The Near-Term Financial Impacts of Predicted Climate Change on Iowa Agriculture

April 2021

K·COE ISOM

EDF ENVIRONMENTAL DEFENSE FUND™ Finding the ways that work

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About Environmental Defense Fund

Environmental Defense Fund is a leading international non-profit organization, founded in 1967, that creates transformational solutions to the most serious environmental challenges. EDF links science, economics, law, and innovative private-sector partnerships. Environmental Defense Fund commissioned K·Coe Isom to conduct this study to further assist the agricultural community in its efforts to address challenges associated with climate change and climate change-related revenue losses.

About K·Coe Isom, LLP

K·Coe Isom, LLP is America's leading agricultural accounting and business advisory firm. With roots dating back to 1932, the professionals at K·Coe Isom help corn and soy producers throughout the Midwest as well as farmers and food and agriculture businesses throughout the U.S. From tax and audit, to estate and succession planning, to sustainability and farm program services, K·Coe Isom helps agricultural producers improve profitability and sustain farming operations for this generation and generations to come.

Reviewers

K·Coe Isom thanks the following individuals for their review and feedback on this report. Inclusion on this list does not indicate endorsement or support of the report or its conclusions:

- Eugene S. Takle, Emeritus Distinguished Professor of Agronomy, Iowa State University
- Wendong Zhang, Assistant Professor of Economics, Iowa State University
- Dave Swenson, Research Scientist III, Department of Economics, Iowa State University[1]
- Ben Gleason, Senior Manager of Sustainable Programs, Iowa Corn Growers Association

[1] K·Coe Isom hired Dave Swenson as a private consultant on this project to conduct the modeling of state revenue, economic productivity, and employment impacts contained in Section V of this study. Mr. Swenson is a research scientist in the Department of Economics, Iowa State University and lecturer in the School of Urban and Regional Planning and Public Policy at the University of Iowa. The work conducted by Mr. Swenson for this study is not associated or affiliated with Iowa State University.

I. EXECUTIVE SUMMARY

Environmental Defense Fund commissioned K·Coe Isom, LLP, a leading agriculture accounting and consulting firm, to estimate the potential effect of climate-change induced yield changes on farm revenue, economic productivity, and government revenues in Iowa in the next two decades (2020 to 2039).

In recent decades, crop yields in the Midwest have increased due to climatic changes and improvements in seed varieties, planting practices, and other agricultural practices.[2] Unfortunately, multiple scientific studies suggest this trend is unlikely to continue.[3] A recent national study of climate change impacts by Hsiang et al. found that climate change is projected to reduce Iowa corn, silage, and soy yields in the coming decades.[4] The Hsiang et al. study found that "average yields in agriculture decline with rising GMST" (global mean surface temperatures).[5] After accounting for the benefits to plant growth from higher CO_2 concentrations, Hsiang et al. conclude that temperature and rainfall changes would likely reduce yields nationwide and would reduce yields for corn and soybeans throughout most of Iowa.[6]

This report uses the Hsiang et al. modeling of climate change impacts in Iowa to analyze the projected economic impacts to Iowa of changes in corn, silage, and soy yields.[7] This report quantifies a range of potential near-term, localized economic impacts from crop-yield changes that may arise in the absence of more ambitious actions to mitigate climate change and to help farmers better adapt to climate change.[8] The report concludes with a set of policy recommendations that the State of Iowa and local governments in Iowa could consider to assist with mitigation and adaptation, including advocating for federal efforts and policies.

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[2] Butler et al., 2018. Particularly pleasant weather for U.S maize. *Proceedings of the National Academy of Sciences of the United States of America* 115 (47), 11935-11940.

[3] Takle, Eugene S. and William J. Gutowski Jr. 2020. *Iowa's Agriculture is Losing its Goldilocks Climate*. Physics Today 73, 2, 27.

[4] Hsiang et al. 2017. Estimating economic damage from climate change in the United States. *Science* 356, 1362–1369.

[5] Id. at 2-3.

[6] Id.

[7] This report analyzes the economic impacts of climate-change induced yield changes on soy, corn and silage under an RCP8.5 scenario as modeled by Hsiang et al. The report modeled yield changes for a twenty-year period (2020-2039) and examines revenue impacts over the coming decade.

This report does not attempt to assess the economic impacts of projected yield changes on wheat or other crops nor does this report seek to assess the economic impacts from climate change on livestock, eggs and poultry, or ethanol. Modeling climate change-induced impacts on agricultural prices is beyond the scope of this analysis, but changes in commodity prices are likely to offset revenue losses to some degree.

[8] As used in this report, the term "mitigation" refers to efforts reduce or stabilize heat-trapping gases in the atmosphere. The term "adaptation" refers to the broad set of responses to the impacts of climate change. In the context of agriculture, adaptation could include such diverse responses such as crop switching, development of more heat- or drought-tolerant crops, expanded irrigation, and other modifications to farming practices.

Key Findings:

- Iowa farmers could see **statewide gross farm revenues reduced by as much as $4.9 billion** per decade – **a loss of 3.6 percent of Iowa farm revenue** from sales of corn, silage, and soy**.**[9] Because with climate change agricultural prices are likely to rise, relative to without climate change, the impact to gross farm revenues from yield impacts will be offset to some degree by higher prices.[10]
- While county-level impacts are more difficult to predict, the yield changes forecast by Hsiang et al. suggest that **ninety-two of Iowa's ninety-nine counties would experience decreases in gross farm revenues. Forty-five of Iowa's counties** are predicted to experience high-end farm revenue **losses of more than $50 million** and **eight counties** are predicted to experience high-end farm revenue **losses of more than $100 million**.
- This reduction in revenues would have a serious impact on the continuing viability of many farms and could significantly reduce available capital for purchasing supplies and equipment and for off-farm expenses including groceries, meals away from home, clothing, entertainment, educational expenses, and personal transportation.
- A sample farm examined in central Iowa would have lost **$50,000 to $90,000 in revenue per year** if projected yield reductions had been in effect over the past five years – **a potential loss to the farm of $360,000**. As noted by the farm owner, this loss would have reduced working capital, increased farm debt, and limited the ability of the farm to continue to be efficient producers of corn and soybeans.
- Because these impacts would reduce capital investment and off-farm spending, this loss would ripple throughout the Iowa economy, **reducing Iowa annual economic output by $367 million to $733 million, causing the statewide loss of 1,270 to 2,530 jobs**, and reducing annual state revenue collections by **$4 million to $8.3 million.**

It is critical to note that these are *average* impacts. In some years, **impacts to farm revenues, economic output, jobs, and state revenue collections could be considerably greater than the impacts calculated in this report** while in some years these impacts could be lower**.** Further, we would expect to see economic impacts increase over time as climate change continues to reduce crop yields. In years where Iowa experiences more significant yield reductions, one would expect an increase in farm bankruptcies and more significant economic dislocation throughout the state.

Fortunately, the range of revenue loss and economic impacts identified in this report and in subsequent years depends in large measure on the effectiveness of global efforts to combat

[9] This loss of gross farm revenue translates into an average annual loss of $224 million to $488 million. In 2019, total farm revenues in Iowa from corn, silage and soy equaled $13,463,266,080. In assessing gross farm revenue impacts, this report will summarize 10-year impacts evaluated against our baseline projections of farm yields. As such, revenue reductions should be noted as relative (assessed against projected yields) rather than as absolute (assessed against today's yields). Note that Section IV of this report examines how projected yield reductions would have affected the financial viability of a model farm during the period 2015-2019. Similarly, Section V of this report examines how project yield reductions would have affected economic productivity, jobs, and state revenue collections had they materialized in 2019.

[10] Moore et al., 2017. New science of climate change impacts on agriculture implies higher social cost of carbon. *Nature Communications* 8, 1607.

climate change and on the degree to which Iowa farmers are able to adapt to the impacts of climate change. While the Hsiang et al. study assumes that agriculture will continue to adapt to climate change, we analyzed scenarios where farmers are able to increase adaptation by an additional 50%. This provides the reader with some context to assess a range of possible economic impacts and to assess how efforts by the State of Iowa and others may help to reduce economic impacts.

II. BACKGROUND

Iowa is blessed with a climate, soil, and topography that has led to productive and efficient agricultural operations. Iowa ranks second among states for agricultural production in terms of cash receipts.[11] Approximately 85 percent of Iowa's 36 million acres is farmland. Of that, 26.5 million acres in Iowa are planted as row crops – mostly corn and soybeans. Of the acres planted for corn production, approximately 360,000 acres are used silage.[12]

In 37 of Iowa's counties, more than one-half of total economic output derives from agriculture and agricultural-related industries.[13] In 30 additional counties, at least one-third of total economic output derives from agriculture and agricultural-related activities.[14] In 2018, Iowa generated around $27.5 billion in agricultural cash receipts, with the highest valued commodities being corn, hogs, and soybeans. This represented 10.2 percent of the total state gross domestic product.[15]

In recent years, Iowa's agricultural economy has experienced some difficult times. Prices for both crops and livestock decreased due to global trade wars, disruptions to ethanol, and shifts in global production.[16] In Iowa, net farm income in 2017 was almost 59 percent lower than the high seen in 2013 and 37 percent lower than the 10-year average.[17] In 2019, Iowa farm debt was the highest in the nation[18] with 44 percent of growers struggling to cover costs.[19]

The August 2020 hurricane-strength derecho storm tore through 57 counties in Iowa, impacting 14 million acres – 57 percent of Iowa's planted acres, and devastating countless farms and grain

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[11] U.S. Department of Agriculture, Economic Research Service, FAQs. https://www.ers.usda.gov/faqs/#:~:text=In%202019%2C%20the%20top%2010,Farm%20Income%20and%20Wealth%20Statistics.

[12] U.S. Department of Agriculture, National Agricultural Statistics Service, 2019 State Agriculture Overview: Iowa. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=IOWA

[13] Miller, David. 2019. *Opportunities for rural Iowa: Time to decentralize*. The Gazette. https://www.thegazette.com/IowaIdeas/stories/agriculture/opportunities-for-rural-iowa-time-to-decentralize-20190225

[14] Ibid

[15] University of Arkansas. Iowa Economic Contribution and Impact Research. https://economic-impact-of-ag.uark.edu/iowa/#:~:text=In%202018%2C%20Iowa%20generated%20around,percent%20of%20total%20state%20GDP. Accessed August 26, 2020.

[16] USDA. 2019. Agricultural Production and Prices. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/agricultural-production-and-prices/. Accessed August 26, 2020.

[17] Miller, David. 2019. *Opportunities for rural Iowa: Time to decentralize*. The Gazette. https://www.thegazette.com/IowaIdeas/stories/agriculture/opportunities-for-rural-iowa-time-to-decentralize-20190225

[18] Iowa State University. 2019. Iowa Farm debt highest in the nation. https://www.econ.iastate.edu/iowa-farm-debt-highest-nation. Accessed August 26, 2020.

[19] Ibid

storage facilities.[20] Although the connections between climate change and derechos remain unclear, extreme weather events, in general, are expected to worsen due to climate change, and the National Oceanic and Atmospheric Administration has indicated that climate change may cause corridors of maximum derecho frequency to shift.[21]

What is more certain, however, is that the agricultural sector is one of the most climate change-vulnerable segments of our economy. Small shifts in the timing, frequency and amount of precipitation and temperature changes can considerably affect crop yields.

Over the past 30 years, Iowa's climate has not experienced the same increase in temperatures seen across the globe but has enjoyed conditions advantageous for farming.[22] With these favorable conditions and improvements in technology and agronomical management, Iowa has been able to reap the benefits of higher yields.[23]

Unfortunately, these conditions are not likely to continue, and the next few decades will likely witness conditions in Iowa less conducive to agricultural production.[24] Hsiang et al. in their study, "Estimating economic damage from climate change in the United States," estimated the economic damage that climate change would cause to six sectors in the United States — agriculture, crime, coastal storms, energy, human mortality, and labor. [25] For agriculture, the study looked at the average yield changes for wheat, corn, and soy for the United States for 2020-2100, using 2012 agricultural production as its baseline year. In this report, we use data from the Hsiang et al. study for each county in Iowa for the 2020-2039 period associated with a 'no climate action' (RCP8.5) scenario.

Hsiang et al. found that "average yields in agriculture decline with rising GMST" (global mean surface temperature).[26] After accounting for the benefits to plant growth from higher CO_2 concentrations, Hsiang et al. conclude that temperature and rainfall changes would reduce yields nationwide and would reduce yields for corn and soybeans throughout most of Iowa.[27]

III. IMPACTS TO GROSS FARM REVENUE IN IOWA AT STATEWIDE AND COUNTY LEVELS

Model Development

To assess the potential economic impacts to Iowa of these predicted climatic impacts, we relied on the average annual countywide yield adjustments projected by Hsiang et al. contained in

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[20] *Farm Policy News,* August 16, 2020. https://farmpolicynews.illinois.edu/2020/08/derecho-damage-begins-to-unfold-estimated-37-7-million-acres-of-farmland-impacted/

[21] Corfidi, Stephen, et al, "About Derechos.", *National Oceanic and Atmospheric Administration*, 15 May, 2018.

[22] Takle, Eugene S. and William J. Gutowski Jr. 2020. *Iowa's Agriculture is Losing its Goldilocks Climate*. Physics Today 73, 2, 27.

[23] Butler et al., 2018; Tackle, 27.

[24] *Id.* At 27 (citing US Global Change Research Program, *Fourth National Climate Assessment, Volume II: Impacts, Risks, and Adaptation in the United States* (2018)).

[25] Hsiang et al. 2017. Estimating economic damage from climate change in the United States. *Science* 356, 1362–1369.

[26] Id. at 2-3.

[27] Id.

Appendix A of this report. [28] Under the yield projections provided by Hsiang et al., ninety-two out of ninety-nine counties in Iowa would experience yield reductions due to climate change. The other seven counties, in the northern part of the state, show projected yield increases due to climate change.[29] The county-level model translates into weighted statewide average yield reductions of:

- Corn (bushels) -3.4%
- Soybeans (bushels) -3.6%
- Corn Silage (tons) -2.9%

To assess the economic impacts from these yield changes, we gathered historic data from the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) database. We compiled yearly data at the county level for the state of Iowa for a 20-year period for corn, silage,[30] and soybeans.[31]

We gathered historical prices for corn and soybeans from the Ag Decision Maker website provided by Iowa State University. This data set provided us with monthly prices by year dating back to 1925 and the average yearly price. We used the average yearly price in the absence of data for monthly crop sales. From there, we derived silage pricing based on Iowa State University's Ag Decision Maker article, "Pricing Forage in the Field", using a mid-yield assumption.[32] Together, this allowed us to generate a rough estimate of historic gross farm revenues by county.

We then developed two baseline projections of agricultural production in Iowa for corn, silage, and soy for the period 2020 to 2029.

For the first baseline projection, we used the previous 10 years' county-level agricultural production data and then projected the same year-over-year change to production data from 2019. Thus, for example, a 2-percent production increase seen between 2009 and 2010, would be projected as a 2-percent production increase between 2019 and 2020. The change in production between 2010 and 2011 would then be applied to the 2020 projection, thus providing a projection of county-level production results for the coming decade.

While this methodology has obvious limitations, it does provide a real-world snapshot of potential high- and low-productivity cycles that may occur over the coming decade due to weather and other factors. Since our goal is to establish a ten-year average production baseline, we are less concerned with the accuracy of forecasts for particular years and are more

[28] Hsiang et al. 2017. Estimating economic damage from climate change in the United States. *Science* 356, 1362–1369.
[29] As noted throughout this report, climate impact analyses at a county level are less certain than impact analyses conducted at a statewide level. We have included a county-level analysis in this report to illustrate the range of impacts that may be experienced across Iowa rather than illustrating impacts that will be experienced by specific counties.
[30] Corn silage is a high-quality forage crop that is shredded and fermented as animal feed. Corn silage includes shredded ears, stalk and leaves. This is in contrast to grain corn of which just the earns/kernels are harvested.
[31] https://www.nass.usda.gov/Data_and_Statistics/index.php
[32] Edwards, William and Hart, Chad, 2018. Iowa State University, Ag Decision Maker: Pricing Forage in the Field, File A1-65. https://www.extension.iastate.edu/AGDm//crops/pdf/a1-65.pdf

concerned with establishing a reasonable production baseline over a ten-year period. We have called this first baseline the "Historic-Projected Model" since it is based on productivity changes experienced over the previous ten-year period.

For the second baseline projection, we used USDA's projections for corn and soy production, for the coming ten years. We used the projected USDA guidance with 2019 production from the NASS database[33] as our baseline year to estimate 2020 through 2029. We refer to this scenario as the "USDA-Projected Model."

For both baselines, we used pricing data compiled by the U.S. Department of Agriculture in USDA Agricultural Projections to 2020.[34] The USDA projections on productivity and price are used by the U.S. government for a wide variety of purposes including budgeting for farm programs. As noted in the USDA report:

> The projections in this report were prepared during July 2019 through January 2020, with the Agriculture Improvement Act of 2018 assumed to remain in effect through the projection period. The scenario presented in this report is not a USDA forecast about the future. Instead, it is a conditional, long-run scenario about what would be expected to happen under a continuation of current farm legislation and other specific assumptions. Critical long-term assumptions are made for U.S. and international macroeconomic conditions, U.S. and foreign agricultural and trade policies, and growth rates of agricultural productivity in the United States and abroad. The report assumes that there are no domestic or external shocks that would affect global agricultural supply and demand. Normal weather is assumed. Changes in any of these assumptions can significantly affect the projections, and actual conditions that emerge will alter the outcomes.[35]

After estimating production for our two models, we adjusted the baselines by the yield reductions projected in Hsiang et al. This resulted in a climate impact-adjusted production estimate for each county for 2020 to 2029 using both the Historic-Projected Model and the USDA-Projected Model. This allowed us to compare projected production and sales to the climate-change adjusted production and sales to derive the economic impact arising from the reduction of yield due to climate change.

Adaptation

Farmers have always navigated weather and economic fluctuations, and as the climate changes, farmers are, to some degree, adapting to the change and thus reducing the impact of climate change on their farming operations. For example, by changing the timing of planting and the varieties of crops that are planted, farmers globally have been able to head off some of the yield impacts that would otherwise be caused by climate change. Hsiang et al. factored historic levels of adaptation into their yield reduction projections. As explained in the study:

> Because the empirical results that we use describe how populations have actually responded to climatic conditions in the past, our damage estimates capture numerous forms of adaptation to the extent that populations have

[33] https://quickstats.nass.usda.gov/

[34] https://www.ers.usda.gov/webdocs/outlooks/95912/oce-2020-1.pdf?v=4584

[35] Id. at

> previously employed them. For example, if farmers have been adjusting their planting conditions based on observable rainfall, the effect of these adjustments will be captured by our results. Although, if there are trends in adaptive behaviors, previously unobserved adaptation "tipping points," or qualitative gains in adaptation related technologies, then our findings may require adjustment.[36]

Two recent studies have suggested that agriculture can prevent *at most* 50% of the impacts of climate change through adaptation including changes in planting practices, switching to alternate crops, and other approaches.

Marshall Burke and Kyle Emerick, in Adaptation to Climate Change: Evidence from US Agriculture,[37] examined recent agricultural adaptation to climate change impacts on corn and soybean production. For corn production, Burke and Emerick concluded that:

> Median estimates from each distribution all indicate that adaption has offset less than 25 percent of short run impacts—and point estimates are actually slightly *negative* in two-thirds of the cases. In almost all cases we can conclude that adaptation has offset at most half of the negative shorter run impacts of extreme heat on corn yields.[38]

Similarly, for soybeans, Burke and Emerick found that: "While the soy results are somewhat noisier than the corn results, the average response to extreme heat across the 39 estimates is −0.0032, giving us a point estimate of longer run adaptation to extreme heat of about 32 percent."[39]

In October of 2020, James Rising and Naresh Devineni looked specifically at the degree to which shifting to other types of crops would allow the United States to adapt to climate change.[40] Rising and Devineni concluded that crop-shifting could offset 50% of climate change impacts at a national scale under an RCP8.5 scenario. It is critical to note that this study did not examine the effectiveness of crop shifting as an adaptation approach on a state or county level.

While Hsiang et al. incorporated historic levels of adaptation into their yield impact forecasts, we have elected to assume a maximum of an additional 50% adaptation above the levels of adaptation assumed by Hsiang et al. We have done this to provide a range of economic impacts for this study. This 50% adaptation scenario is optimistic and significantly reduces potential costs – it was added to provide the reader with a band of estimates ranging from a historic level of adaptation to estimates that incorporate increased mitigation and adaptation that could be realized through adoption of climate policies at the federal, state, and local levels.

By including this extreme adaptation scenario in this study, we also aim to reflect some of the inherent uncertainty incumbent in climate modeling and to capture the likelihood that some

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[36] Hsiang et al. at 6. *Note that* Hsiang et al. also factored in storage as one factor that would smooth projected yield adjustments. *See* Supplementary Materials for Estimating economic damage from climate change in the United States, B.1.1 Storage, 12-13.

[37] Burke, M. and Emerick, K., Adaptation to Climate Change: Evidence from US Agriculture, *American Economic Journal: Economic Policy 2016, 8(3): 106-140.*

[38] *Id.* at 125-126.

[39] *Id.* at 127.

[40] Rising, J. and Devineni, N., Crop switching reduces agricultural losses from climate change in the United States by half under RCP 8.5, *Nature Commun*, 11, 4991 (2020).

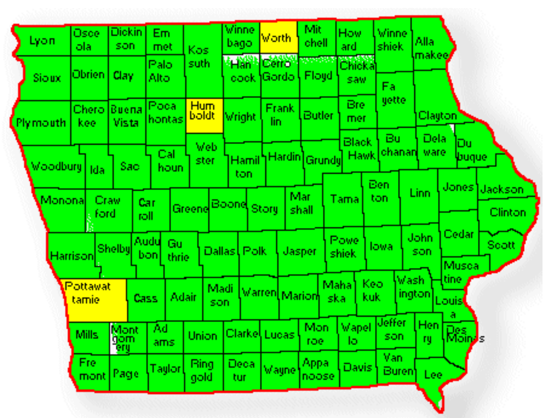
degree of economic impact would be offset by crop insurance and other government payment policies. The degree to which such government intervention would offset climate impacts in the future is unknowable and thus we have not made an effort to separately calculate this offset as another form of economic adaptation.

Findings

The following sections of the report summarize estimated impacts to gross farm revenues in Iowa using both the Historic-Projection Model and the USDA-Projection Model and also analyzing the results using model runs that assume adaptation reduces economic impacts by an additional fifty percent.

Using these two models and the adaptation assumption, we examine gross farm revenue impacts from yield adjustments to corn, silage,[41] and soybeans. We first examine statewide gross farm revenue impacts. The body of the report examines total projected statewide farm-revenue impacts. We have included separate statewide analyses for corn, silage, and soy in Appendix B to this report.

After examining statewide impacts, we then analyze county-level impacts for three specific counties to illustrate the range of revenue impacts that farmers may experience across Iowa:



- Pottawattamie County —the county projected by Hsiang et al. to experience the greatest yield reductions and thus the greatest decline in farm revenue.
- Humboldt County – the county projected by Hsiang et al. as the median for yield impacts (forty-nine counties in Iowa are expected to experience smaller farm revenue losses than Humboldt County and forty-nine counties in Iowa are anticipated to experience greater farm revenue losses than Humboldt County.
- Worth County – the county projected by Hsiang et al. to experience the greatest yield increase and thus the greatest increase in farm revenue.

We have included an in-depth analysis of the impacts on the three sample counties and a complete listing of the impacts estimated for each county in Iowa, along with illustrative charts, as Appendix C to this report.

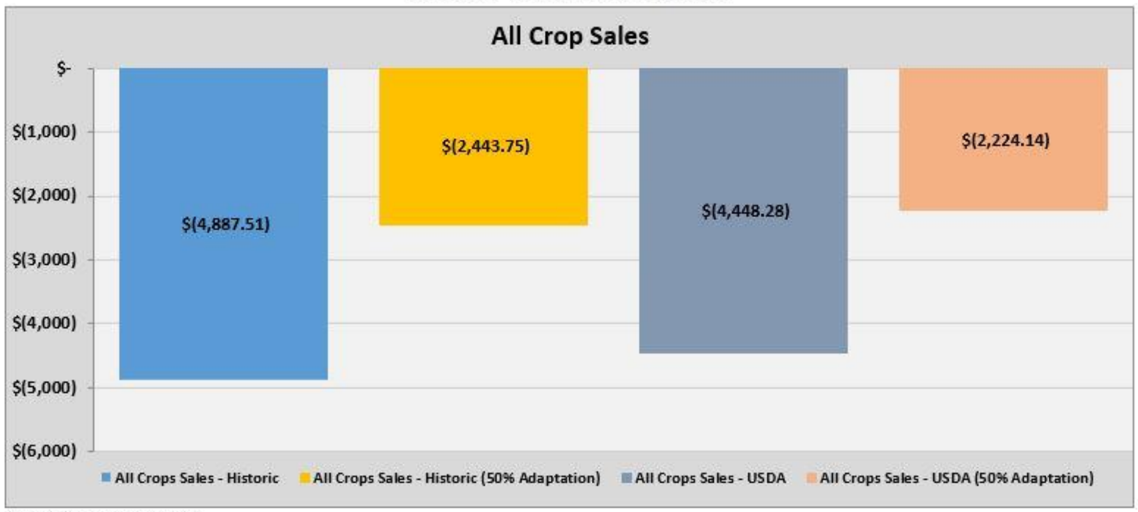
Statewide Impacts

Climate change impacts on agricultural yields are projected to cause a significant decrease in gross farm revenues in the state of Iowa. The following chart details projected statewide farm revenue losses from yield reductions to corn, silage, soybeans. Over a ten-year period, decreasing corn, silage, and soybean yields due to climate change would **reduce statewide gross**

[41] Silage is

farm revenues by 2-3 percent reducing revenue to Iowa farmers a total of **$2.2 billion to $4.8 billion.**[42]

Statewide - Impact to All Crop Sales

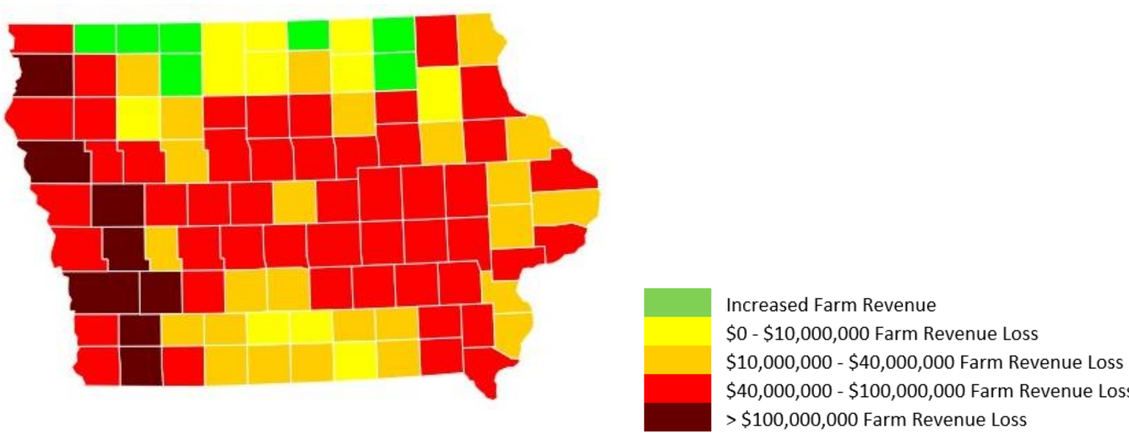


*Represented in millions ($)

**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

County-Level Comparative Analysis

While the statewide loss of revenue from climate-change induced reductions in crop yields is significant, the modeling by Hsiang et al. suggests that there will be some variability in impacts experienced across the state of Iowa. As shown in the following map, the counties that Hsiang et al. project to fare worst under climate-change induced yield changes are all located on the



western side of Iowa. The counties that are projected to fare the best are located in the northern tier of counties.[43]

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[42] The Historic-Projected Model projects 10-year combined gross farm revenues from corn, silage, and soybeans at $144.6 billion while the USDA-Projected Model projects slightly lower combined gross farm revenues from corn, silage, and soybeans of $131.1 billion.

[43] A valid interpretation of this variance could be that northern counties will experience reduced negative effects of climate change over this period (likely due to a longer growing season and more favorable rain;

Model projections of future climate scenarios are essentially always considered inaccurate at the highest level of model resolution, particularly in a region like Iowa where orographic features (e.g., mountains, large water bodies, coastal influences, major soil differences) have a relatively low influence on distinguishing the climates of two adjacent counties. Therefore, this map should be interpreted as illustrating a range of potential impacts rather than predicting with certainty the impact that would be experienced in any particular county.

As shown in the following charts, the range of predicted farm revenue losses varies dramatically by county. The worst hit county under the Hsiang et al. modeling (in this case Pottawattamie) suffered a maximum ten-year farm revenue loss of $274 million while the county predicted to fare the best (Worth County) experienced a maximum $23 million increase in farm revenue over the same ten-year period.[44] For an analysis of revenue impacts for these counties separated out for corn, silage, and soy, see the charts in Appendix B.

Historic-Forecast Model
Impact to Total Sales

Revenue represented in millions.

Historic-Forecast Model
Impact to Total Sales

Revenue represented in millions.

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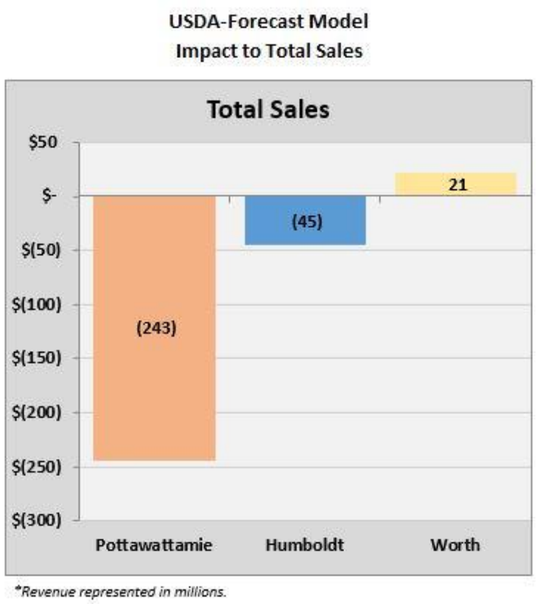
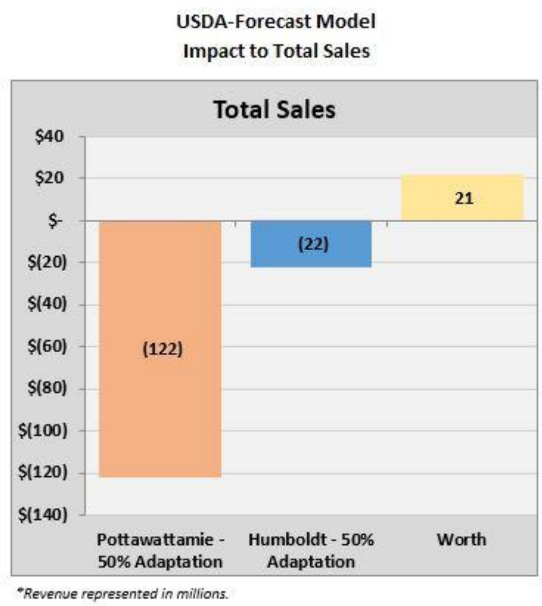
and western Iowa counties will experience higher-than-statewide losses (likely due to less or more-variable growing season precipitation; Butler et al., 2018.

Note that county-level financial impacts reflected in this map do not include the 50-percent adaptation model runs.

[44] We have not reduced beneficial impacts under the 50% adaptation scenario.

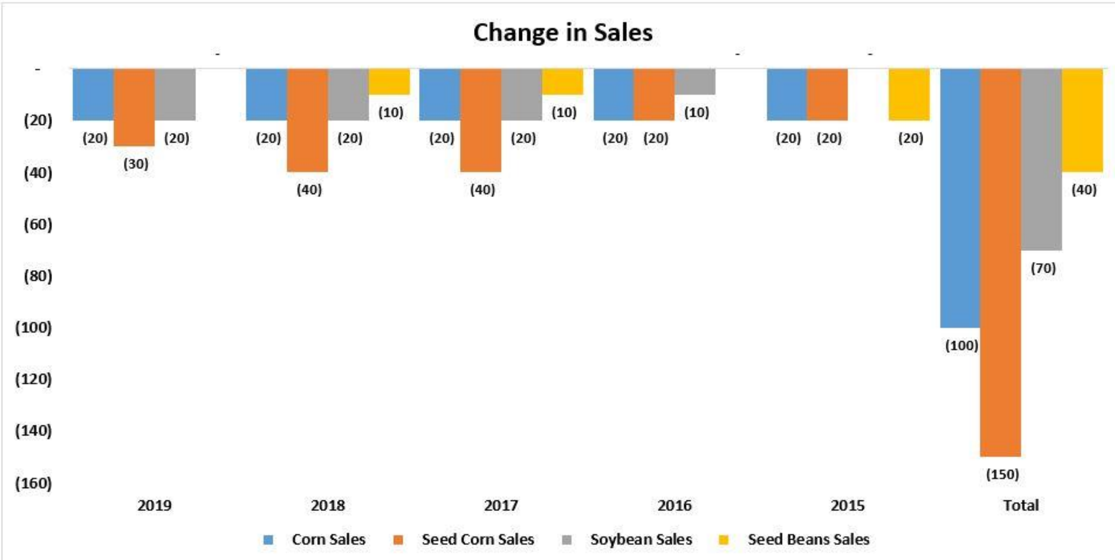




IV. IOWA FARM CASE STUDY

To examine how revenue impacts would be felt at the farm level, we modeled impacts for a family corn and soybean operation located in central Iowa. The farm we selected has under 5,000 planted acres and annual revenues ranging between $2 million and $4 million.[45] We obtained the financial data for this farm including harvest, sales, and capital expenditure data and modeled the impact of projected yield reductions on farm revenue over a five-year period (2014-2019). If climate-change induced yield projections found in this study would have occurred during the years 2015 through 2019 (with prices holding constant), the sample farm would have lost between $50,000 and $90,000 in revenue per year equaling a total potential loss of $360,000 over the five-year period.

[45] We have slightly modified the financial and other details about the operation to preserve client anonymity and confidentiality. The family farming operation used in this case study consented to the use of their farming data for the purposes of this report. We appreciate their participation in this analysis.



**Represented in thousands ($)*

When presented with this data, one of the owners of the farm provided feedback on what these revenue losses would have meant to their farm:

> It was interesting to see what the impact of the forecast yield reductions would have been for our farm, especially knowing that those reductions would have also hit during a farm economy season when the infusion of government program money played a key role in making us profitable.
>
> After already working to trim input expenses and maximize efficiency of people and equipment, this reduction in income would have contributed to a larger decline in working capital. Having to access more financing for operating and to help cover equipment purchases would have increased farm debt. That is a good alternative in a tight year, but it does just delay the principal payment which may continue to be a concern if these yield reductions continue.
>
> During this time period our operation has been actively working to transition the farm to the next generation. A reduction in revenue would have slowed the pace of that transition. It may also have made returning to the farm a less desirable choice for the next generation. Those family members would seriously have to weigh the cost of returning to the family business or explore more lucrative opportunities in the ag business sector.
>
> Some of our equipment and infrastructure decisions were a result of wanting to create a work environment that would attract needed employees and excite family members to invest in the operation. Having to further limit those capital expenditures could have impacted our ability to be efficient producers of corn and soybeans and provide a safe and more productive work environment. It would also impact our decisions on how to grow and expand the operation as opportunities became available.

> Since owner draws come after expenses are paid, the ability to compensate owners for their time and sacrifices would be limited. This would be especially hard on those families newest to farming who have not had an opportunity to benefit from more profitable years in the past.

While this individual case study does not represent all farms in Iowa, it does demonstrate the significant negative impacts that climate-change induced yield losses could have on farming operations across the state.

V. DERIVATIVE IMPACTS TO THE IOWA ECONOMY

Introduction

In addition to assessing direct impacts on farm revenues in Iowa, we wanted to also assess the derivative impacts that would ripple through the Iowa economy. Sections II and III of this report estimated revenue losses for corn, corn silage, and soybeans yield impacts projected against a production baseline for 2020 through 2039. The farm case study listed above analyzed how yield reductions would have impacted revenues for the model farming operation over the period 2015-2019. Our analysis of derivative impacts on the Iowa economy applies the weighted statewide average loss as measured in terms of yield reductions to the most recent crop year in Iowa (2019). This estimation uses an input-output model (IO) of the Iowa economy that was modified to accurately reflect the value of the production of these commodities in 2019 for Iowa.[46]

Model Development

Three sectors were established in the model to reflect 2019 total receipts for corn, soybeans, and corn silage. The corn silage sector was created using an existing unused sector in the model (sugar) and populating that sector with production coefficients that align with corn production, but with modifications which take into account that silage is an on-farm feed input. The value of corn silage per ton was set at nine times the average price received for corn in Iowa in 2019.[47] Suitably adjusted, the IO model was recompiled.

The first step was to estimate the economic value of each sector to the Iowa economy using a procedure called industry contribution analysis. This procedure eliminates feedback loops that will over-describe a sector and allows for a clean determination of how much and what types of economic activity are supported by different industrial sectors.[48] Separate analyses were made for each commodity so that both the sizes of the industrial sectors (corn, soybeans, and silage)

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[46] Mr. Swenson conducted the modeling in this section of the report using IMPLAN, Inc., an input-output modeling system that annually provides data for the U.S., its states, and its counties.

[47] The value of corn silage per ton is a function of yield and can range per ton from 8 to 10 times the price per bushel of corn. Nine was the mid-point and used here. See Iowa State University Ag Decision Maker File A1-65 for more information on forage pricing: https://www.extension.iastate.edu/agdm/crops/pdf/a1-65.pdf

[48] This procedure involves setting regional purchasing coefficients to zero for the three crops considered in this study. The importance of industrial contribution analysis is nicely summarized here: https://implanhelp.zendesk.com/hc/en-us/articles/360025854654-ICA-Introduction-to-Industry-Contribution-Analysis

were isolated as also were their multiplied-through linkages to the rest of the Iowa economy. These became the baseline values from which the impacts of yield reductions were estimated.

Yield Reduction Assumptions and Specifying the Model Responses

Based on Hsiang et al., we calculated average statewide yield reductions for the 2020 through 2039 period. The average annual statewide projected yield reductions are:

- Corn (bushels) -3.4%
- Soybeans (bushels) -3.6%
- Corn Silage (tons) -2.9%

These values were applied to the model in the form of quantity (not price) reductions. IO models are fixed-price models that assume fixed quantities of production associated with output levels reported in the model. Under this scenario, it was assumed that the climate change-induced yield reductions would result in a reduction of not only the quantity of grain or silage produced, but also reductions in the land available to produce these crops. As marginal land would come out of production, the full schedule of previously required inputs needed to produce crops on those more marginal acres would also lessen.[49]

Understanding Input Output Models and Terminology

IO models are sophisticated estimates of buying and selling transactions among all industries within a study region, in this case, the state of Iowa. These estimates result in an extensive accounting framework that is mathematically transformed to produce sets of multipliers. For this study, four types of economic data are summarized:

- Industrial output is the value of what industries produce during a calendar year, whether that commodity was sold or not.
- Labor income is composed of the wages and salaries paid to hired workers and the payments that proprietors make to themselves for their labor and management.
- Value added is composed of labor income (above) plus returns to proprietors (profits) along with payments to investors (as dividends, interest payments, and rents) and indirect tax payments that are part of the production process.

[49] Alternate scenarios could have left production quantity levels unchanged, but instead lowered returns to proprietorship in the model. This works for a short-run situation where, for example, trade policy abruptly interferes with expected prices and they drop precipitously, as was the case for soybeans in 2018, but the volume of output (bushels) did not. In those instances, the IO can demonstrate the expected losses that farmers would absorb and what that would mean when farm proprietors received lowered returns on their efforts. In this study, however, it is assumed that climate change consequences are not producing a price shock. They are producing a reduction in the quantity, and, it is assumed, the gross profitability of producing these three crops. Accordingly, using a quantity-reduction approach does a much better job of simulating a reduction in the volume of agricultural output that would result from this scenario.

- Jobs are the number of full-time and part-time positions in the economy. There are always more jobs in an economy than employed persons because many employed persons hold more than one job.

There are three levels of economic information or effects reported for each of these types of economic data:

- Direct effects refer to the specific industrial activities scrutinized in the study scenario (corn, soybean, and silage production).
- Indirect effects describe all of the suppliers to the direct sector. As examples, all commodity producers need raw, manufactured, financial, transportation, and service-sector goods.
- Induced effects accrue when the workers in the direct and the indirect sectors convert their labor incomes into household spending. In so doing, they induce a third round of economic activity.

Total economic activity is the sum of all direct, indirect, and induced effects.

Findings

The following tables sum the yield reduction consequences for corn, silage, and soybeans. At the direct, or farm, level, total output in 2019 would have declined by $436 million, costing 740 jobs and $43 million in labor income. For the economy as a whole, the total losses would multiply through to result in a reduced total output of $733 million and value-added would have been down by $255 million.[50] The labor income component of value-added would have declined by $125 million to 2,530 Iowa jobholders.

Simulated Economic Impact of Corn, Soybean, and Silage Losses Based on 2019 Crop Production

	Jobs	Labor Income	Value Added	Output
Direct	-740	-$43,000,000	-$108,000,000	-$436,000,000
Indirect	-1,250	-$59,000,000	-$105,000,000	-$222,000,000
Induced	-540	-$23,000,000	-$42,000,000	-$75,000,000
Total	-2,530	-$125,000,000	-$255,000,000	-$733,000,000

Appendix D contains a detailed analysis separating out impacts by crop-type and provides a more detailed explanation of the methodology used to arrive at these conclusions.

If farmers are able to further adapt to climate change through the adoption of new technologies or farming practices, they may be able to lessen yield reduction impacts and thereby reduce farm revenue and derivative economic impacts. The following table estimates derivative economic impacts assuming an additional 50% level of adaptation beyond that assumed by Hsiang et al.

[50] To put this in context, the $730 million reduction in economic output is greater than the $630 million annual operating budget of Iowa State University in 2020. Flesher, Charles, "Iowa Board of Regents approves $65.4 million in cuts to state's public universities." *Des Moines Register*, 29 July, 2020.

Simulated Economic Impact of Corn, Soybean, and Silage Losses Based on 2019 Crop Production Assuming 50 Percent Additional Adaptation

	Jobs	Labor Income	Value Added	Output
Direct	-370	-$22,000,000	-$54,000,000	-$218,000,000
Indirect	-630	-$30,000,000	-$53,000,000	-$111,000,000
Induced	-270	-$11,000,000	-$21,000,000	-$38,000,000
Total	-1,270	-$63,000,000	-$128,000,000	-$367,000,000

Economic impacts caused by estimated yield reductions would also reduce annual revenue collections by the State of Iowa. While the agricultural sector in Iowa is not heavily taxed, as the economic impacts ripple through the Iowa economy, sales tax, licenses, and income tax collections would all be reduced. Below, we analyze the expected annual revenue collection reductions under our baseline and 50-percent additional adaptation scenarios and conclude that annual revenue collections would have been reduced by between $4.6 million to $8.3 million.[51]

Potential Iowa State Government Tax Collections Consequences

General & selective sales taxes	-$4,000,000
Licenses	-$800,000
Individual income tax	-$3,000,000
Corporation income tax	-$400,000
All other taxes	-$100,000
Total Taxes	-$8,300,000

Potential Iowa State Government Tax Collections Consequences at 50 Percent Additional Adaptation

General & selective sales taxes	-$2,000,000
Licenses	-$400,000
Individual income tax	-$2,000,000
Corporation income tax	-$200,000
All other taxes	-$43,000
Total Taxes	-$4,643,000

[51] To put this in context, in 2020, the Iowa legislature passed budget cuts to Iowa's public universities totaling $8 million. Id.

Derivative Impacts to the Iowa Economy: Conclusion

This report took estimated weighted average annual corn, soybean, and silage crop volume reductions due to climate change for the 2020 to 2039 period and applied those reductions to conditions from 2019. In effect, this simulation describes the economic effects that would have transpired if those annual average reductions occurred in 2019.

The modeling is not capable of anticipating what economic losses would be, on average, for the future as commodity prices, input prices, labor and technology costs, farm policy, and land utilization are all variables that will change over time and carry a great deal of uncertainty. Further, this analysis does not just reduce returns to farmers; it assumes that over the next 20 years there will be associated reductions in crop production on marginal land. Therefore, these results reflect not just lower volumes per acre, but fewer cropped acres as well. In so doing, however, no assumptions are made as to alternative uses to which those foregone acres would be put, including into alternative crops or conservation programs. Note, however, that the 50% additional adaptation scenario is designed to factor in this uncertainty and show a range of likely economic impacts that include adaptive practices such as crop switching.

VI. POLICY RECOMMENDATIONS

State and local governments in Iowa should adopt policies, programs, and incentives to address climate change and avert or minimize financial impacts of climate on Iowa. Such efforts should focus on climate mitigation – efforts that reduce or stabilize heat-trapping gases in the atmosphere by limiting the amount of greenhouse gases (GHGs) entering the atmosphere – and should be designed to also help farmers further adapt to climate change thereby reducing the scale of negative economic impacts. Policies that create financial incentives for Iowa farmers to limit GHG emissions and improve soil health would help address the underlying climate challenges and may enhance the financial bottom line for farmers in the state. Given the limited financial resources available, state and local governments should work closely together and with the federal government to stretch limited resources and increase efficiency.

The following sections of this report highlights some existing state and federal programs that support climate mitigation and adaptation and includes some options that the State of Iowa and local governments should consider adopting. This list is not exhaustive and is not listed in order of priority.

Management Practices

Policies should seek to incentivize management practices that limit GHG emissions, improve soil health, and build resilience in agriculture.

Nutrient Management- Policies should support agricultural producers in reducing emissions from nitrogen fertilizers and manure applied to farmers' fields, for instance through preparing and implementing nutrient management plans, assisting in soil sampling, and providing aid in identifying site-specific information regarding sensitive areas and potential nutrient-loss pathways.

Soil Health and Organic Matter- Policies should incentivize soil-health improvement and soil-management practices. Conservation tillage practices such as no-till and strip-till and cover crops can protect and enhance soil resources. These practices can improve soil health, increase organic matter in upper soil layers, and reduce on-farm fuel use.

Research

Governments should support research to inform the management of carbon-cycle dynamics through soil amendments, tillage, and the use of perennials; controlling water through drainage, storage, and irrigation; and understanding the root structures, water- and nitrogen-use efficiencies, and declining nutritional values of plants.[52]

Technology- Programs should provide funding for the development of climate-resilient seeds, improvements to nutrient management, and other climate-adaptation technologies. The National Institute of Food and Agriculture (NIFA) funds studies that develop new approaches for the agriculture sector to adapt to changing environmental conditions.

Applied Research- Governments should strive to ensure that research is made readily available to farmers to implement on the ground. Enabling farmers to access data and learn from others at a broad scale is a key to implementation. The State of Iowa should consider investing additional funding in its public university system to assist with creation of practical, publicly available research.

Incentives

There are existing programs and incentives that encourage landowners to participate in conservation practices. For farmers who are able to utilize Natural Resource Conservation Service (NRCS) programs, these programs generally have widespread support. The State of Iowa should look for opportunities to promote these programs and should consider providing cost-share to expand the scope of these programs where appropriate.

Farm Bill Conservation Programs and USDA Grants- Agricultural producers are familiar with, and utilize, Farm Bill programs. Many existing programs utilize and incentivize climate-friendly practices such as conservation tillage and nutrient management. The Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), and the Regional Conservation Partnership Program (RCPP) all provide services to agricultural producers that can help meet climate challenges. Similarly, the Rural Energy for America Program (REAP) can assist farms with the installation costs for renewable energy equipment.

The Biden Administration is expected to seek to use existing conservation programs to promote climate change mitigation and adaption. We also expect that the Biden Administration will aim to innovate in this space either through the use of existing tools or through advocacy for new programs as part of the upcoming farm bill, such as the establishment of a carbon bank. The State of Iowa and local governments in Iowa should engage proactively in these discussions and in efforts to expand existing programs and to develop new programs to help Iowa farmers.

Tax Credits- The State of Iowa should consider providing tax credits to farmers who implement GHG sequestration and conservation best management practices and should encourage development of federal tax credits to achieve these same goals.

Carbon Markets- Market-based opportunities can play an important role in helping to mitigate climate change. Carbon markets would allow farmers to generate credits by

[52] Takle, Eugene S. and William J. Gutowski Jr. 2020. *Iowa's Agriculture is Losing its Goldilocks Climate*. Physics Today 73, 2, 27.

implementing conservation practices. Historically, carbon markets have been difficult to implement in agricultural contexts: uncertainty and complexity have limited participation from potential market investors and agricultural landowners. Nonetheless, efforts to reduce transaction costs and recent approaches (such as jurisdictional instead of project-based crediting) show promise in overcoming these limitations. If the Biden Administration seeks to implement carbon markets that can benefit Iowa farmers, the State of Iowa should engage as an active participant in such discussions.

Crop Insurance and Agricultural Lending- Federally subsidized crop insurance is an important shock absorber for farmers, but it is not sufficient to protect farmers or the broader agricultural economy from climate risk over the long-term. The USDA's Economic Research Service estimates that without farmer adaptation to climate change, the cost of the Federal Crop Insurance Program could increase by over a third in the second half of this century.[53] In addition, the crop insurance program relies on historical crop yield data, which may not accurately predict future yield impacts under climate change. The State of Iowa should advocate for changes to the federal crop insurance program to incorporate the risk reduction benefits of resilient farm management strategies in order to offer an incentive to farmers who take action to reduce their yield risks.

The State of Iowa may also be able to engage with agricultural lenders to create incentives for Iowa famers who adopt practices that help with climate mitigation or adaption. The Commodity Futures Trading Commission (CFTC) recently released a report from its Climate-Related Market Risk Subcommittee of the Market Risk Advisory Committee titled "Managing Climate Risk in the U.S. Financial System." The report recommends that federal regulators should assess the exposure and implications of climate-related risks for the portfolios and balance sheets of the government-sponsored enterprises (GSEs), a category which includes the Farm Credit System, and strongly encourage the GSEs to adopt and implement strategies to monitor and manage those risks. Another recent report titled "Financing Resilient Agriculture: How agricultural lenders can reduce climate risk and help farmers build resilience" by Environmental Defense Fund is renewing the conversation on the climate risks faced by agricultural lenders and their role in collaborating with farmer borrowers to build resilience.

Technical Expertise

There are myriad existing and proposed federal programs that may be available to Iowa farmers. Many farmers, however, do not have time to navigate complicated and complex programs and paperwork. Further, as we look towards the possibility of more complex transactions involving carbon banking and requiring extensive technical verification, farmers may need assistance if they are to engage in such offerings in addition to running their core business. Assistance with project management and administration is as important as technical assistance for project implementation. The State of Iowa should consider establishing additional mechanisms to support farmers as they apply for federal assistance and track and report progress.

[53] Crane-Droesch, Andrew et al. (2019, July.) Climate change and agricultural risk management into the 21st century. U.S. Department of Agriculture Economic Research Service. Retrieved from: https://www.ers.usda.gov/webdocs/publications/93547/err-266.pdf?v=9932.1

CONCLUSION

Agriculture is the lifeblood of Iowa's rural economy. If corn and soy yields are negatively impacted by climate change as projected by Hsiang et al., Iowa could see average annual gross farm revenues reduced by $4.88 billion over the course of the next decade. The Hsiang et al. modeling suggests that ninety-two counties in Iowa could experience decreases in average annual gross farm revenues with eight counties experience gross farm revenue losses over a ten-year period of more than $100 million. In the case study examined in this report, the sample farm we examined in central Iowa would have lost $50,000 to $90,000 per year in revenue due to yield reductions projected by Hsiang et al. Such reductions in farm revenue at the state, county, and individual farm level would reduce overall economic output for Iowa, cause a loss of jobs and reduce revenue collections by the State of Iowa impacting funding for education, infrastructure, and other government services.

Ignoring climate-related risks to agricultural production in Iowa is expected to have grave consequences. Hsiang et al. have modeled the yield impacts on corn and soybeans in Iowa for the coming decades. Furthermore, as Tackle and Gutowski state in their study, Iowa's Agriculture is Losing its Goldilocks Climate, "Beyond midcentury, increases in growing-season heat are projected to lead to substantial crop yield reductions."[54] The costs of inaction would detrimentally impact the financial health of individual producers and state and local governments in Iowa. The range of revenue disruption depends in large measure on the degree to which technology, management changes, and government support can mitigate yield reductions caused by climate change, and the extent to which agricultural prices would rise in response. It is imperative that farmers and the State of Iowa focus on climate change mitigation and adaptation strategies.

In the past, Iowa's agricultural producers have successfully adopted new practices and implemented new technologies to address changing conditions. There is a risk in assuming this will continue to be possible given larger climatic impacts. Timely and sensible actions should be implemented to address climate change impacts. Landowners have demonstrated they are willing to participate in existing agricultural programs and implement sound practices. State and local policies in Iowa should focus on eliminating barriers to participation, adequately shaping sound management and adaptation practices, ensuring agricultural producers can survive extreme weather events, and supporting and expanding existing programs. Enacting policies that ensure climate resilience can reduce the risk for Iowa's agricultural producers, save farms, protect revenue, and help Iowa maintain its position as the global provider of safe, high-quality food. At the same time, it is important to realize there is a limit to adaptation. States with a strong agricultural economy such as Iowa should do everything in their power to reduce the likelihood of extreme temperature changes by supporting overall climate mitigation policies.

[54] Takle, Eugene S. and William J. Gutowski Jr. 2020. Iowa's Agriculture is Losing its Goldilocks Climate. *Physics Today* 73, 2, 33.

Appendix A – Hsiang et al. County-Level Yield Projections

The county-level yield projections found here were prepared by Environmental Defense Fund. It was compiled with Iowa specific data (median values, RCP8.5, 2020-2039, total ag yields, county level) that was pulled from the larger Rhodium/Climate Impact Lab data set.[55] ArcMap was used to join county-level data from the US Census Bureau's 2017 TIGER/Line shapefile with median data (column q0.5) from the Hsiang et al. study (yields-total-rcp85-2020-absolute.csv and yields-total-rcp8.5-2020b.csv).

County Name	Ag Yields	Ag Yields % Change
Adair County	-35323.67151	-7.17031765
Adams County	-12838.02461	-4.508204753
Allamakee County	-6658.779015	-2.540533197
Appanoose County	-4945.242687	-3.679251689
Audubon County	-12116.05865	-2.377116089
Benton County	-26652.25485	-2.875623585
Black Hawk County	-27773.88672	-3.925878861
Boone County	-25257.49097	-3.27421231
Bremer County	-23386.23294	-4.009191568
Buchanan County	-12443.19206	-1.586849769
Buena Vista County	-4156.303852	-0.495408787
Butler County	-12129.41576	-1.571916207
Calhoun County	-17551.51292	-2.043907065
Carroll County	-31643.70277	-3.979607687
Cass County	-36987.95387	-6.438591474
Cedar County	-25629.03626	-3.399256327
Cerro Gordo County	-12284.75314	-1.513526253
Cherokee County	-22371.56189	-3.095653202
Chickasaw County	4048.081763	0.672190447
Clarke County	-4712.588287	-3.8102661
Clay County	-9435.523975	-1.26522525
Clayton County	-22969.04817	-4.054395254
Clinton County	-6088.521113	-0.725099742
Crawford County	-45448.21867	-5.17912374
Dallas County	-30527.38299	-4.685829047
Davis County	-9185.310857	-5.725631856
Decatur County	-7814.767368	-5.777311215
Delaware County	-16291.95187	-2.129783957
Des Moines County	-15253.91297	-4.156620827

[55] Rising, James, Amir Jina, Solomon Hsiang, Robert Kopp, & Michael Delgado. 2017. Total Agricultural Climate Impact Distributions [Data set]. Zenodo. http://doi.org/10.5281/zenodo.581696.

County Name	Ag Yields	Ag Yields % Change
Dickinson County	1237.48574	0.283592663
Dubuque County	-5006.712524	-0.997046179
Emmet County	1737.762282	0.298255651
Fayette County	-3610.239824	-0.435155571
Floyd County	-4222.175256	-0.638906691
Franklin County	-23679.08098	-2.653482844
Fremont County	-39489.57838	-7.384597542
Greene County	-39434.52266	-4.74937599
Grundy County	-19348.72999	-2.271675734
Guthrie County	-24648.941	-4.996074539
Hamilton County	-26630.74511	-2.952927676
Hancock County	-42.65333383	-0.004990788
Hardin County	-24900.19946	-2.830883838
Harrison County	-49856.09063	-6.563321826
Henry County	-25086.11164	-6.164699107
Howard County	3757.600435	0.711454981
Humboldt County	-21805.16326	-3.194346788
Ida County	-25116.53385	-4.433187207
Iowa County	-16653.16523	-3.028051954
Jackson County	-19124.49795	-5.1342026
Jasper County	-37485.72648	-4.288551444
Jefferson County	-23402.34234	-7.98991859
Johnson County	-37425.57408	-7.410154275
Jones County	-15501.08581	-2.463210124
Keokuk County	-20135.74973	-4.100347254
Kossuth County	-35.25523168	-0.002289996
Lee County	-23095.37464	-6.469472183
Linn County	-35888.61163	-5.223684347
Louisa County	-12874.2334	-3.548402416
Lucas County	-5023.775073	-5.040858542
Lyon County	-20151.70281	-2.655606633
Madison County	-13348.41285	-4.441465624
Mahaska County	-27689.60663	-4.649196455
Marion County	-20440.71326	-5.607910511
Marshall County	-25911.3705	-3.373904531
Mills County	-40870.66106	-8.869280387
Mitchell County	-1206.596333	-0.190009192
Monona County	-20368.97067	-2.757368451
Monroe County	-4536.627971	-4.028712413

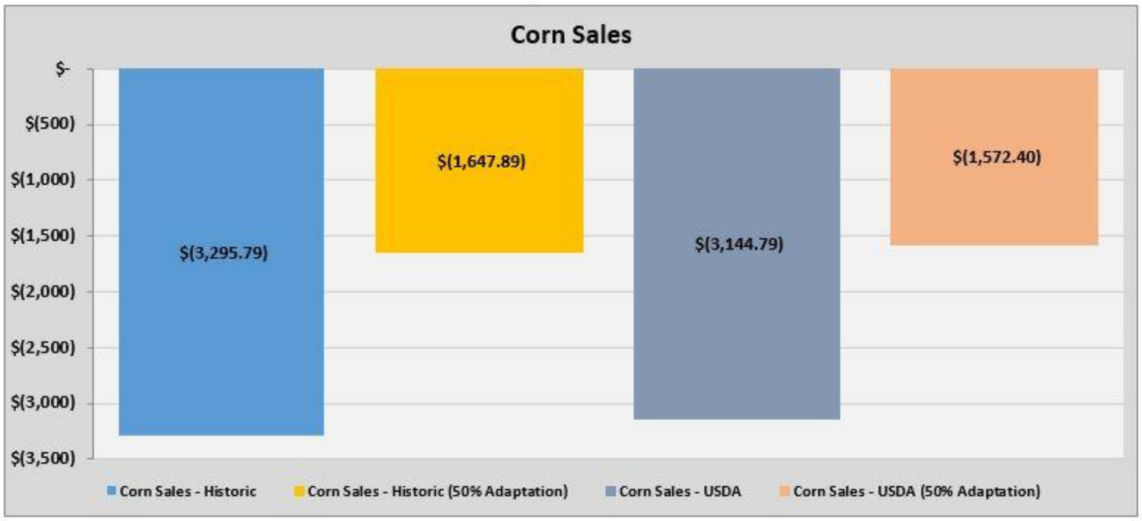
County Name	Ag Yields	Ag Yields % Change
Montgomery County	-38458.48644	-8.862712777
Muscatine County	-26934.9139	-6.329905491
O'Brien County	-19037.97254	-2.287990329
Osceola County	3593.036297	0.625062278
Page County	-45061.22028	-9.621094061
Palo Alto County	1057.198042	0.133699012
Plymouth County	-30011.23848	-2.864557244
Pocahontas County	-27044.88349	-2.96491215
Polk County	-35691.99142	-7.543254353
Pottawattamie County	-100668.9474	-9.28159738
Poweshiek County	-15052.90084	-2.293939061
Ringgold County	-9046.159411	-4.790333942
Sac County	-18577.73498	-2.365194302
Scott County	-33674.90937	-5.95731387
Shelby County	-39934.80012	-5.380193954
Sioux County	-58901.75258	-5.112499204
Story County	-18984.5565	-2.256975833
Tama County	-22098.01356	-2.578206519
Taylor County	-24097.72514	-7.751803009
Union County	-10246.24827	-4.483174019
Van Buren County	-17470.34014	-9.294227485
Wapello County	-13510.60154	-5.396125873
Warren County	-14038.47604	-4.480393943
Washington County	-28625.65582	-5.094408521
Wayne County	-10032.96979	-4.895513698
Webster County	-32781.70662	-3.129118558
Winnebago County	-500.664522	-0.080441641
Winneshiek County	-16891.94265	-3.119575232
Woodbury County	-60228.06694	-6.902262159
Worth County	10461.02958	1.902978496
Wright County	-25201.90535	-2.767775489

Appendix B – Statewide Farm Revenue Impacts

Statewide – Corn

Over a ten-year period, decreasing corn yields due to climate change would **reduce statewide gross farm revenues from corn by 2-3%** reducing revenue to Iowa farmers **$1.6 billion to $3.3 billion**.[56]

Statewide - Impact to Gross Corn Sales



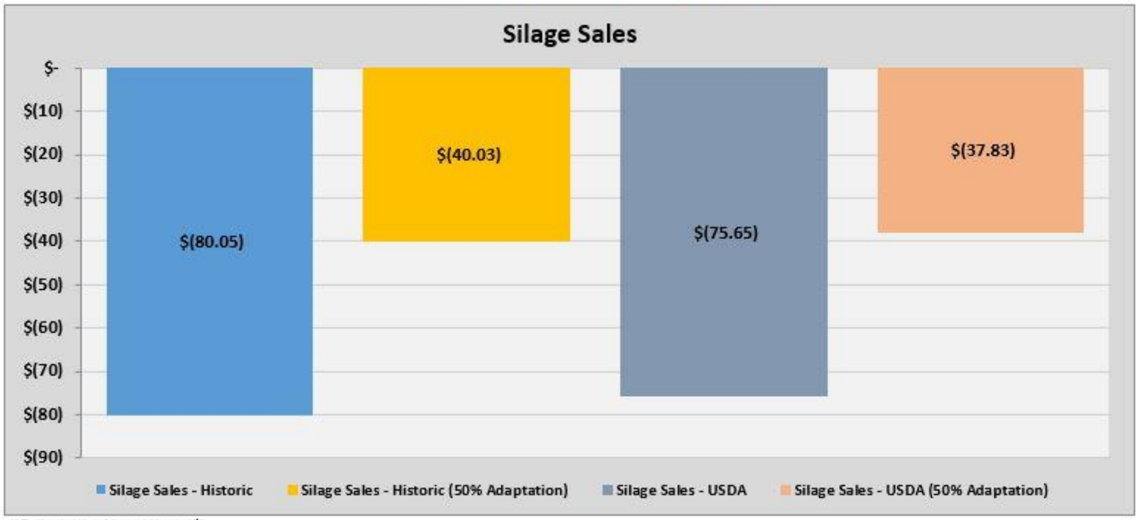
**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Statewide – Silage

Over a ten-year period, decreasing yields of silage due to climate change would **reduce statewide gross farm revenues from silage by 2-3%** reducing revenue to Iowa farmers by an additional **$38 million to $80 million.**[57]

56 The Historic-Projected Model projects 10-year gross farm revenues from corn sales at $99.6 billion while the USDA-Projected Model projects slightly lower gross farm revenues from corn of $94.2 billion.
57 The Historic-Projected Model projects 10-year gross farm revenues from silage at $2.8 billion while the USDA-Projected Model projects slightly lower gross farm revenues from silage of $2.6 billion.

Statewide - Impact to Gross Silage Sales

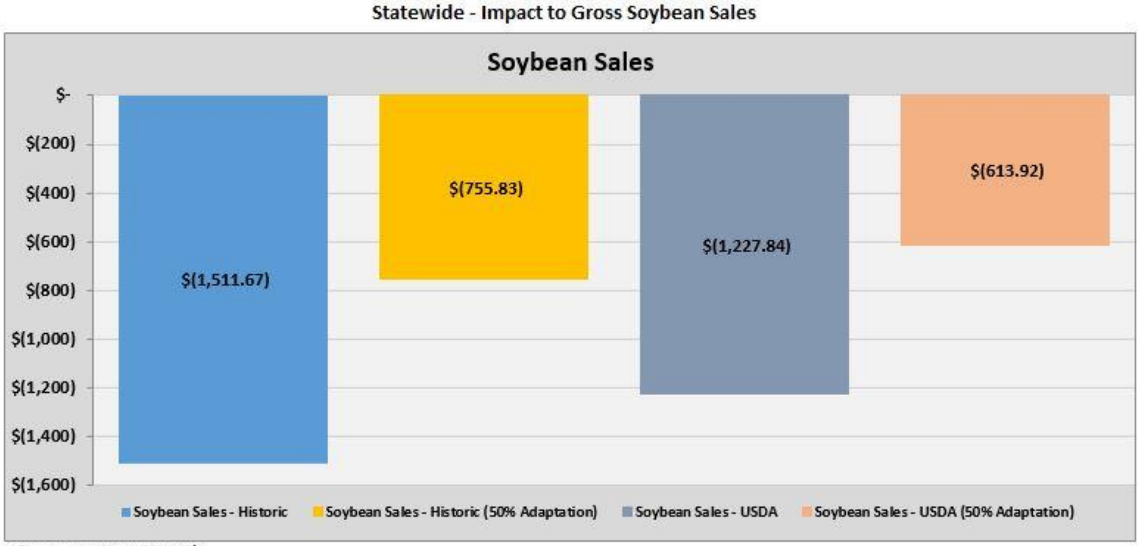


Represented in millions ($)
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Statewide – Soybeans

Over a ten-year period, decreasing soybean yields due to climate change would **reduce statewide gross farm revenues from soybean by 2-4%** reducing revenue to Iowa farmers by an additional **$613 million to $1.5 billion.**[58]

Statewide - Impact to Gross Soybean Sales



Represented in millions ($)
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

[58] The Historic-Projected Model projects 10-year gross farm revenues from soybeans at $42.2 billion while the USDA-Projected Model projects slightly lower gross farm revenues from soybeans of $34.3 billion.

Appendix C – County-Level Farm Revenue Impacts

County-Level Analysis — Pottawattamie County (Largest Decrease)

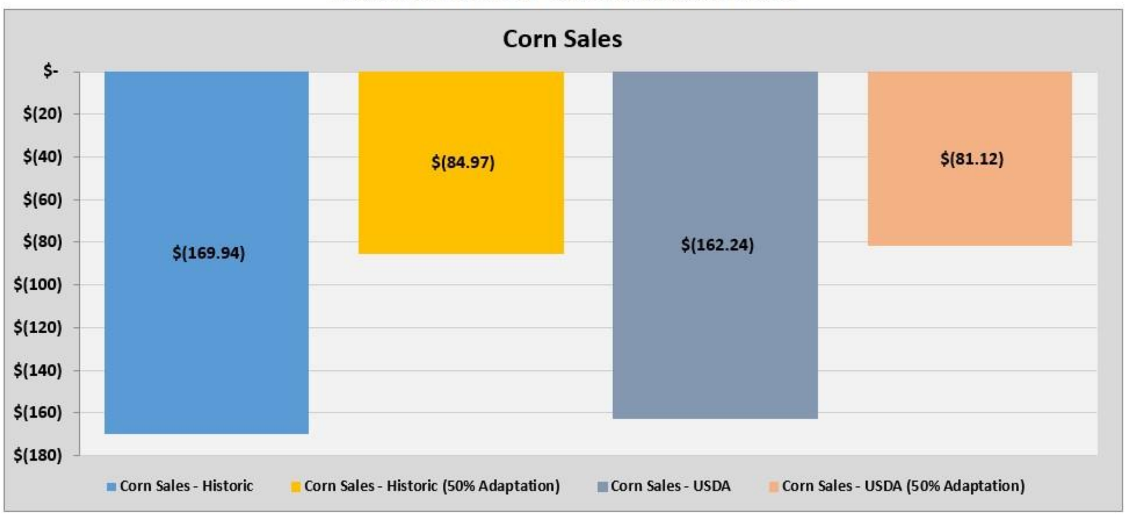
Based on the Hsiang et al. yield modeling, Pottawattamie County would experience the largest decrease in gross farm revenues due to climate change impacts. The following charts detail revenue losses in Pottawattamie County by corn, silage, soybeans, and total crops.[59]

Pottawattamie County - Corn

Ten-year revenue losses from decreasing corn yields for Pottawattamie County are modeled to range from $81 million (assuming 50 percent mitigation) to $170 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Pottawattamie County corn sales would decline by $169,944,000 while the USDA-projected model indicates corn sales would decline by $162,238,000. With 50 percent adaptation, gross farm revenue impacts from reduced corn yields would range from $81,119,000 (USDA-projected) to $84,972,000 (historic-projected model).

By way of comparison, Pottawattamie County revenues for the year beginning on July 1, 2020 are projected to be approximately $82 million.[60] The low-end ten-year estimated farm revenue losses from decreasing corn yields alone would roughly equal this year's entire county budget.

Pottawattamie County - Impact to Gross Corn Sales



**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Pottawattamie County – Silage

Revenue impacts from decreasing silage yields for Pottawattamie County are expected to range from -$800,000 (assuming 50 percent mitigation) to -$1.7 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total

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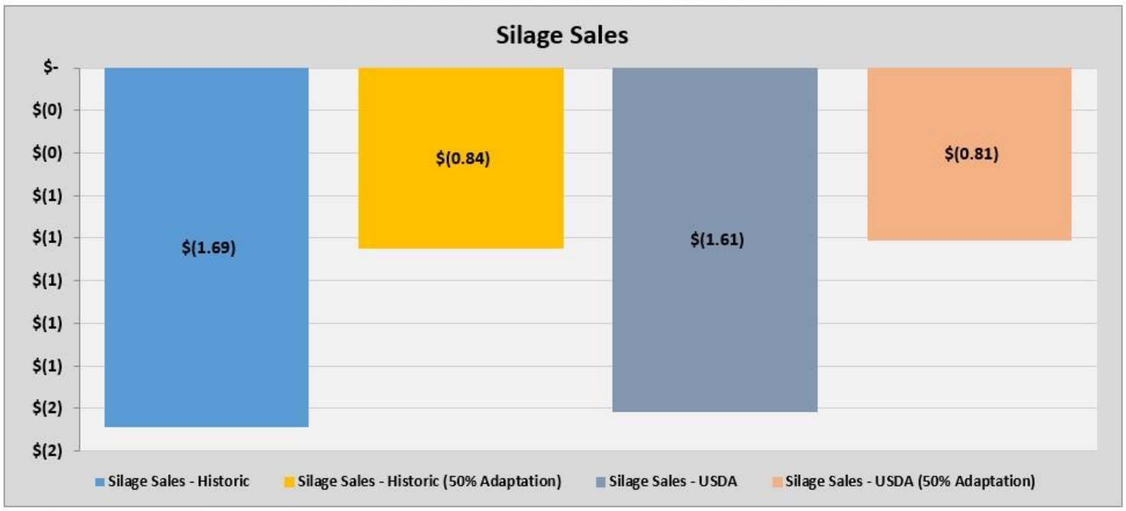
[59] As noted throughout, climate modeling at the county level is inherently uncertain. As such, the discussion of county-level impacts should be used to inform a general discussion about the range of impacts that would be experienced by Iowa counties under an RCP8.5 scenario rather than as a specific forecast for each individual county.

Note too that revenue losses in this report are measured against future baseline projections not against current revenues.

[60] Leu, John, "Pottawattamie County budget for coming year approved", *The Daily Nonpareil*, 9 April 2020.

Pottawattamie County silage sales would decline by $1,690,000 while the USDA-projected model indicates silage sales would decline by $1,613,000. With 50 percent adaptation, gross farm revenue impacts from reduced silage yields would range from -$807,000 (USDA-projected model) to -$845,000 (historic-projected model).

Pottawattamie County - Impact to Gross Silage Sales

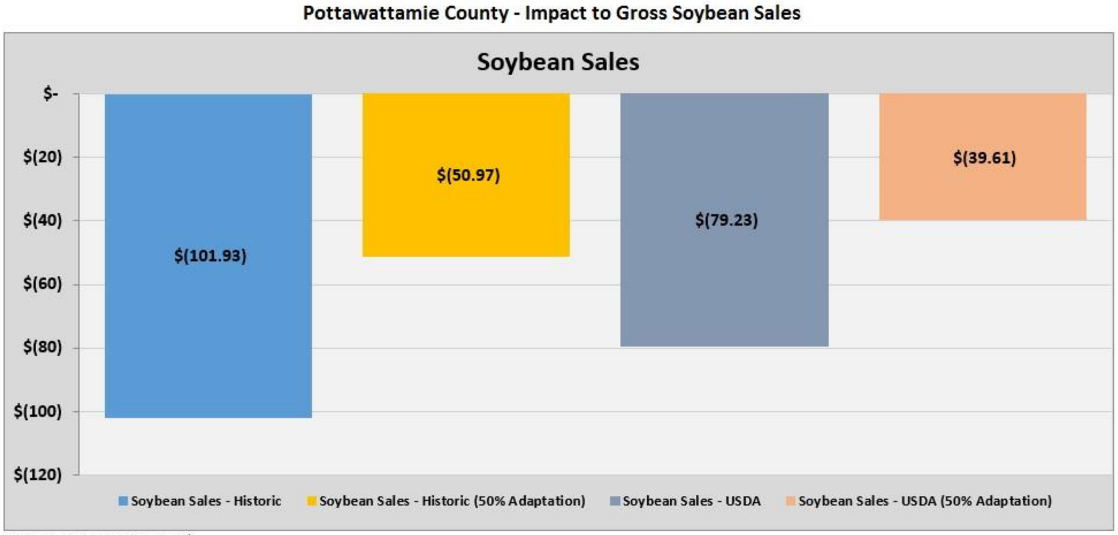


**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Pottawattamie County – Soybeans

Revenue impacts from decreasing soybean yields for Pottawattamie County are expected to range from -$40 million (assuming 50 percent mitigation) to -$100 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Pottawattamie County soybean sales would decline by $101,933,000 while the USDA-projected model indicates soybean sales would decline by $79,228,000. With 50 percent adaptation, gross farm revenue impacts from reduced soybean yields would range from -$39,614,000 (USDA-projected model) to -$50,967,000 (historic-projected model).

Pottawattamie County - Impact to Gross Soybean Sales

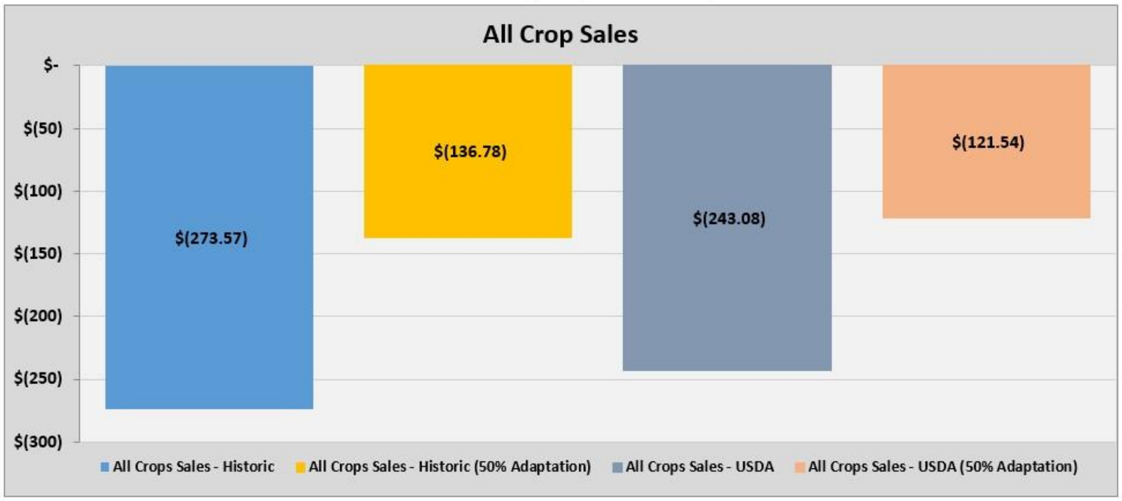


**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Pottawattamie County – Total Crops

Revenue impacts from decreasing yields for total crops in Pottawattamie County are expected to range from -$122 million (assuming 50 percent mitigation) to -$274 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Pottawattamie County crop sales would decline by $273,567,000 while the USDA-projected model indicates crop sales would decline by $243,079,000. With 50 percent adaptation, gross farm revenue impacts from reduced crop yields would range from -$121,539,000 (USDA-projected model) to -$136,783,000 (historic-projected model).

Pottawattamie County - Impact to All Crop Sales



**Represented in millions ($)*

***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

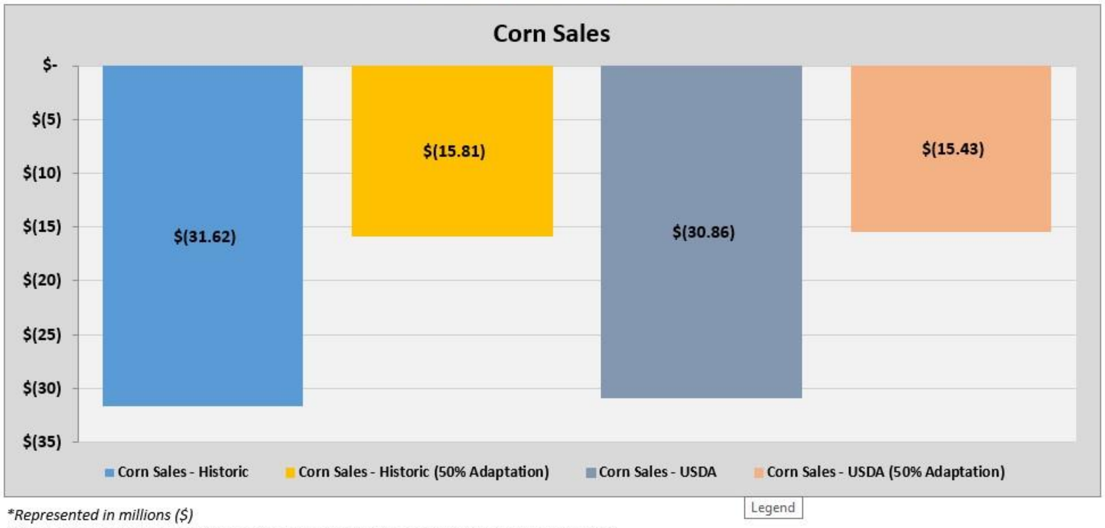
County-Level Analysis – Humboldt County (Median County)

Under the Hsiang et al. analysis, Humboldt County represents the mean county in Iowa in terms of yield declines. In other words, under the Hsiang et al. modeling, half of the counties in Iowa would perform worse that Humboldt County and half would perform better in terms of crop yield impacts. The following charts detail revenue losses in Humboldt County by corn, silage, soybeans, and total crops.

Humboldt County – Corn

Ten-year revenue impacts from decreasing corn yields in Humboldt County are expected to range from -$15 million (assuming 50 percent mitigation) to -$32 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Humboldt County corn sales would decline by $31,618,000 while the USDA-projected model indicates corn sales would decline by $30,859,000. With 50 percent adaptation, gross farm revenue impacts from reduced corn yields would range from -$15,429,000 (USDA-projected model) to -$15,809,000 (historic-projected model).

Humboldt County - Impact to Gross Corn Sales

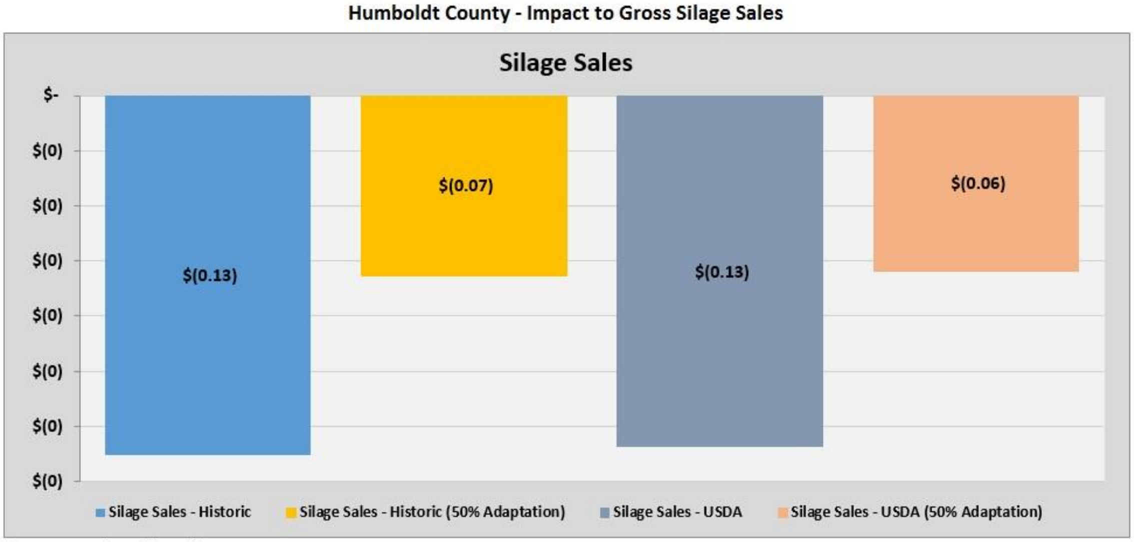


*Represented in millions ($)
**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

Humboldt County – Silage

Revenue impacts from decreasing silage yields in Humboldt County are expected to range from -$64,000 (assuming 50 percent mitigation) to -$130,000 (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Humboldt County silage sales would decline by $130,000 while the USDA-projected model indicates silage sales would decline by $127,000. With 50 percent adaptation, gross farm revenue impacts from reduced silage yields would range from -$64,000 (USDA-projected model) to -$65,000 (historic-projected model).

Humboldt County - Impact to Gross Silage Sales

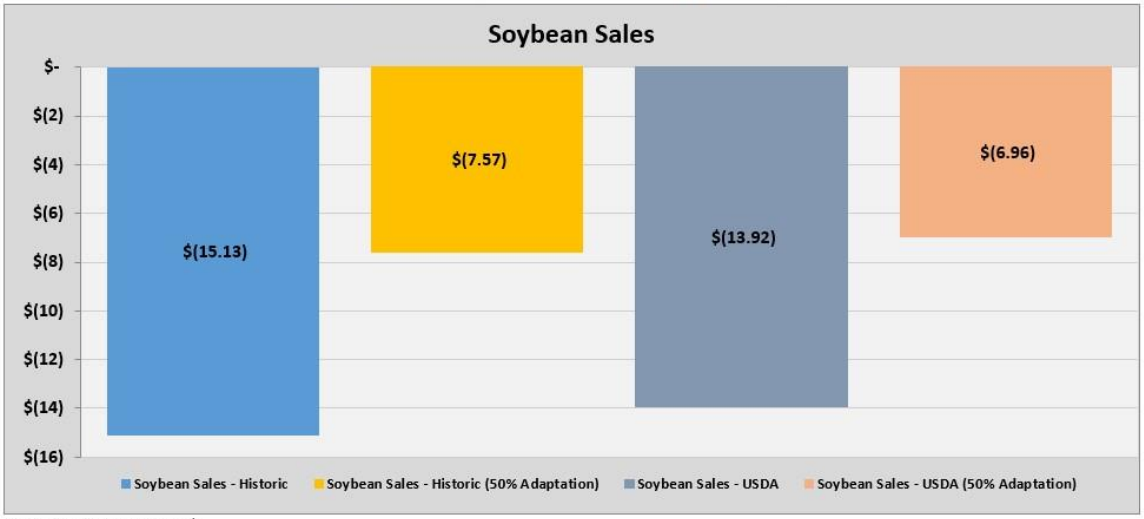


*Represented in millions ($)
**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

Humboldt County – Soybeans

Revenue impacts from decreasing soybean yields in Humboldt County are expected to range from -$7 million (assuming 50 percent mitigation) to -$15 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Humboldt County soybean sales would decline by $15,132,000 while the USDA-projected model indicates soybean sales would decline by $13,924,000. With 50 percent adaptation, gross farm revenue impacts from reduced soybean yields would range from -$6,962,000 (USDA-projected model) to -$7,566,000 (historic-projected model).

Humboldt County - Impact to Gross Soybean Sales

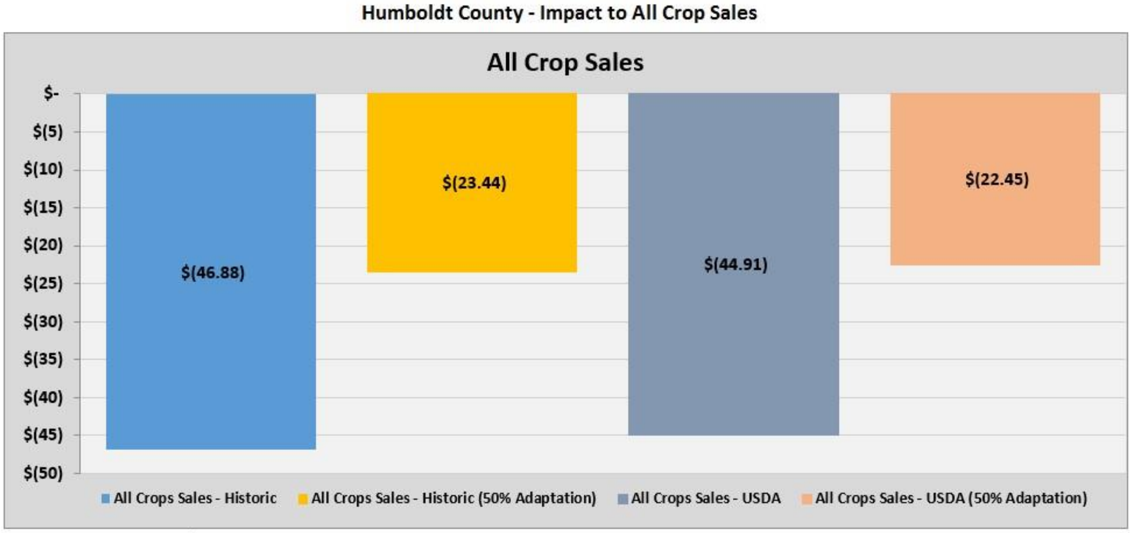


**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

Humboldt County – Total Crops

Revenue impacts from decreasing total crop yields in Humboldt County are expected to range from -$22 million (assuming 50 percent mitigation) to -$47 million (assuming zero mitigation). The historic-projected model shows that without accounting for adaptation and mitigation, total Humboldt County crop sales would decline by $46,880,000 while the USDA-projected model indicates total crop sales would decline by $44,910,000. With 50 percent adaptation, gross farm revenue impacts from reduced crop yields would range from -$22,455,000 (USDA-projected model) to -$23,440,000 (historic-projected model).

Humboldt County - Impact to All Crop Sales



**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

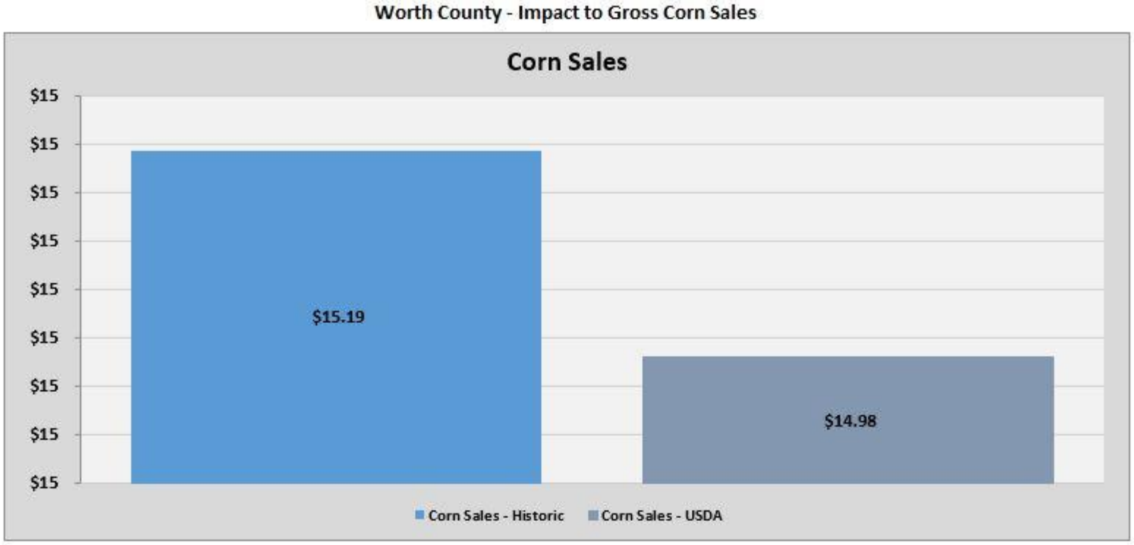
County-Level Analysis – Worth County (Largest Increase)

Not all Iowa counties would suffer loss in yield and revenue. The Hsiang et al. modeling suggests that seven northern Iowa counties would experience a modest increase in yields and a corresponding increase in farm revenues. These counties are Emmet, Palo Alto, Dickenson, Osceola, Howard, Chickasaw and Worth County.

Worth County is projected to see the largest increase with corn leading the way. Ten-year revenue impacts from increasing corn yields would be expected to range from +$14,981,000 (USDA-projected model) to +$15,193,000 (historic-projected model).[61] Revenue impacts from increasing silage yields would be expected to range from +$123,000 (USDA-projected model) to +$125,000 (historic-projected model) and the county could expect farm revenue increases from soybean yields to range from $6,378,000 (USDA-projected model) to $7,367,000 (historic-projected model).

In total, revenue impacts from increasing total crops yields in Worth County would be expected to range from between +$21,482,000 (USDA-projected model) to +$22,685,000 (historic-projected model).

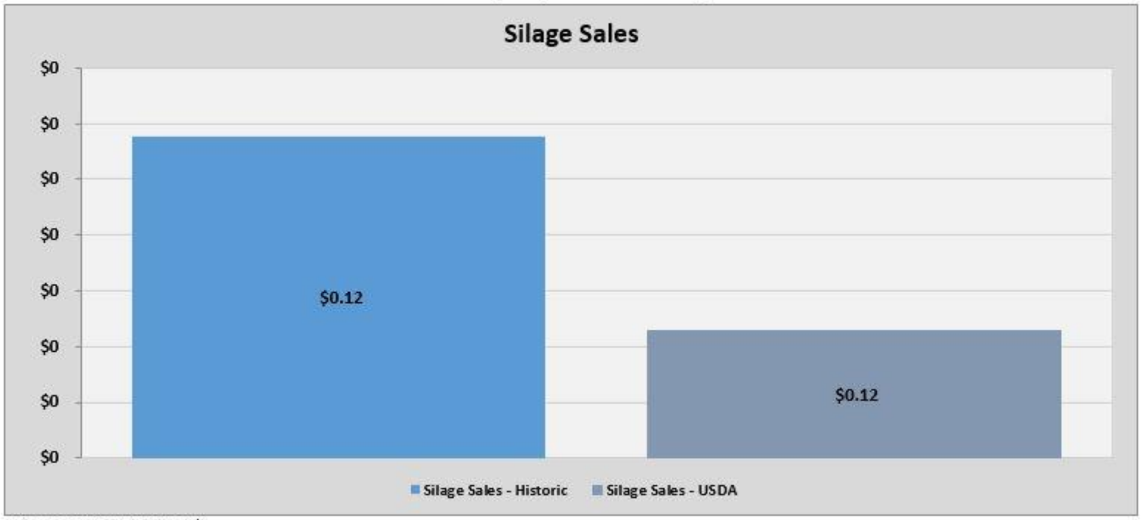
Worth County - Impact to Gross Corn Sales



**Represented in millions ($)*
***Economic impact calculated based on ten-year yield forecasts for the period 2021-2030*

[61] Because modeling suggests yields could increase in these seven counties, we have not factored in the role of mitigation or adaptation responses.

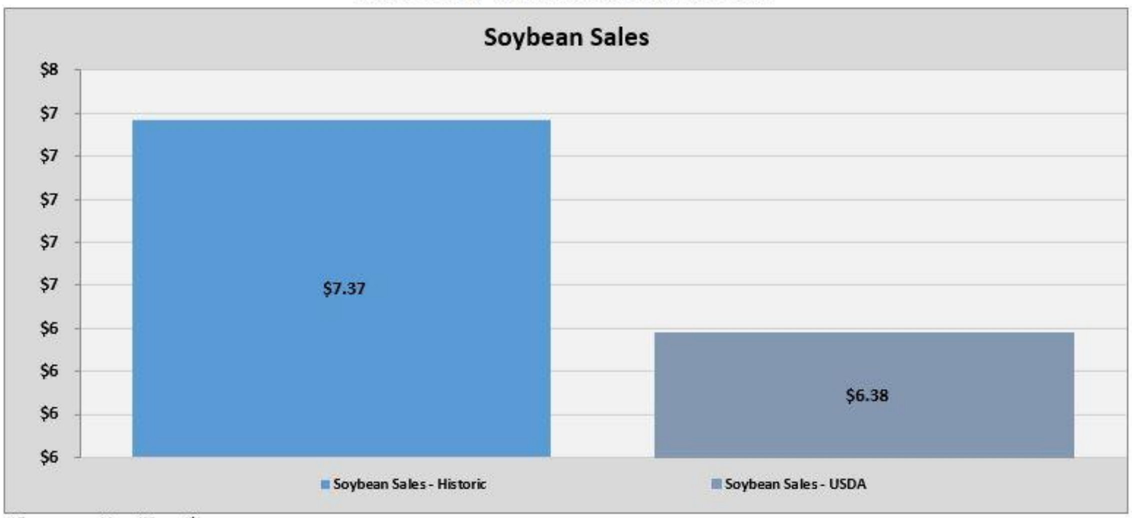
Worth County - Impact to Gross Silage Sales



*Represented in millions ($)

**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

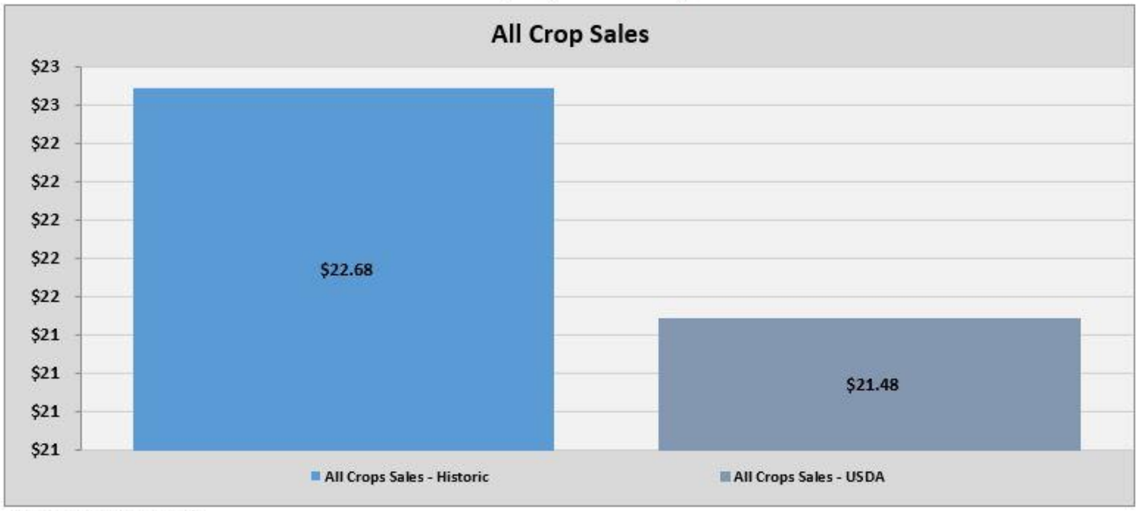
Worth County - Impact to Gross Soybean Sales



*Represented in millions ($)

**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

Worth County - Impact to All Crop Sales



*Represented in millions ($)

**Economic impact calculated based on ten-year yield forecasts for the period 2021-2030

Appendix D – Derivative Economic Impacts

In the first table, for the year 2019, a 3.4 percent reduction in the quantity of corn produced would have resulted in a loss of $293 million in output in that sector, which would have required the labor of 600 workers and proprietors making $25 million in labor income. This loss in direct activity would have resulted in $160 million in reduced indirect output among suppliers, reducing their employment by 900 jobs and labor income by $43 million. Losses in labor income in the direct and the indirect sector would have reduced induced output by $50 million, reducing that sector's labor income by $15 million to 360 jobholders. Summed, this reduction in the quantity of corn produced in Iowa would have reduced output by $503 million and value-added by $164 million, of which $83 million would have been labor income to 1,860 jobholders.

Simulated Economic Impact of Corn Losses Based on 2019 Crop Production

	Jobs	Labor Income	Value Added	Output
Direct	-600	-$25,000,000	-$60,000,000	-$293,000,000
Indirect	-900	-$43,000,000	-$76,000,000	-$160,000,000
Induced	-360	-$15,000,000	-$28,000,000	-$50,000,000
Total	-1,860	-$83,000,000	-$164,000,000	-$503,000,000

Next modeled was a 3.6 percent reduction in the quantity of soybeans produced. This would have reduced direct output in that sector in 2019 by $143 million, and labor income by $18 million to 140 farmworkers and proprietors. After all effects have multiplied through, total output in Iowa would have declined by $231 million and value-added would have declined by $90 million, of which $42 million would have been labor income to 680 total workers.

Simulated Economic Impact of Soybean Losses Based on 2019 Crop Production

	Jobs	Labor Income	Value Added	Output
Direct	-140	-$18,000,000	-$47,000,000	-$143,000,000
Indirect	-350	-$16,000,000	-$29,000,000	-$62,000,000
Induced	-190	-$8,000,000	-$14,000,000	-$26,000,000
Total	-680	-$42,000,000	-$90,000,000	-$231,000,000

A reduction in corn silage tonnage yields of 2.9 percent was considered next. The modeled effects suggest that if they had occurred in 2019, this yield impact would have reduced direct output by $10 million, costing 20 farm-level jobs making $700,000 in labor income. After accounting for all rounds of indirect and induced effects, the total statewide output would have declined by $15 million and value-added would have declined by $4.7 million, of which $2.1 million would have been labor income to 60 jobholders.

Simulated Economic Impact of Corn Silage Losses Based on 2019 Crop Production

	Jobs	Labor Income	Value Added	Output
Direct	-20	-$700,000	-$2,000,000	-$10,000,000
Indirect	-30	-$1,000,000	-$2,000,000	-$4,000,000
Induced	-10	-$400,000	-$700,000	-$1,000,000
Total	-60	-$2,100,000	-$4,700,000	-$15,000,000

Simulated Economic Impact of Corn Losses Based on 2019 Crop Production Assuming 50 Percent Additional Adaptation

	Jobs	Labor Income	Value Added	Output
Direct	-300	-$12,000,000	-$30,000,000	-$146,000,000
Indirect	-450	-$21,000,000	-$38,000,000	-$80,000,000
Induced	-180	-$8,000,000	-$14,000,000	-$25,000,000
Total	-930	-$41,000,000	-$82,000,000	-$251,000,000

Simulated Economic Impact of Soybean Losses Based on 2019 Crop Production Assuming 50 Percent Additional Adaptation

	Jobs	Labor Income	Value Added	Output
Direct	-70	-$9,000,000	-$24,000,000	-$71,000,000
Indirect	-180	-$8,000,000	-$15,000,000	-$31,000,000
Induced	-90	-$4,000,000	-$7,000,000	-$13,000,000
Total	-340	-$21,000,000	-$46,000,000	-$115,000,000

Simulated Economic Impact of Silage Losses Based on 2019 Crop Production Assuming 50 Percent Additional Adaptation

	Jobs	Labor Income	Value Added	Output
Direct	-10	-$300,000	-$800,000	-$5,000,000
Indirect	-10	-$600,000	-$900,000	-$2,000,000
Induced	-10	-$200,000	-$400,000	-$700,000
Total	-30	-$1,100,000	-$2,100,000	-$7,700,000