Summary Results: Economic Analysis of AFREC-funded Projects

Updated November 2023

Fertilizer is a major input, and expense, for most crop farming operation. Growers optimize economic and environmental benefits when fertilizer is optimally applied. It takes research to determine those optimal conditions, including place, time, rate, and source. The Agricultural Fertilizer Research and Education Council (AFREC) has been funding fertilizer research and education in Minnesota since 2008.

Fertilizer research and education aim to determine how one of three economic scenarios can be experienced to reduce costs and/or increase income. Those three scenarios are:

- Fertilizer use decreases and yields remain constant,
- Fertilizer use remains constant and yields increase,
- Fertilizer use increases while increasing yields.

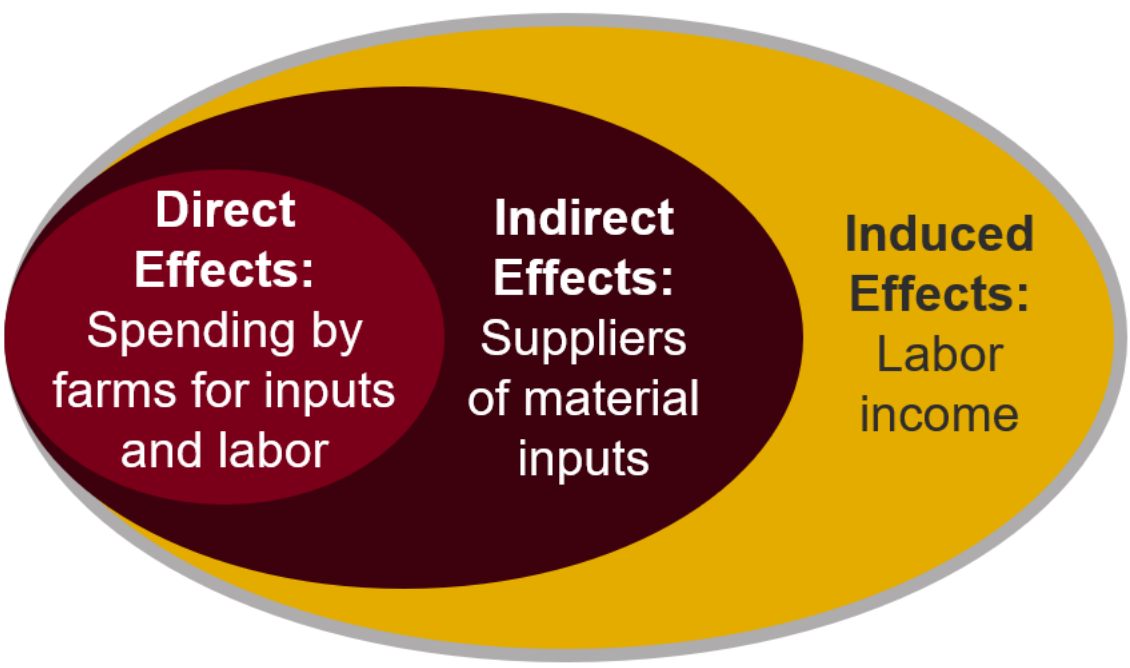
University of Minnesota research documents that these outcomes are possible. This summary highlights AFREC-funded research at the U of M have affected fertilizer use and yields, and how the research, if implemented by farmers, could affect Minnesota's economy.

For this project, team include team was assembled who specialized in agricultural economics, soil science and communications. The first step was to conduct a review of all projects funded by AFREC since 2008. Then, for selected projects, personal interviews with the researchers were conducted. Projects were selected for interviews based on representation of fertilizer/nutrient issues and crops grown in Minnesota. The interviews were then assessed to determine the economic scenario they fit based on the major outcomes of the research. Finally, the team identified case studies that best exemplified each of the economic scenarios that exhibited clear, documented outcomes.

To show the impact on Minnesota's economy, the team's economists used input-output modeling. There are a few critical terms that help in interpreting the results. For more detail on the terms, please see the appendix.

- **Direct effects:** Direct effects are the initial change in the local/state economy. These are the primary changes resulting from the fertilizer research and education. For example, in cases where fertilizer use decreases, the direct effect will be a negative impact to the local/state economy as farmers are directly spending less on fertilizer. This is despite the fact that the producer may realize a positive economic impact by spending less on fertilizer.

- **Indirect effects:** Indirect effects are business-to-business impacts. In this research, these are primarily impacts from farmers investing profits from increased yields (or reduced fertilizer expenses) into their operations. As they invest, they buy more from their suppliers, thus increasing demand for businesses in the supply chain at the local and state level.
- **Induced effects:** Induced effects are household-to-business impacts. In this research, these are primarily the impacts from farmers using their increased profits for household spending. As they spend money in the community, the businesses that serve them increase their economic activity.
- **Leakages:** Direct, indirect, and induced effects all pertain to the economy in which they occur. In this study, Extension is looking at the impact on Minnesota's economy. If a farmer or a supplier goes out of state to buy their products, this represents a leakage out of the economy. This becomes critical in this study, as much of the fertilizer used is manufactured outside of the state and thus the majority of a dollar spent on fertilizer leaves the state (or leaks out) since it goes to the state or country where fertilizer is manufactured.



I. Fertilizer Use Decreases, Yields Constant

Under this scenario, growers maintain their current yields but decrease the use of fertilizer. On a farm-level, this approach allows growers to maintain a level of income per acre but decrease the cost per acre. For Minnesota's economy, this means farmers spend less on fertilizer purchases (a decrease in statewide economic activity) but have additional farm income to spend on their households or reinvest in the farm. On an environmental level, decreased fertilizer use means fewer potential negative externalities.

AFREC-funded Projects (selected):

Of the studies reviewed for this project, seven had the primary strategy of decreasing fertilizer use, while maintaining yields. They include:

- Improving predictability and adoption of alfalfa N credits for corn (Coulter),
- Evaluation of critical phosphorus and potassium levels in Minnesota soils (Kaiser),
- Nitrogen response and soil microbial activity in potato cropping systems as affected by fumigation (Rosen),
- Establishing nitrogen credits following a sweet corn crop on non-irrigated soils (Rosen),
- Potassium fertilization requirements for intensively managed modern alfalfa (Sheaffer),
- Urea and urea additives as fertilizer sources for corn production in Minnesota (Fernandez),
- Long-term impact of nitrogen fertilization on corn production, soils and nitrogen cycling processes in Minnesota (Fernandez).

Featured Research Project #1: Corn Nitrogen Rate Calculator

AFREC-funded research conducted by Dr. Fabian Fernandez focuses on nitrogen management for corn. The information gathered through the research informs the corn nitrogen rate calculator. The corn nitrogen rate calculator is a decision tool that provides nitrogen rate recommendations for Minnesota farmers based on a robust database of recent nitrogen rate research in the state and current nitrogen fertilizer and corn prices. Surveys by the Minnesota Department of Agriculture indicate that, in many cases, particularly on acres where corn is grown after soybeans, growers are overapplying nitrogen compared to the research-based recommendations of the

Key Assumptions:

2,208,375 Corn Acres Overapplied	30 Pounds per Acre in Saved Nitrogen	$0.60 per Pound of Nitrogen

calculator. The research indicates that corn-after-soybean farmers could decrease nitrogen application by 30 pounds per acre and maintain their current yields.[i]

This scenario quantifies the potential economic impact if farmers were to decrease their nitrogen application rates to match the nitrogen calculator recommendations. The first step is to determine on how many acres nitrogen is overapplied. Research conducted by the Minnesota Department of Agriculture in 2012 and 2014 indicates that farmers apply nitrogen at rates exceeding the calculator recommendations on 40 to 50 percent of corn (after soybeans) acreage in the state. Thus, there are approximately 2.2 million acres in Minnesota that could continue to maintain yields while decreasing nitrogen use.

Assuming all corn growers would implement the practice on those acres, farmers would spend $39.8 million less on fertilizer purchases. As fertilizer costs decrease, farm incomes would correspondingly increase. Farmers would have more income to spend on their households and to reinvest in their farms.

The economic impact of this scenario is shown in **Table 1**. The direct effects are negative. As explained earlier, direct effects are the primary change in the economy. In this example, the primary change in the economy is a decrease in the amount of money spent on fertilizer. While fertilizer expenditures decrease by $39.8 million, the direct impact on Minnesota is only about -$960,000. Nitrogen fertilizer is primarily imported from outside the state, so the impact of decreased fertilizer spending is limited to those who resell it (e.g., crop input dealers and cooperatives).

The indirect and induced effects are positive, reflecting the cost savings impact on the state's economy. Farmers have more money to reinvest in their farms, which is represented in the indirect effects. Indirect effects are business-to-business impacts. As farmers spend additional funding on their supplies, that causes their suppliers to increase their production, and so forth on the supply chain. These impacts can be added to get the indirect effect.

Corn growers also have additional money to spend for their households. Households buy groceries, go out to dinner at local restaurants, and purchase health care. As the businesses that serve them increase their production, this also creates economic activity. These impacts are measured through the induced effects.

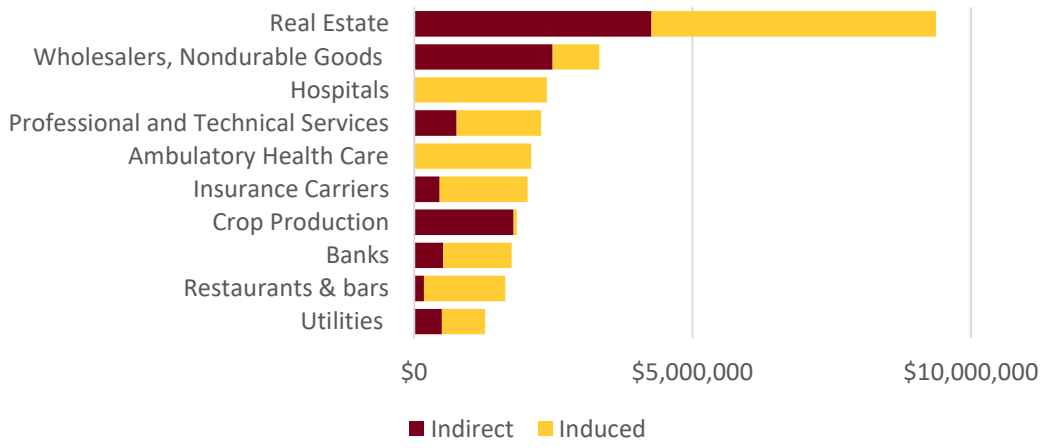
Table 1: Potential economic impact of using the corn nitrogen rate calculator, Minnesota

	Output	Employment	Labor Income
Fertilizer expenditures decrease by $39,750,750			
Farm profits increase by $39,750,750			
Direct	-$958,350	-1	-$93,250
Indirect	$17,260,130	90	$4,801,100
Induced	$30,715,940	180	$10,290,690
Total	$47,017,720	269	$14,998,540

In total, if all growers who are overapplying were able to implement the nitrogen calculator's recommendations and achieve similar results, it would benefit Minnesota's economy by $47 million, including nearly $15 million in additional labor income. The practice would support 269 jobs. These are jobs at places that serve farmers, like agricultural service providers, trucking companies, and banks. Also included are jobs at places that serve farm families such as hospitals, grocery stores, and mechanics.

Chart 1 shows which industries would benefit the most from a decrease in the application of nitrogen fertilizer by corn growers. The real estate industry, including land rents and purchases, benefits the most significantly. Nondurable good wholesalers and health care also benefit.

Chart 1: Potential economic impact of following recommendations of the corn nitrogen calculator, top industries affected, indirect and induced effects



Featured Research Project #2: Nitrogen application for crops following sweet corn

AFREC-funded research also explored the nitrogen credit provided by sweet corn. Dr. Carl Rosen's research concluded that sweet corn provides a 20 pound per acre nitrogen credit for the crops grown the following year. In other words, farmers can reduce the amount of nitrogen applied by 20 pounds per acre when growing nitrogen-requiring crops in fields the year after sweet corn was grown.

Minnesota farmers planted 97,400 acres of sweet corn in 2022. The University research team conservatively estimated that about 75 percent of the acreage was planted the next year into a crop that requires nitrogen (for example, field corn or sugarbeets). Thus, there are approximately 73,050 acres where farmers could decrease nitrogen application and maintain current yields.

Key Assumptions:

73,050 Acres of Sweet Corn with Nitrogen Credit	20 Pounds per Acre of Nitrogen Credit	$0.60 per Pound of Nitrogen

If farmers were to reduce their nitrogen application following sweet corn, the purchases of nitrogen fertilizer would decrease by $867,600 across the state. Farmers would then have cost savings to either reinvest in their farming operation or to use for household expenditures.

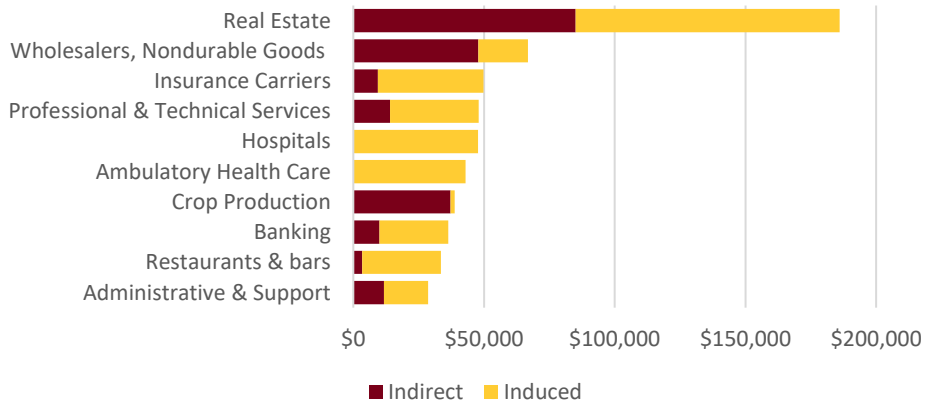
The economic impact of this scenario is shown in **Table 2**. As with the previous scenario, the direct impact is negative since farmers are purchasing fewer inputs (fertilizer). However, the positive impacts of the cost savings (via farm and household spending) outweigh the negative impacts. In total, farmers adopting these recommendations would generate an estimated $970,750 in economic activity in Minnesota. The practice would also support 5 jobs paying $312,630 in labor income.

Table 2: Potential economic impact of decreasing nitrogen application for crops following sweet corn, Minnesota

	Output	Employment	Labor Income
Fertilizer expenditures decrease by $876,600			
Farm profits increase by $876,600			
Direct	-$20,920	-1	-$2,500
Indirect	$335,990	2	$98,390
Induced	$655,680	4	$225,740
Total	$970,750	5	$321,630

Chart 2 illustrates the industries that would most benefit from the adoption of the nitrogen reduction. Real estate benefits most significantly. With the cost savings, farmers might choose to purchase more land or make improvements to their family's housing. Nondurable good wholesalers and insurance carriers round out the top three industries that would benefit.

Chart 2: Potential economic impact of decreasing nitrogen application on crops following sweet corn, top industries affected, indirect and induced effects



Featured Research Project #3: Potassium application for alfalfa

A third project that explored the potential to reduce fertilizer application, while maintaining yield levels, focused on potassium (K_2O) application for Minnesota's alfalfa fields. Research led by Dr. Craig Sheaffer found that shifting the approach to determining the potassium needs of alfalfa fields with soil testing would lead to a decrease in application rates while maintaining yield. By testing the soil and applying research-based recommended rates, farmers can determine the most effective amount of fertilizer needed to achieve their yield goals. For many farmers, this would result in fertilizer savings of around 90 pounds K_2O per acre.

Minnesota farmers harvested 700,000 acres of alfalfa in 2023. Assuming they used soil testing to determine their potassium application rates, Minnesota farmers could potentially save $26.6 million in fertilizer costs. This money could then be reinvested in the farm or spent as household income.

Key Assumptions:

700,000 Acres of Alfalfa	90 Pounds K_2O per Acre Saved	$0.43 per Pound of K_2O

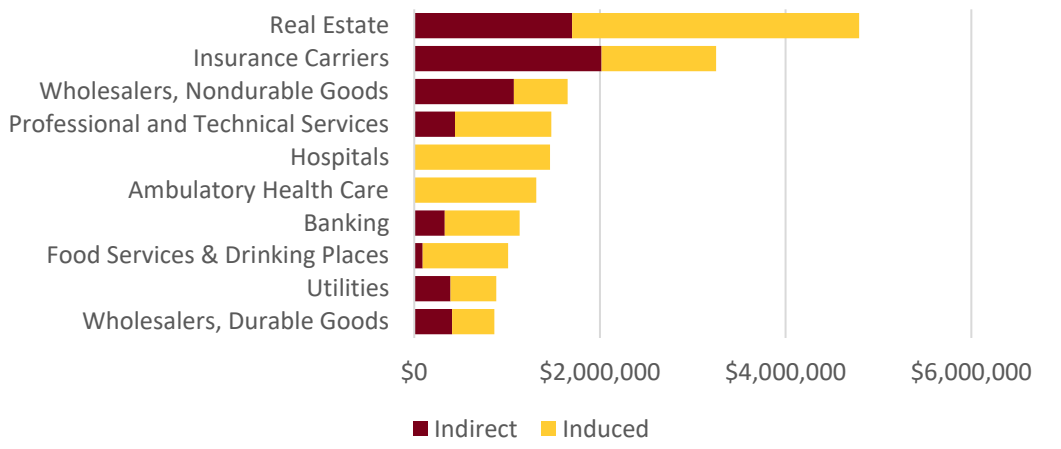
Decreasing potassium application could generate $30.1 million in economic activity in Minnesota (**Table 3**). The direct effect is negative, as farmers purchase less fertilizer. As farmers use the cost savings to invest in their farms and families, positive impacts are created. The adoption of the soil testing recommendation would also support 159 jobs paying nearly $10 million in labor income.

Table 3: Potential economic impact of decreasing potassium application for alfalfa, Minnesota

	Output	Employment	Labor Income
Fertilizer expenditures decrease by $26,614,000			
Farm profits increase by $26,614,000			
Direct	-$489,420	-1	-$102,850
Indirect	$10,566,600	50	$3,192,450
Induced	$20,071,030	110	$6,909,400
Total	$30,148,210	159	$9,999,000

Industries that would most benefit from the fertilizer savings include real estate, insurance carriers, and nondurable good wholesalers. Health care would also see measurable impacts (**Chart 3**).

Chart 3: Potential economic impact of decreasing potassium application on alfalfa crops, top industries affected, indirect and induced effects



II. Fertilizer Use Constant, Yields Increase

For some Minnesota farmers, there are scenarios to boost yields while maintaining the current level of fertilizer use. Improved fertilizer timing, placement, and source can increase farm profits without the addition of a higher rate of fertilizer. For those farmers, this translates into higher revenue per acre while maintaining existing expenses. For Minnesota's economy, this means farmers have higher profits they can use in a variety of ways, including investing in their farming operations or paying for household expenses. For the environment, fertilizer use remains the same.

AFREC-funded Projects (selected):

Of the studies reviewed for this project, three of them focused on strategies for maintaining fertilizer use while increasing yields. They include:

- Optimal utilization of phosphorus, potassium, and sulfur fertilization in corn-soybean rotation (Kaiser),
- Optimizing use of polymer-coated urea for irrigated potatoes production and the effects on nitrate leaching (Rosen),
- Effect of variable rate irrigation and nitrogen fertilizer rates on crop productivity and water quality (Sharma).

Featured Research Project #4: Managing Irrigation and Nitrogen for Corn after Corn

To understand the potential economic impact of increasing yields, while maintaining current fertilizer use, the research team selected a project conducted by Dr. Vasudha Sharma.

This project investigated the timing of nitrogen application paired with irrigation for continuous corn. The project concluded that, when irrigation and nitrogen applications were timed appropriately, yields increased by 12 bushels per acre, with a 25 percent reduction in irrigation.

Key Assumptions:

280,400 Irrigated Corn Acres	12 Bushels per Acre Increase	$4.45 per Bushel Corn Price	$3.50 per Acre Inch for Irrigation

Assuming this practice could be replicated on all of Minnesota's irrigated corn acreage with similar results, Minnesota corn growers could produce an additional 3.4 million bushels of corn, increasing revenue by $14.97 million. At the same time, irrigation costs would decrease. Assuming an average of 6 inches of water per acre in a typical year, growers could save $1.5 million on irrigation costs.[1] In total, farmers would have $16.4 million in additional income to spend.

The economic impact of these changes is shown in **Table 4**. The direct effects are negative, as farmers are spending less on irrigation. The lost output figure is not $1.5 million, as some of the spending occurs outside of the state.

The indirect and induced effects are positive. The indirect effects reflect growers' reinvestment in their farming operations. As the growers earn additional revenue, they will probably reinvest into their farming operation, causing their suppliers to increase the amount of product they produce, and so on, along the supply chain.

The induced effects reflect growers' investments in their households and families. As farmers have higher revenue, they also use a portion of the farm income for household spending. As their households buy groceries, go out to dinner, or buy a new vehicle, this also creates activity in the economy.

In total, if all growers were able to implement this practice and achieve similar results, it would benefit Minnesota's economy by $16.5 million, including $5.1 million in additional labor income. The practice would support 95 jobs.

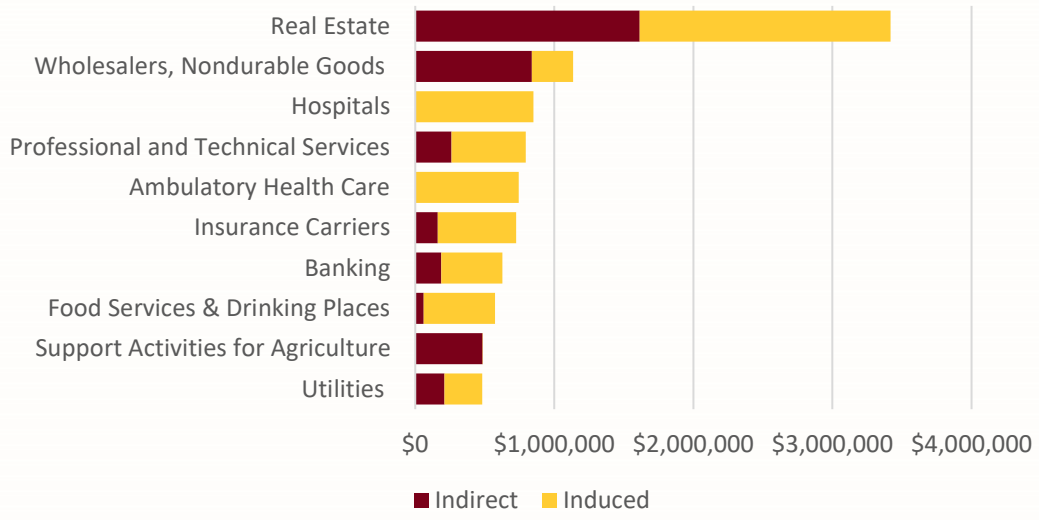
Table 4: Potential economic impact of managing irrigation and nitrogen research project, Minnesota

	Output	Employment	Labor Income
Farm income increases by $16,445,460			
Irrigation costs decrease by $1,472,100			
Direct	-$446,100	-3	-$264,670
Indirect	$6,063,760	34	$1,747,550
Induced	$10,859,440	64	$3,638,900
Total	$16,477,100	95	$5,121,780

[1] All data related to acres, prices, and irrigation come from the National Agricultural Statistics Service and are Minnesota-specific figures.

The industries that economically benefit the most are shown in **Chart 4**. The real estate industry (including farm rental payments and mortgages), nondurable good wholesalers, and health care are the industries that would receive the biggest increases under this strategy.

Chart 4: Potential economic imapct of managing irrigation and nitrogen research project, top industries affected, indirect and induced effects



III. Fertilizer Use Increases While Yields Increase

Under this scenario, fertilizer use increases (guided by a fertilizer management plan) and yields also increase. The additional revenue generated from the yield increase is greater than the cost for additional fertilizer. For the farmer, the management plan helps guide targeted fertilizer investments that return the highest yield levels, thus maximizing revenues as compared to costs. For Minnesota's economy, this translates into higher spending on fertilizer, which generates a positive economic effect, as well as higher revenues for farmers.

AFREC Funded Projects (selected):

Of the studies reviewed for this project, six had the primary result of increasing fertilizer use while also increasing yields at a rate that maximizes the application. They include:

- Advancing intensive management of corn systems in Minnesota (Coulter),
- Advancing intensive management of continuous corn on irrigated sands (Coulter),
- Utilizing on-farm research to revise fertilizer recommendations in low-yielding zones (Wiebers),
- Fine-tuning sulfur guidelines for alfalfa (Kaiser),

- Understanding mechanisms of sulfur cycling in MN soils and availability from fertilizer (Kaiser),
- Zinc and sulfur fertilization for high yield corn production (Vetsch).

Featured Research Project #5: Sulfur application for corn grown after soybeans

To highlight the economic scenario in which the research project was designed to provide increased yields through marginal increases in fertilizer application, the research team selected a project by U of M researcher Jeff Vetsch. The project primarily looked at applying sulfur on fields where corn was planted after soybeans. At the time of the study, 2008 to 2010, sulfur application was not as common in Minnesota as it is today, and the results showed how yields on differing types of soils increase with the application of sulfur. In the study, sulfur application increased yields by 4.3 bushels per acre on average.

Key Assumptions:			
3,073,330 Acres with Additional Sulfur Application	2 Gallon Increase in Fertilizer Per Acre	$4.50 per Bushel of Corn	$2.20 per Gallon in Fertilizer Costs

Minnesota crop producers widely adopted the increased sulfur application guidelines. According to the USDA, Minnesota farmers applied 8.5 million pounds of sulfur fertilizer products to corn fields in 2010. By 2021, this had increased to 54.6 million pounds of sulfur products. Based on recommended application rates, an estimated 3,073,330 acres of corn are now receiving sulfur applications.

Thus, Minnesota's corn producers could grow an additional 13.2 million bushels of corn in a year, generating $56.8 million in additional revenues. Fertilizer costs would also increase, by an estimated $13.5 million.[2]

The economic impact of these potential changes is shown in **Table 5**. Directly, farmers would spend more on fertilizer. The increase in fertilizer spending has a positive impact on Minnesota's economy. Because most fertilizer is imported into Minnesota, the effects on the economy are primarily limited to the suppliers that handle the fertilizer.

The indirect and induced effects, however, are more significant. Farmers have additional revenue to invest in their operations – and that spending creates ripple effects throughout the economy, as shown in the indirect effects. Farmers also have more money to spend via their household budgets, which creates induced effects.

[2] To verify the results, Extension also looked at the number of acres with soil types that were included in the expanded recommendations. That analysis showed 3.6 million acres as potential for additional sulfur application.

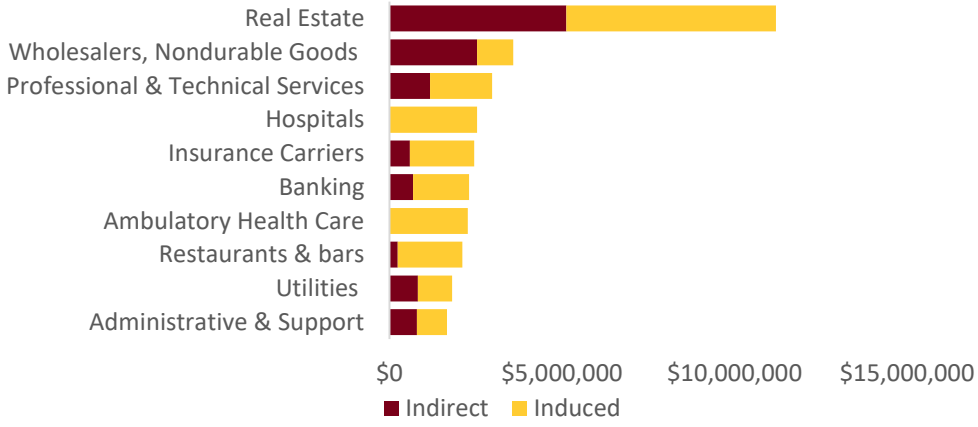
In total, the increased yields, even with increased fertilizer expenditures, would create $65.2 million in economic activity in Minnesota, including $20.98 million in labor income. The spending changes would support 380 jobs.

Table 5: Potential economic impact of sulfur application for corn after soybeans research project, Minnesota

	Output	Employment	Labor Income
Farm profit increases by $43,303,270			
Fertilizer spending increases by $13,522,670			
Direct	$7,082,910	40	$2,439,450
Indirect	$20,957,990	120	$6,241,880
Induced	$37,162,830	220	$12,298,900
Total	$65,203,730	380	$20,980,230

The industries that would benefit most significantly from the increase in yields include real estate, nondurable goods wholesalers, and professional and technical services (**Chart 5**).

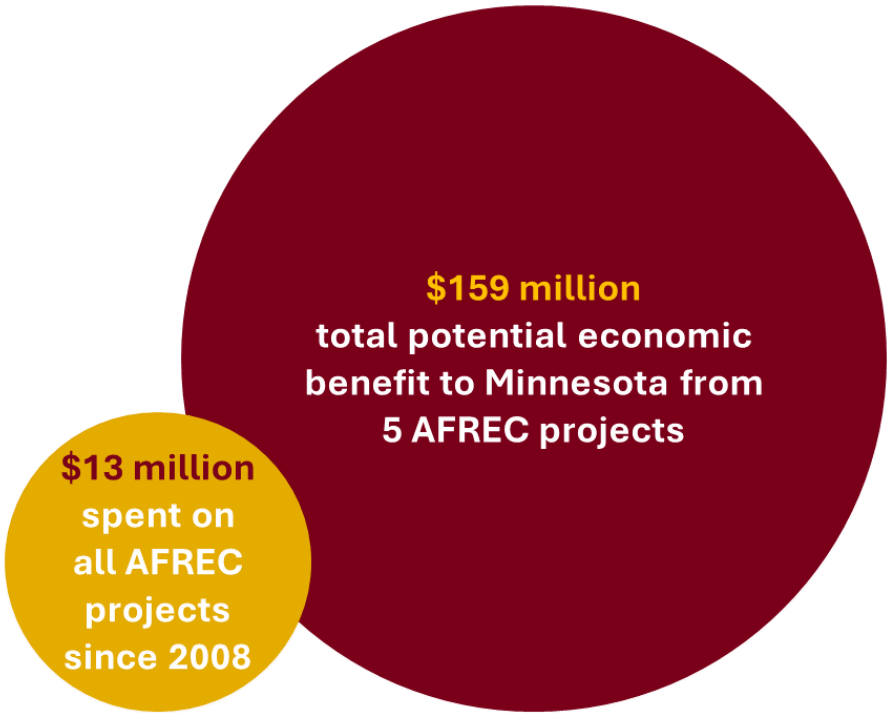
Chart 5: Potential economic impact of sulfur application on corn after soybeans research projects, top industries affected, sorted by indirect and induced effects



Research Project Summary

This economic research project carefully assessed all of the research projects AFREC has supported since 2008. Through the intensive process of evaluation, two primary economic conclusions can be made regarding AFREC funding for soil fertility research.

1. Fertilizer research and education can bring significant economic benefits to Minnesota's economy. The included economic scenarios all indicated a positive economic impact. The magnitude of the actual economic impact varies by numerous factors as these reported impacts all used (conservative) assumptions. Influencing farmers to apply the most effective fertilizer rates will have a positive outcome for the farmer as well as the Minnesota economy.
2. Guiding farmers save on input costs when research/recommendation support this will allow funds to reinvest in their farms or use to support their families, also has positive economic benefits. While there are losses for businesses that supply fertilizer when sales decrease, the power of local spending by farmers outweighs those losses.



Appendix: Economic impact defined

Special models, called input-output models, exist to conduct economic impact analysis. There are several input-output models available, and IMPLAN is one such model. Many economists use IMPLAN for economic contribution analysis because it can measure output and employment impacts, is available on a county-by-county basis and is flexible for the user. While IMPLAN has some limitations and qualifications, it is one of the best tools available to economists for input-output modeling. Understanding the IMPLAN tool's capabilities and limitations helps ensure the best results from the model.

One of the most critical aspects of understanding economic impact analysis is the distinction between the "local" and "non-local" economy. The model-building process identifies the local economy. Typically, the study area (the local economy) is a county or a group of counties that share economic linkages. In this report, the study area is the entire state of Minnesota.

A few definitions are essential to properly interpret the results of an IMPLAN analysis. These terms and their definitions are provided below.

Output

Output is measured in dollars and is equivalent to total sales. The output measure can include significant "double counting." Think of corn, for example. The value of corn is counted when it is sold to the feed mill, again when the ground feed is sold to the livestock farmer, and yet again when the farmers sells their animal. The value of the corn is built into the price of each of these items, and then the sale of each item is added to determine total sales (or output).

Employment

IMPLAN includes total wage and salaried employees, as well as the self-employed, in employment estimates. Because employment is measured in jobs and not in dollar values, it tends to be a very stable metric.

Labor Income

Labor income measures the value added to the product by the labor component. So, in the corn example, when the corn is sold to the feed mill, a certain percentage of the sale is for the labor to raise the corn. Then when the ground feed is sold to the farmer, it includes some markup for its labor costs in the price. When the livestock farmer sells the finished animal, he/she includes a value for the labor. These individual value increments for labor can be measured, which amounts to labor income. Labor income does *not* include double counting.

Labor income includes both employee compensation and proprietor income. It is measured as wages, salaries, and benefits.

Direct Impact

Direct impact is equivalent to the initial activity in the economy.

Indirect Impact

Indirect impact is the summation of changes in the local economy that occur due to spending for inputs (goods and services) by the industry or industries directly impacted. For instance, if employment in a manufacturing plant increases by 100 jobs, this implies a corresponding increase in output by the plant. As the plant increases output, it must also purchase more inputs, such as electricity, steel, and equipment. As

the plant increases purchases of these items, its suppliers must also increase production, and so forth. As these ripples move through the economy, they can be captured and measured. Ripples related to the purchase of goods and services are indirect impacts.

Induced Impact

The induced impact is the summation of changes in the local economy that occur due to spending by labor—that is, spending by employees in the industry or industries directly impacted. For instance, if employment in a manufacturing plant increases by 100 jobs, the new employees will have more money to spend on housing, groceries, and going out to dinner. As they spend their new income, more activity occurs in the local economy. This can be quantified and is called the induced impact.

Total Impact

The total impact is the summation of the direct, indirect, and induced impacts.

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[i] Minnesota Department of Agriculture. (2018). *Statement of need and reasonableness: in the matter of proposed permanent rules relating to groundwater protection.* https://www.mda.state.mn.us/sites/default/files/2018-08/sonargwprule.pdf