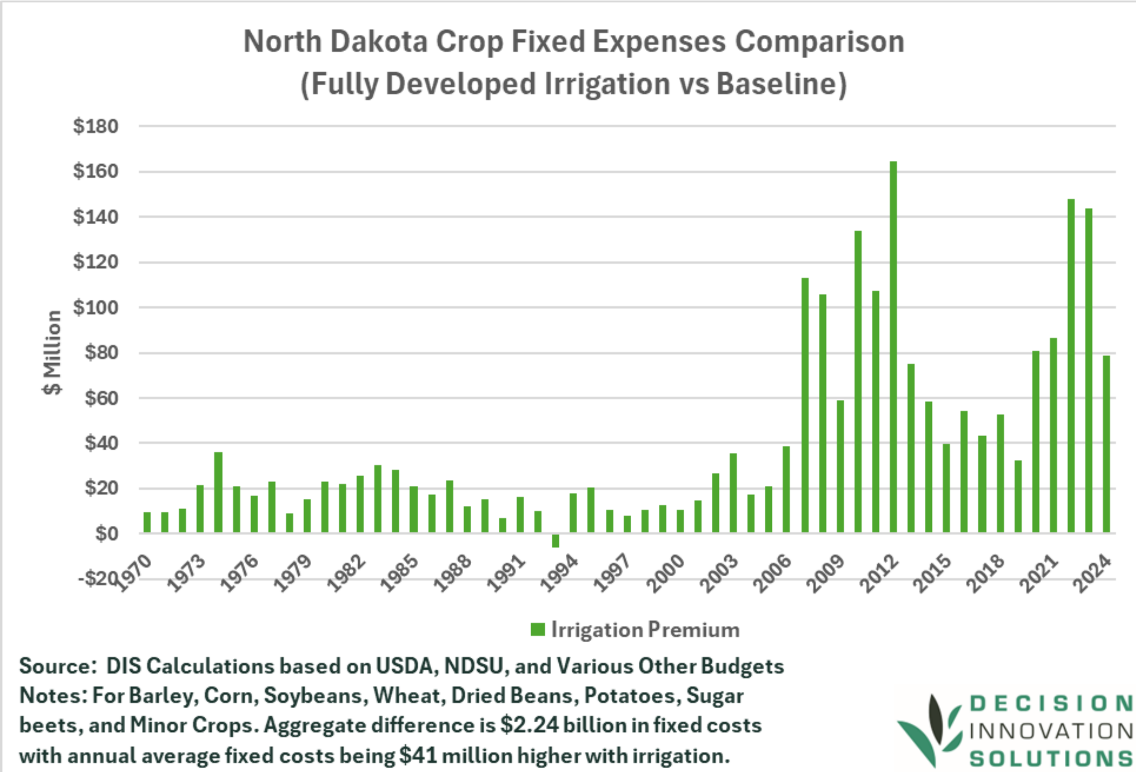


Figure 18. North Dakota Crop Fixed Expenses Comparison (Fully Developed Irrigation vs Baseline)

Fertilizer expenses would have increased with the higher yields expected due to irrigation. The aggregate increased fertilizer expenditures for fully developed irrigation would have been $3.26 billion more than the baseline with the annual average increased expenditure being $59.3 million (Figure 19 and Figure 20).

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

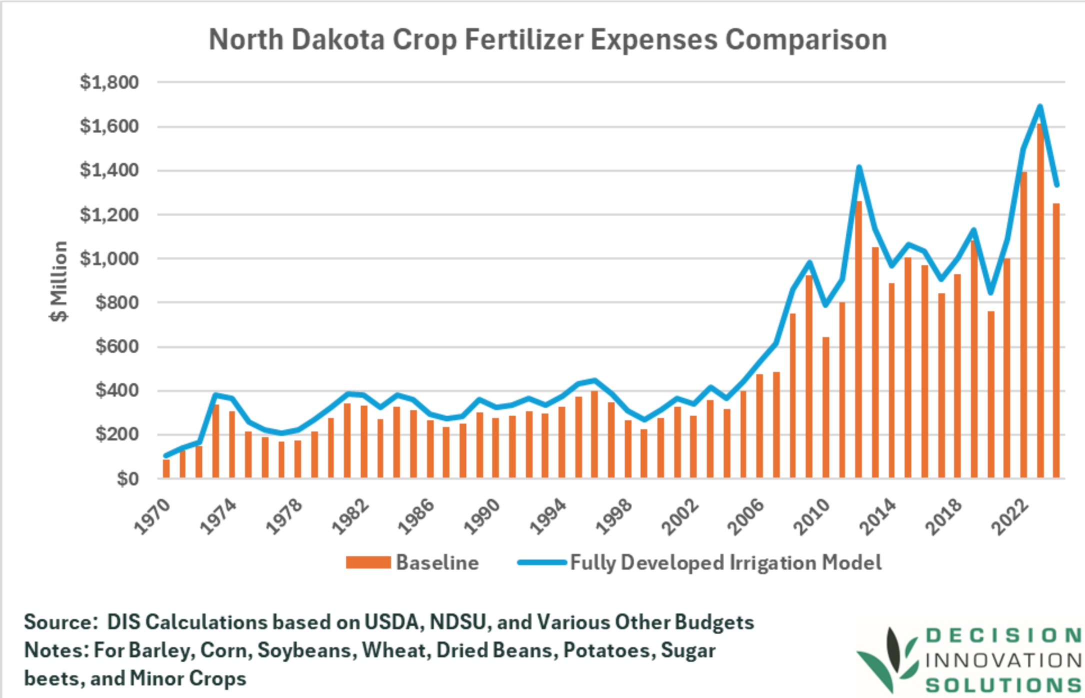


Figure 19. North Dakota Crop Fertilizer Expenses Comparison

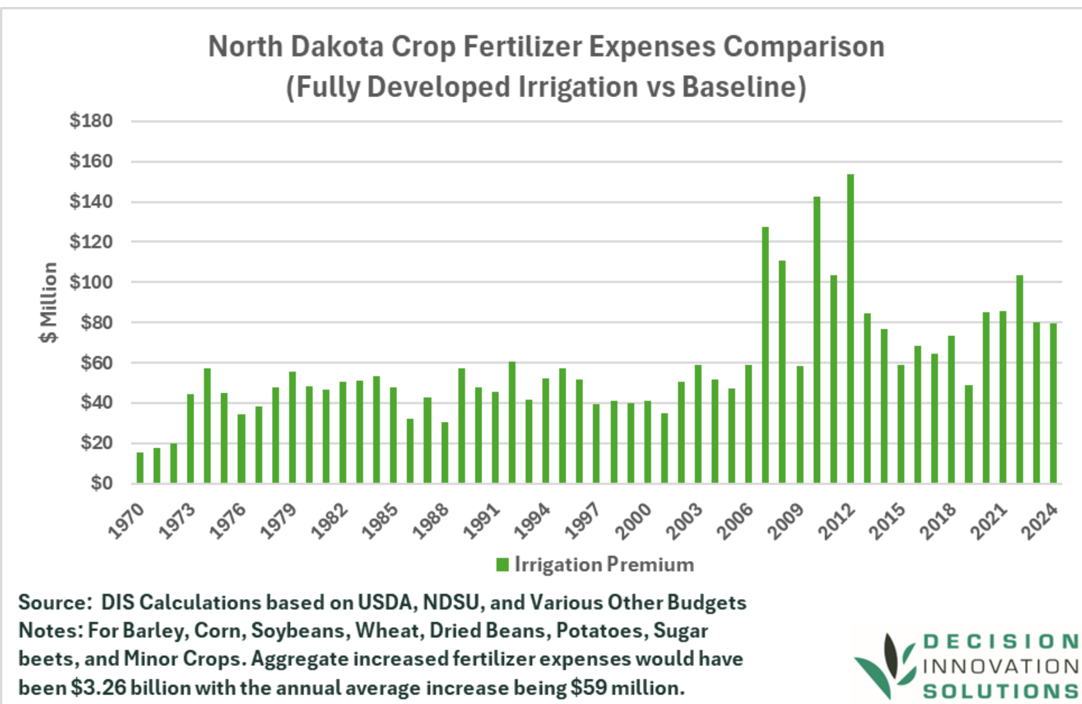


Figure 20. North Dakota Crop Fertilizer Expenses Comparison (Fully Developed Irrigation vs Baseline)

Seed expenses vary by crop and can tend to be higher with irrigation due to higher planting populations for some crops with irrigation. The aggregate increase in seed cost with fully developed irrigation is $201 million with the annual average difference being $3.7 million (Figure 21 and Figure 22).

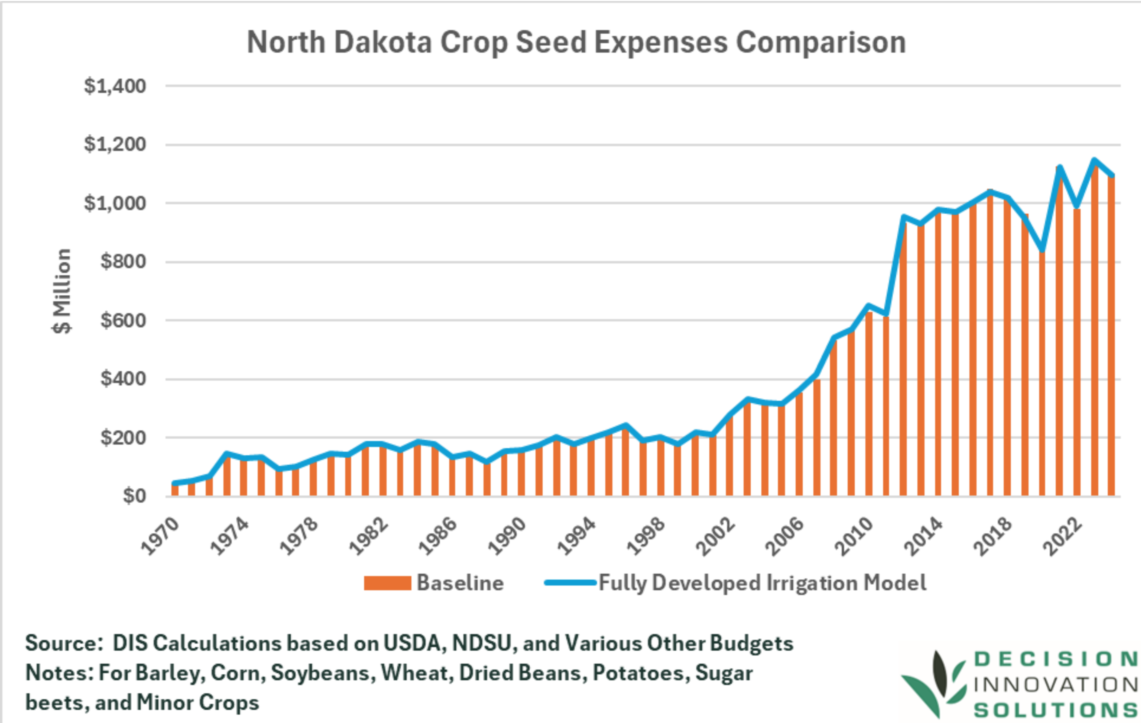


Figure 21. North Dakota Crop Seed Expenses Comparison

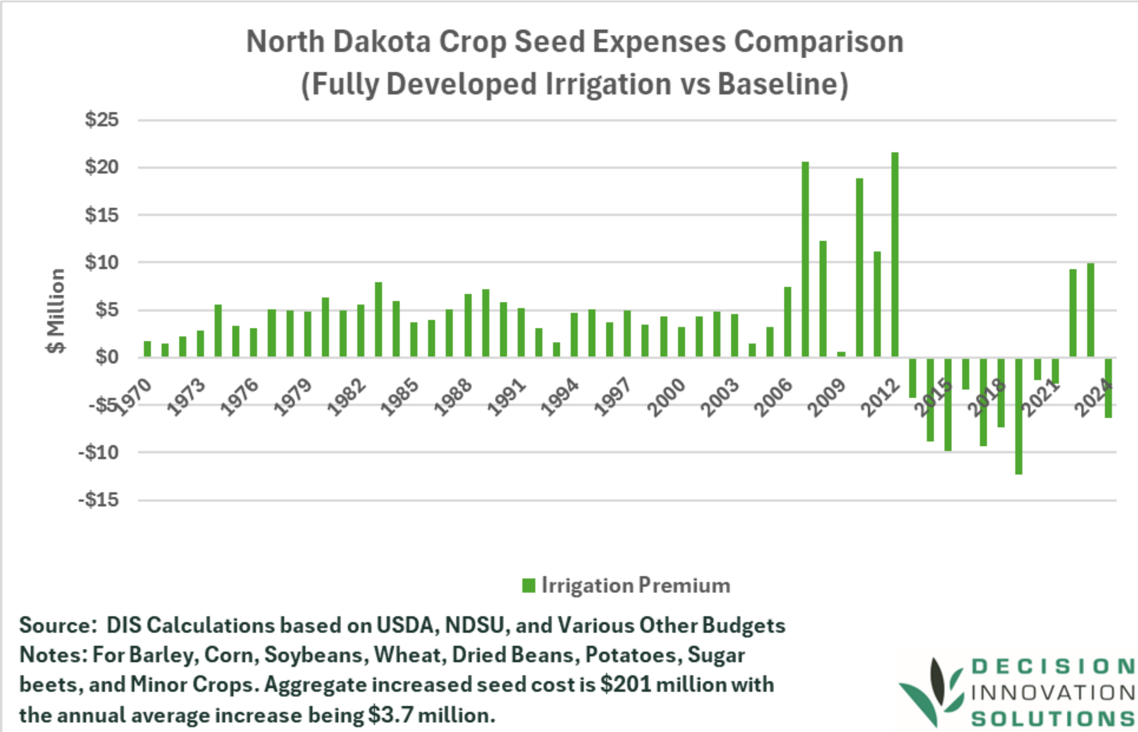


Figure 22. North Dakota Crop Seed Expenses Comparison (Fully Developed Irrigation vs Baseline)

Interest expenses vary by crop and can be greater with increased usage of crop production inputs such as seed and fertilizer as well as increased fixed expenses. The aggregate increased interest expenses would have been $165 million with the annual average increase being $3 million (Figure 23 and Figure 24).

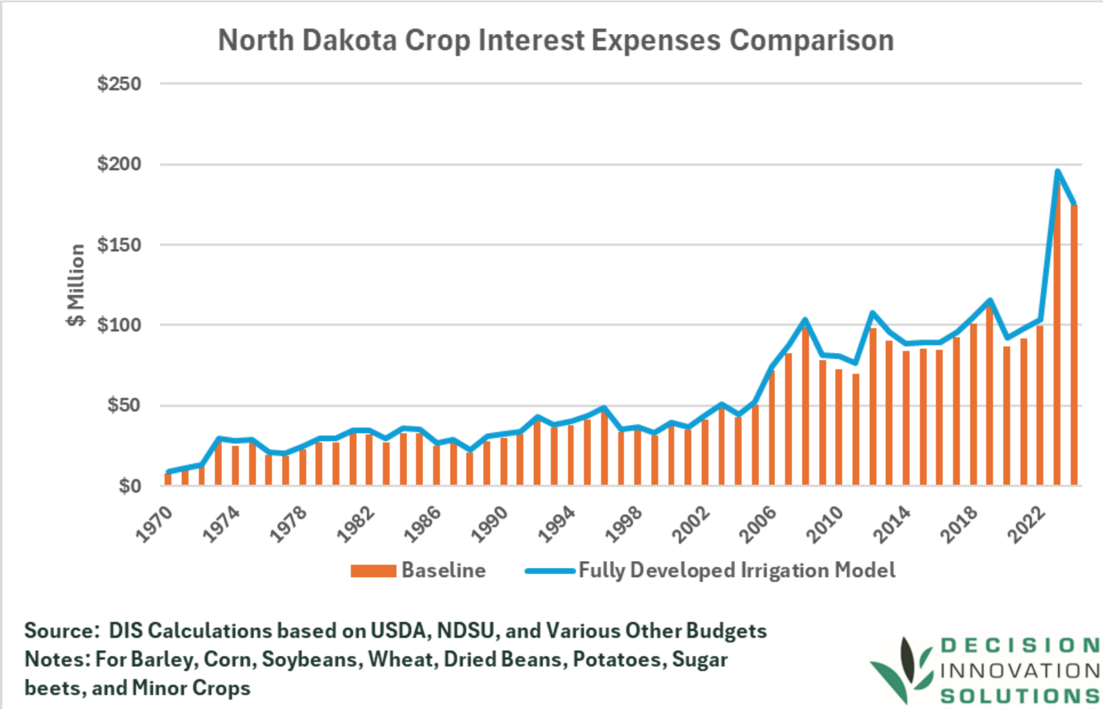


Figure 23. North Dakota Crop Interest Expenses Comparison

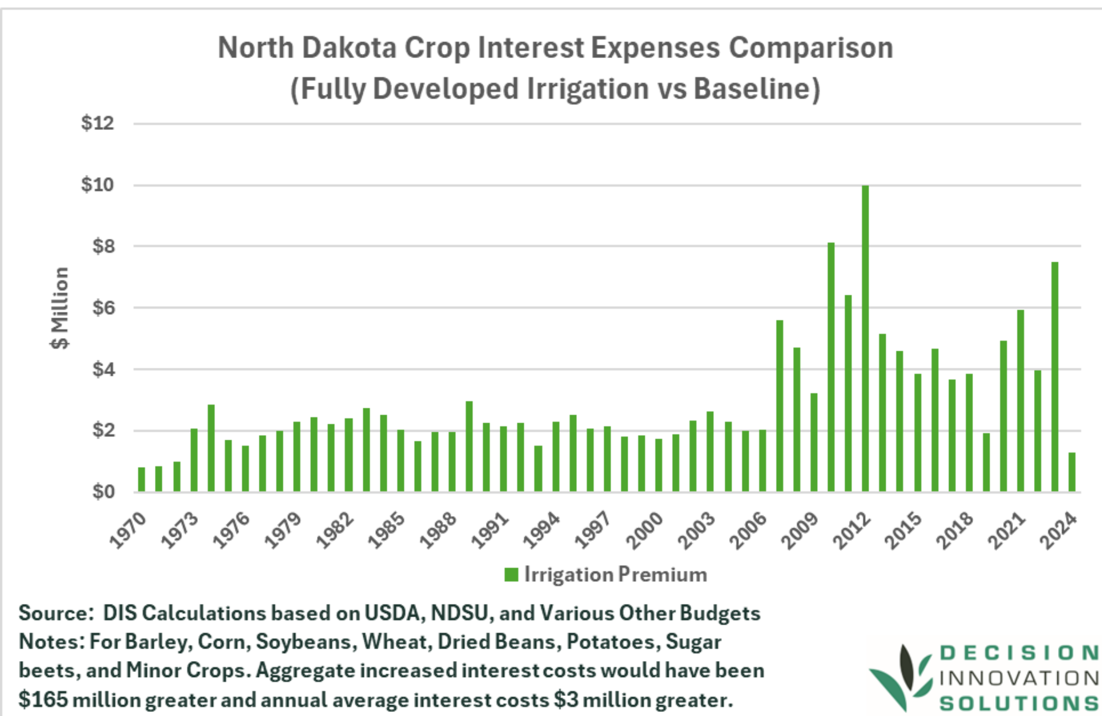


Figure 24. North Dakota Crop Interest Expenses Comparison (Fully Developed Irrigation vs Baseline)

3.2.2 Economic Impact and Contribution Terminology

This study was conducted using a combination of IMPLAN and Microsoft Excel. IMPLAN is an input-output model used to understand industry relationships and conduct economic assessments for specified local economies. IMPLAN datasets are constructed annually and are derived from many different sources, including the U.S. Bureau of Labor Statistics (BLS), the U.S. Bureau of Economic Analysis (BEA), the U.S. Bureau of Economic Analysis Benchmark Input-Output Account of the U.S., the BEA output estimates, the U.S. Census Bureau's economic censuses and surveys, the U.S. Department of Agriculture's census, and more.

Within IMPLAN, the effects of an economic impact or contribution event are expressed in terms of direct, indirect, and induced effects. These different effect types are defined as follows:

- **Direct Effects:** The economic activity directly attributable to the industry under analysis; for example, the on-farm activities associated with crop production.
- **Indirect Effects:** The effects of local inter-industry spending throughout the supply chain; for example, the equipment, energy, and other inputs used by a local business to produce their goods and services.
- **Induced Effects:** The results of employees of the directly and indirectly affected industries spending their income throughout the local economy.
- **Total Effect:** The sum of direct, indirect, and induced effects.

The results of this analysis are presented using the following common economic modeling terms:

- **Output:** The broadest measure of economic activity – also commonly referred to as "sales." Output refers to the total value of all sales of an industry within a study area without any deductions for the cost or origination of inputs that were used in the production process.
- **Value Added:** A component of output, this measure includes the total sales minus the costs of inputs. Alternatively, value added is calculated as the sum of labor income (further defined below), taxes on production and imports, and other property-type income. An industry's value added is equivalent to its contribution to GDP.
- **Labor Income:** A subset of value added, includes the sum of employee compensation (i.e., wages and benefits) and proprietor income (i.e., income of self-employed workers).
- **Employment (Jobs):** A measure of part- and full-time job positions, including contract workers, without regard to their full-time equivalence. Since it is not representative solely of full-time positions or full-time equivalents, care must be made when drawing comparisons to other measures of employment.

3.2.3 Output Contribution

The revenue and expenses shown above in Section 3.2.1 (and further detailed in Section 5.3) were used as inputs to estimate the total economic contribution of crop production under the baseline and fully developed irrigation scenario for the following years: 1970, 1980, 1990, 2000, 2010, 2020, and 2024. These total contribution values include impacts from farm input purchases (seed, fertilizer, equipment, etc.) and income spent by farmers within North Dakota in addition to direct economic activity at the farm level.

Figure 25 shows the increase in output contribution for the fully developed irrigation scenario relative to the baseline in each USDA Agricultural Statistics District. The increase in output at the state level is $52.7 million in 1970, peaks at $477.5 million in 2010, and is $421.9 million in 2024. The West Central district consistently shows the largest growth in output contribution from fully developed irrigation and has an estimated increased output of $124 million in 2024. The Northwest district is second ($70 million), followed by Southeast ($59 million), South Central ($54 million) and North Central ($54 million).

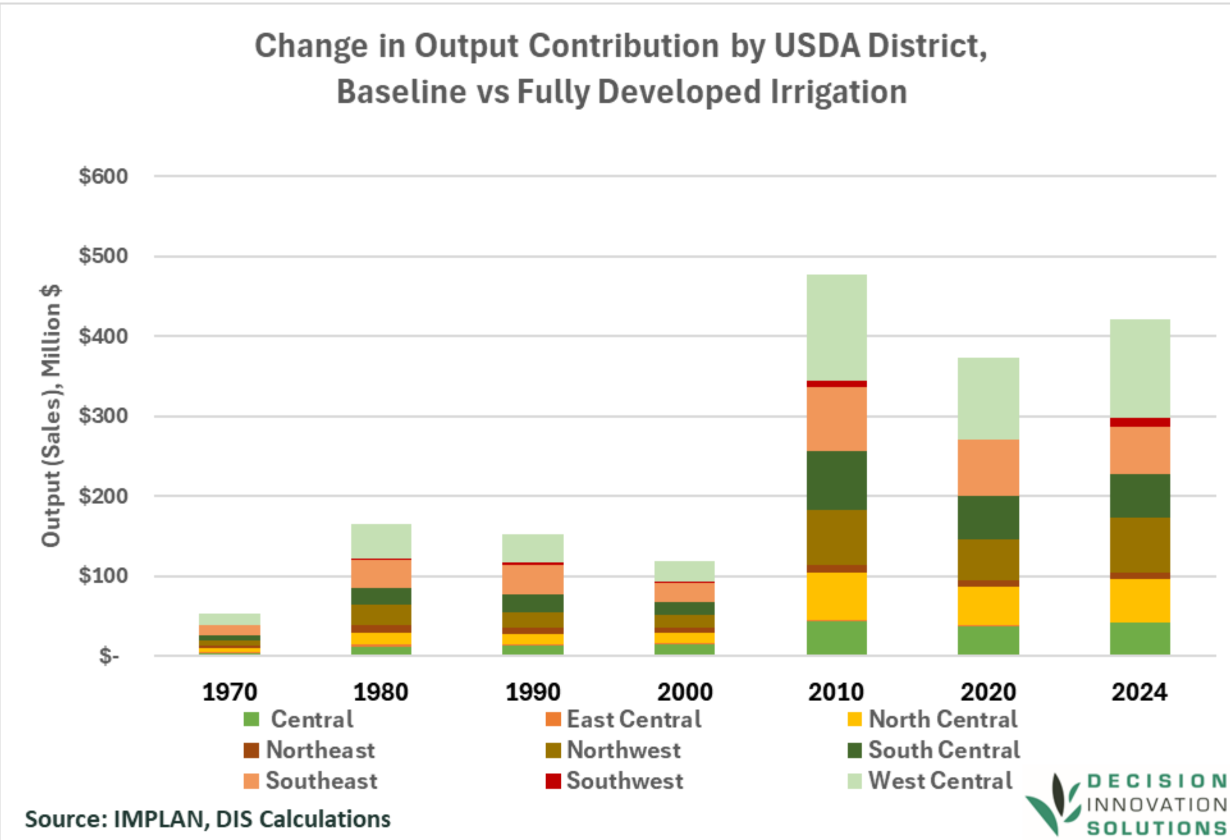


Figure 25. Change in Output Contribution by USDA District, Baseline vs Fully Developed Irrigation

Output contribution from crop production grows from $617.3 million in 1970 to $13.4 billion in 2024 in the baseline model. The output from baseline irrigated crop production is $14.7 million in 1970 and $598.4 million in 2024 (Figure 26). Under the fully developed irrigation scenario, total output grows from $670.0 million in 1970 to $13.8 billion in 2024, while irrigated crop output grows from $115.6 million in 1970 to $1.7 billion in 2024 (Figure 27).

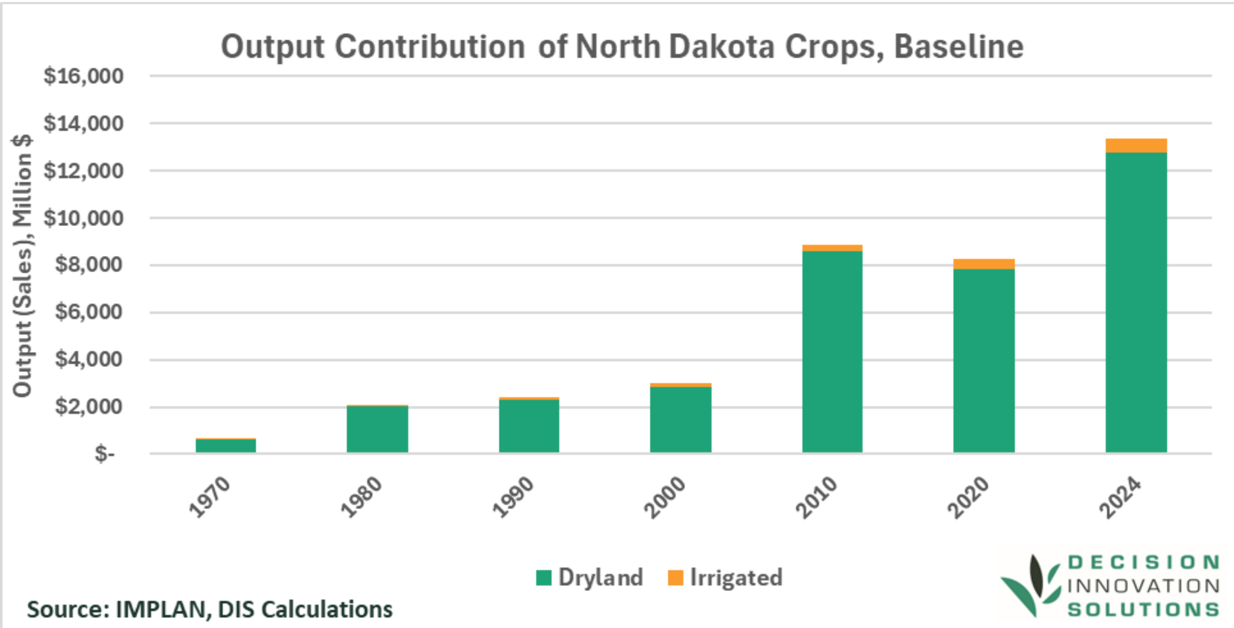


Figure 26. Output Contribution of North Dakota Crops, Baseline

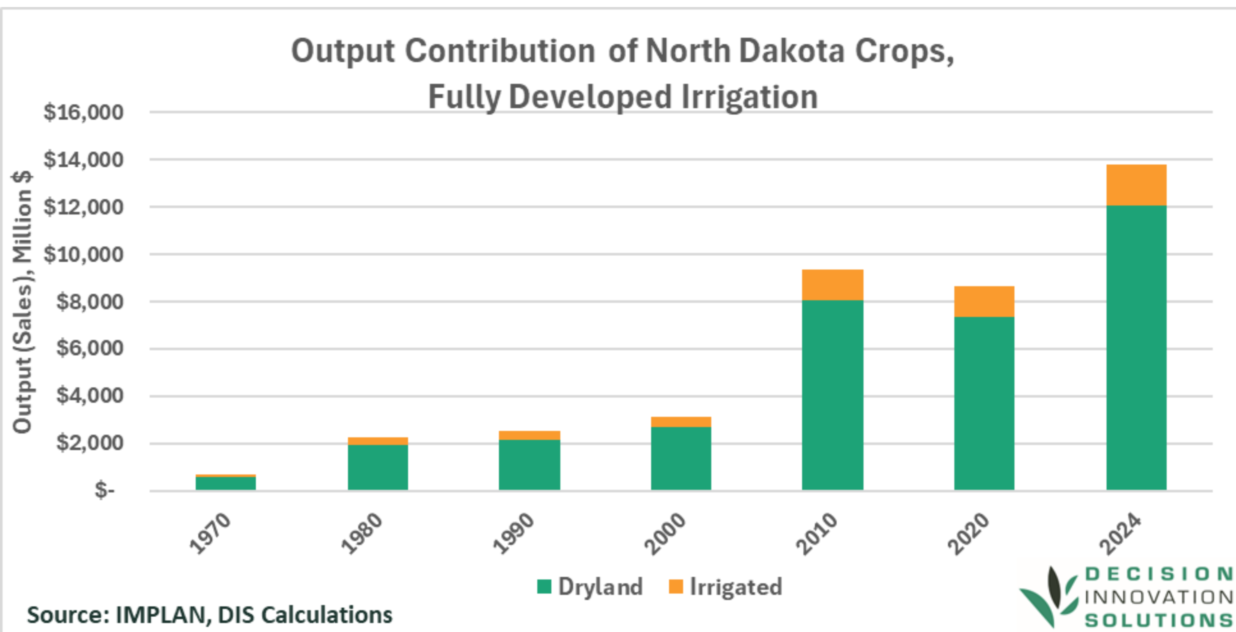


Figure 27. Output Contribution of North Dakota Crops, Fully Developed Irrigation

Figure 28 shows the change over time in dryland and irrigated crop output in the fully developed irrigation scenario relative to the baseline. Output contribution from irrigated crops in 2024 is $1.7 billion in the fully developed irrigation scenario compared to $598.4 million in the baseline. Growth in contribution in irrigated crops is partially offset by reduced dryland acres and production ($726.2 million in 2024). Net contribution in terms of output grows from $52.7 million in 1970 to $421.9 million in 2024.

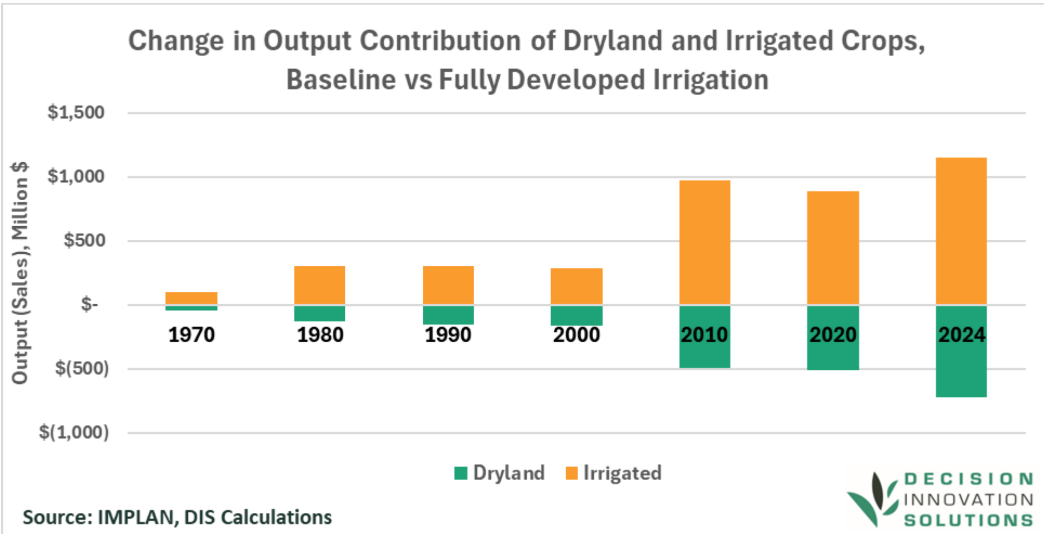


Figure 28. Change in Output of Contribution of Dryland and Irrigated Crops

The change in output varies significantly by crop. A majority of the increased output comes from corn, as a result of increased irrigated corn acres. Soybean and wheat also significantly drive the increase in output. Barley, dry beans, sugar beets, and other minor crops all slightly decrease in output in the fully developed irrigation scenario as a result of reduced dryland acres for those crops (Figure 29).

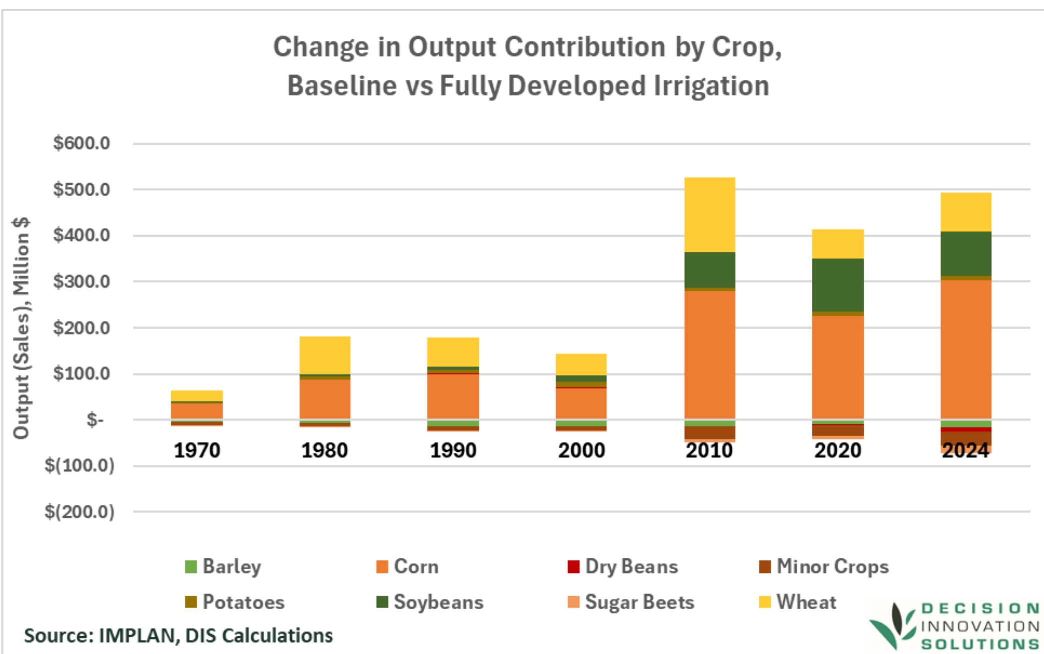


Figure 29. Change in Output Contribution by Crop, Baseline vs Fully Developed Irrigation

3.2.4 Value Added Contribution

Figure 30 shows the increase in value added contribution for the fully developed irrigation scenario relative to the baseline in each USDA Agricultural Statistics District. The increase in value added at the state level is $14.7 million in 1970, is between $40.0 and $60.0 million from 1980 to 2000, rises to $100.0 million in 2010, and is $185.7 million in 2024. The West Central district shows the largest increase in value added contribution in 2020 ($37.3 million) and 2024 ($48.9 million). The South Central district has the largest increase in 2010 of $20.3 million, and the Southeast district has the largest increase from 1970 ($5.3 million) to 2000 ($12.4 million).

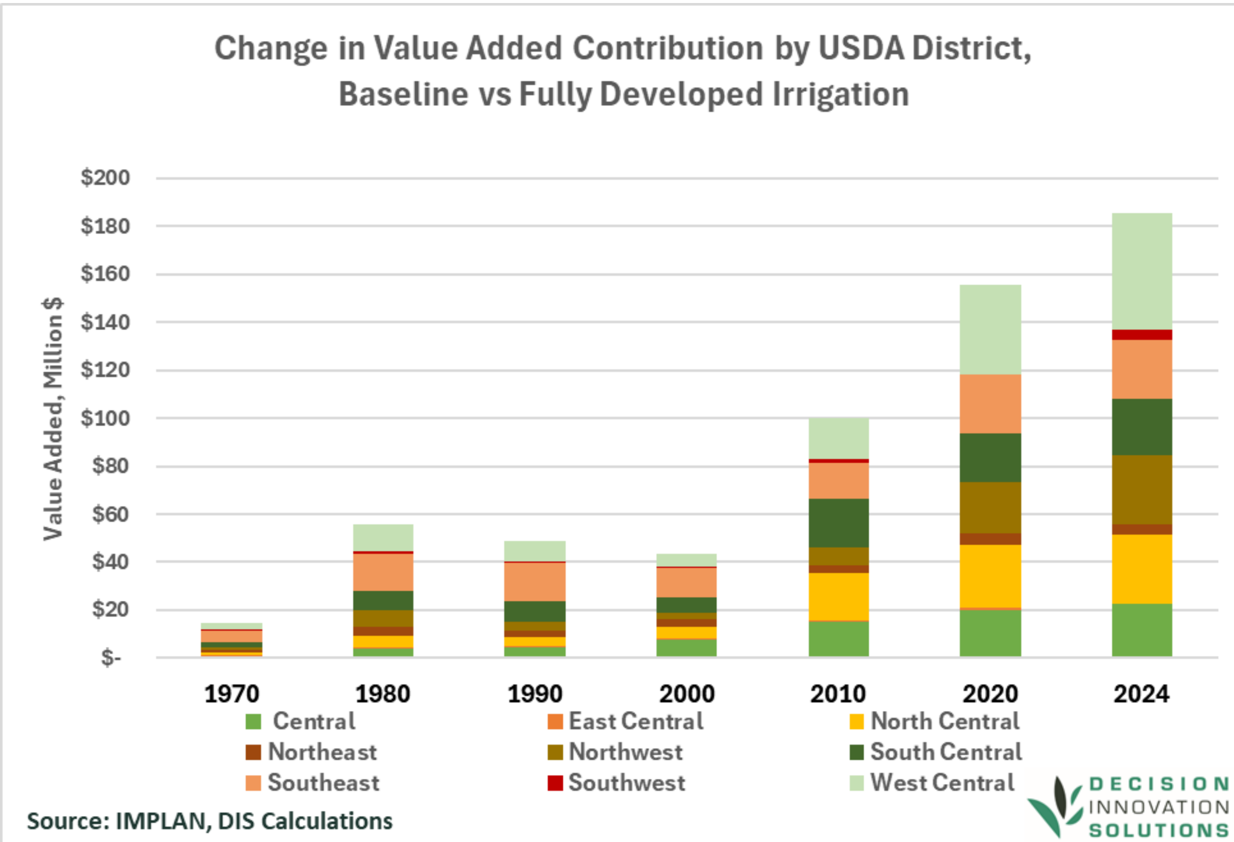


Figure 30. Change in Value Added Contribution by USDA District

Figure 31 shows the change over time in dryland and irrigated crop value added contribution in the fully developed irrigation scenario relative to the baseline. The increase in value added contribution in the fully developed irrigation scenario is $36.7 million in 1970, $377.9 million in 2010, and $507.3 million in 2024. The increase in contribution from irrigated crops is partially offset by reduced dryland acres and production by values of $22.0 million in 1970, $277.9 million in 2010, and $321.6 million in 2024.

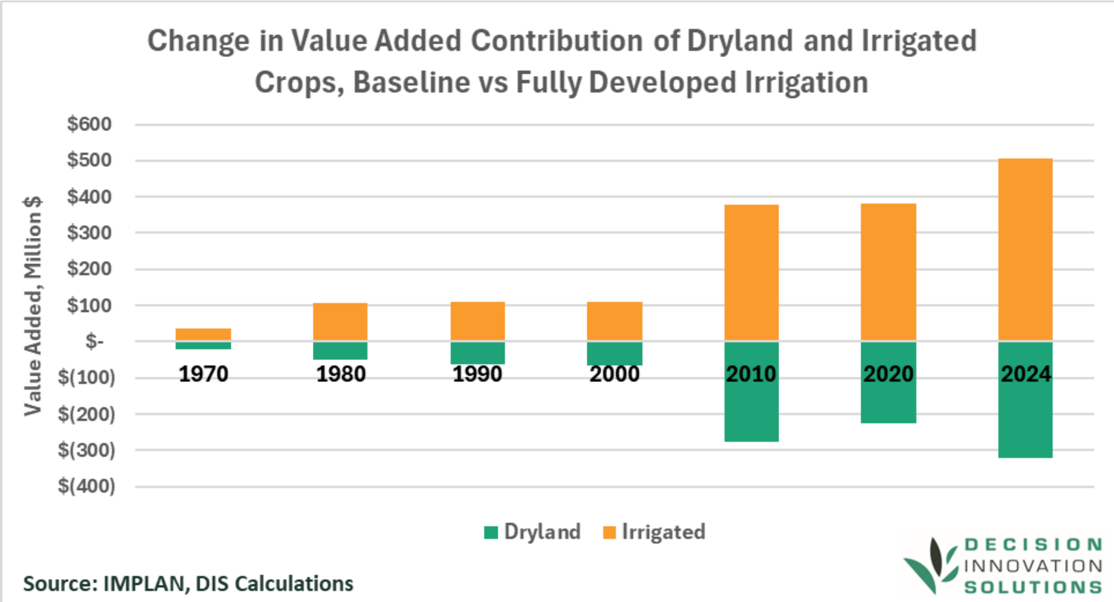


Figure 31. Change in Value Added Contribution of Dryland and Irrigated Crops

As shown in Figure 32, a much greater portion of increases in value added contribution are generated through corn and soybean production compared to increases in output. Potential increases in value added from corn production grow from $13.8 million in 1970 to $123.7 million in 2024. Similar to changes in output, decreases to value added in some crops occur because of a shift away from dryland production.

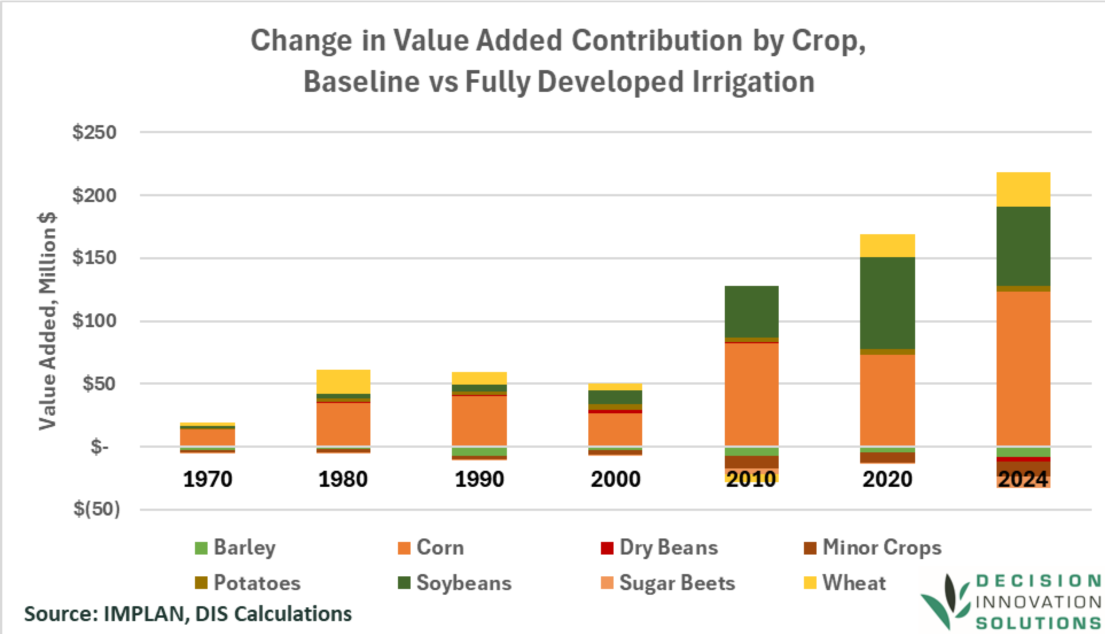


Figure 32. Change in Value Added Contribution by Crop

3.2.5 Labor Income Contribution

Figure 33 shows the increase in labor contribution for the fully developed irrigation scenario relative to the baseline by USDA Agricultural Statistics District. The increase in labor income at the state level is $18.6 million in 1970, peaks at $97.2 million in 2020, and is $95.2 million in 2024. The Southeast district shows the largest increase in labor income contribution in every year except for 2010, with this value increasing from $8.2 million in 1970 to a high of $26.7 million in 2020. The West Central district has the largest increase in 2010 of $18.1 and is the second or third most affected district in other years. In addition to the Southeast and West Central, the South Central, Central, North Central, and Northwest districts each have an additional labor income contribution greater than $10.0 million in 2024 relative to the baseline.

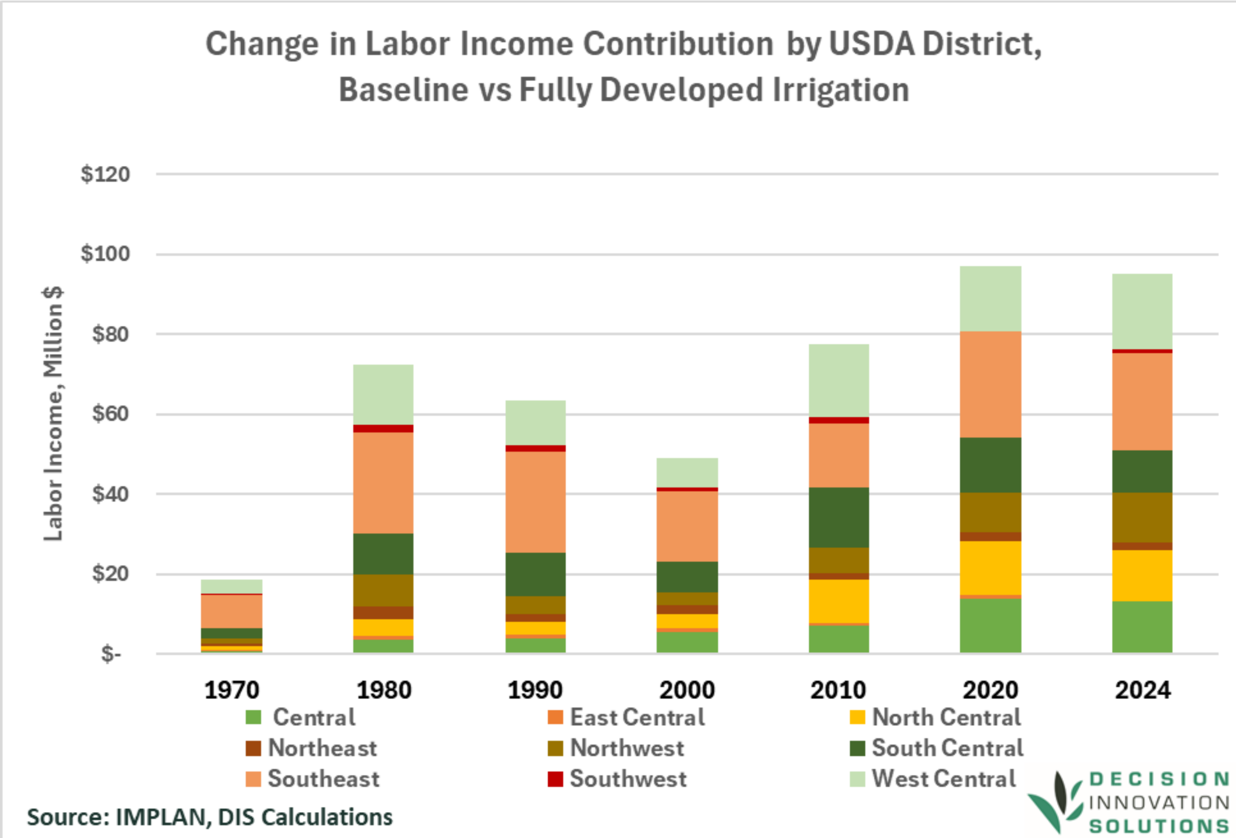


Figure 33. Change in Labor Income Contribution by USDA District

Figure 34 shows the change over time in dryland and irrigated crop labor income contribution in the fully developed irrigation scenario relative to the baseline. The increase in labor income from irrigated crop production is highest in 2010 at $372.1 million, being offset by a loss in labor income from dryland crop production of $294.6 million.

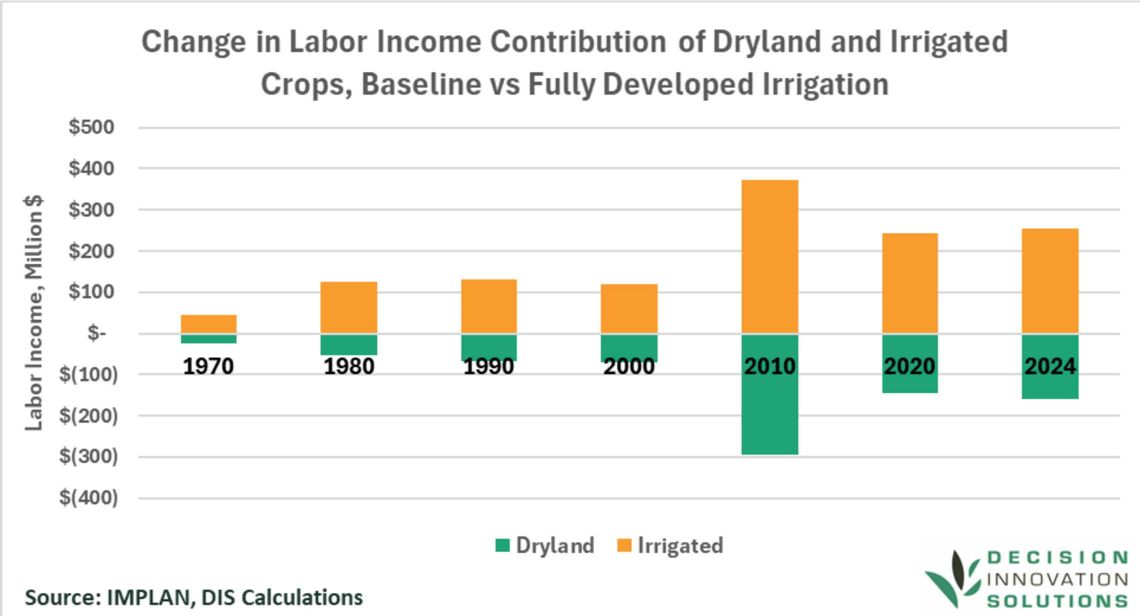


Figure 34. Change in Labor Income Contribution of Dryland and Irrigated Crops

Corn and soybean production are responsible for the majority of the increase in labor income for the fully developed irrigation scenario relative to the baseline. Additional labor income from corn production is $19.2 million in 1970, $81.3 million in 2010, and $79.9 million in 2024. Additional labor income from soybean production is $1.9 million in 1970, $21.0 million in 2010, and $18.4 million in 2024 (Figure 35).

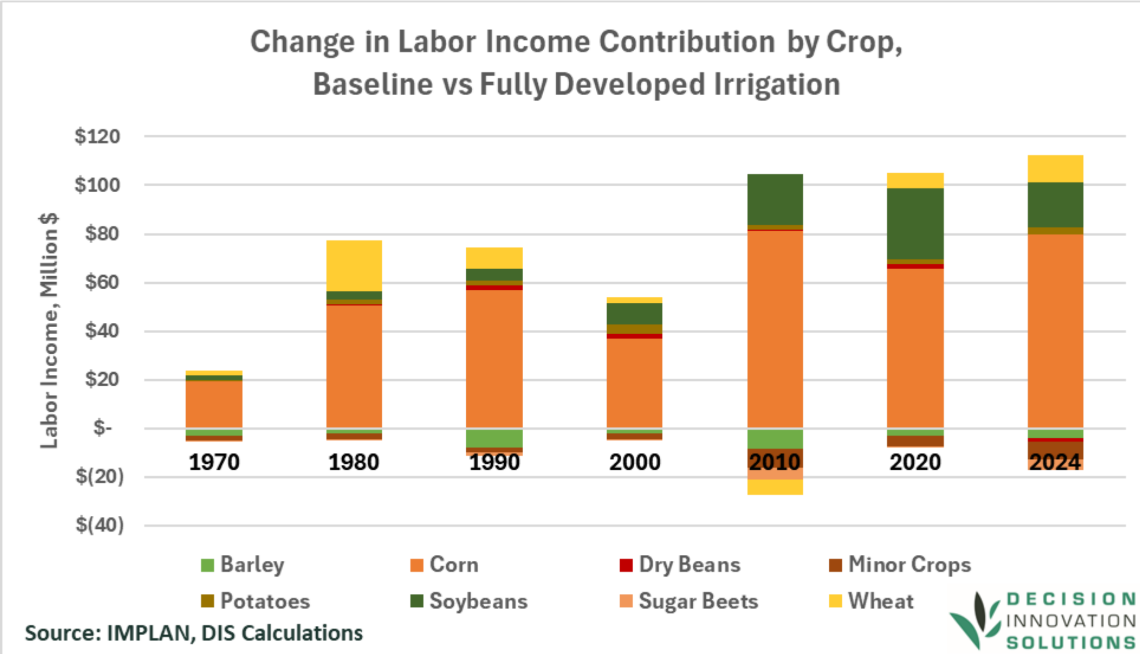


Figure 35. Change in Labor Income Contribution by Crop

3.2.6 West Central District Highlight

The West Central district, consisting of Dunn, McKenzie, McLean, Mercer, and Oliver counties, has the most to gain from fully developed irrigation, with potential output gains of $13.6 million in 1970, $133.0 million in 2010, and $123.8 million in 2024. In 2024, the change in irrigation and crop patterns would result in a $342.1 million gain in irrigated crop output partially offset by a $218.3 million loss in dryland crop output (Figure 36).

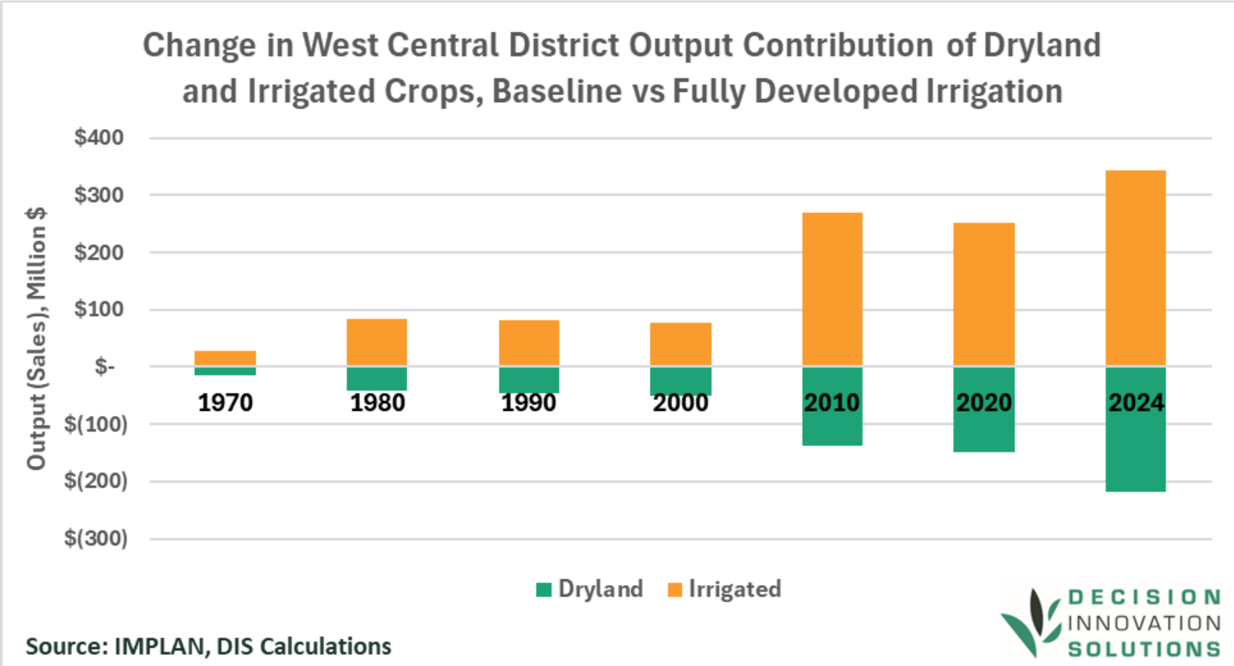


Figure 36. Change in West Central District Output Contribution of Dryland and Irrigated Crops

Increases in output in the West Central district are primarily driven by additional wheat irrigation from 1970 to 2000. While wheat production is also a major part of output gains from 2010 through 2024, these gains are supplemented by additional increases in irrigated corn and soybean production, with additional output from corn rising from $4.6 million in 2000 to $68.5 million in 2024 (Figure 37).

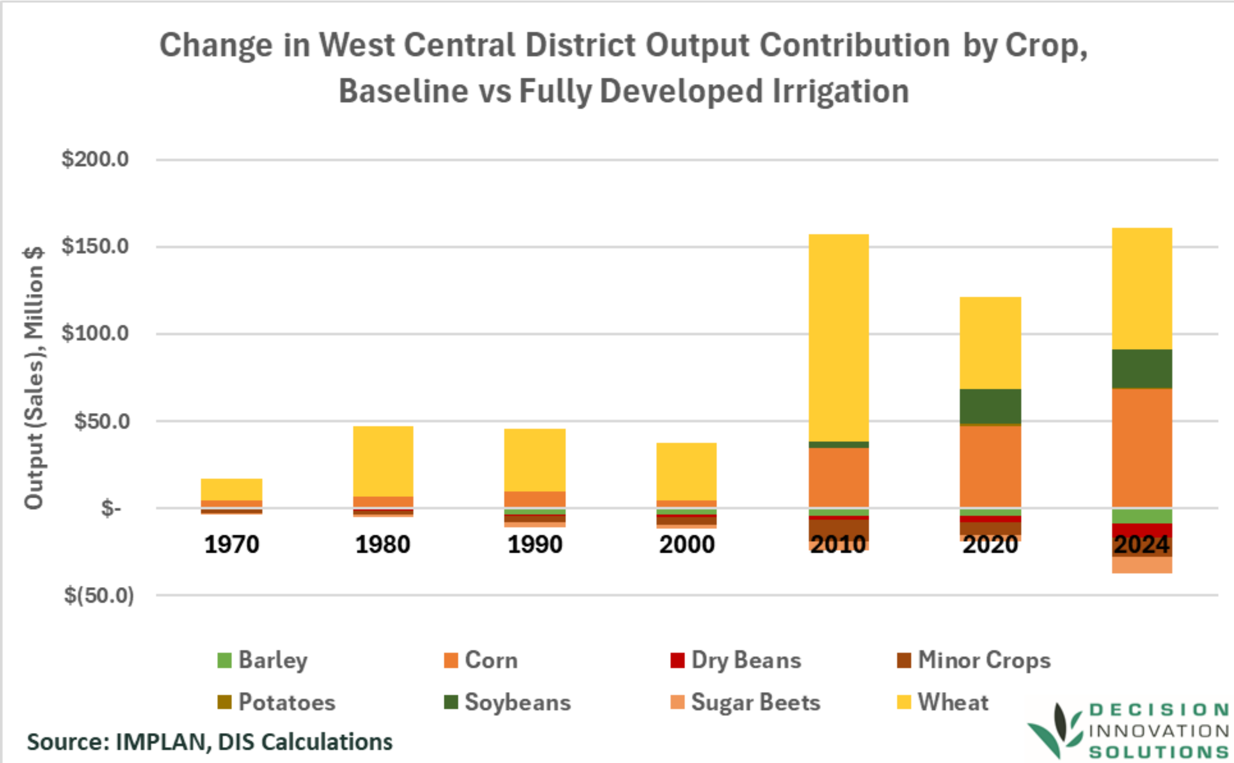


Figure 37. Change in West Central District Output Contribution by Crop

The net increase in value added contribution to the West Central district is $2.9 million in 1970, $17.0 million in 2010, and $48.9 million in 2024. Similar to the change in output contribution, increases to value added are driven primarily by wheat from 1970 to 2000, with corn and soybeans joining from 2010 to 2024. Additional value added in the fully developed irrigation scenario in 1970 is $2.4 million for wheat and $1.9 million for corn, with no soybeans in the West Central district. In 2024, increased value added is $23.2 million for wheat, $28.0 million for corn, and $14.8 million for soybeans. These gains are partially offset by reduced dryland production of other crops, primarily sugar beets (loss of $5.1 million) and barley (loss of $4.5 million) (Figure 38).

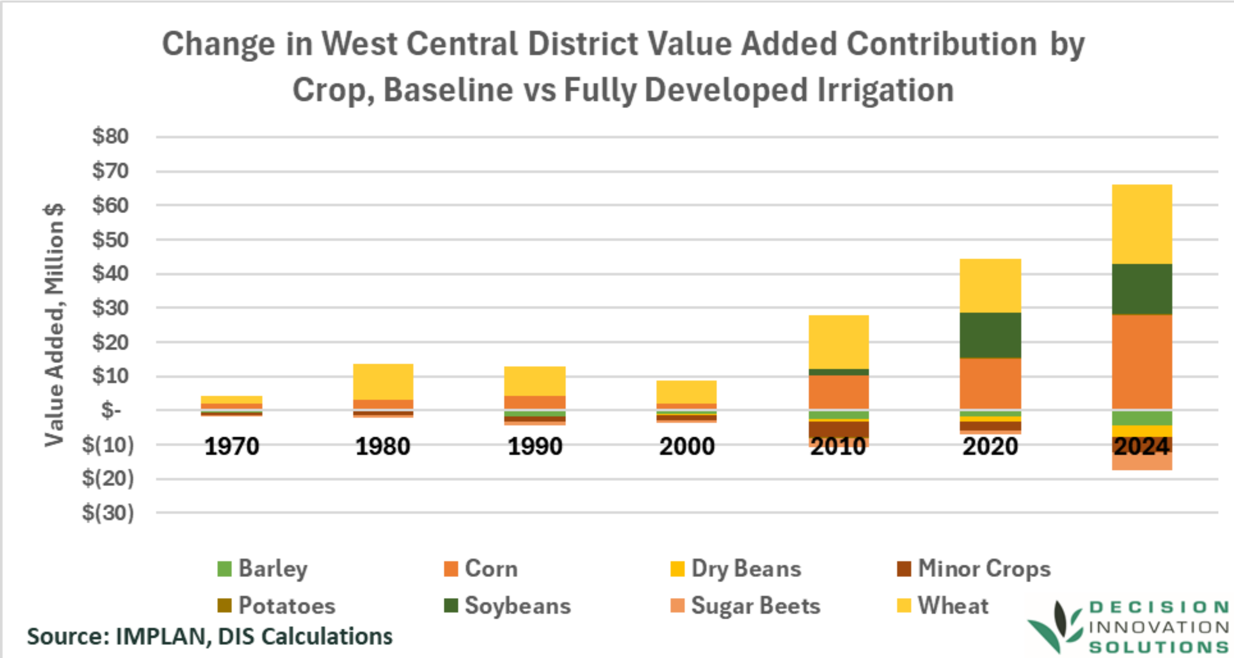


Figure 38. Change in West Central District Value Added Contribution by Crop

Net labor income contribution in the West Central District was $3.6 million in 1970 and grew to $19.1 million in 2024. Increases in labor income from wheat production are high throughout the period, and increases from corn production are highest in 2010 with $13.7 million (Figure 39).

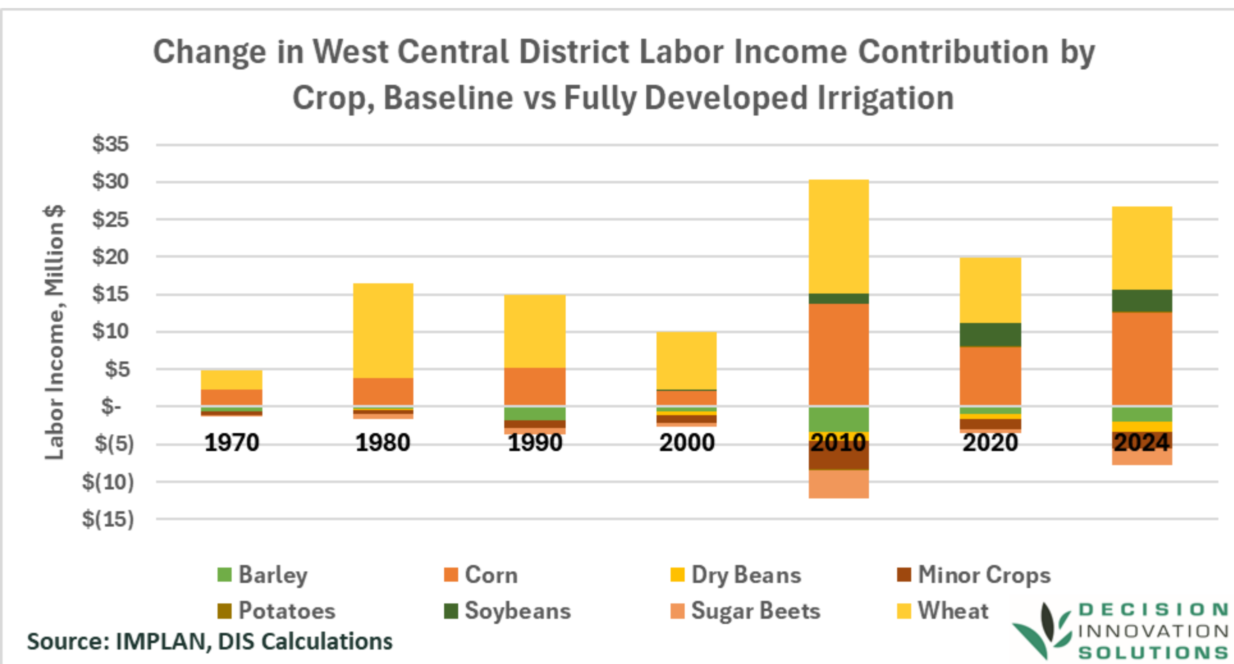


Figure 39. Change in West Central District Labor Income Contribution by Crop

3.3 Economic Contribution of North Dakota Legal Drains

Significant portions of North Dakota are very flat with little variation in elevation or good avenues for water drainage. As a result, large precipitation events can cause vast swaths of farmland to be overwhelmed with water, harming yields or potentially making crop production impossible. To limit the effect of persistent standing water inhibiting the ability to grow crops, a series of conveyance ditches, or "legal drains" have been constructed in many parts of North Dakota. These legal drains allow fields to be adequately drained. To capture the extent of legal drains in North Dakota, maps were obtained from 12 North Dakota counties. While maps were obtained from as many North Dakota counties as possible, there are likely some counties with legal drains that are not included in this analysis. Additionally, North Dakota has private drains that were not included in this analysis.

The estimated annual statewide economic contribution of additional crop production due to legal drains is shown in Table 3. Higher crop yields from adequately drained land results in an additional direct revenue (output) to farmers of $65.8 million along with an increase of $41.8 million in value added, $23.0 million in labor income, and 149 jobs supported. After accounting for the additional crop inputs (seed, fertilizer, etc.) and spending of additional income earned through higher production, the total contribution of legal drains throughout the state is 260 jobs, $30.7 million in labor income, $54.0 million in value added, and $87.9 million in output.

Table 3. Economic Contribution of North Dakota Legal Drains

Economic Contribution of North Dakota Legal Drains				
Impact Type	Annual Employment	Labor Income ($ Million)	Value Added ($ Million)	Output ($ Million)
Direct	149	$ 23.0	$ 41.8	$ 65.8
Indirect	48	$ 4.2	$ 5.6	$ 10.7
Induced	63	$ 3.5	$ 6.6	$ 11.3
Total	**260**	**$ 30.7**	**$ 54.0**	**$ 87.9**

The total (annual) economic contribution of legal drains in each county where they are present is shown in Table 4. In terms of value added, Cass County receives the highest contribution from legal drains with $10.4 million, followed by Richland and Traill with $9.8 million each and Pembina with $6.7 million.

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

Table 4. Total Economic Contribution of Legal Drains by County

Total Contribution of Legal Drains by County				
County	Total Employment	Total Labor Income ($ Million)	Total Value Added ($ Million)	Total Output ($ Million)
Cass	48	$ 5.9	$ 10.4	$ 16.9
Richland	47	$ 6.5	$ 9.8	$ 15.7
Traill	43	$ 4.2	$ 9.8	$ 15.6
Pembina	29	$ 3.0	$ 6.7	$ 11.3
Grand Forks	34	$ 3.5	$ 5.7	$ 9.3
Walsh	29	$ 2.6	$ 5.0	$ 8.5
Sargent	11	$ 2.0	$ 2.3	$ 3.7
Wells	7	$ 1.1	$ 1.7	$ 2.7
Dickey	6	$ 1.1	$ 1.3	$ 2.0
Ransom	4	$ 0.6	$ 0.8	$ 1.3
Cavalier	2	$ 0.2	$ 0.3	$ 0.6
Foster	1	$ 0.1	$ 0.2	$ 0.2
Total	**260**	**$ 30.7**	**$ 54.0**	**$ 87.9**

3.4 Economic Impact Studies

Access to increased irrigation in North Dakota would open up new opportunities for agricultural development in the state. Higher crop yields from irrigation could lead to additional value-added processing of crops, such as a wheat mill, ethanol plant, or soybean processor. Greater crop production could also lead to more livestock production within the state. It is also possible for additional acreage to be devoted to crops that would benefit from access to reliable irrigation and drainage. These potential opportunities are highlighted by a series of economic impact studies for the following new potential North Dakota enterprises: a 12,500 head dairy, a 42.5 million bushel per year soybean processor, and a 1,000-acre irrigated onion farm.

3.4.1 Economic Impact of 12,500 Head Dairy

The construction of a new 12,500 head dairy in North Dakota is estimated to directly support 391 jobs earning a combined $35.4 million in labor income and provide $44.3 million in value added and $85.8 million in total sales (output). After accounting for indirect (i.e., professional services, materials for construction, etc.) and induced (spending of earned income) effects, the total impact increases to $71.6 million in value added, $136.9 million in output, $50.7 million in labor income, and 603 jobs supported (Table 5). Additionally, an estimated $12.9 million in total tax revenue is generated, with $10.4 million paid at the federal level and $2.5 million paid at the state and local levels (Table 6).

Table 5. North Dakota Dairy Construction Economic Impact

North Dakota Dairy Construction Economic Impact				
Impact Type	Annual Employment	Labor Income ($ Million)	Value Added ($ Million)	Output ($ Million)
Direct	391	$ 35.4	$ 44.3	$ 85.8
Indirect	73	$ 6.6	$ 12.1	$ 24.8
Induced	139	$ 8.7	$ 15.2	$ 26.3
Total	**603**	**$ 50.7**	**$ 71.6**	**$ 136.9**

Table 6. North Dakota Dairy Construction Tax Impact

North Dakota Dairy Construction Tax Impact			
Impact Type	State and Local ($ Million)	Federal ($ Million)	Total ($ Million)
Direct	$ 0.7	$ 7.0	$ 7.7
Indirect	$ 0.9	$ 1.5	$ 2.4
Induced	$ 0.9	$ 1.9	$ 2.8
Total	**$ 2.5**	**$ 10.4**	**$ 12.9**

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

The industries most impacted by the construction of a new dairy in North Dakota in terms of value added include construction of new commercial structures, owner-occupied housing[3], farm machinery and equipment manufacturing, truck transportation, and wholesale suppliers (Table 7).

Table 7. North Dakota Dairy Construction Top Industries Impacted

North Dakota Dairy Construction Top Industries Impacted	
Industry	**Total Value Added ($M)**
Construction of new commercial structures, including farm structures	$ 42.6
Owner-occupied housing	$ 2.2
Hospitals	$ 1.5
Farm machinery and equipment manufacturing	$ 1.3
Wholesale - Other durable goods merchant wholesalers	$ 1.2
Truck transportation	$ 1.1
Monetary authorities and depository credit intermediation	$ 0.9
Offices of physicians	$ 0.8
Other real estate	$ 0.7
Wholesale - Petroleum and petroleum products	$ 0.6

Once operational, the 12,500 head dairy in North Dakota is expected to hire 45 workers and directly provide $4.2 million in labor income, $17.4 million in value added, and $68.3 million in output annually to the state economy. After accounting for indirect (i.e., feed, transportation, veterinary, etc.) and induced effects (spending of earned income), the estimated total operations impact is 176 jobs, $14.5 million in labor income, $35.8 million in value added, and $113.9 million in total sales (Table 8). In addition, the dairy's operations are estimated to generate $11.4 million in tax revenue annually, with $3.4 million paid at the federal level and $8.0 million paid at the state and local levels (Table 9).

Table 8. North Dakota Dairy Operations Economic Impact

North Dakota Dairy Operations Economic Impact				
Impact Type	**Annual Employment**	**Labor Income ($ Million)**	**Value Added ($ Million)**	**Output ($ Million)**
Direct	45	$ 4.2	$ 17.4	$ 68.3
Indirect	89	$ 7.7	$ 13.8	$ 37.7
Induced	41	$ 2.6	$ 4.5	$ 7.8
Total	**176**	**$ 14.5**	**$ 35.8**	**$ 113.9**

[3] The owner-occupied dwellings industry represents the spending of homeowners on their homes. It includes property taxes, the interest portion of mortgage payments, and home improvements and maintenance.

Table 9. North Dakota Dairy Operations Tax Impact

North Dakota Dairy Operations Tax Impact			
Impact Type	State and Local ($ Million)	Federal ($ Million)	Total ($ Million)
Direct	$ 6.6	$ 1.2	$ 7.8
Indirect	$ 1.1	$ 1.6	$ 2.7
Induced	$ 0.3	$ 0.6	$ 0.8
Total	**$ 8.0**	**$ 3.4**	**$ 11.4**

In addition to the dairy cattle and milk production industry, some of the industries most impacted by the operations of a new dairy farm in North Dakota are grain farming, other animal food manufacturing, truck transportation, and various wholesale suppliers (Table 10).

Table 10. North Dakota Dairy Operations Top Industries Impacted

North Dakota Dairy Operations Top Industries Impacted	
Industry	Total Value Added ($M)
Dairy cattle and milk production	$ 17.0
Wholesale - Other nondurable goods merchant wholesalers	$ 2.3
Grain farming	$ 1.5
Wholesale - Petroleum and petroleum products	$ 1.1
Other animal food manufacturing	$ 0.9
Truck transportation	$ 0.7
Owner-occupied housing	$ 0.7
Wholesale - Machinery, equipment, and supplies	$ 0.6
Support activities for agriculture and forestry	$ 0.5
Other real estate	$ 0.5

3.4.2 Economic Impact of Soybean Processing Facility

The construction of a new soybean processor with a capacity of 42.5 million bushels in North Dakota is estimated to directly support 938 jobs earning a combined $83.5 million in labor income and provide $199.7 million in value added and $336.7 million in output. After accounting for indirect (i.e., professional services, materials for construction, etc.) and induced (spending of earned income) effects, the total impact increases to $123.6 million in labor income, $266.2 million in value added, $457.0 million in output, and 1,502 jobs supported (Table 11). An estimated $36.5 million in total tax revenue is generated as a result of this construction activity, with $29.9 million paid at the federal level and $6.6 million paid at the state and local levels (Table 12).

Table 11. North Dakota Soybean Processor Construction Economic Impact

North Dakota Soybean Processor Construction Economic Impact				
Impact Type	Annual Employment	Labor Income ($ Million)	Value Added ($ Million)	Output ($ Million)
Direct	938	$ 83.5	$ 199.7	$ 336.7
Indirect	212	$ 18.8	$ 29.1	$ 55.7
Induced	352	$ 21.3	$ 37.4	$ 64.6
Total	**1,502**	**$ 123.6**	**$ 266.2**	**$ 457.0**

Table 12. North Dakota Soybean Processor Construction Tax Impact

North Dakota Soybean Processor Construction Tax Impact			
Impact Type	State and Local ($ Million)	Federal ($ Million)	Total ($ Million)
Direct	$ 2.8	$ 21.1	$ 23.8
Indirect	$ 1.6	$ 4.0	$ 5.7
Induced	$ 2.2	$ 4.8	$ 7.0
Total	**$ 6.6**	**$ 29.9**	**$ 36.5**

Industries in North Dakota that are expected to be highly impacted by the construction of a new soybean processor include construction of new manufacturing structures, architectural and engineering services, machinery and equipment wholesalers, truck transportation, and healthcare (Table 13).

Table 13. North Dakota Soybean Processor Construction Top Industries Impacted

North Dakota Soybean Processor Construction Top Industries Impacted	
Industry	Total Value Added ($M)
Construction of new manufacturing structures	$ 199.7
Architectural, engineering, and related services	$ 5.7
Owner-occupied housing	$ 5.6
Monetary authorities and depository credit intermediation	$ 4.0
Hospitals	$ 3.8
Construction of new highways and streets	$ 2.8
Wholesale - Machinery, equipment, and supplies	$ 2.1
Offices of physicians	$ 1.9
Truck transportation	$ 1.8
Other real estate	$ 1.6

Once constructed and operating at full capacity, a new (42.5 million bushel) soybean processor is estimated to employ 75 workers with a combined labor income of $7.1 million. The processor is expected to generate $632.1 in sales and $43.8 million in value added. Including indirect and induced effects, the total impact increases to 1,266 jobs, $158.9 million in labor income, $494.8 million in value added, and nearly $1.2 billion in output annually[4] (Table 14). An estimated $71.6 million in total tax revenue is generated as a result of this construction activity, with $41.1 million paid at the federal level and $30.5 million paid at the state and local levels (Table 15).

Table 14. North Dakota Soybean Processor Operations Economic Impact

North Dakota Soybean Processor Operations Economic Impact				
Impact Type	Annual Employment	Labor Income ($ Million)	Value Added ($ Million)	Output ($ Million)
Direct	75	$ 7.1	$ 43.8	$ 632.1
Indirect	712	$ 123.0	$ 400.2	$ 454.9
Induced	480	$ 28.9	$ 50.8	$ 87.8
Total	**1,266**	**$ 158.9**	**$ 494.8**	**$ 1,174.8**

Table 15. North Dakota Soybean Processor Operations Tax Impact

North Dakota Soybean Processor Operations Tax Impact			
Impact Type	State and Local ($ Million)	Federal ($ Million)	Total ($ Million)
Direct	$ 1.6	$ 3.0	$ 4.6
Indirect	$ 25.9	$ 31.6	$ 57.5
Induced	$ 3.0	$ 6.5	$ 9.5
Total	**$ 30.5**	**$ 41.1**	**$ 71.6**

Industries in North Dakota that are expected to be highly impacted by the new processor's operations include oilseed farming, banking, wholesale suppliers, healthcare, truck transportation, and electric power transmission and generation (Table 16).

[4] Note that a substantial portion of the indirect impacts occur in the soybean farming industry. While farmers in the vicinity of the new processor may alter their crop mix to more soybeans relative to other crops, this does not necessarily represent new economic activity.

Table 16. North Dakota Soybean Processor Operations Top Industries Impacted

North Dakota Soybean Processor Operations Top Industries Impacted	
Industry	**Total Value Added ($M)**
Oilseed farming	$ 366.7
Soybean and other oilseed processing	$ 43.8
Monetary authorities and depository credit intermediation	$ 10.0
Owner-occupied housing	$ 7.7
Wholesale - Other nondurable goods merchant wholesalers	$ 5.8
Hospitals	$ 5.2
Electric power transmission and distribution	$ 4.5
Electric power generation - Fossil fuel	$ 2.9
Truck transportation	$ 2.7
Offices of physicians	$ 2.6

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

3.4.3 Economic Impact of an Irrigated Onion Farm

A 1,000-acre irrigated onion farm in North Dakota is estimated to generate $5.8 million in direct revenue (output) each year, employ 6 workers earning a combined $0.7 million in labor income, and generate $1.8 million in direct value added. Accounting for indirect and induced impacts throughout the state, the total impact increases to 22 jobs, $1.9 million in labor income, and $3.8 million in value added annually (Table 17). The onion farm is estimated to generate $0.9 million in total tax revenue each year, with $0.5 million paid at the state and local levels, and $0.4 million paid at the federal level (Table 18).

Table 17. North Dakota Onion Farm Operations Economic Impact

North Dakota Onion Farm Operations Economic Impact				
Impact Type	Annual Employment	Labor Income ($ Million)	Value Added ($ Million)	Output ($ Million)
Direct	6	$ 0.7	$ 1.8	$ 5.8
Indirect	10	$ 0.8	$ 1.4	$ 2.2
Induced	6	$ 0.3	$ 0.6	$ 1.0
Total	**22**	**$ 1.9**	**$ 3.8**	**$ 9.1**

Table 18. North Dakota Onion Farm Operations Tax Impact

North Dakota Onion Farm Operations Tax Impact			
Impact Type	State and Local ($ Million)	Federal ($ Million)	Total ($ Million)
Direct	$ 0.2	$ 0.2	$ 0.3
Indirect	$ 0.3	$ 0.2	$ 0.4
Induced	$ 0.0	$ 0.1	$ 0.1
Total	**$ 0.5**	**$ 0.4**	**$ 0.9**

In addition to the vegetable and melon farming industry that represents onion farming, other industries impacted by a new onion farm in North Dakota include wholesale suppliers of machinery and fuel, warehousing and storage, agricultural support activities, and banking (Table 19).

Table 19. North Dakota Onion Farm Operations Top Industries Impacted

North Dakota Onion Farm Operations Top Industries Impacted	
Industry	**Total Value Added ($M)**
Vegetable and melon farming	$ 2.0
Wholesale - Petroleum and petroleum products	$ 0.4
Warehousing and storage	$ 0.2
Wholesale - Machinery, equipment, and supplies	$ 0.1
Monetary authorities and depository credit intermediation	$ 0.1
Support activities for agriculture and forestry	$ 0.1
Owner-occupied housing	$ 0.1
Hospitals	$ 0.1
Commercial and industrial equipment repair and maintenance	$ 0.1
Other real estate	$ 0.0

4 Climate and Weather Summary

North Dakota features a continental climate with warm summers and cold, windy winters, generally featuring higher precipitation in the east (13–20 inches annually) and semi-arid conditions in the west (Figure 40).

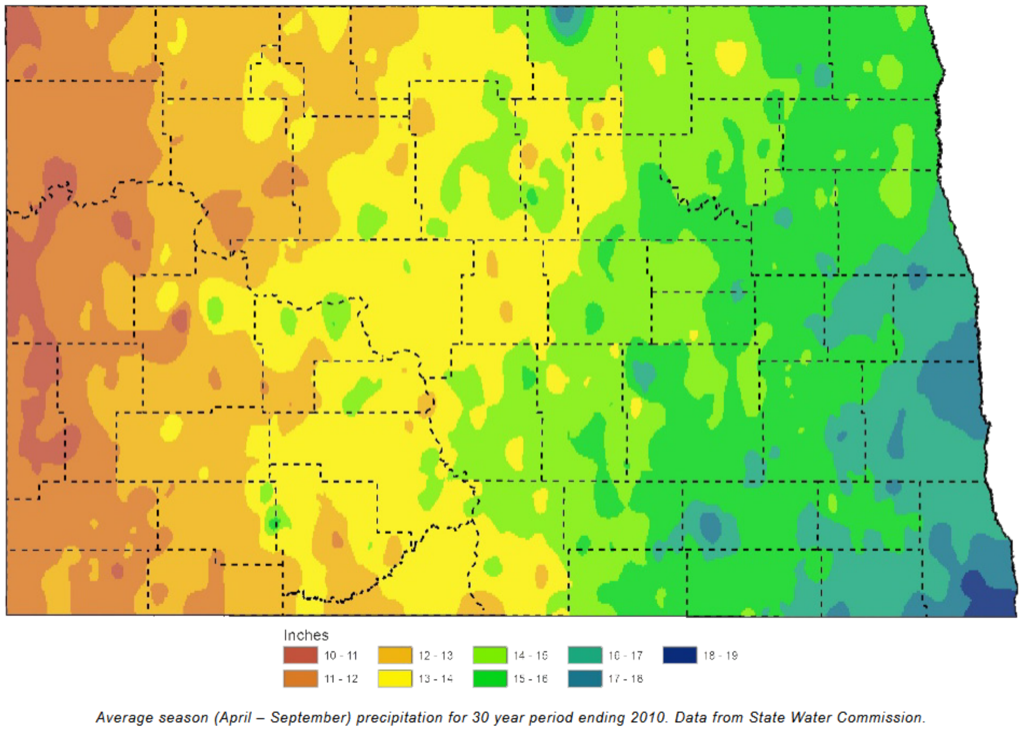


Figure 40. Average Annual Precipitation Map, North Dakota

Statewide average temperatures range from 10°F in January to 69°F in July (Figure 41).

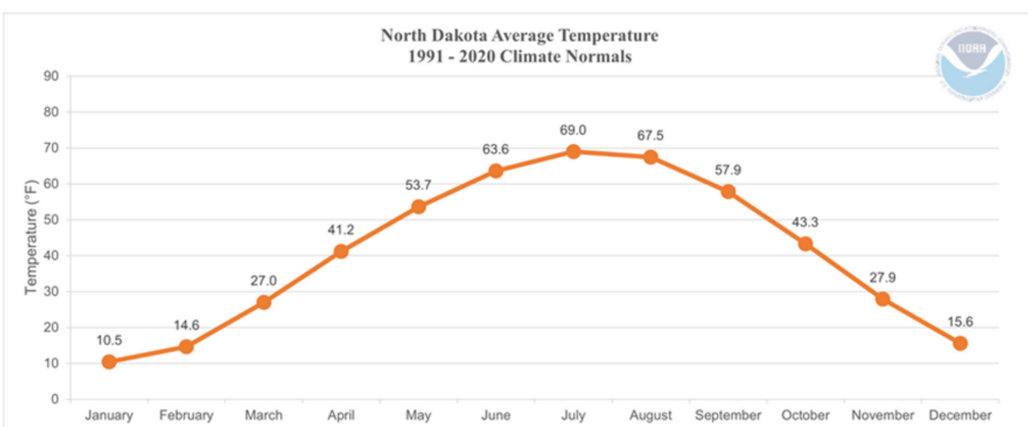


Figure 41. North Dakota Average Temperatures, Monthly

North Dakota is a land of temperature extremes. While the average summer temperature in July is less than 70 degrees, it can get very hot on a daily basis anytime during May through September (Table 20).

Table 20. Record Maximum Temperatures (North Dakota)

Record Maximum Temperatures (North Dakota)					
Location	May	June	July	August	September
Bismarck	102	111	114	109	105
Williston	106	108	110	108	104
Dickinson	102	109	114	108	104
Minot	105	109	109	107	106
Jamestown	107	107	118	107	107
Note: The highest temperature ever recorded in North Dakota was 121F in Steele on July 6, 1936					DECISION INNOVATION SOLUTIONS

Likewise, it can get very cold in North Dakota. While the average temperature is 10F in January, very cold temperatures can be seen during November through February (Table 21).

Table 21. Record Minimum Temperatures (North Dakota)

Record Minimum Temperatures (North Dakota)				
Location	November	December	January	February
Bismarck	-30	-43	-45	-45
Williston	-27	-50	-42	-50
Dickinson	-22	-37	-44	-47
Minot	-27	-44	-47	-49
Jamestown	-27	-40	-41	-42
Note: The lowest temperature ever recorded in North Dakota was -60F in Parschall on February 15, 1936				DECISION INNOVATION SOLUTIONS

The number of days with maximum temperatures greater than 90° F increased in Bismarck, Dickinson, and Williston, cities in central or west North Dakota. This number has decreased in Grand Forks and Fargo, cities in eastern North Dakota (Figure 42).

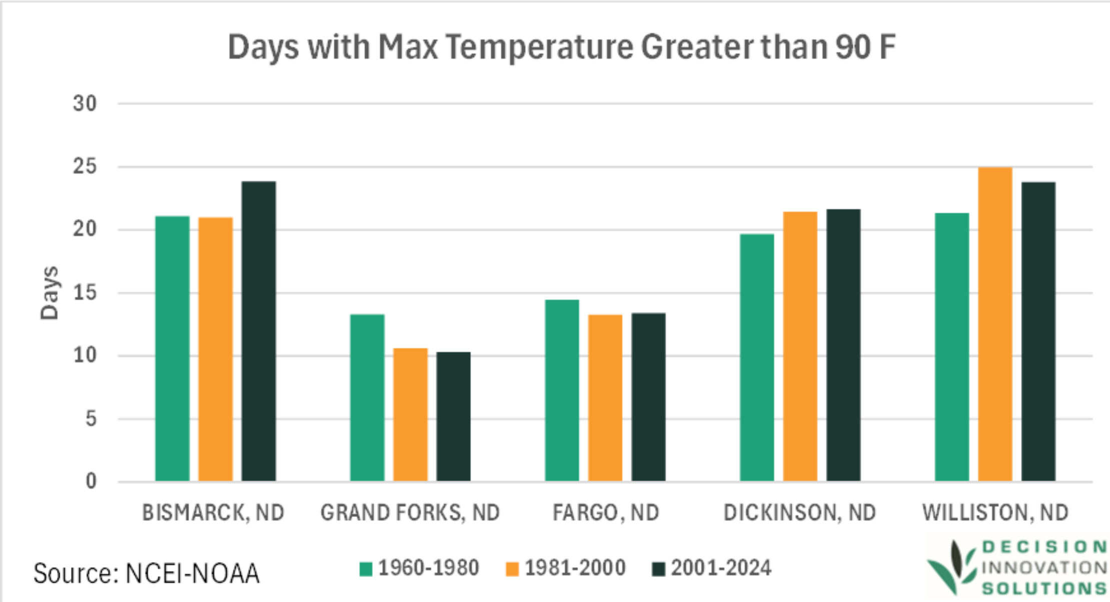


Figure 42. Days with Maximum Temperature Greater than 90 F

Days with maximum temperatures below 32° F has decreased in all the cities listed since the 1960-1980 period (Figure 43).

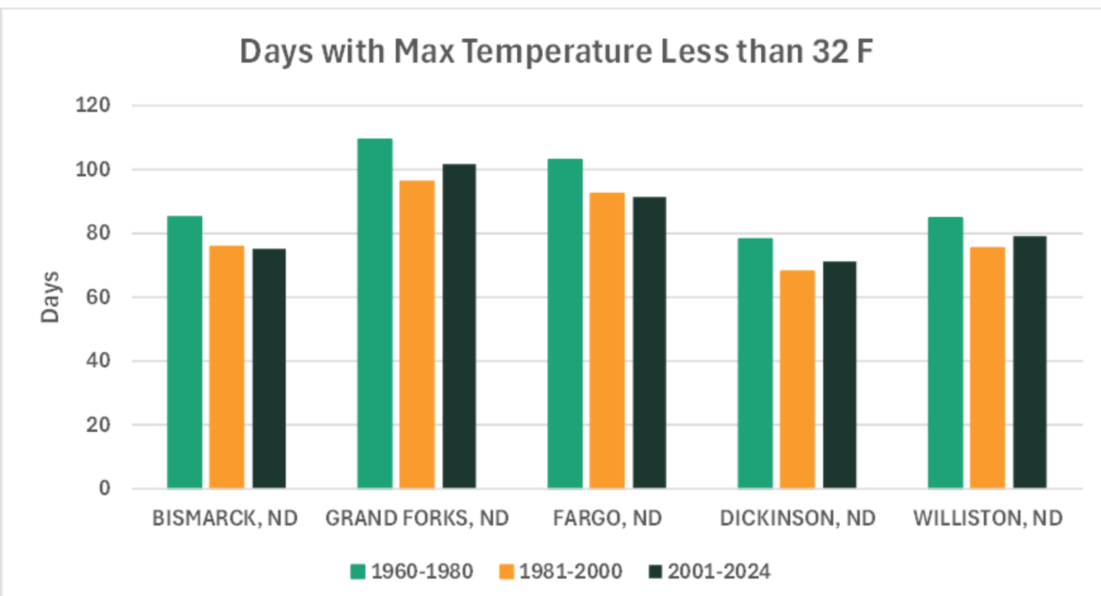


Figure 43. Days with Maximum Temperature Less than 32 F

4.1 Summer Precipitation and Temperatures

Summer precipitation in North Dakota has remained relatively stable since 1945 with about 8 inches, on average received during the June-August period. Most of the time, precipitation during the summer ranges between 6 and 10 inches with a few years of less than 5 inches, and only one year with greater than 12 inches (1993) (Figure 44). Precipitation in the summer months has also changed over time. Precipitation in June has decreased by 0.03" each decade, but in July and August it has increased by 0.02" and 0.01" each decade, respectively.

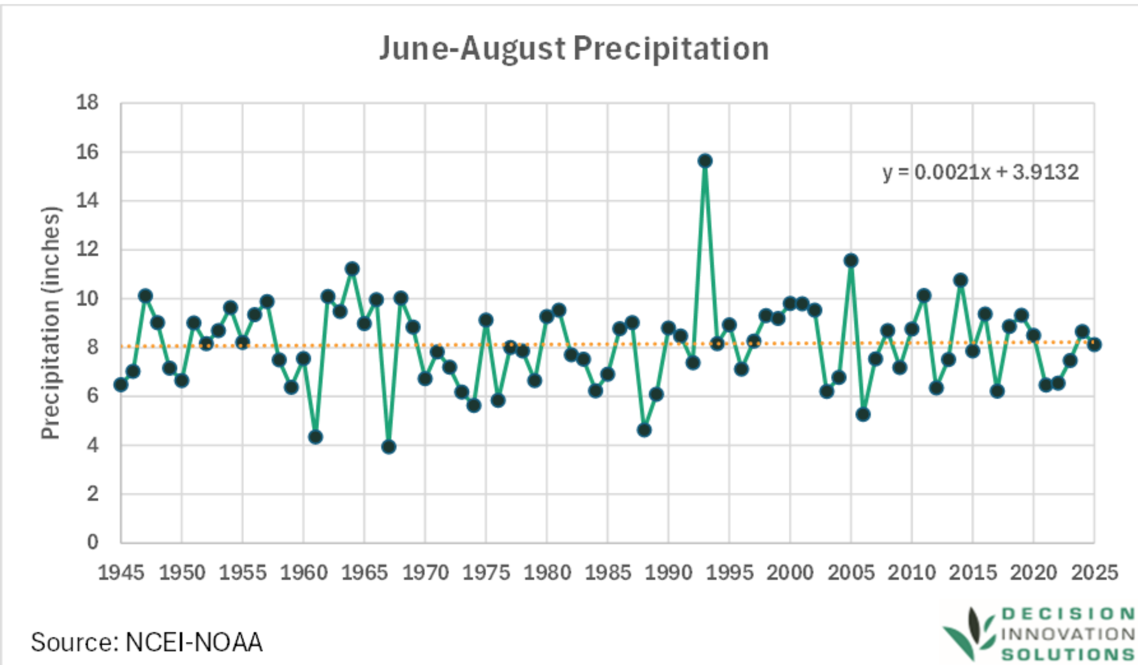


Figure 44. North Dakota Summer Precipitation 1945-2025

Heavy rainfall events are relatively infrequent in North Dakota. There is typically only about 1 day per year with more than 1 inch of rain in a 24-hour period. As shown in Figure 45, there are 35-45 days with more than 0.1 inch of rain in a day and the number of days with 0.1 or more inch of rain are increasing over time in Bismarck, Fargo, Grand Forks, and Williston. In Dickinson, however, the contrary is true with the frequency of rainfall days greater than 0.1 inch/day declining.

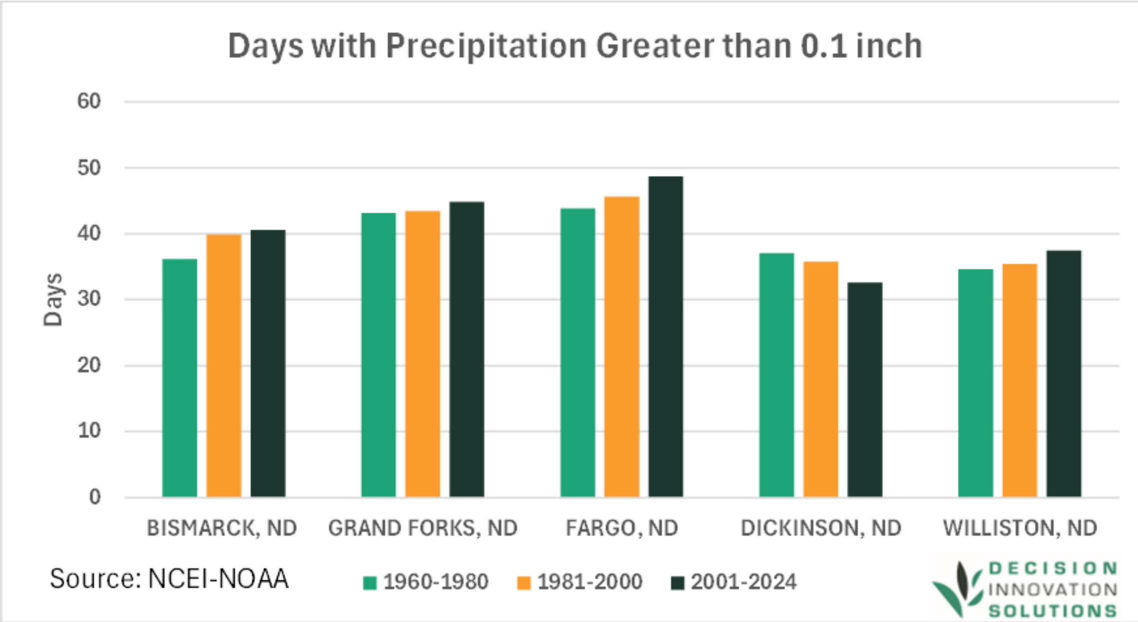


Figure 45. Days with Precipitation Greater than 0.1 Inch

Average temperature has increased by 0.2˚F in June and August but only increased by 0.1˚F in July (Figure 46).

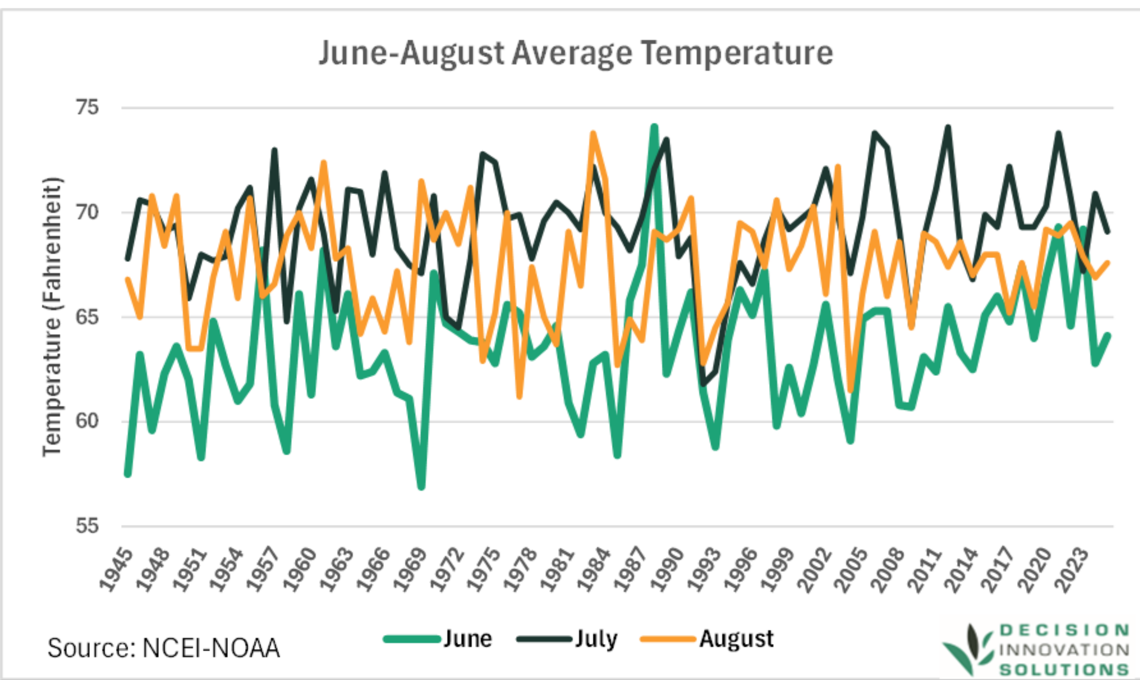


Figure 46. Average Summer Temperature

4.2 Winter Precipitation & Temperatures

According to the National Centers for Environmental Information (NCEI) and the National Oceanic and Atmospheric Administration (NOAA), winter precipitation has gradually changed over time. Precipitation in December has increased by 0.01” each decade, but in January and February it has fallen by 0.01” each decade (Figure 47).

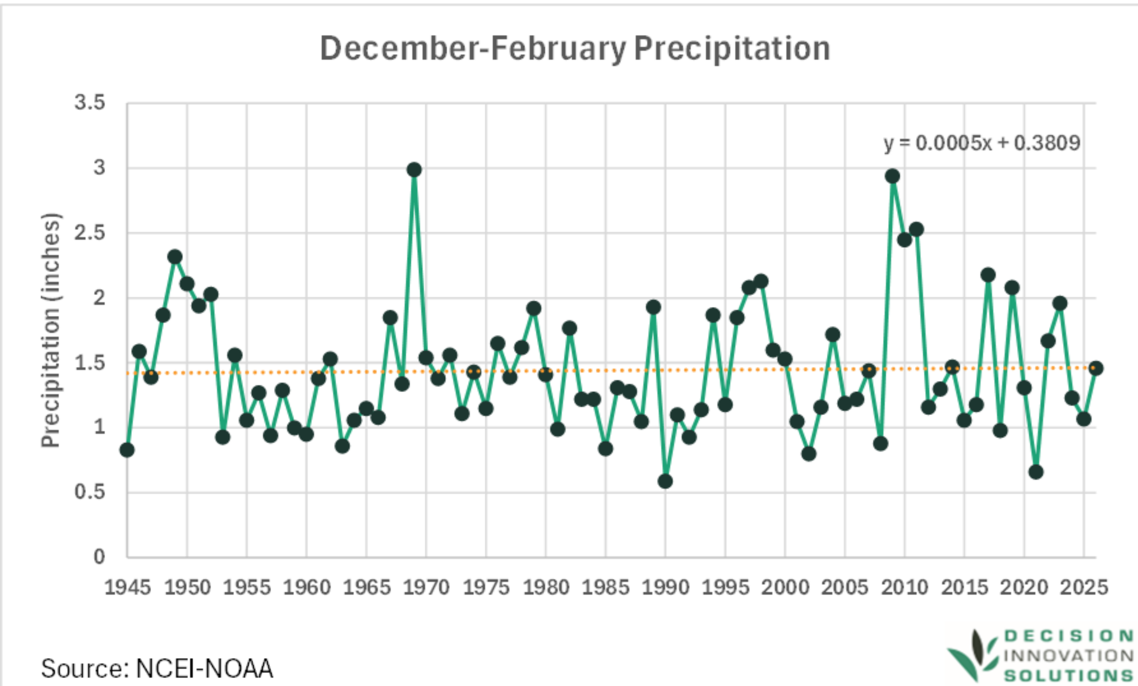


Figure 47. North Dakota Winter Precipitation 1945-2025

While most of North Dakota only has 10-15 days with more than 1 inch of snowfall (Figure 48), due to the cold winter temperatures, snow cover tends to persist with most of North Dakota having 90 to 110 days with more than 1 inch of snow depth on the ground (Figure 49).

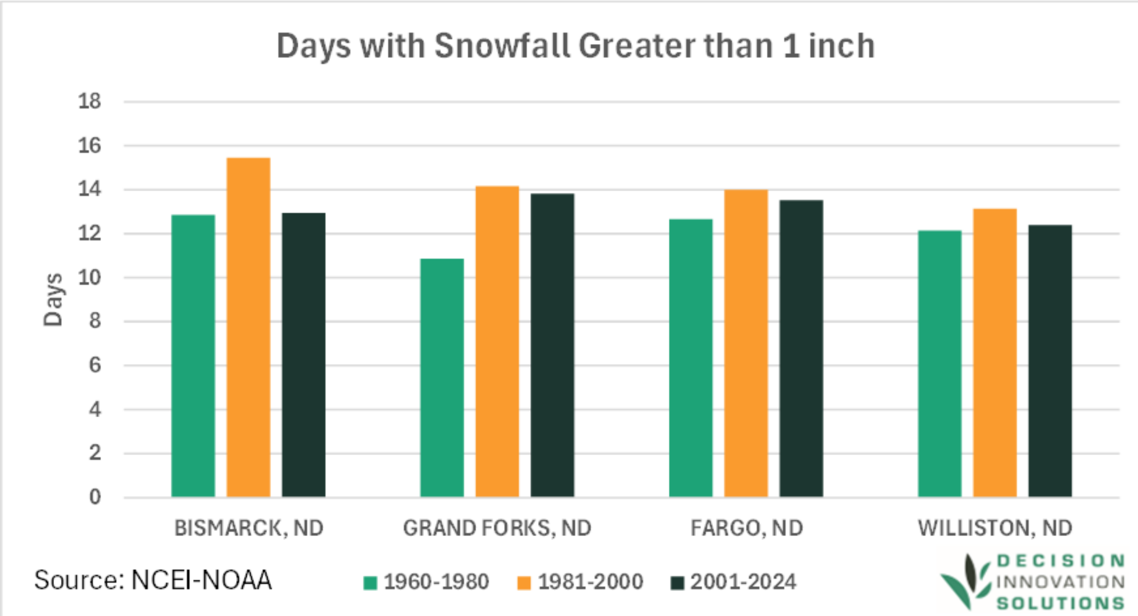


Figure 48. Days with Snowfall Greater than 1 Inch

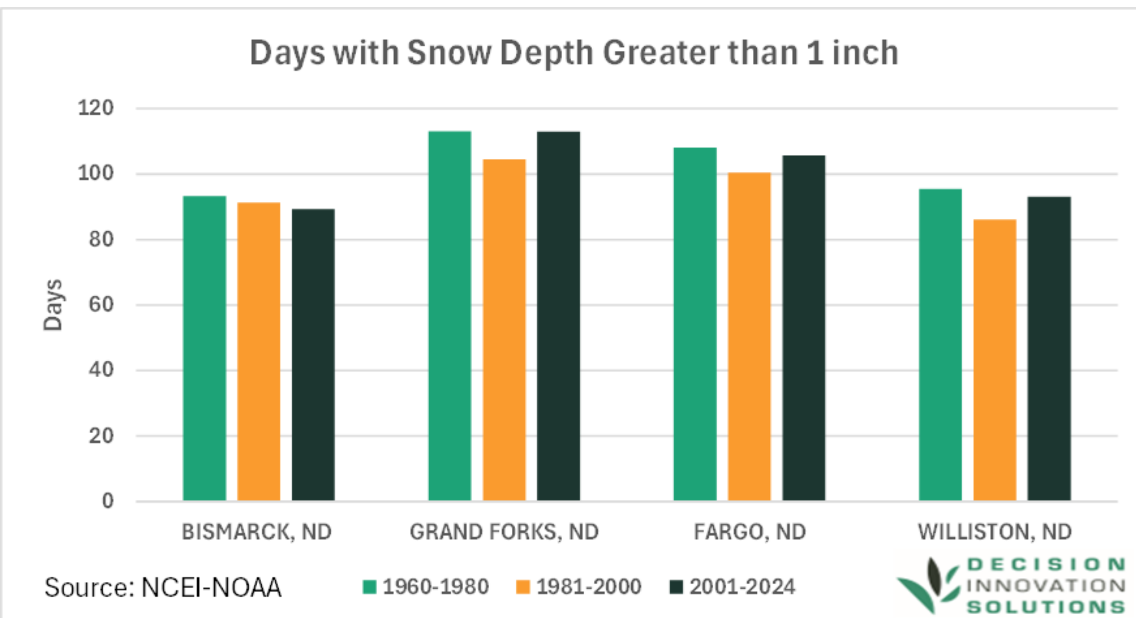


Figure 49. Days with Snow Depth Greater than 1 inch

The average temperature in December has increased by 0.3˚F each decade and in both January and in February it has increased by 0.6˚F each decade (Figure 50).

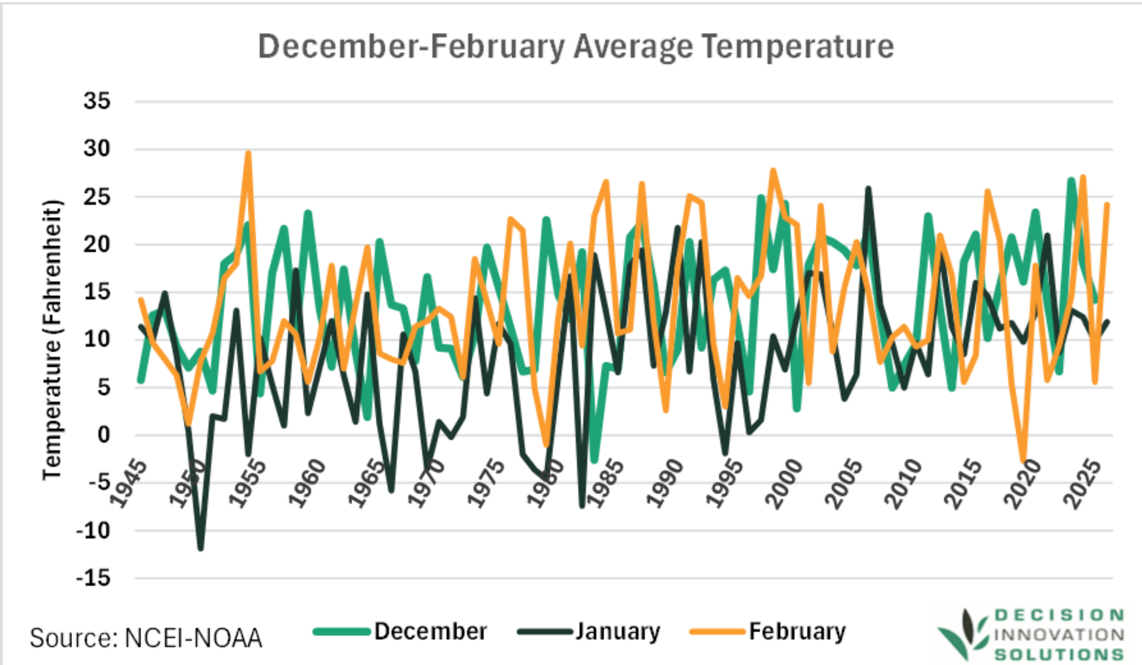


Figure 50. Average Winter Temperature

4.3 Red River and Missouri River Depth Gauges

Figure 51 and Figure 52 represent the average annual height of the Red River at two locations, Fargo and Grand Forks, North Dakota. At Fargo, the Red River has risen by 0.05 feet per year from 1960-2023. At Grand Forks, the Red River has risen by 0.21 feet per year from 1960-2023.

Figure 53 represents the height of the Missouri River at Stanton, North Dakota. In 1965, the height of the river fell from 53 inches to just over 18 inches, due to the completion of the six Missouri River dams. Since 1965, the Missouri River at Stanton has fallen by 0.14 feet per year.

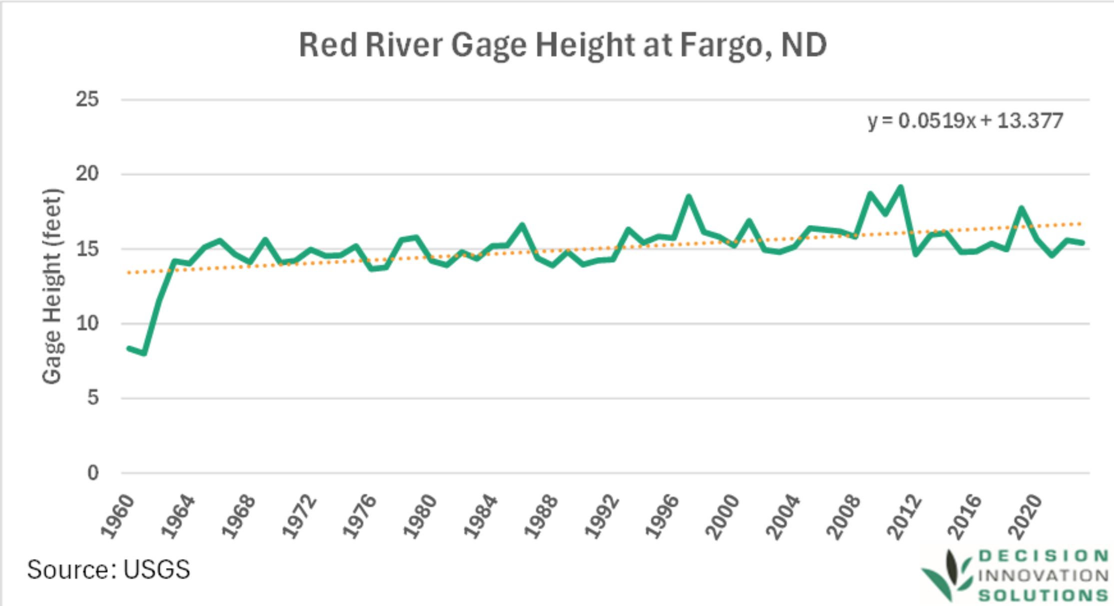


Figure 51. Red River Average Annual Gage Height at Fargo, ND 1960-2023

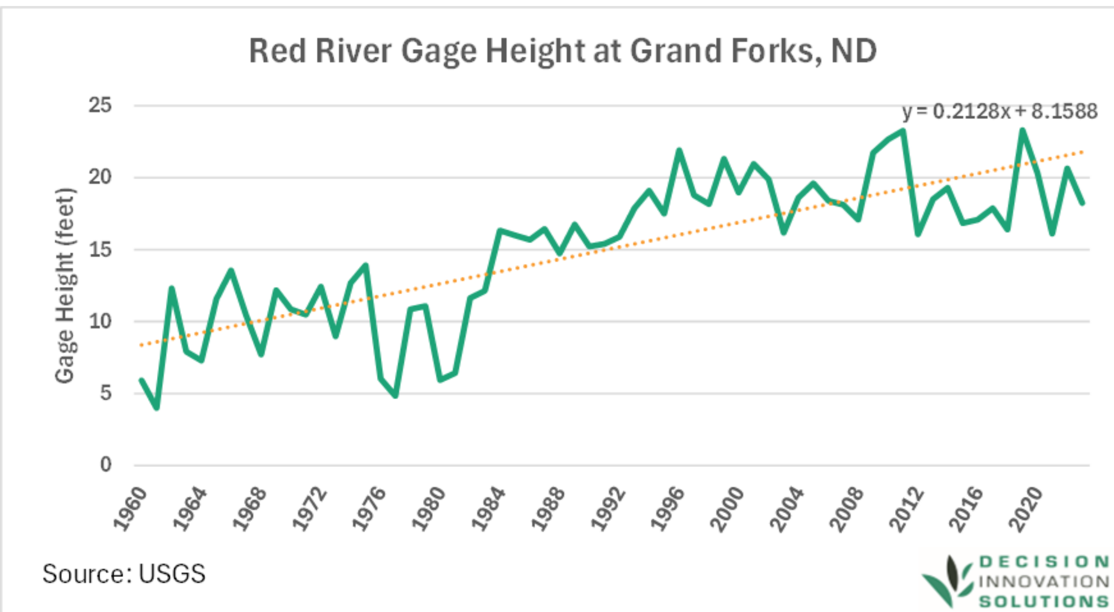


Figure 52. Red River Average Annual Gage Height at Grand Forks, ND 1960-2023

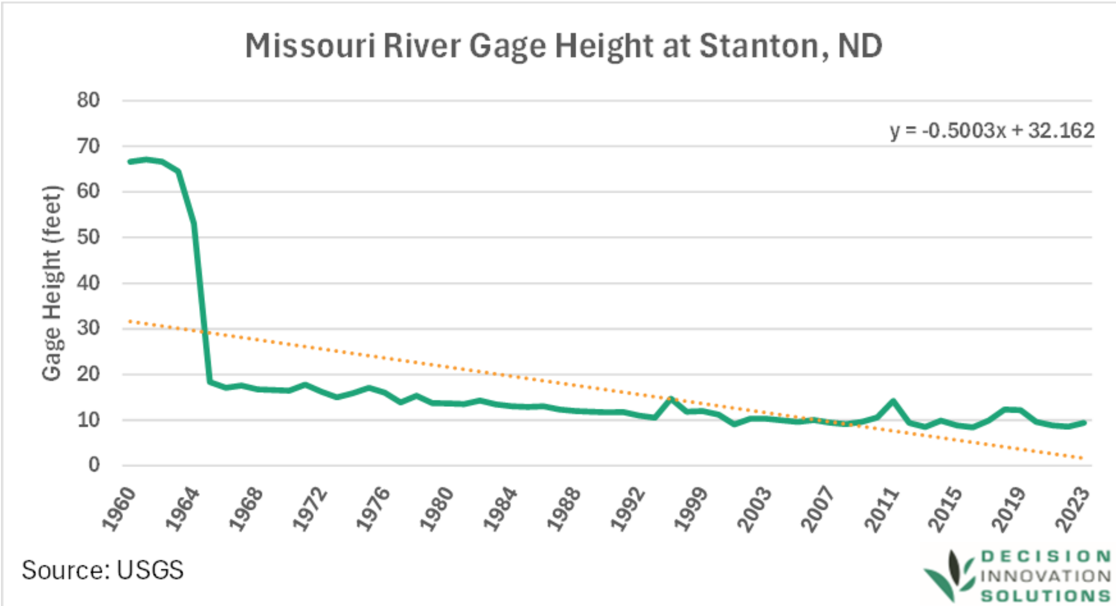


Figure 53. Missouri River Average Annual Gage Height at Stanton, ND 1960-2023

4.4 Water Use for Corn

As illustrated in Figure 54, growing 150-bushel-per-acre corn generally requires roughly **16 to 20 inches** of water (including rainfall and soil moisture) throughout the growing season. This translates to approximately 10–12 acre-inches of water, or roughly 400,000–550,000 gallons per acre, depending on weather and irrigation efficiency. Growing 200-bushel-per-acre corn requires 20 to 23 inches of total water (including precipitation and soil moisture). The critical water demand is highest during the silking stage, needing about 0.3 inches per day, or up to 2 inches per week.[5]

[5] Source: https://crops.extension.iastate.edu/cropnews/2017/06/corn-water-use-and-evapotranspiration

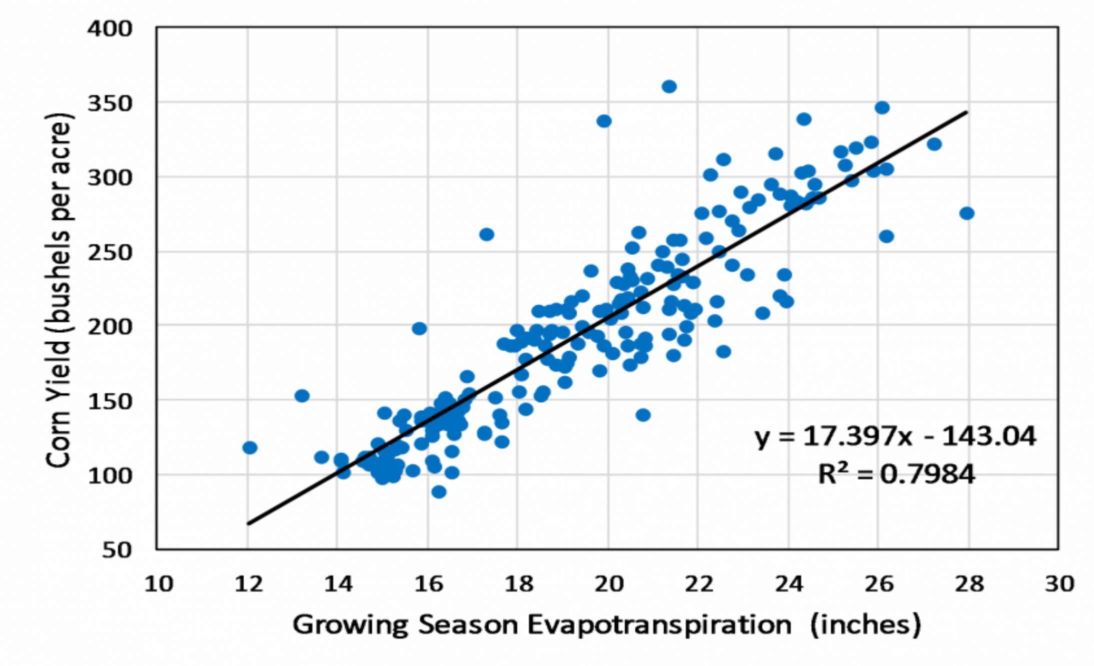


Figure 54. Relationship Between Evapotranspiration and Corn Yields

Since 1970, North Dakota corn yield has nearly tripled and is growing by 1.82 bushels per acre per year. In much of North Dakota, irrigation is essential to achieving high corn yields (Figure 55).

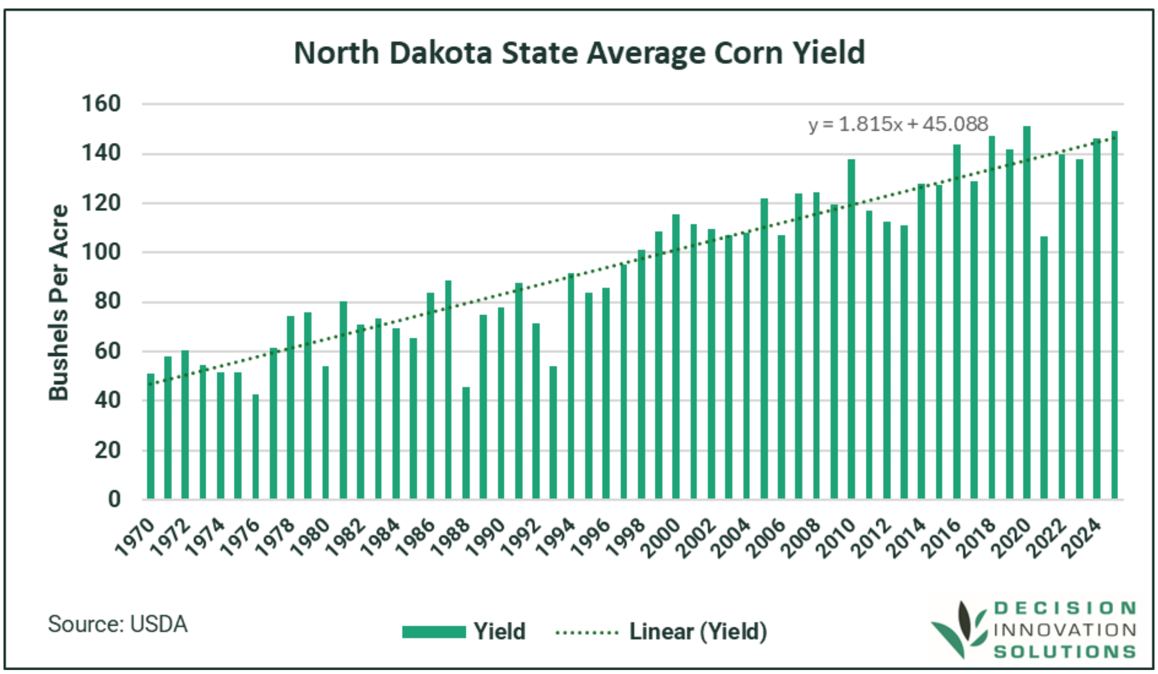


Figure 55. North Dakota State Average Corn Yield

5 Methodology

5.1 The Hidden Costs of Not Developing Irrigation (State Level)

North Dakota has missed out on economic activity that would have occurred since the Pick-Sloan Plan was developed in the 1940s and 1950s if irrigation plans had been fully developed. These missed opportunities could have created and sustained significant amounts of economic activity over the last 75+ years, very likely leading to a much different agricultural and economic landscape than what exists in North Dakota today. To quantify this "opportunity cost", the following considerations are addressed and summarized in this report:

- Estimated cumulative historical value of foregone crop production due to lack of irrigation development at the state level
- Estimated foregone economic activity for inputs and next-level handling and processing that could have occurred if crop production had been enhanced through irrigation development in a timely fashion

To estimate the potential agricultural production impacts of irrigation development associated with the Pick-Sloan Plan, a counterfactual framework was developed to allocate potential irrigated and dryland acreage across crops within each USDA agricultural district. The approach combines observed crop acreage patterns with modern irrigation intensity patterns to simulate how crop acreage could have been distributed between irrigated and dryland production systems had irrigation potential been fully realized by 1970.

For each USDA agricultural district, the potential irrigated acreage was first identified based on previously estimated irrigation potential. This district-level irrigation potential was used as a cap representing the maximum acreage that could be feasibly irrigated within each district. To determine how these acres would be distributed across crops, crop-specific irrigation weights were calculated using each crop's share of total irrigated acreage which is an average of 2020 and 2025 irrigation share. These irrigation shares serve as an indicator for the relative irrigation intensity of each crop. For each crop and year, a weighting factor was calculated by multiplying the crop's share of irrigated average by district irrigation potential acres and by the total observed acreage of that crop within the district. These weights capture both the size of each crop and its relative tendency to be irrigated.

$$Weight_{c,y} = Irrigation\ Share_{c} \times\ District\ Irrigation\ Potential \times\ Crop\ Acres_{c,y}$$

Counterfactual irrigated acres were calculated in two steps. Additional irrigated acreage is calculated by multiplying remaining irrigated acres by the ratio of each crop's weight to the sum of weights across all crops. Then the resulting values were added to the existing irrigated acres to capture the full irrigation potential. This ensures that the counterfactual irrigated acreage equals the district-level irrigation potential while allowing the distribution of irrigation to vary based on crop acreage patterns.

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

$$Additonal\ Irrigated\ Acres_{c,y} = Remaining\ Irrigated\ Acres_{y} \times \left(\frac{Crop\ Weight_{y}}{Sum\ of\ Weights_{y}}\right)$$

$$Counterfactual\ Irrigated\ Acres_{c,y} = Additional\ Irrigated\ Acres_{c,y} + Existing\ Irrigated\ Acres_{c,y}$$

After estimating counterfactual irrigated acreage, counterfactual dryland acreage was calculated. Potential dryland acreage within each district is total acreage minus district-level irrigation potential.

$$Potential\ Dryland\ Acres_{c,y} = Total\ District\ Acres_{y} - District\ Potential\ Irrigated\ Acres$$

Counterfactual dryland acres for each crop were calculated by multiplying potential dryland acreage by the crop's share of district dryland acreage each year.

$$Counterfactual\ Dryland\ Acres_{c,y} = Potential\ Dryland\ Acres_{c,y} \times Dryland\ Share_{c,y}$$

These counterfactual irrigated and dryland acres make up the fully developed irrigation scenario.

5.2 Crop Acreage

Historical crop acreage data for North Dakota was compiled from 1945-2024 using a combination of agricultural datasets, government reports, and supporting studies. Primary data sources include USDA-NASS annual acreage reports, USDA-FSA crop acreage certification data, Census of Agriculture reports, and additional USDA survey-based data[6]. The combination of these sources allowed DIS to both interpolate and extrapolate missing data to ensure consistency and robustness for the agricultural and economic analysis.

Acres planted is the primary variable used to measure acreage since it provides the most direct measure of producer decision-making and land allocation across crops. However, instances where planted acreage data were unavailable, acres harvested from Census of Agriculture reports were used as a proxy, with appropriate consideration given to differences between planted and harvested acreage due to crop loss or abandonment.

To construct a continuous series of North Dakota agricultural production, missing data was estimated using a combination of interpolation and trend-based methods. Where gaps occur between two known data points, linear interpolation was implemented through averaging adjacent years to estimate missing values. In cases involving longer gaps where there is evidence of production, the Excel "trend" function

[6] Crop acreage data was obtained from U.S. Census of Agriculture reports from 1945 through 2022 and from USDA-NASS annual acreage reports. Additional information on irrigated crop acreage was obtained from USDA-FSA crop acreage certification data from the North Dakota Department of Agriculture.

was applied to estimate missing values based on the existing trajectory of the data. For other gaps, rolling averages were used in select instances to smooth volatility and generate more stable estimates.

Irrigated acreage was sparsely reported, resulting in multiple interpolation and extrapolation methods being used. When partial data was available, particularly in earlier years, missing irrigated acreage values were estimated by extending observed irrigated acreage. In other cases, a ratio-based approach was applied, using known proportions of irrigated acreage relative to total acreage to estimate missing values. These methods ensured that irrigated estimated remained consistent with both observed trends and the relative scale of total crop acreage.

Together, these data compilation and estimation methods established a baseline dataset of total, irrigated, and dryland acreage across North Dakota from 1945 to 2024.

5.3 Comparison of Economic Contribution Per Acre (Irrigated/Dryland)

The economic contribution of agriculture on a per acre basis was quantified for the various combinations of irrigated vs. dryland.

5.3.1 Crop Budget Development for Non-irrigated and Irrigated Crops

The following steps were taken:

- Models of crops production costs and inputs by county were created. Cropping models (especially input categories) might change due to development of new crop production technologies and expanded irrigation capacity.
- To create comparisons between dryland and irrigated crop production, non-irrigated budgets and irrigated budgets from North Dakota State University (NDSU) were used along with crop budgets from other states when North Dakota data was not available.
- Historical Budgets were constructed for the following crops:
    - Corn
    - Barley
    - Soybeans
    - Spring Wheat
    - Dry Beans
    - Sugar beets
    - Potatoes
    - Minor Crops (Consolidated into a Minor Crops Index)
        - Buckwheat
        - Canola
        - Chickpeas
        - Flaxseed
        - Lentils

- Millet
- Mustard
- Oats
- Dry Peas, Edible
- Rye
- Safflower
- Sunflower, Oil-type

For both non-irrigated and irrigated crops, the general methodology used to build a North Dakota budget database across multiple years was as follows:

- Estimate the share of direct and indirect cost relative to revenue for each crop based on the years with crop budget data available.
- To build North Dakota budgets across years without data, the estimated direct and indirect cost shares were multiplied by the revenue for each crop across the years. The revenue was estimated using North Dakota prices and yields for each crop as available. Irrigated yields without data available were calculated by applying the difference between non-irrigated and irrigated yields during the years with data available. If this data did not exist, these differentials were sourced from published reports.

The following section presents a detailed methodology used for budget development for both non-irrigated and irrigated crops. This section also includes resulting budgets built for selected regions and at the state level. This data was prepared for inclusion in the economic contribution of irrigation and drainage to the North Dakota economy.

5.3.2 North Dakota Regional Non-Irrigated Crop Budgets

North Dakota regional non-irrigated crop budgets are created annually by NDSU and include 9 regions. Figure 56 shows the counties included in each of these regions.

For non-irrigated spring wheat, corn, barley, and minor crops NDSU published crop budget data for the 2004-2024 years[7]. For non-irrigated soybeans, NDSU budgets encompassed the years of 2014-2024. Data for three regions of the non-irrigated crop budgets (i.e., North West, North Central, and South East), was collected for this analysis. Due to data availability, for non-irrigated dry beans, the budget data was for the North Valley, South East, and South Valley.

[7] https://www.ndsu.edu/agriculture/extension/ag-topics/farm-management/crop-economics/projected-crop-budgets

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

North Dakota Counties by Budget-Specific Regions (Non-Irrigated Crops)

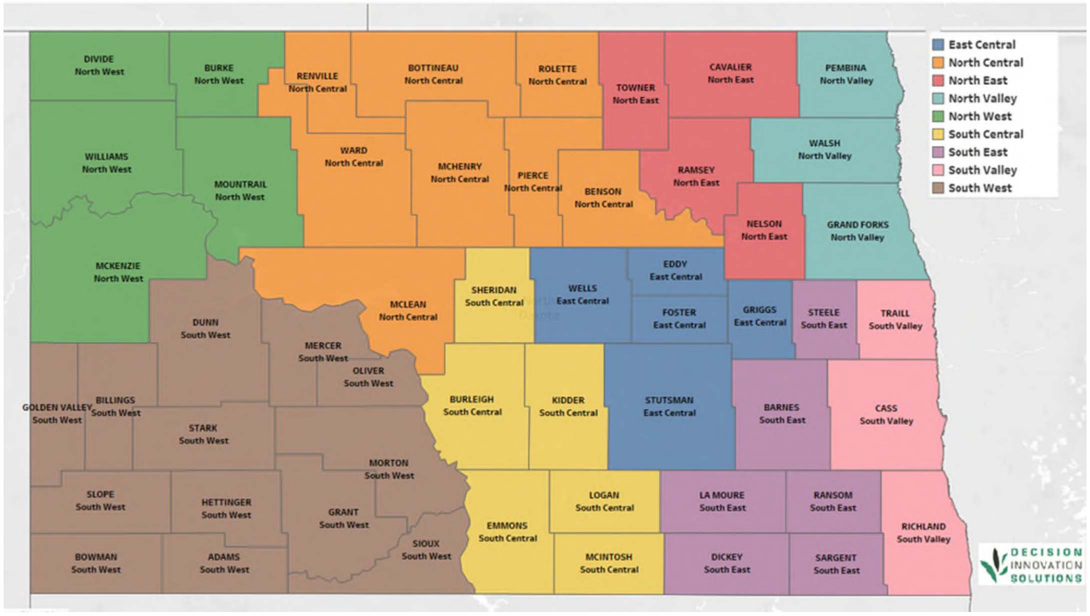


Figure 56. North Dakota Crop Budget Regions (Non-Irrigated Crops)

Data on regional non-irrigated crop budgets from 2004-2024 were used to build regional crop budget datasets for 1945 through 2024 for non-irrigated crops, except for dry beans, which covered the 1970-2024 period. This analysis included state yields and prices from USDA-NASS; these two variables were used to estimate market revenues for the 80-year period of 1945-2024. For each crop, direct and indirect costs for the 1945-2003 period were estimated based on the 2004-2024 average direct and indirect cost shares relative to average market revenue during that 21-year period (2004-2024). Some direct costs such herbicides, fertilizers, fuels & lubrication, repairs, and miscellaneous costs for 1945-2003, were based on USDA-ERS's Commodity Costs and Returns database for the commodities and years that were available in that database. For 2004 to 2024 the direct and indirect costs were published by NDSU in crop budget reports.

Yields for North Dakota dry beans were available only for the 2019 to 2024 period. Dry beans (including chickpeas) yield data was available from 1970 to 2018. Using this latter yield series and the relationship of chickpeas planted acres to dry beans including chickpeas planted acres (2.7%)[8], dry bean yields were estimated for 1970 to 2018, which was added to the 2019 to 2024 dry beans yield series.

When data was available, the non-irrigated minor crops included budgets for 12 crops (buckwheat, canola, chickpeas, flaxseed, lentils, millet, mustard, oats, edible dry peas, rye, safflower, and sunflower).

---

[8] Using USDA-NASS's North Dakota available data for chickpeas planted acres for the 1999 to 2018 and dry beans (including chickpeas) planted acres for the same period, it was estimated that chickpeas planted acres were about 2.7% of dry beans (including chickpeas) planted acres during that period, on average. This percentage was used in yield estimation due to the lack of data.

A weighted average index for these minor crops was built for the 2004 to 2024 period. For each year, the weighted average index was based on the share of each minor crop's acres harvested in 2022 relative to wheat acres harvested in 2022.

The market revenue for these minor crops for the 1945-2003 period was estimated based on the ratio of minor crop average revenue for 2004-2024 to wheat average revenue from 2004 to 2024. This ratio was applied to the spring wheat revenue for 1945-2003 to estimate the annual minor crop revenue for the 1945-2003 period.

For the minor crops, the average of each direct and indirect cost for 2004-2024 was divided by the wheat average revenue for the 2004-2024 period to estimate cost ratios relative to wheat average revenue. Those ratios were applied to the corresponding annual spring wheat revenue to estimate each cost for each year for the 1945-2003 period. For 2004-2024, the costs were estimated by the weighted average index, as explained above.

As examples of regional crop budget datasets built for 1945 through 2024 period, Figure 57 shows non-irrigated spring wheat revenue and summary of expenses for North Dakota's North West region. Figure 58 shows non-irrigated minor crops' revenue and summary of expenses for North Dakota's North West region.

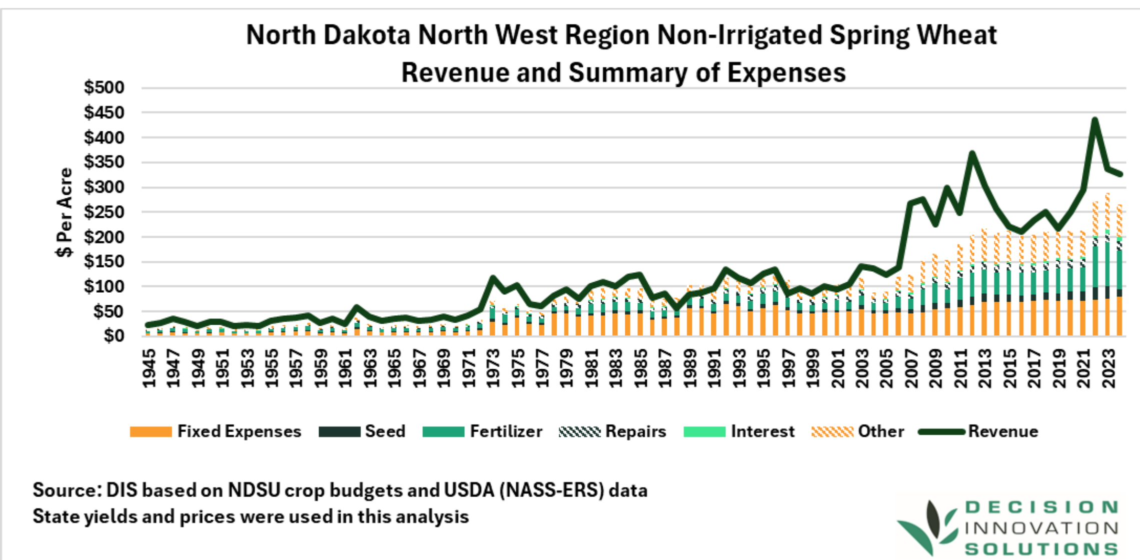


Figure 57. North Dakota North West Region Non-Irrigated Spring Wheat Revenue and Summary of Expenses

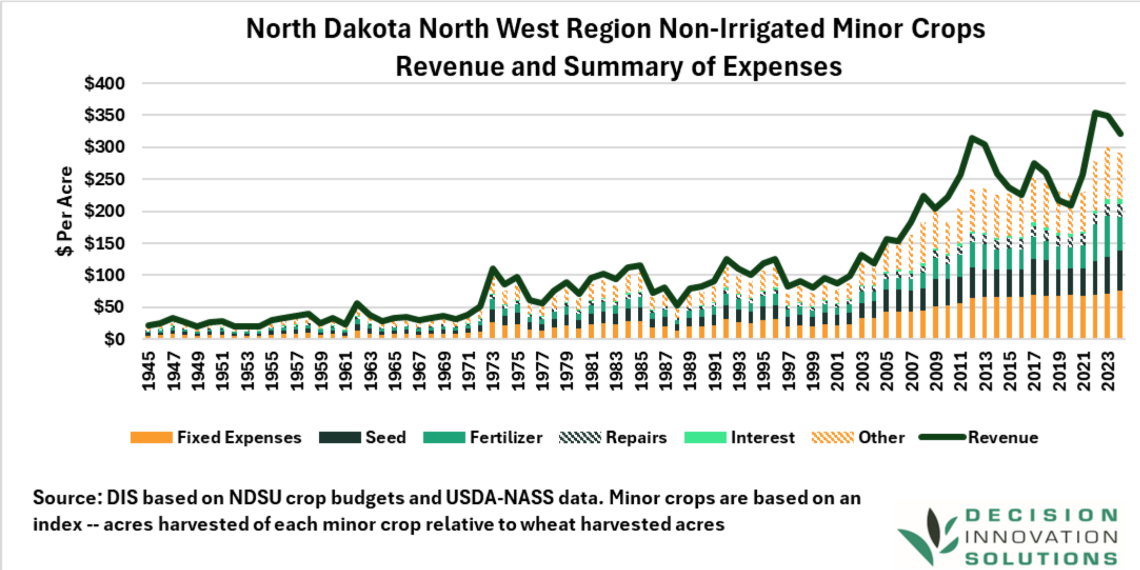


Figure 58. North Dakota North West Region Non-Irrigated Minor Crops Revenue and Summary of Expenses

5.3.3 State level Non-Irrigated Crop Budgets

A weighted average state budget was estimated for each of the major crops (spring wheat, corn, barley, soybeans, and dry beans). The weighted average state budget component of each non-irrigated major crop was based on the 3 selected regions' (North West, North Central, and South East[9]) harvested acres from 1945 to 2024[10]. Each component of the state budget was weighted by the region's share of total average harvested acres of the 3 regions. In the case of soybeans, due to lack of data, agricultural district soybean planted acres were used instead of harvested acres.

The state budget for the minor crops was based on agricultural district data for canola for 1945-2024. Canola was the crop with the largest share of harvested acreage among the minor crops in the Agricultural Census of 2022, relative to spring wheat harvested acres during the same year.

Figure 59 to Figure 64 show the state revenue and summary of expenses for non-irrigated barley (Figure 59), corn (Figure 60), soybeans (Figure 61), spring wheat (Figure 62), dry beans (Figure 63), and minor crops (Figure 64).

[9] For dry beans the selected regions were North Valley, South East, and South Valley.

[10] For dry beans the state budget was built for 1970 to 2024.

5.3.3.1 Barley – Non-Irrigated

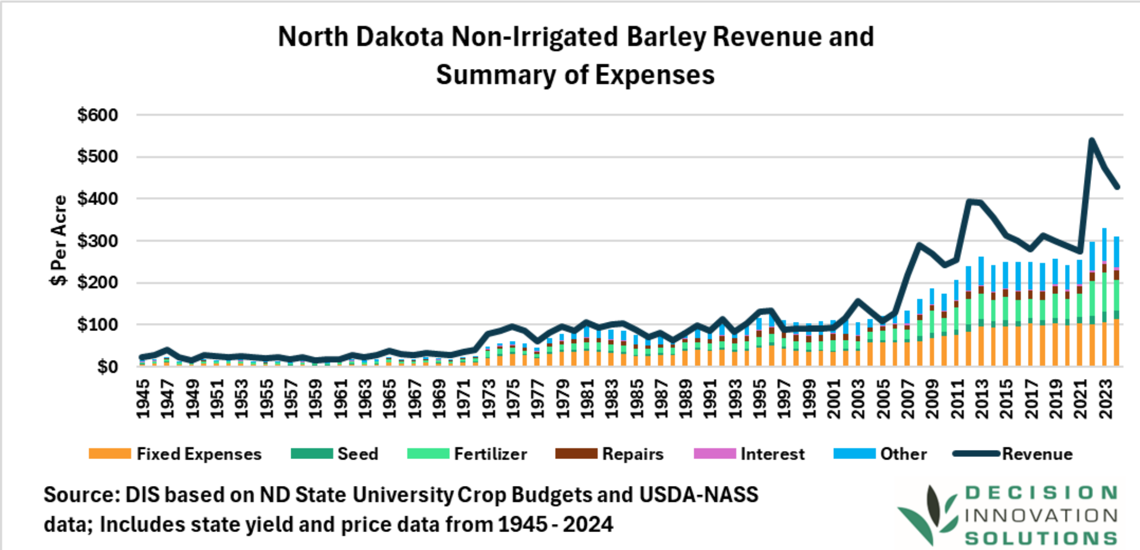


Figure 59. North Dakota Non-Irrigated Barley Revenue and Summary of Expenses

5.3.3.2 Corn – Non-Irrigated

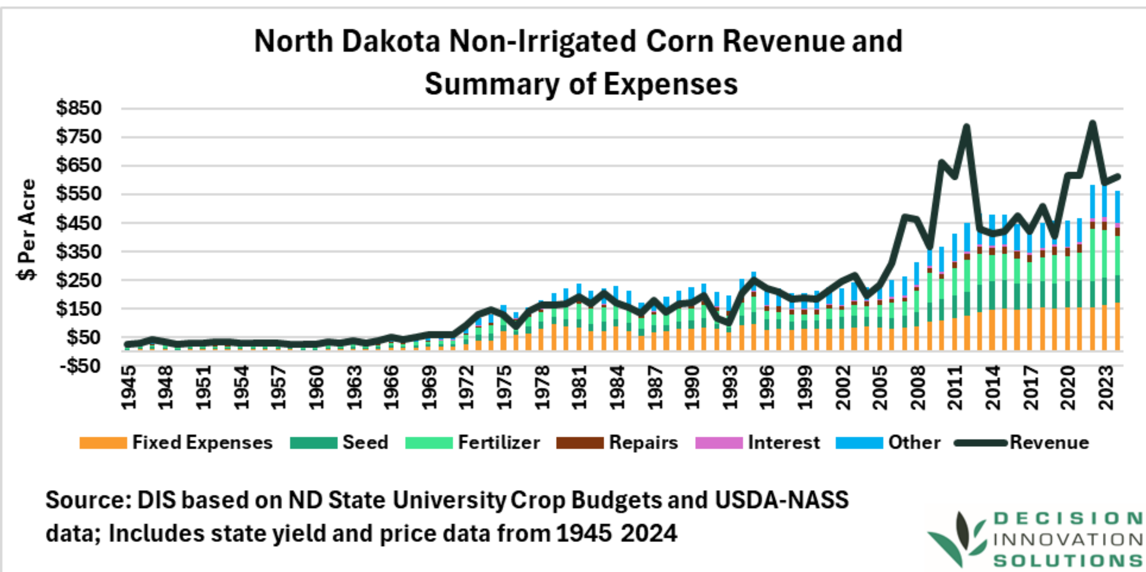


Figure 60. North Dakota Non-Irrigated Corn Revenue and Summary of Expenses

5.3.3.3 Soybeans – Non-Irrigated

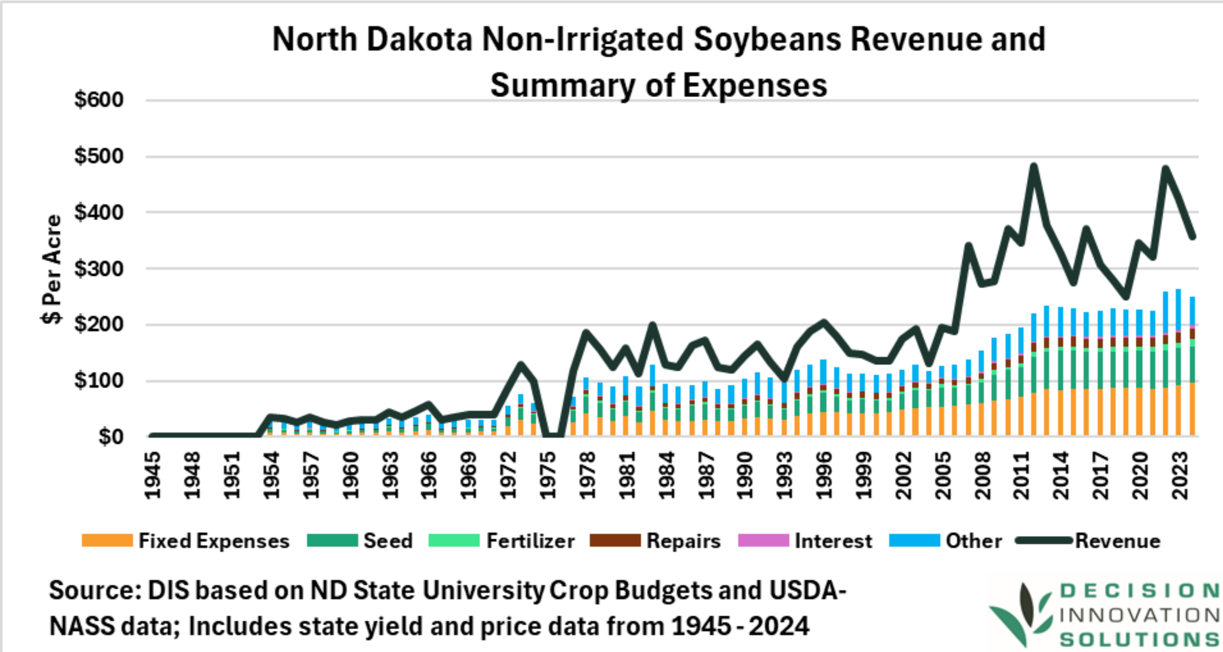


Figure 61. North Dakota Non-Irrigated Soybeans Revenue and Summary of Expenses

5.3.3.4 Spring Wheat – Non-Irrigated

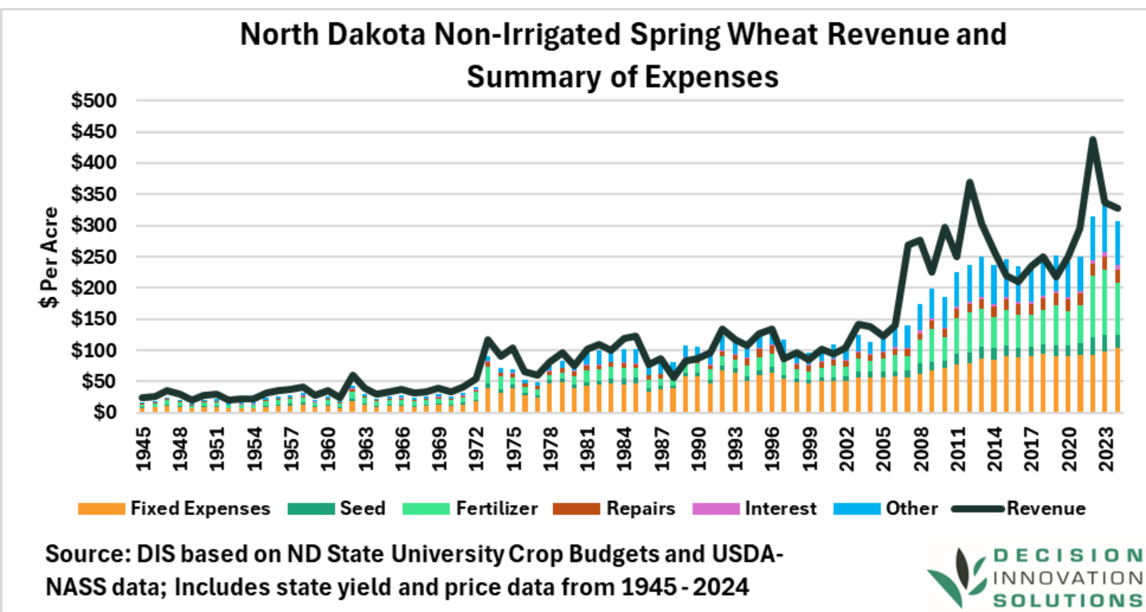


Figure 62. North Dakota Non-Irrigated Spring Wheat Revenue and Summary of Expenses

5.3.3.5 Dry Beans – Non-Irrigated

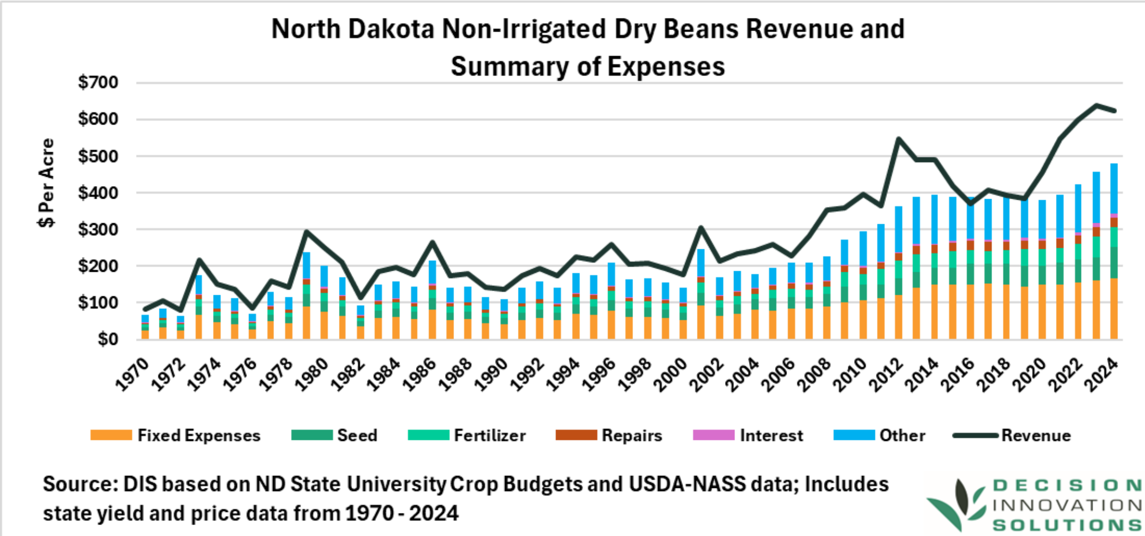


Figure 63. North Dakota Non-Irrigated Dry Beans Revenue and Summary of Expenses

5.3.3.6 Minor Crops (Index) – Non-Irrigated

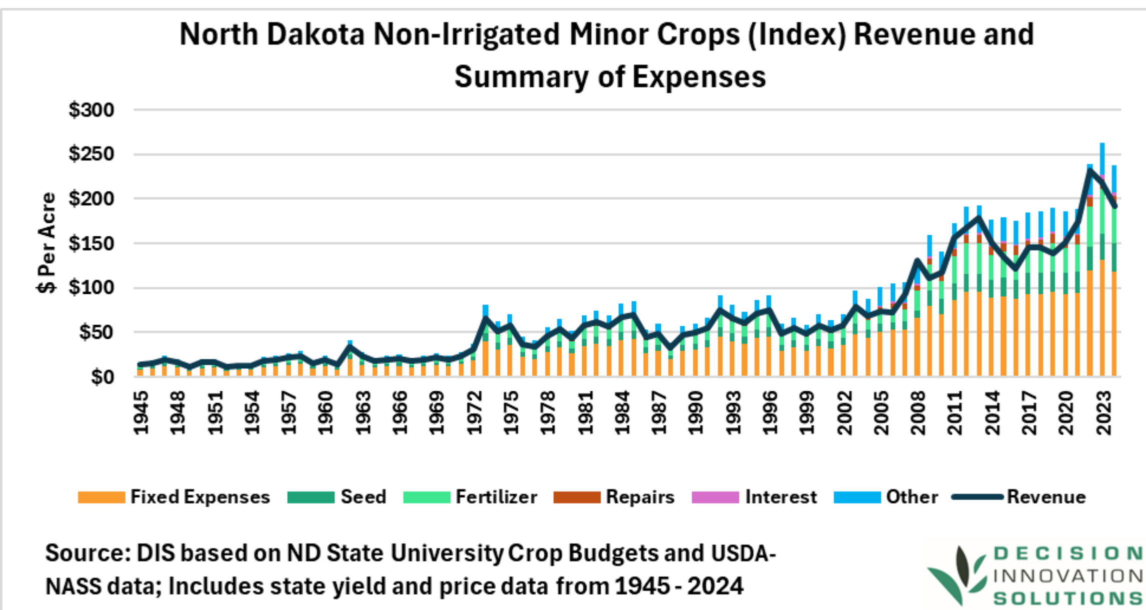


Figure 64. North Dakota Non-Irrigated Minor Crops (Index) Revenue and Summary of Expenses

5.3.3.7 Potatoes – Non-Irrigated

North Dakota non-irrigated potato budgets are not currently available, except for Red Norland non-irrigated potatoes. A North Dakota non-irrigated potatoes weighted budget was built based on crop budgets for Idaho dryland Russet potatoes and North Dakota non-irrigated Red Norland potatoes. Each component of the weighted North Dakota non-irrigated potato budget incorporated 60% from the Russet potato budget and the remaining 40% was from the Red Norland potato budget. Based on this weighted budget, the percentage of each the direct and indirect costs relative to the revenue were estimated. These percentages were used to generate North Dakota direct and indirect costs for the non-irrigated potato budgets in combination with North Dakota potato revenues from 1970 to 2024. Potato revenues were calculated from USDA yields and prices reported by NASS as contained in the USDA Quick Stats website. USDA reported prices for 1970 to 2024 were used. Figure 65 shows revenue and a summary of expenses for non-irrigated potatoes from 1970 to 2024.

USDA reports North Dakota's potato yields in general (overall yields)[11] for the period of 1970 to 2024 and non-irrigated yields for the period of 1994 to 2009. The years without non-irrigated yields (1970 to 1993 and 2010 and 2024) were estimated by applying the percentage difference between overall yields and non-irrigated yields during 1994 and 2009.

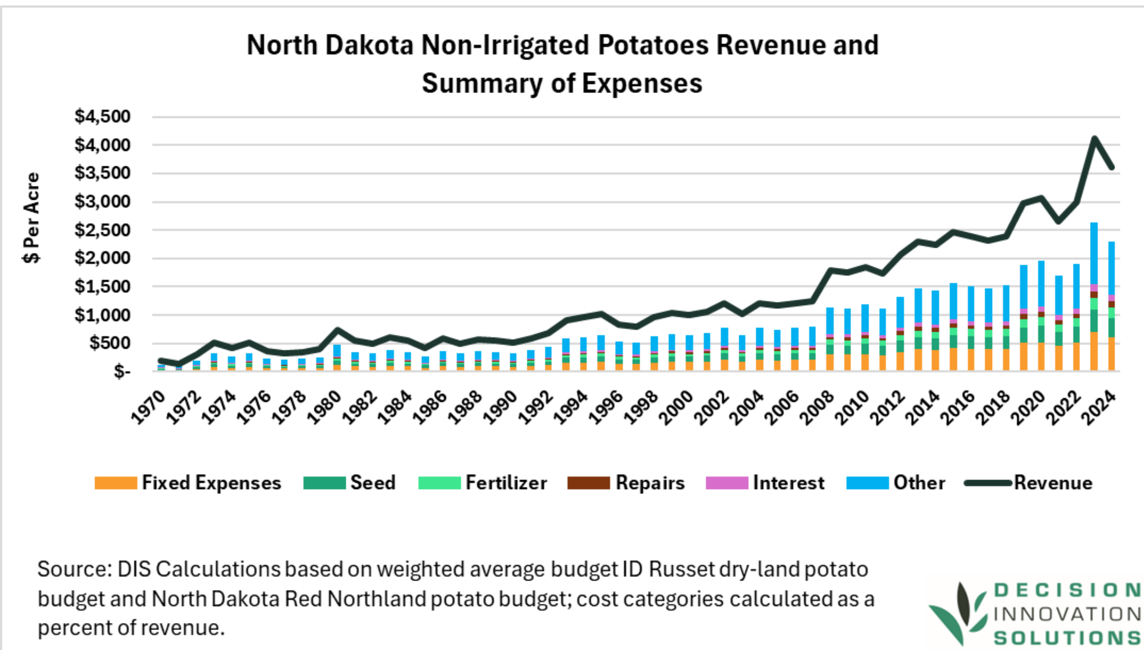


Figure 65. North Dokota Non-Irrigated Potato Revenue and Summary of Expenses

---

[11] Mostly refers to fall potato yields.

5.3.3.8 Sugar Beets – Non-Irrigated

Sugar beet production, cost, and revenue data were obtained from the Northland Farm Business Management reports published by Northland College in Moorhead, MN[12]. These reports were available for 1999 through 2025. The annual data was used directly for 1999 through 2025. Yield and price data were available for 1970 through 1998 and expenses for 1970 through 1998 were modeled as a percentage of revenue based on the five-year average percentage from the 1999 through 2003 data. Figure 66 shows the revenue, fixed expenses, and a summary of the direct expenses for sugar beet production in North Dakota for 1970 through 2024.

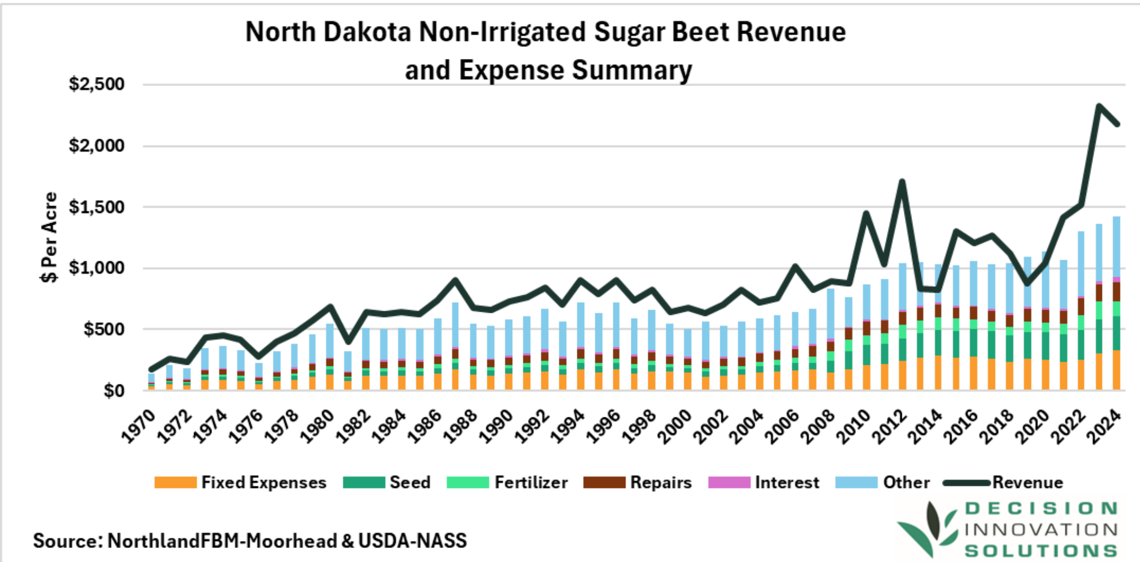


Figure 66. North Dakota Non-Irrigated Sugar beet Revenue and Expense Summary

5.3.4 North Dakota Regional Irrigated Crop Budgets

North Dakota regional irrigated crop budgets include 3 regions (Eastern, Central, and Western). These budgets were further developed for a multicounty region. Figure 67 shows the counties included in each of the 3 regions. NDSU has irrigated budget crop data available for the 2022 and 2023 years for spring wheat, corn grain, malting barley, soybeans, and dry beans, among others (i.e., alfalfa, alfalfa seeding, and corn silage).

Data on regional irrigated crop budgets from 2022 and 2023 were used to build regional crop budget datasets for 1945 through 2021 and 2024 for irrigated crops[13]. This analysis included state yields and prices from USDA-NASS. The state yield data for irrigated crops was limited: spring wheat and barley:

[12] http://www.northlandfbm-moorhead.com/New%20Reports.html

[13] Built regional irrigated dry beans budget dataset included only the years of 1970 through 2021 and 2024.

1972-2003, corn: 1982-2009. For soybeans, irrigated yield data was not available. To "fill in" the years without irrigated yield data for spring wheat, corn, and barley, the average percentage differential between irrigated and non-irrigated yield during the years of irrigated data available was used. Irrigated soybean yields were based on the average differential between irrigated and non-irrigated soybeans estimated in trials conducted by NDSU Extension[14] at two locations in North Dakota (Carrington Research Extension Center and the Oakes Irrigation Research site). Results averaged from 10 years showed a seed yield differential between dryland and irrigated Roundup Ready soybean varieties of 13.0 bushels/acre at Carrington and 21.0 bushels/acre at Oakes, for an average of the two locations of 17 bushels/acre. The average yield differential between irrigated and non-irrigated soybeans was used to estimate irrigated soybeans for the 1945-2021 and 2024 period.

Yields of irrigated dry beans from 1970 to 2021 and 2024 were based on the average differential between irrigated and non-irrigated beans during 2022 and 2023. The yields of irrigated dry beans were reported in the crop budgets published by NDSU for 2022 and 2023. The methodology followed for yield estimation of non-irrigated dry beans was explained in section 5.3.2.of this report. Yield estimates for non-irrigated dry beans were 63% of irrigated dry bean yields. This average yield differential between irrigated and non-irrigated dry beans was used to estimate irrigated dry beans for 1970 to 2021 and 2024.

Prices and irrigated yields were used to estimate market revenues for the 80-year period of 1945-2024[15]. For each crop, direct and indirect costs for the 1945-2021 and 2024 period were estimated based on the 2022 and 2023 average direct and indirect cost shares relative to market revenue during those two years. Figure 68 shows irrigated spring wheat revenue and summary of expenses for North Dakota's Western region.

[14] North Dakota Soybean Production Field Guide 2023 (A1172)
https://www.ndsu.edu/agriculture/sites/default/files/2024-10/a1172.pdf

https://www.ndsu.edu/agriculture/extension/ag-topics/farm-management/crop-economics/irrigated-crop-budgets

[15] Dry beans included the years of 1970-2024

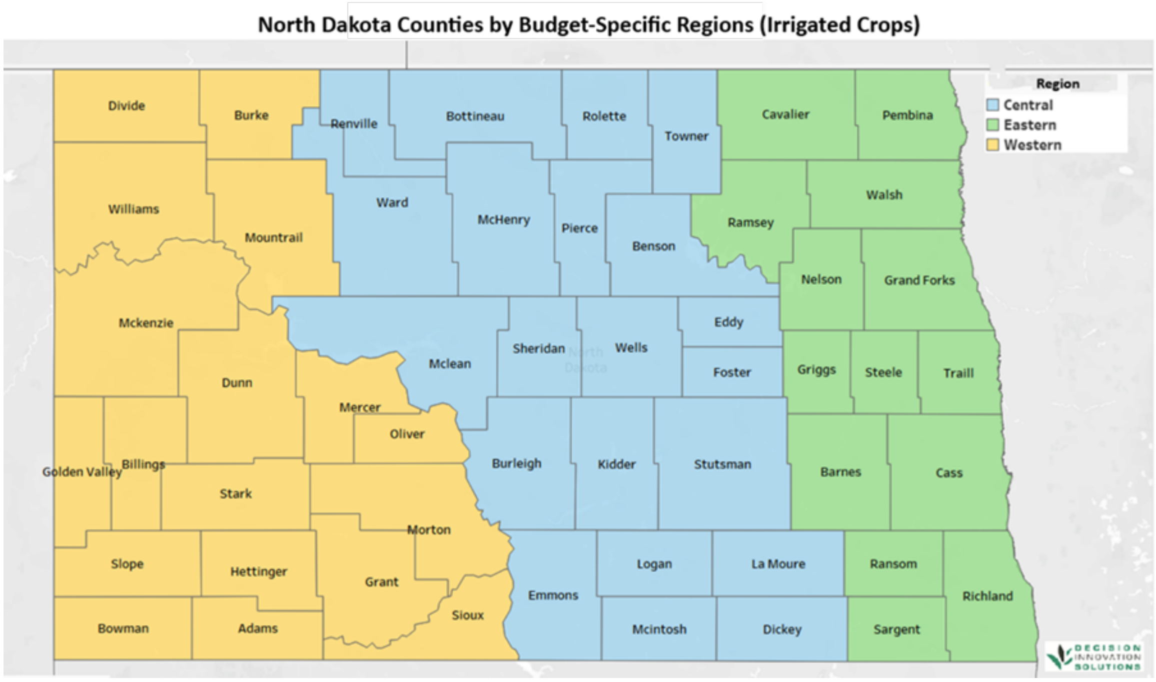


Figure 67. North Dakota Counties by Budget-Specific Counties (Irrigated Crops)

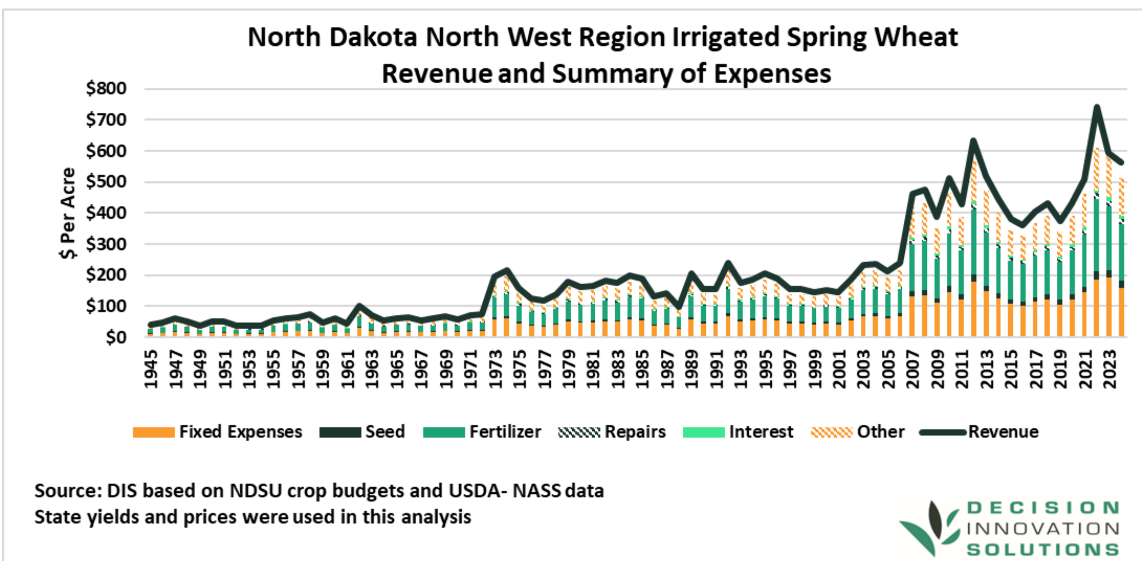


Figure 68. North Dakota Western Region Irrigated Spring Wheat Revenue and Summary of Expenses

5.3.5 North Dakota State-level Irrigated Crop Budgets

Similarly to non-irrigated crops, for each major irrigated crop (spring wheat, corn, barley, soybeans and dry beans), a weighted average state budget was created. For irrigated spring wheat, corn, and barley, the irrigated state crop budgets were based on each crop's three regional (western, central, and eastern) irrigated budgets. Each region's share of the irrigated crop harvested acres relative to the total harvested acres of the three regions served in weighing the contribution of the region's budget in the state budget components. The harvested acres were sourced from USDA-NASS survey data.

A similar procedure was used for irrigated soybean and dry bean state budgets, except that instead of survey data, USDA-NASS Censuses of Agriculture data were used. The acres data for irrigated soybeans came from the 1964, 1982, 2002, and 2022 census years. Since the database for dry beans was built for the 1970 to 2024 period, the irrigated data corresponded to the 1982, 2002, and 2022 censuses. For each region, the irrigated acres were estimated based on the average of irrigated acres across the census years. Data from agricultural censuses was used due to the lack of survey data. Figure 69 to Figure 73 show state revenue and summary of expenses for irrigated barley (Figure 69), corn (Figure 70), soybeans (Figure 71), spring wheat (Figure 72), and dry beans (Figure 73).

5.3.5.1 Barley – Irrigated

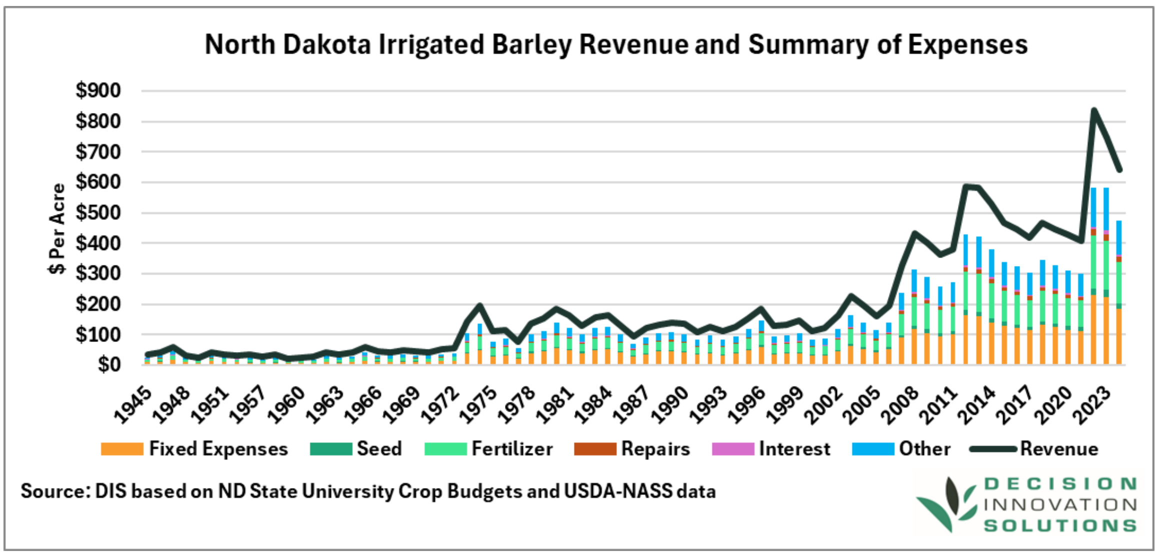


Figure 69. North Dakota Irrigated Barley Revenue and Summary of Expense

5.3.5.2 Corn – Irrigated

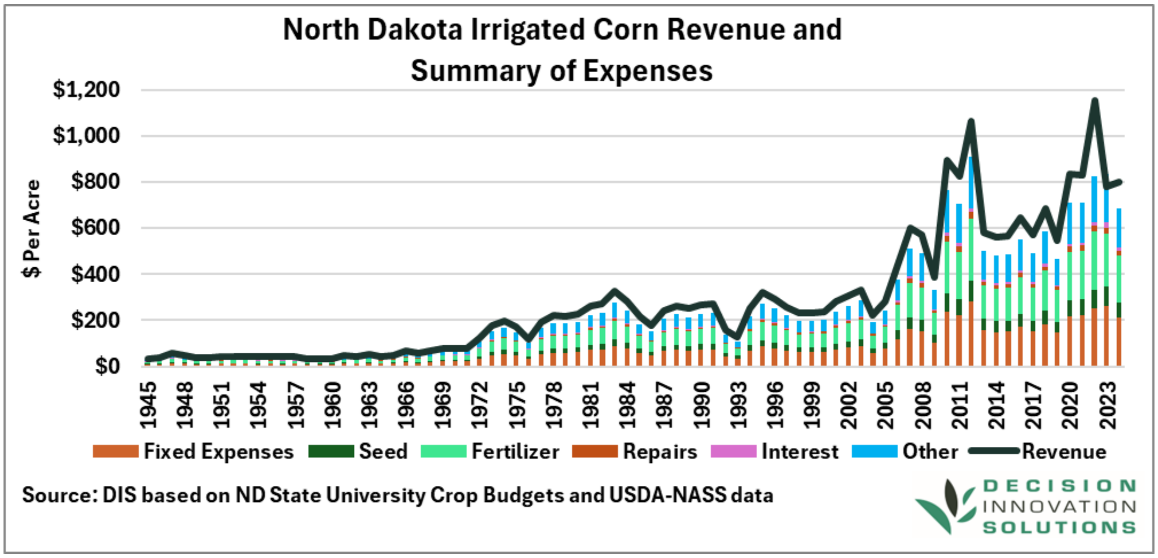


Figure 70. North Dakota Irrigated Corn Revenue and Summary of Expenses

5.3.5.3 Soybeans – Irrigated

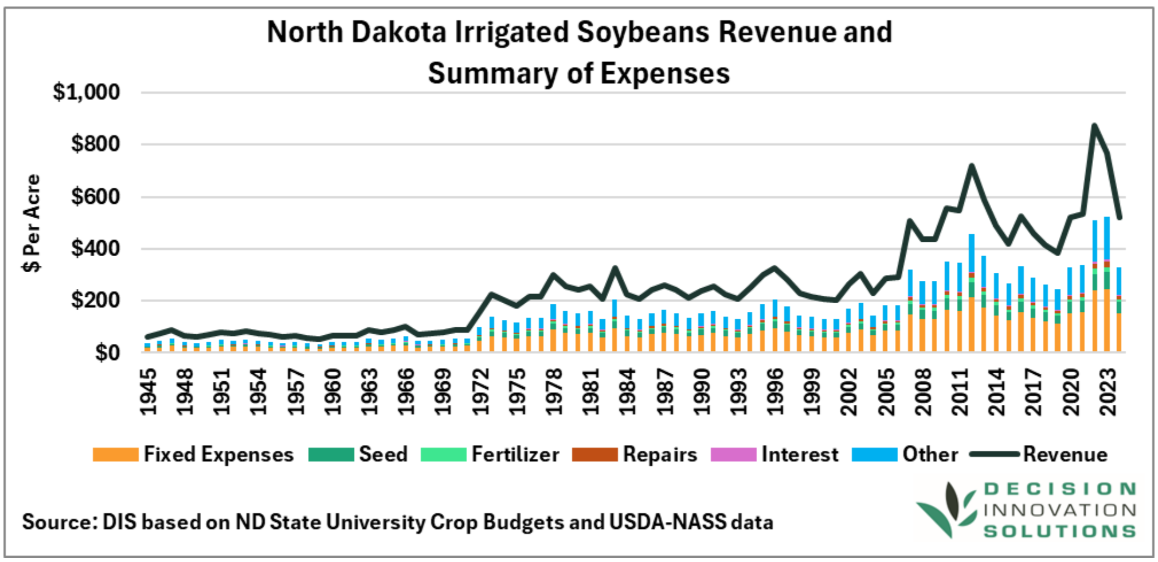


Figure 71. North Dakota Irrigated Soybeans Revenue and Summary of Expenses

5.3.5.4 Spring Wheat – Irrigated

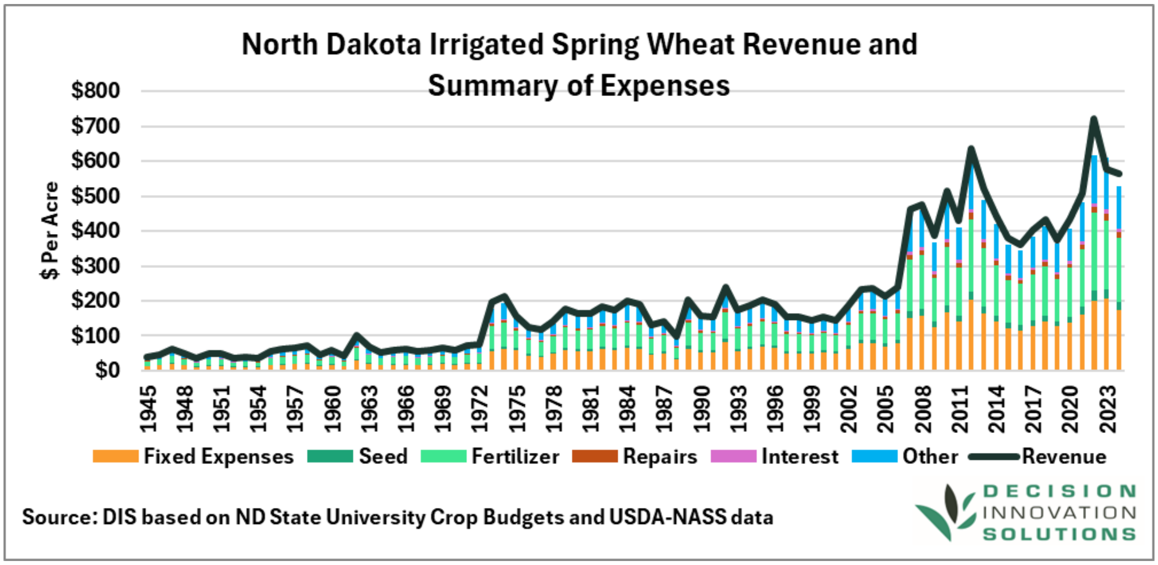


Figure 72. North Dakota Irrigated Spring Wheat Revenue and Summary of Expenses

5.3.5.5 Dry Beans – Irrigated

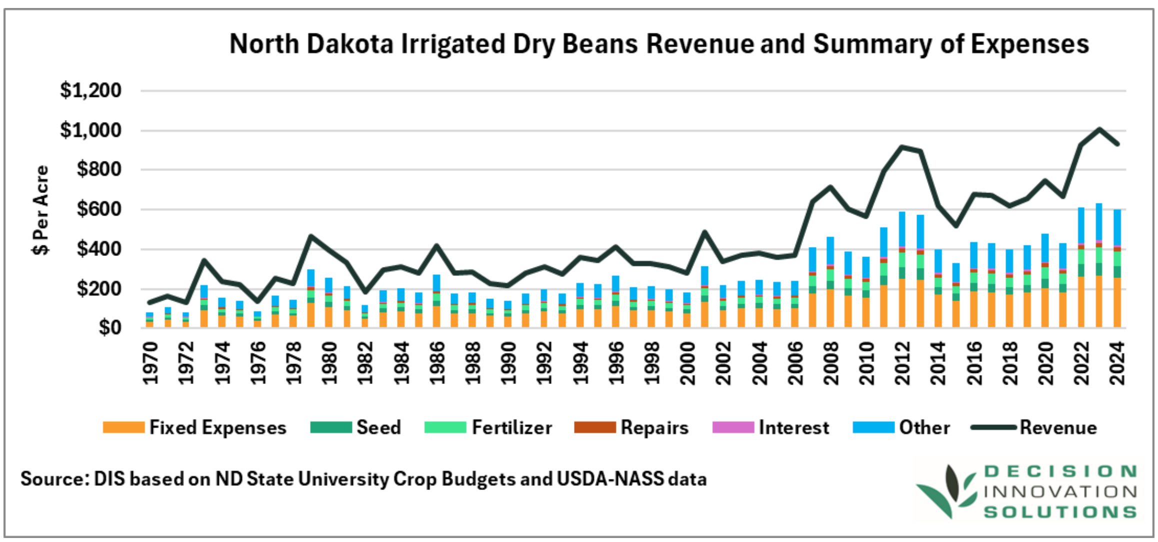


Figure 73. ND Dry Beans Irrigated Revenue and Summary of Expenses

5.3.5.6 Minor Crops – Irrigated

Due to the lack of published budgets for irrigated minor crops and given the low acreage planted to irrigated minor crops, budgets were not developed for these minor crops.

5.3.5.7 Potatoes – Irrigated

North Dakota irrigated potato budgets are not available. A North Dakota irrigated potato weighted budget was built based on budgets for Idaho russet potatoes and Manitoba yellow potatoes. Each component of the weighted budget included 80% from the russet potato budget and the remaining 20% was from Manitoba yellow potato budget. Based on this weighted budget, the percentage of direct and indirect costs relative to the revenue were estimated. These percentages were used to generate direct and indirect costs for the irrigated potato budgets in combination with North Dakota potato revenues from 1970 to 2024. The potato revenues were calculated from yields and prices reported by USDA-NASS as contained in the USDA Quick Stats website. USDA reported potato prices for 1970 to 2024 were used.

USDA reports North Dakota state potato yields in general (overall yields) for the period of 1970 to 2024 and irrigated yields for the period of 1994 to 2009. The years without irrigated yields (1970 to 1993 and 2010 and 2024) were estimated by applying the percentage difference between overall yields and irrigated yields during 1994 and 2009. Figure 74 shows state revenue and summary of expenses for irrigated potatoes.

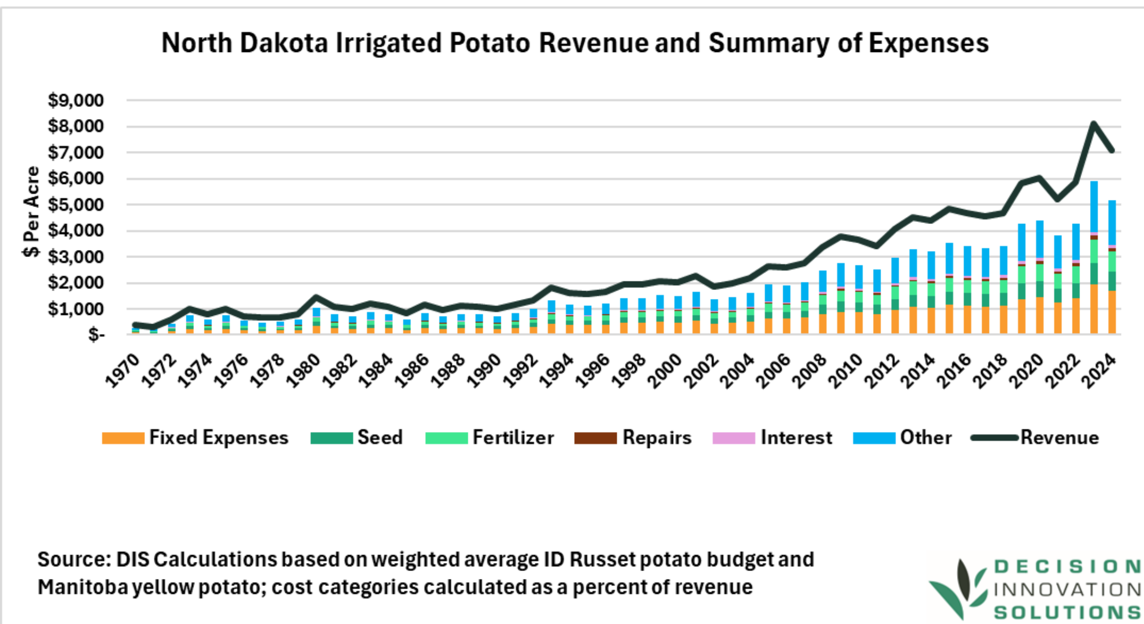


Figure 74. ND Potatoes Irrigated Revenue and Summary of Expenses

5.3.5.8 Sugar Beets – Irrigated

Due to the lack of data, the North Dakota irrigated sugar beet budget was based on a budget for Idaho (Eastern) irrigated sugar beets. The percentage of Idaho budget cost components relative to the revenue were used to build a North Dakota budget for 1970 to 2024. North Dakota irrigated sugar beet revenues from 1970 to 2024 were based on prices and yields available from 1970 to 2024, which were published by USDA-NASS. North Dakota irrigated yields were adjusted based on a 1999 report published by NDSU (Extension), along with University of Minnesota (Extension) and University of Wisconsin-Madison (Department of Agronomy)[16] indicating that sugar beet yields in North Dakota and Minnesota under irrigation were about 15% to 30% greater than non-irrigated sugar beet yields. Figure 75 shows state revenue and a summary of expenses for irrigated sugar beets.

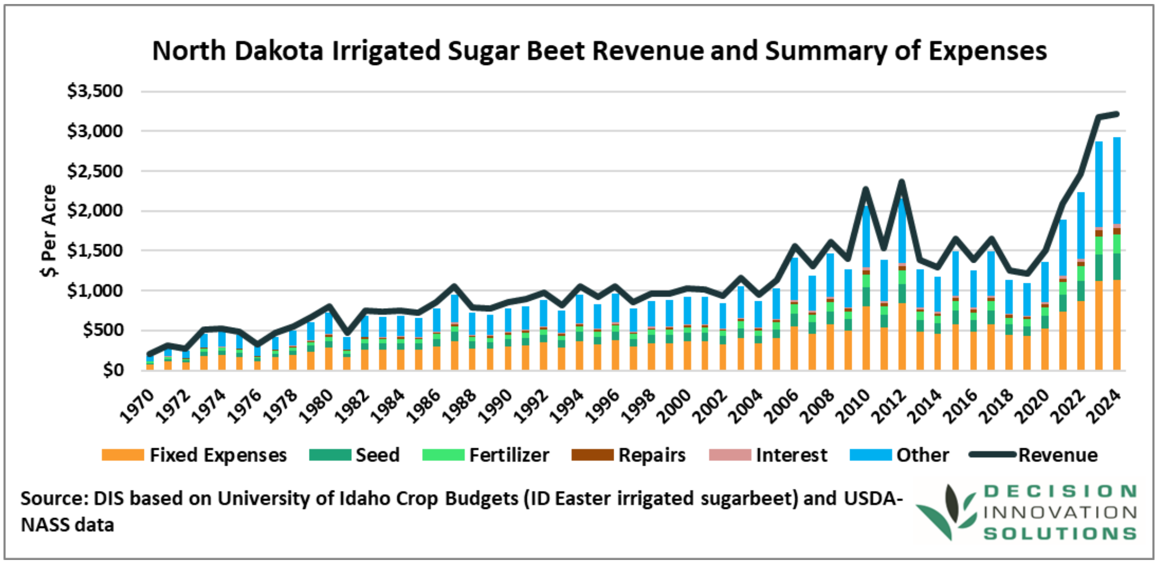


Figure 75. North Dakota Irrigated Sugar Beet Revenue and Summary of Expenses

[16] https://corn.agronomy.wisc.edu/Crops/Sugarbeet.aspx

5.4 North Dakota Agricultural and Climate Trends

To characterize historical climate conditions and variablity relevant to agricultural production in North Dakota, a comprehensive dataset of weather and climate indicators was assembled using data from the National Centers for Environmental Information (NCEI), part of the National Oceanic and Atmospheric Administration (NOAA). Data was accessed through the Climata Data Online (CDO) platform for the years of 1960-2024 for multiple locations across North Dakota.

The selected variables were chosen to capture both average climate conditions and the frequency and intensity of extreme weather events that are particularly relevant to agricultural productivity. Specifically, the dataset includes annual and count-based indicators of precipitation, snowfall, temperature extremes, and snowfall conditions. These variables include:

- Annual precipitation
- Annual snowfall
- Number of days with precipitation greater than 0.1 inch
- Number of days with snowfall greater than 1 inch
- Number of days with snow depth greater than 1 inch
- Number of days with maximum temperature below 32˚F
- Number of days with maximum temperature above 90˚F

In addition to meteorological variables, river gage height data from 1960-2024 were collected to capture hydrologic variability and flood risk conditions that influence agricultural land use and productivity. Gage height observations were collected for key locations along major river systems, including the Red River at Fargo, ND and Grand Forks, ND, as well as the Missouri River at Stanton, ND and Nohly, MT. These locations were selected to represent both downstream and upstream hydrologic conditions affecting North Dakota agriculture.

5.5 Economic Contribution of Irrigation and Drainage to the North Dakota Economy (Regional and State Levels)

The state-level budgets detailed in Section 5.3 were used to create IMPLAN events that matched each crop’s revenue and expenses per acre for each of the following years: 1970, 1980, 1990, 2000, 2010, 2020, and 2024. IMPLAN models were created for each North Dakota Agricultural Statistics District by combining the models for the counties in each district for the 2024, 2020, 2010, and 2001 data years. Note that 2001 is the oldest year for which IMPLAN models are available and was used to create the 2000, 1990, 1980, and 1970 contribution estimates. Since the event inputs use nominal dollars and defined revenue and expense values for each year, using an IMPLAN model of a more recent year will not dramatically alter the dollar-denominated result values. However, jobs estimated are based on a fixed dollar per job ratio within the model and would therefore be significantly underestimated in the 1970, 1980, and 1990 results. For this reason, the jobs contribution for the potential gains from irrigation is not reported.

Crop events for each district in each year were scaled according to that districts' crop acres in the baseline and fully developed irrigation scenario. District models for each year were run together in a Multi-Region Input-Output (MRIO) analysis, which allows events in one region to impact industries in another region according to trade flows defined within the IMPLAN modeling system. The state results presented in this report are the sum of all regional results.

5.6 Economic Contribution of North Dakota Legal Drains

In some areas in North Dakota, elevation is very flat with little variation. As a result, snowmelt and rain events can easily inundate large areas of agricultural land, very often rendering them unsuitable for planting, growing and harvesting crops. To limit the effect of persistent standing water inhibiting the ability to grow crops, a series of conveyance ditches, or "Legal Drains" have been constructed in many parts of North Dakota. Figure 76 illustrates the presence of these legal drains (depicted as red lines) in a portion of Cass County, North Dakota.

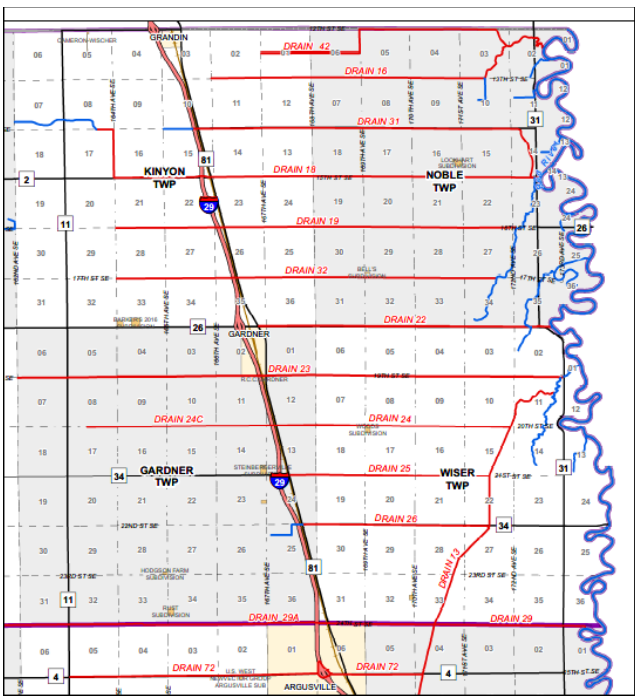


Figure 76. Legal Drains Example

As with the productivity gains experienced from crop ground in North Dakota being tiled, crop ground that relies upon a system of legal drains to remove excess water is equally important to experiencing more consistent growing conditions. Legal drains allow land to be adequately drained, improving yields. This yield improvement varies according to a variety of factors, such as soil type and how well-drained the land is prior to drainage improvements.

Maps of legal drains were obtained from North Dakota counties, with twelve counties providing a map of their legal drain coverage. The number of acres affected by legal drains in each county, shown in Table 22, was estimated according to the number of fields (aggregated up to a quarter section consisting of 160 acres) making contact with a legal drain. This value was adjusted for each county according to that county's ratio of crop planted acres to total acres to account for fallow, pasture, forest, or other land utilization.

Table 22. Estimated Acres Affected by Legal Drains by County

Estimated Acres Affected by Legal Drains by County		
County	Estimated Acres Affected by Legal Drains	Crop Acres Affected by Legal Drains
Grand Forks	101,760	76,830
Foster	2,560	2,260
Dickey	20,960	16,742
Cavalier	7,200	6,335
Cass	151,840	128,360
Pembina	149,280	125,925
Ransom	17,120	11,998
Richland	163,840	141,068
Sargent	40,480	33,864
Traill	144,320	143,997
Walsh	105,760	88,904
Wells	31,040	25,843

All acres affected by legal drains were assumed to be corn, soybeans, or wheat according to each county's mix of those three crops. Average additional income and production cost per acre was estimated using the Iowa State University Farmland Tile Drainage Investment Analysis Tool[17]. The default inputs were used for corn and soybeans, which resulted in a field average yield increase of approximately 15% for corn and 20% for soybeans. Wheat was added to the model using a North Dakota 3-year average yield of 52.3 bushels per acre, a 10-year average price of $6.15 per bushel (according to USDA NASS data), and a relative yield improvement similar to corn. Additional production costs were derived from the crop budgets detailed in Section 5.3.

5.7 Economic Impact Studies

5.7.1 12,500 Head Dairy Impact Inputs

Construction inputs are based on estimated costs provided by an industry source. The estimated cost for a 12,500 head dairy in North Dakota is $92 million. Milking equipment, representing roughly 10% of the total expenditure, is assumed to come from outside of the state and is therefore not included in the broader construction impact for locally purchased equipment but the labor to install and commission

[17] https://www.extension.iastate.edu/agdm/wholefarm/xls/c2-90tilinganalysis.xlsx

the equipment is included. The net value of $82.5 million was used as the input of an impact analysis using the “Construction of new commercial structures, including farm structures” industry in IMPLAN.

Operations inputs are based on the 3-year average North Dakota milk price of $22.73 per cwt and annual production of 234 cwt per cow, according to USDA NASS. These values result in an estimated annual revenue of $5,324 per cow, or $66.5 million for a 12,500 head dairy. This value was used as the input of an impact analysis using the “Dairy cattle and milk production” industry in IMPLAN.

5.7.2 Soybean Processor Impact Inputs

Inputs for a new soybean processor were derived from an analysis of soybean processing by Cheng and Rosentrater[18]. Estimates were made for a processing capacity of 42.5 million bushels, resulting in a total construction cost of $336.7 million. This value was used as the input of an impact analysis using the “construction of new manufacturing structures” industry, and the industry’s spending pattern was adjusted to match the input expenses identified by Cheng and Rosentrater.

Operations inputs are based on 5-year average prices of $12.95 per bushel of soybeans, $0.083 per kwh of electricity, $5.28 per 1,000 cubic feet of natural gas, $0.18 per pound of soybean meal, and $0.57 per pound of soybean oil according to a combination of USDA and EIA data. These values were used to calculate revenue and expenses for an impact analysis using the “soybean and other oilseed processing” industry in IMPLAN with an estimated revenue of $632.1 million and non-labor expenses of $588.3 million.

5.7.3 Irrigated Onion Farm Impact Inputs

Onion operations inputs are based on an onion production budget from Oregon State University Extension[19]. Prices were adjusted forward from the 2019-2021 three-year average used in the budget to the 2023-2025 three-year average using data from USDA NASS. Yield was assumed to be the national 2023-2025 three-year average of 531 cwt per acre according to USDA NASS data. Total revenue was input into the “vegetable and melon farming” industry, and expenses were adjusted to match those found in the budget.

---

[18] https://www.sciencedirect.com/science/article/abs/pii/S0926669017305010

[19] https://extension.oregonstate.edu/catalog/cost-onion-production-eastern-oregon-idaho

6 Budget and Acreage References

University of Idaho Extension. Idaho Irrigated Russet Potato Budgets, South Central Idaho Magic Valley (several years). *Note*: Crop budget data was obtained directly from the University of Idaho Extension via email.

University of Idaho Extension. Idaho (Eastern) Irrigated Sugarbeet Budget (2019). https://www.uidaho.edu/extension/food/idaho-agbiz/crop-budgets

Manitoba Potato Budget (2022). https://www.gov.mb.ca/agriculture/farm-management/cost-production/pubs/cop-crop-irrigated-potato.pdf

North Dakota State University (NDSU). Non-irrigated Crop Budgets (2004-2024). https://www.ndsu.edu/agriculture/extension/ag-topics/farm-management/crop-economics/projected-crop-budgets

NDSU. Irrigated Crop Budgets (2022-2023). https://www.ndsu.edu/agriculture/extension/ag-topics/farm-management/crop-economics/irrigated-crop-budgets

NDSU Extension. North Dakota Soybean Production Field Guide (January 2023). https://www.ndsu.edu/agriculture/sites/default/files/2024-10/a1172.pdf

NDSU, University of Minnesota Extension, Department of Agronomy, and University of Wisconsin-Madison College of Agricultural and Life Sciences Cooperative Extension Service. Sugarbeet. https://corn.agronomy.wisc.edu/Crops/Sugarbeet.aspx

NDSU. Red Norland Potato Budget Non-Irrigated (2018). https://www.ag.ndsu.edu/potatoextension/non-irrigated-red-norland-crop-budget

Northland Community and Technical College-Moorhead, MN. Sugarbeet Budgets (several years). http://www.northlandfbm-moorhead.com/New%20Reports.html

USDA-Economic Research Service (ERS). Commodity Costs and Returns. https://www.ers.usda.gov/data-products/commodity-costs-and-returns

USDA-NASS, Quick Stats. https://quickstats.nass.usda.gov/

USDA-NASS Census data. USDA - National Agricultural Statistics Service - Census of Agriculture

National Oceanic and Atmospheric Administration National Centers for Environmental Information. Climate at a Glance: Statewide Time Series (2025). https://www.ncei.noaa.gov/access/monitoring/climate -at-a-glance/statewide/time-series/32/tavg/1/7/1945-2026?

National Oceanic and Atmospheric Administration National Centers for Environmental Information. Global Summary of the Month (2025). https://www.ncei.noaa.gov/access/search/data-search/global-summary-of-the-month

United States Geological Survey. USGS Water Data for the Nation: Monitoring Location (2025). https://waterdata.usgs.gov/monitoring-location

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

7 Appendix

7.1 State Level Precipitation

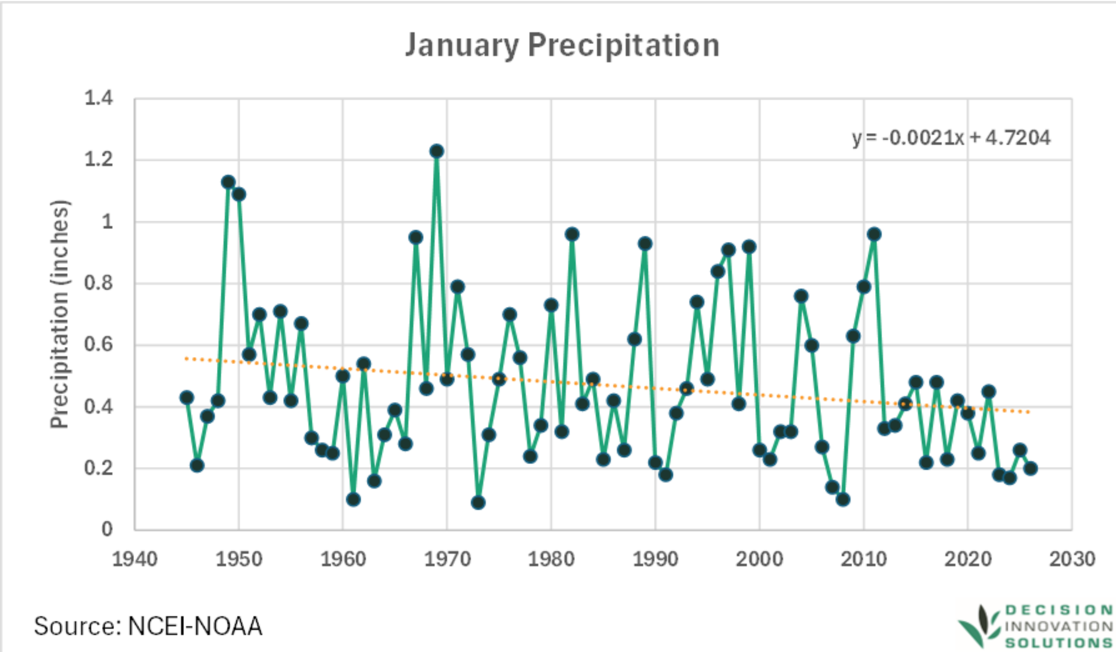


Figure 77. January Precipitation 1945-2026

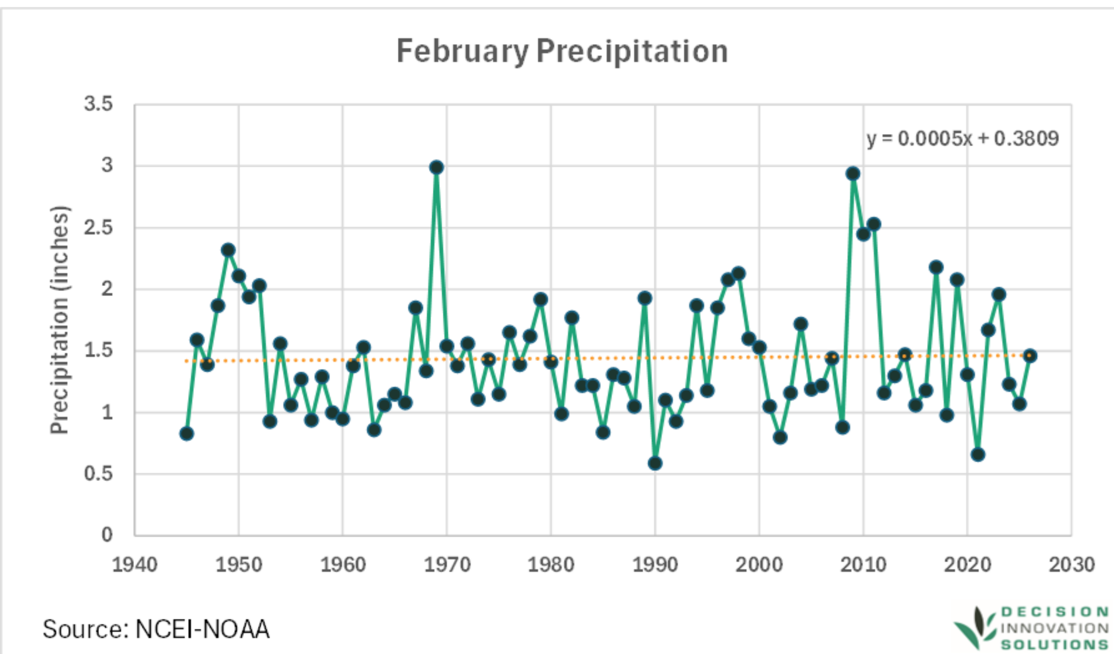


Figure 78. February Precipitation 1945-2026

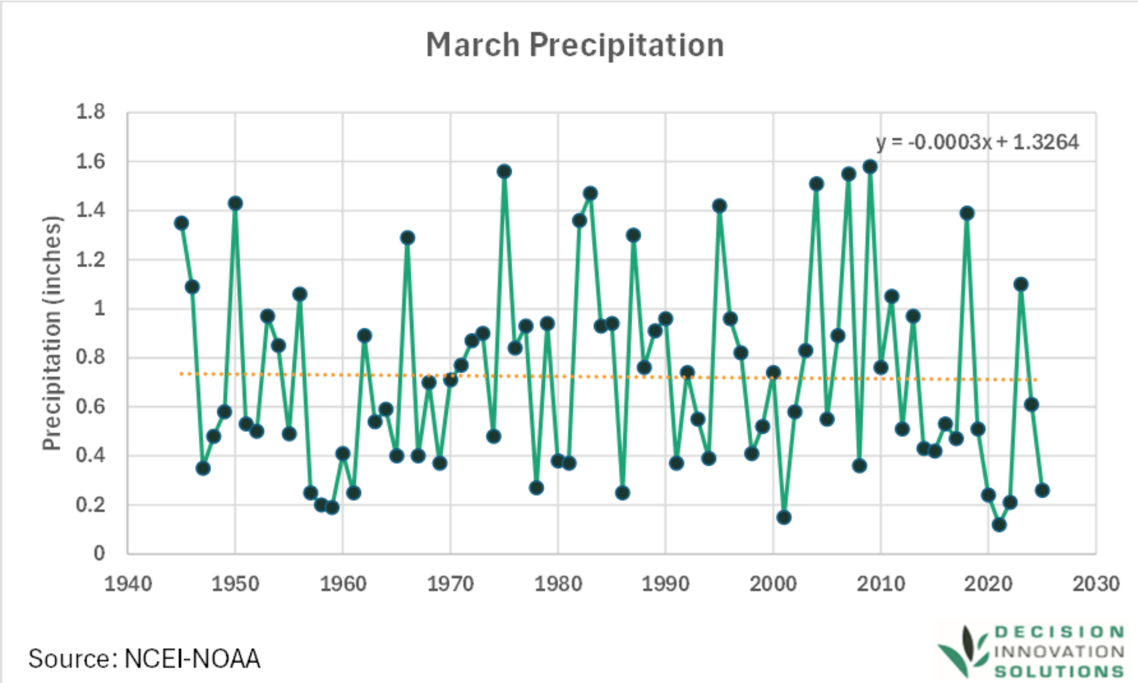


Figure 79. March Precipitation 1945-2025

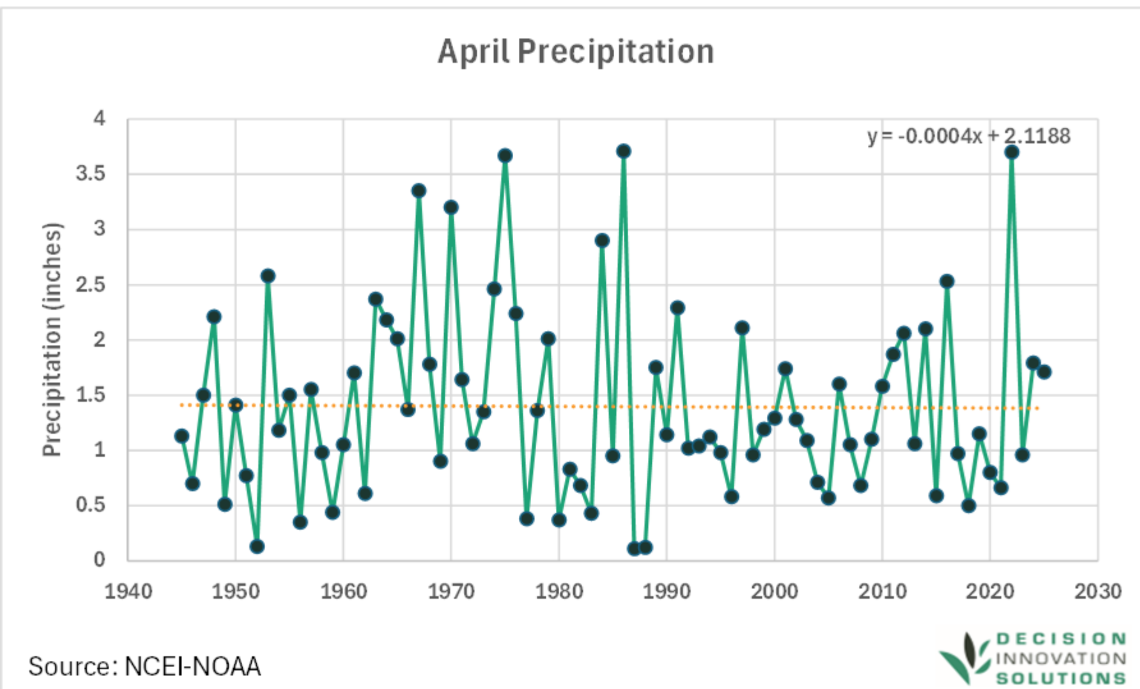


Figure 80. April Precipitation 1945-2025

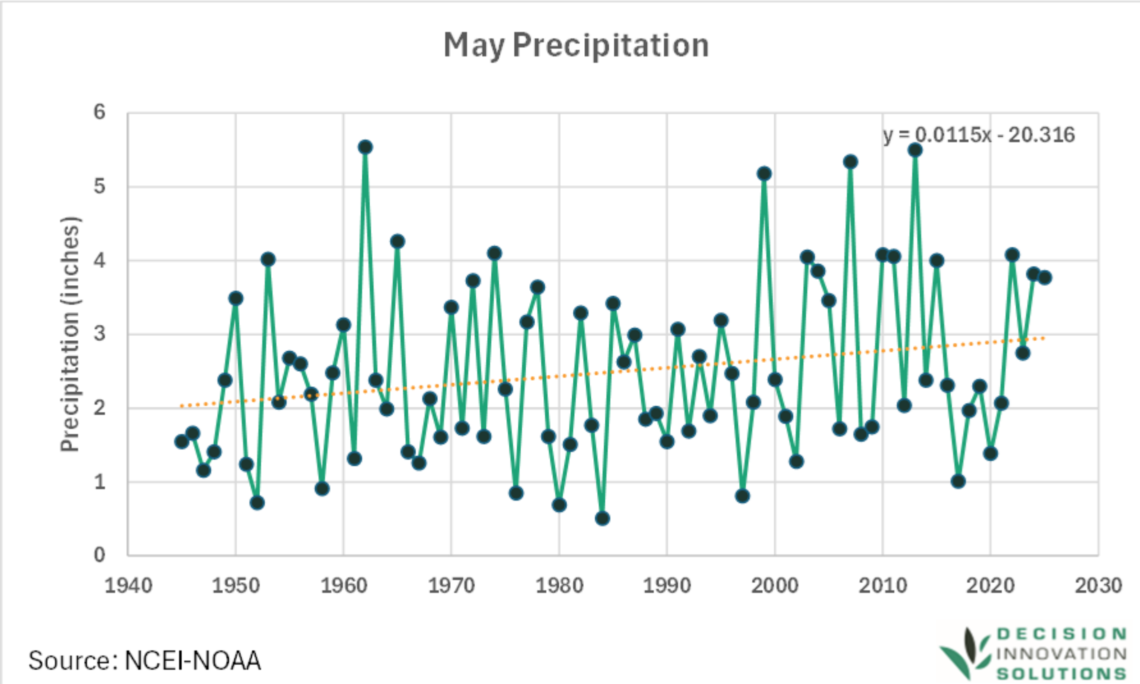


Figure 81. May Precipitation 1945-2025

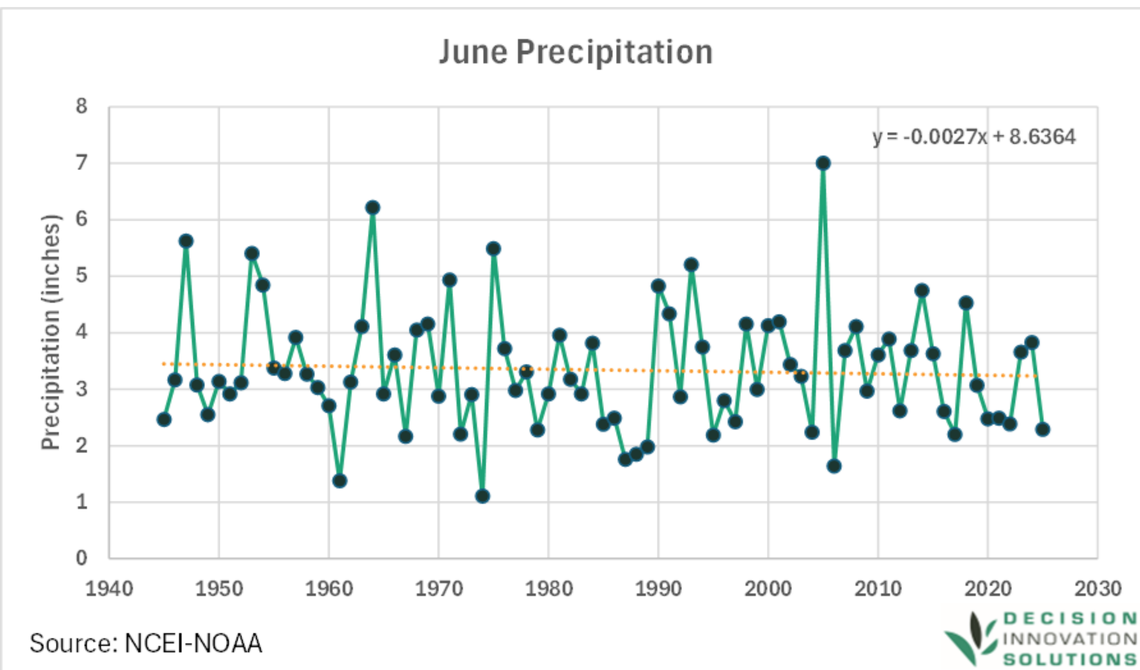


Figure 82. June Precipitation 1945-2025

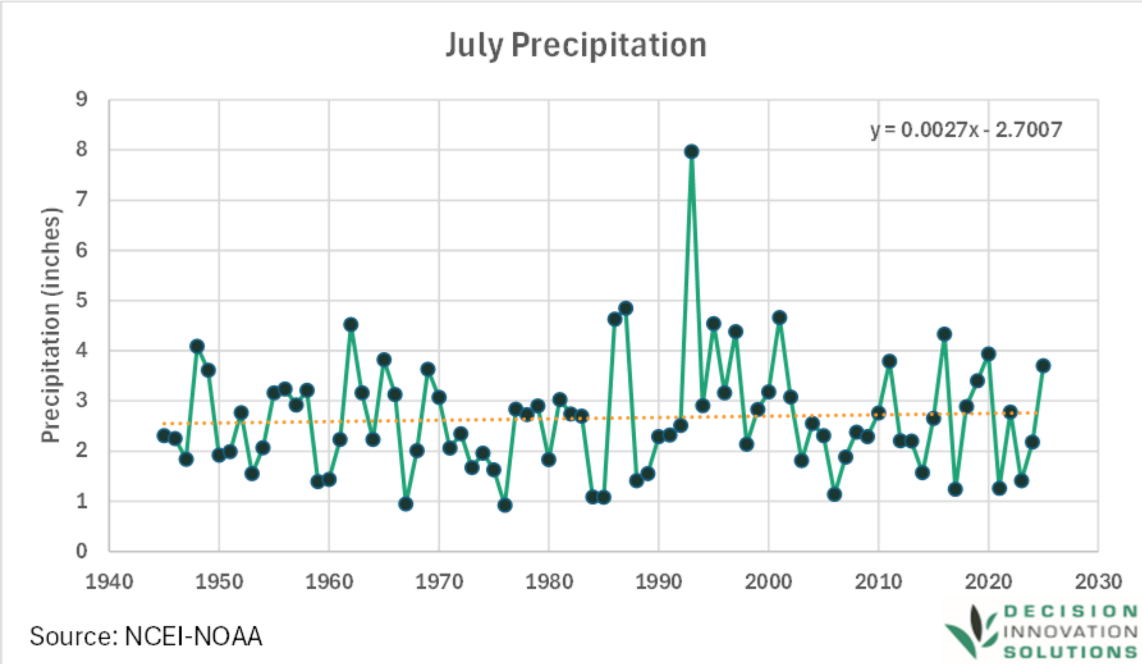


Figure 83. July Precipitation 1945-2025

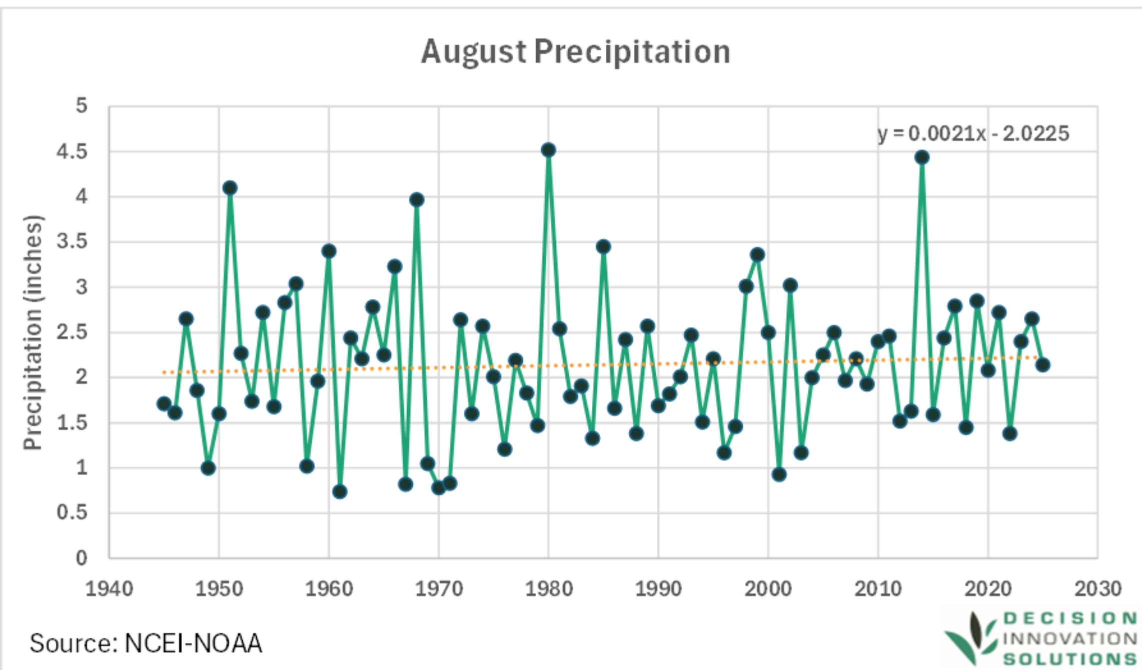


Figure 84. August Precipitation 1945-2025

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

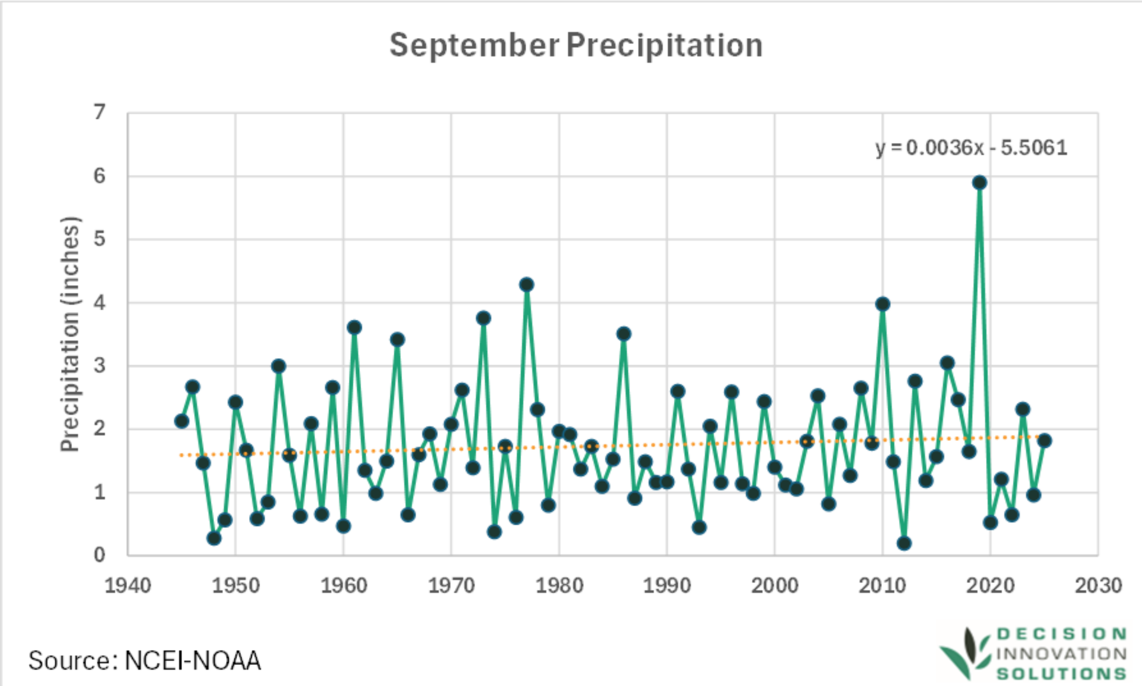


Figure 85. September Precipitation 1945-2025

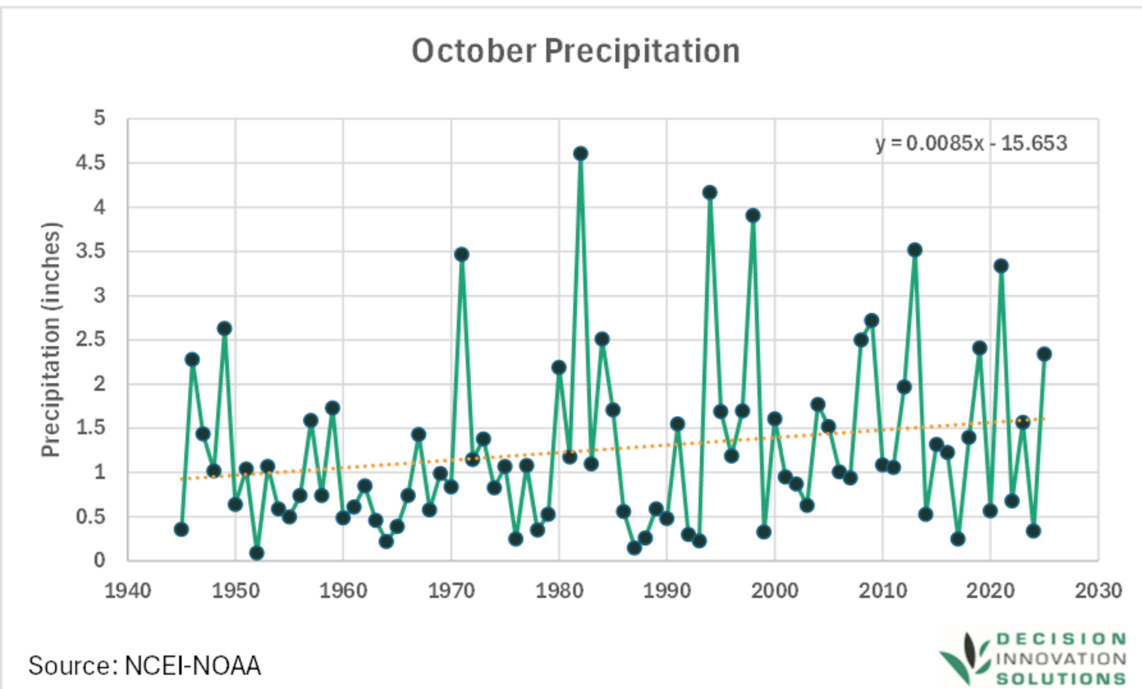


Figure 86. October Precipitation 1945-2025

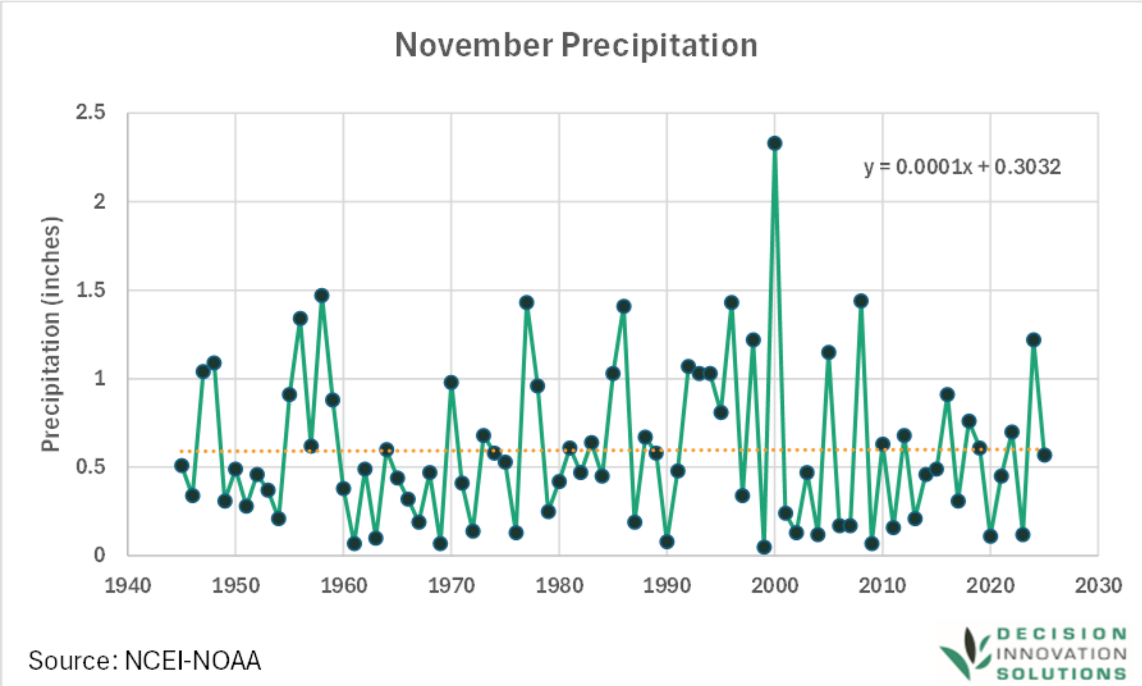


Figure 87. November Precipitation 1945-2025

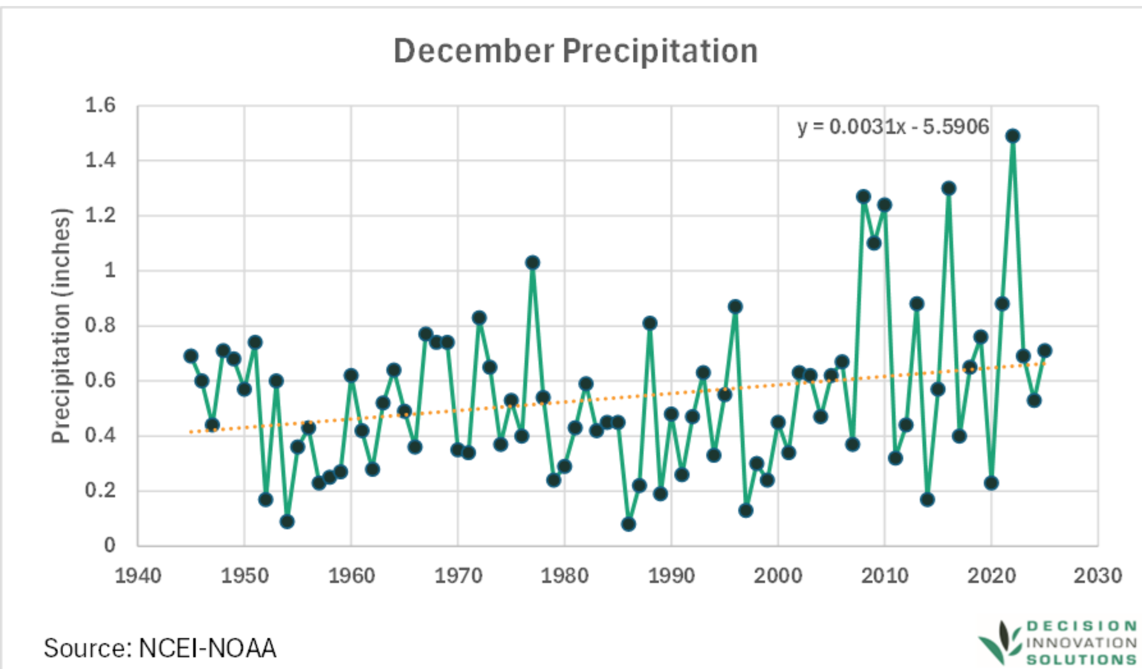


Figure 88. December Precipitation 1945-2025

7.2 Net Irrigation Impacts

Net Impact of Irrigated Crop Production per 1,000 acres				
Crop	**Impact**	**Net Labor Income**	**Net Value Added**	**Net Output**
Barley	**Total**	**$ 102,113**	**$ 155,800**	**$ 328,063**
Barley	Direct (Farm Impact)	$ 71,603	$ 101,612	$ 221,840
Barley	Indirect/Induced (Broader Economy Impact)	$ 30,510	$ 54,188	$ 106,223
Corn	**Total**	**$ 77,900**	**$ 111,614**	**$ 222,008**
Corn	Direct (Farm Impact)	$ 65,018	$ 92,267	$ 196,244
Corn	Indirect/Induced (Broader Economy Impact)	$ 12,882	$ 19,347	$ 25,764
Dry Beans	**Total**	**$ 211,636**	**$ 317,141**	**$ 425,319**
Dry Beans	Direct (Farm Impact)	$ 172,784	$ 245,198	$ 304,274
Dry Beans	Indirect/Induced (Broader Economy Impact)	$ 38,852	$ 71,943	$ 121,045
Potatoes	**Total**	**$ 1,367,567**	**$ 2,484,107**	**$ 4,860,505**
Potatoes	Direct (Farm Impact)	$ 915,323	$ 1,613,274	$ 3,493,041
Potatoes	Indirect/Induced (Broader Economy Impact)	$ 452,244	$ 870,833	$ 1,367,464
Soybeans	**Total**	**$ 43,368**	**$ 139,814**	**$ 207,716**
Soybeans	Direct (Farm Impact)	$ 32,856	$ 131,846	$ 169,536
Soybeans	Indirect/Induced (Broader Economy Impact)	$ 10,512	$ 7,968	$ 38,180
Sugar Beets	**Total**	**$ 477,814**	**$ 829,849**	**$ 2,098,916**
Sugar Beets	Direct (Farm Impact)	$ 161,432	$ 281,245	$ 1,072,222
Sugar Beets	Indirect/Induced (Broader Economy Impact)	$ 316,381	$ 548,604	$ 1,026,694
Wheat	**Total**	**$ 78,340**	**$ 121,680**	**$ 361,404**
Wheat	Direct (Farm Impact)	$ 45,493	$ 64,559	$ 247,831
Wheat	Indirect/Induced (Broader Economy Impact)	$ 32,847	$ 57,121	$ 113,573

Net Irrigation Impact Multipliers			
Crop	**Labor Income**	**Value Added**	**Output**
Barley	1.43	1.53	1.48
Corn	1.20	1.21	1.13
Dry Beans	1.22	1.29	1.40
Potatoes	1.49	1.54	1.39
Soybeans	1.32	1.06	1.23
Sugar Beets	2.96	2.95	1.96
Wheat	1.72	1.88	1.46

Ratio of Irrigated to Dryland Total Economic Contribution per Acre		
Crop	**Value Added**	**Output**
Barley	1.46	1.49
Corn	1.28	1.21
Dry Beans	1.67	1.42
Potatoes	1.90	1.89
Soybeans	1.45	1.38
Sugar Beets	1.59	1.64
Wheat	1.60	1.70
Average	**1.57**	**1.53**

11107 Aurora Ave Urbandale, IA 50322 (515) 639-2900 decision-innovation.com

This report was made possible thanks to the

69th North Dakota Legislative Assembly

and these Valuable Partners

North Dakota Department of Agriculture
Agriculture Commissioner Doug Goehring

North Dakota Corn Growers Association

ADS
Our reason is water.

ND North Dakota Dry Bean Council

ND Soybean Council

Cass County Electric Cooperative

North Dakota Dry Pea & Lentil Council

Red River Valley Sugarbeet Growers Association

Field Drain Tile
Chad's Excavating Inc
701-430-0182

North Dakota Farmers Union

Simplot

Ellingson

NDIA

LFD
Litzau Farm Drainage

Thank you!