Report prepared for the Institute for Feed Education & Research

Grant Title: Impact of Non-GM Livestock and Poultry Feed on the U.S. Feed Industry

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Contents

Project Summary

The grant team undertook a thorough examination of the impact of non-genetically modified (GM) swine, layer, broiler, beef and dairy feed on the U.S. feed industry and sought to address nine priorities: 1) land occupation, 2) the environment, 3) input use, 4) shipment of goods, 5) energy use, 6) manufacturing equipment use and processes, 7) costs for segregating GM versus non-GM feed at animal feed manufacturing facilities, 8) livestock and poultry (broiler and layer) ration producer costs and 9) consumer costs.

The time period 2007-16 was examined with regard to land use in primary crop-producing states across the United States, revealing a net shift away from grassy habitat to crops, driven by higher net operating revenue for crops relative to grassy habitat. During this same period, GM crop technologies gained popularity. The potential for higher net operating revenues for organic crops slowed, but could not stop the reductions in planted acres of both total non-GM corn and total non-GM soybeans. The research revealed that corn is the driver for a farmer's production methodology preference (either GM or non-GM). For the time period under examination, non-GM planted corn acres decreased while non-GM soybean planted acres remained relatively stable. A shift away from non-GM holds quantifiable benefits having produced between 6.8 million to 15.9 million acres of land sparing and 35% to 65% less land conversion from grassy habitat to crop production than would have occurred otherwise. The current study calculated that, on a per acre basis, GM corn production emits 0.0086 MT/acre CO_2 less than non-GM corn production a decrease of 21% CO_2 per acre. No-till corn production emits 0.0185 MT/acre CO_2 less than conventional tillage corn production, a 42% decrease in CO_2 per acre. Based on an 5% increase in corn planted from GM corn to non-GM, GHG emissions would increase by 196,151 MT $CO_{2,}$, a 7% increase from current levels. If all corn were produced with non-GM technology, nitrogen emissions from fertilizer volatilization would be expected to increase by 2.7%; nitrogen emission from drainage leaching would be expected to increase 4.3% and nitrogen emission from denitrification would be expected to decrease by 0.6%.

From a monetary viewpoint, GM seeds are more expensive than non-GM seed and herbicide costs for GM corn production can be higher or lower than non-GM herbicide costs, depending on the area of production and chemicals used. For soybeans, GM seeds are typically priced higher than non-GM seed, but the herbicide costs are typically significantly lower than for non-GM soybean production. In most cases, the higher costs of GM seed are offset by lower costs for herbicides, insecticides and field operations when compared to non-GM production. In addition, to the extent that higher yields are realized with GM technology, the overall cost of production on a per bushel basis can be substantially lower with GM technology than with non-GM technology. For a farmer to consider switching to non-GM farming from GM-farming, a significant premium on non-GM grains is needed to offset the production cost difference.

The researchers undertook an examination of historical premiums for non-GM crops. U. S. Department of Agriculture price data was obtained for non-GM crops for the period January 2017-March 2020 and compared to the Chicago Board of Trade's pricing for conventional crops over the same time period. Interestingly, the USDA non-GM price data is divided into two regions: Region 1, which includes states east of the Mississippi River (Eastern Corn Belt) and Region 2, which includes states west of the Mississippi (Western Corn Belt). For corn, the average percentage premium across the three-year period was 7.51% in Region 1 and 0.61% in Region 2, and the average premium across both regions is 4.06%. For soybeans, the average percentage premium across the three-year period was 14.27% in Region 1, 10.60% in Region 2, and 12.43% across both regions. Across the period January 2017-March 2020, the average price premium for non-GM corn is $0.12 per bushel and for non-GM soybeans is $1.11 per bushel. The difference in price premium trends between Region 1 and Region 2 may pose different opportunities regionally for non-GM markets to emerge.

Fairly large-scale, systemic changes would be needed to accommodate increasing production of non-GM grain, as handling two differentiated product streams deviates from the high-volume commodity system that has developed in the U.S. The current study modeled these costs under a variety of feed supply chain scenarios as they would fall to farmers, elevators and feed mills. Isolation distance is the most expensive factor for achieving segregation at the farm, while testing is the most expensive at both the elevator and feed mill. Under the variety of scenarios examined, the cost of segregation on farm did not exceed $0.05 per bushel. At the elevator, it cost an additional $0.05 to $0.07 per bushel to handle and segregate non-GM soybeans compared with regular soybeans, and $0.07 to $0.09 per bushel for non-GM corn. Finally, at the feed mill, the additional cost of segregating non-GM ingredients ranges from $4.91 to $9.08 per ton for swine feed, $4.93 to $9.11 per ton for broiler feed, and $5.14 to $9.32 per ton for layer feed. At the feed mill, the choice of the segregation strategy has greater weight in the final additional cost, with spatial segregation entailing higher costs, especially for smaller facilities, relative to temporal segregation or dedication.

A second probabilistic model was created somewhat in parallel with the economic model described above to inform the extent of segregation strategies needed at the farm, elevator and feed mill to have a high probability of achieving three common trade tolerances for adventitious presence (AP, the unintended presence of low levels of transgenic material in non-GM ingredients or products) of GM in non-GM grains (0.9%, 3% and 5%). Again, scenarios were developed representing a variety of supply chain strategies useful for achieving segregation in the feed supply chain and then analyzed to determine the feasibility of meeting either a 0.9%, 3% or 5% tolerance level under that scenario. Incoming grain impurity has a strong influence on the level of adventitious presence. For all of the segregation scenarios modeled, a 5% tolerance was achievable. Elevator configuration plays a significant role in determining segregation capability, with increased flexibility leading to a higher probability of achieving the lower tolerances for AP. But, a key finding is that even facilities that may not be ideally configured can still implement combinations of strategies and achieve AP goals with reasonable confidence. At the feed mill, a similar trend was generally true: the greater the flexibility, the more likely one could achieve lower tolerance levels for AP. But, for a feed mill with a single processing line, 0.9% AP was achievable with a robust combination of segregation strategies. An ongoing effort is the merging of modeling of economic costs and segregation implementation strategies, with an end goal of determining how much it costs to achieve compliance with a given tolerance level for AP under select supply chain scenarios.

Finally, armed with the knowledge generated on production costs, segregation costs, premiums, etc. associated with non-GM grains and feed produced with non-GM grains, and in tandem with data from the Livestock Marketing Information Center database, estimates of the cost to final product consumers of pork, chicken and eggs were determined. The cost of pork is estimated to increase by $0.64 per pound, which is a 16.71% increase. The retail price of pork produced with GM feed is $3.83 per pound whereas the estimated non-GM pork retail price is $4.47 per pound. For retail composite chicken, the price per pound increases by $0.25 per pound, which is a 13.09% increase. The retail price of composite chicken produced with GM feed is $1.91 per pound whereas the estimated non-GM composite chicken retail price is $2.16 per pound. The cost of eggs produced with GM feed is $1.80 per dozen. However, the estimated non-GM eggs would be $2.04 per dozen. So, there is an increase of $0.24 per dozen for GM eggs retail to non-GM eggs retail prices which is a 13.33% increase. For retail beef cutouts, the price per pound increases by $0.04 per pound, which is a 0.40% increase. The retail price of beef produced with GM feed is $8.81 per pound, whereas the estimated non-GM beef retail price is $8.85 per pound. For retail milk, the price increases by $0.08 per gallon, which is a 2.26% increase. The retail price of milk produced with GM feed is $3.33 per gallon, whereas the estimated non-GM milk retail price is $3.40 per gallon.

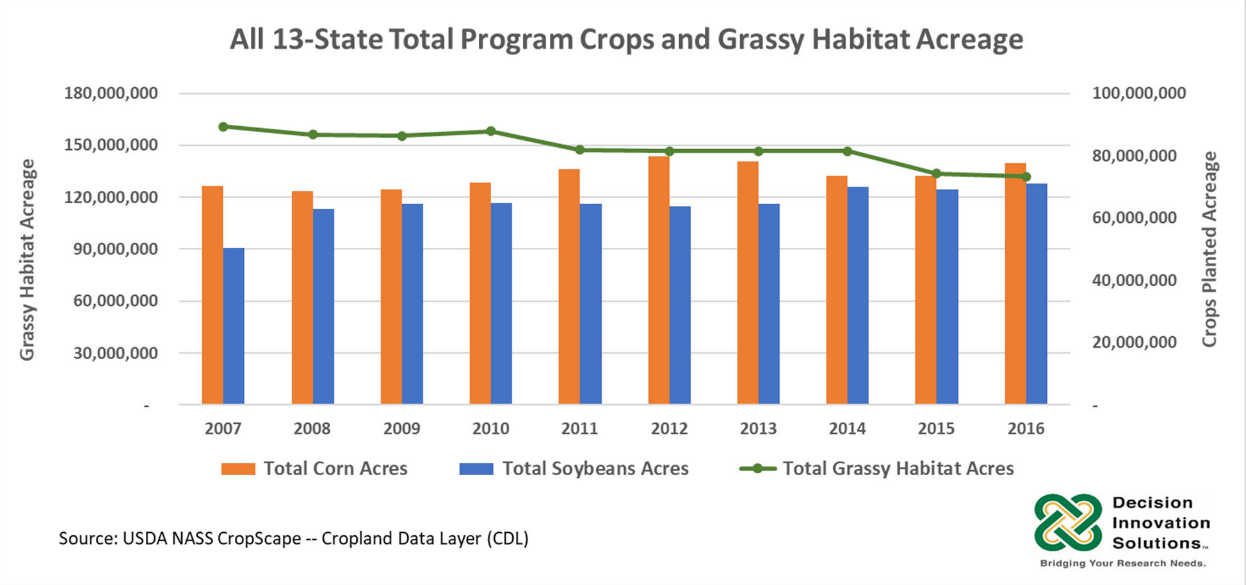
Objective 1: Examine the differences between GM and non-GM grain production, in terms of land, energy and input use (IFEEDER priorities 1, 2, 3, 5)

Land Use Study (Priority 1)

Introduction

For Priority 1, Decision Innovation Solutions (DIS) estimated land use changes that occurred in the 13 study area states including Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, Missouri, Arkansas, Michigan, South Dakota, Ohio, North Dakota and Wisconsin. These states were studied over three time periods: 2007-12, 2012-16 and 2007-16, to identify potential factors that contribute to land use changes. Land use change from crops to grassy habitat and grassy habitat to crops was evaluated. Additionally, DIS estimated the acreage change between genetically modified (GM) and non-GM corn and soybean acreage.

From a historical perspective on the land use in the 13-state study area, total acreage devoted to program crops, i.e., corn and soybeans, for the area ranged from a low of 143.42 million acres in 2007 to a high of 169.54 million acres in 2016. Total acreage devoted to grassy habitat (varied by state) for the 13-state area ranged from a low of 132.01 million acres in 2016 to a high of 160.73 million acres in 2007, shown in Figure 1. 13-State Total Program Crops and Grassy Habitat Acreage (2007-16).



Source: USDA NASS CropScape -- Cropland Data Layer (CDL)

Figure 1. 13-State Total Program Crops and Grassy Habitat Acreage (2007-16)

From USDA Economic Research Service (USDA/ERS), the shares of planted acreage for non-GM corn and non-GM soybeans (excluding all GM varieties) relative to total planted acreage of either corn or soybeans for the 13 states and U.S. total are shown in Figure 2, with yellow and green colors, respectively. The planted acreage for non-GM corn in the state of Arkansas is unknown, due to the lack of data. Within the study period, the percent of non-GM corn planted acreage has decreased for all 12 states (excluding Arkansas), and the percent of non-GM soybean planted acreage remained in a stable range, with a range from 6% to 9%, at the national level.

Source: USDA ERS

Figure 2. Share of Planted Acreage of Non-GM Corn and Soybeans for 13 States and U.S. Total from 2007 – 16

Methods

Data Description

The single most important data source for the land use component is the USDA National Agricultural Statistics Service (USDA/NASS) Cropland Data Layer (CDL) dataset. For purposes of this land use analysis, the periods selected were 2007-12, 2012-16 and 2007-16, which allows for the analysis of specified annual land use category totals, defined below, and three period changes in land use. Annual data in the USDA/NASS CDL has historically provided estimates of land use in 132 possible land cover types across the United States. Geography necessarily precludes any one area from having all possible land cover types present. Because the degree to which the CDL data are classified is computationally intensive, the study-related land use types were aggregated into seven categories, which are detailed in Appendix A, Land Use Types. The analyzed categories are corn and soybeans (called program crops) and grassy habitat. Other categories were used to support some of the calculations in the econometric analysis section. Below are the seven land use categories used in this analysis:

1. Corn (program crop)
2. Soybeans (program crop)
3. Grassy Habitat
4. Wheat
5. Sorghum
6. Rice
7. Cotton

ArcGIS was used to aggregate the CDL data based on the above listed seven aggregation categories. Once this was completed for the 2007, 2012 and 2016 (i.e., the "endpoint years") raster sets, the 2016 values were subtracted from the 2007 values to determine the land use change, if any, which occurred during the six-year period. Similar calculations were made for the 2007-12 and 2012-16 periods. Once the raster datasets were combined to determine change, the raster was converted to a polygon dataset to calculate the areas of each individual land use change.

To determine individual county data, each county was clipped out of the statewide polygon for each endpoint year to determine changes. Individual county files were summarized according to each possible land use change and then exported to be used in a SAS software application (SAS Institute Inc., Cary, NC) for the summarization of county-specific change data. State change totals were also calculated.

An important point worth mentioning regarding the spatial analysis methodology is that, whereas some analyses have endeavored to understand habitat acreage changes from a "converted from habitat" basis, the present study analyzed land use changes on a net basis. In other words, the expectation for this research assumed land use changes can move both directions (both to and from grassy habitat). To not account for land use changes on a net basis would produce research and results that could be biased, marginalized and rendered useless. Or worse yet, could lead to inaccurate conclusions regarding the magnitude of land use changes that are occurring and the drivers of land use change. The goal has been to provide a rigorous analysis that withstands scrutiny.

All spatial results discussed in this section are what would be considered the most accurate interpretation of such data. There may still be issues with the data (primarily overstatement of grassland), but this has been minimized due to the method of aggregation.

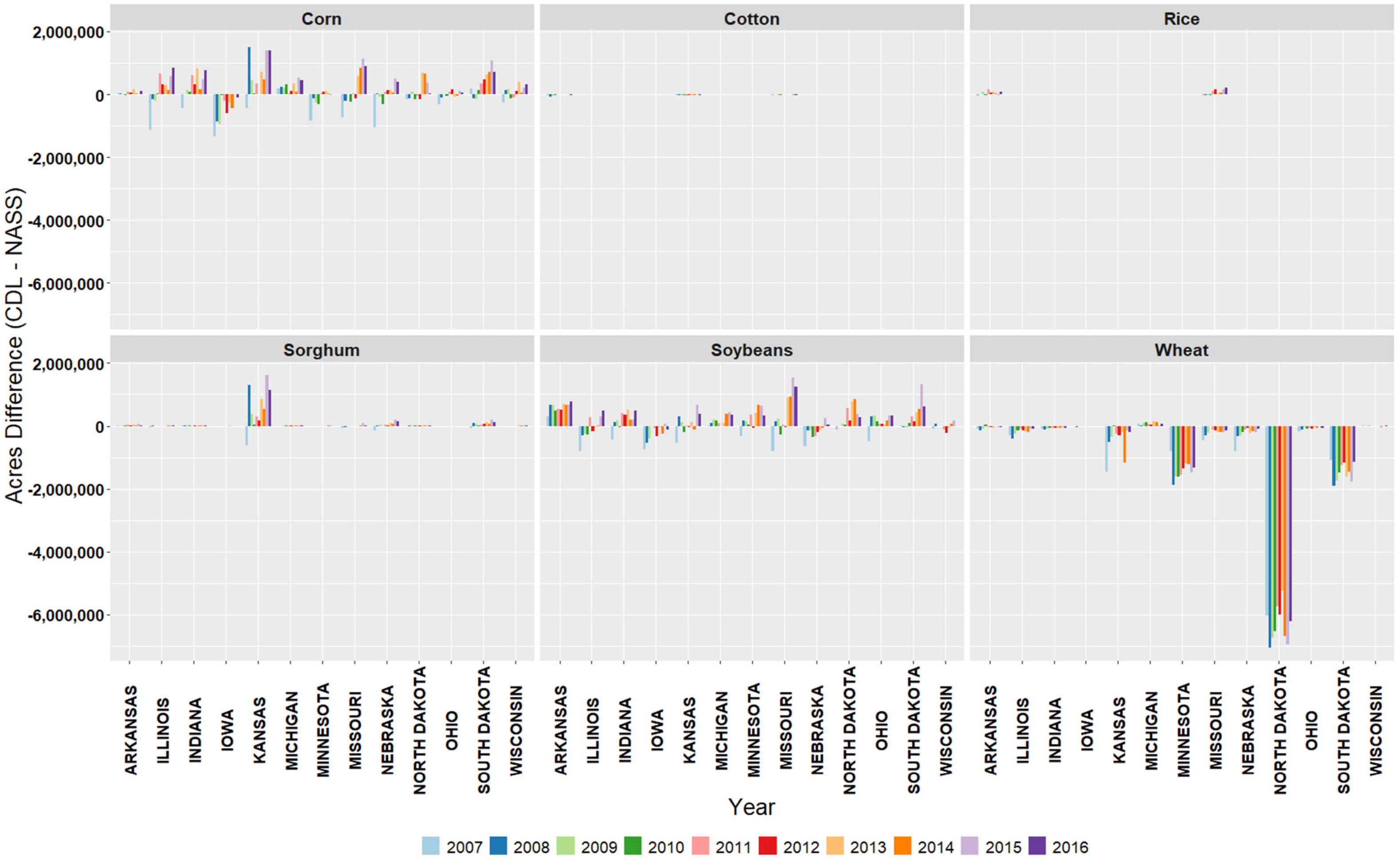
Land Use Acreage Comparison

USDA/NASS survey data and CDL are two solid data sources for crop acreage and land use, but each is based on its own methodology. The planted acreage data for crops from USDA/NASS are based on surveys, and in some cases, the Census of Agriculture. The CDL acres are calculated and estimated by pixel count measurement, which was claimed that “in general, the large area row crops have producer accuracies ranging from mid-80% to mid-90%” on the CDL documentation website.

Drilling down to various crops within both sets of data sources for all the studied states are shown in Figure 3. This figure shows the differences in the total acreage for crops between the CDL data and the USDA/NASS survey data (CDL data minus USDA/NASS data). A negative number means CDL acreage is lower than the USDA/NASS survey data.

Corn, soybeans and wheat are widely grown in the 13-state study area. Below are some observations about these comparisons:

- There was consistent underreporting of corn and soybean acres by CDL versus USDA/NASS in 2007.
- The more "major" the crop is (such as corn and soybeans in Iowa and Illinois) the less the difference between CDL and USDA/NASS after 2007.
- The acreage difference of wheat was larger than other crops, especially for North Dakota, South Dakota and Minnesota, in descending order. But overall, as shown in the figure, it is apparent the CDL data is getting closer to USDA/NASS data over time.



Source: USDA CDL and NASS

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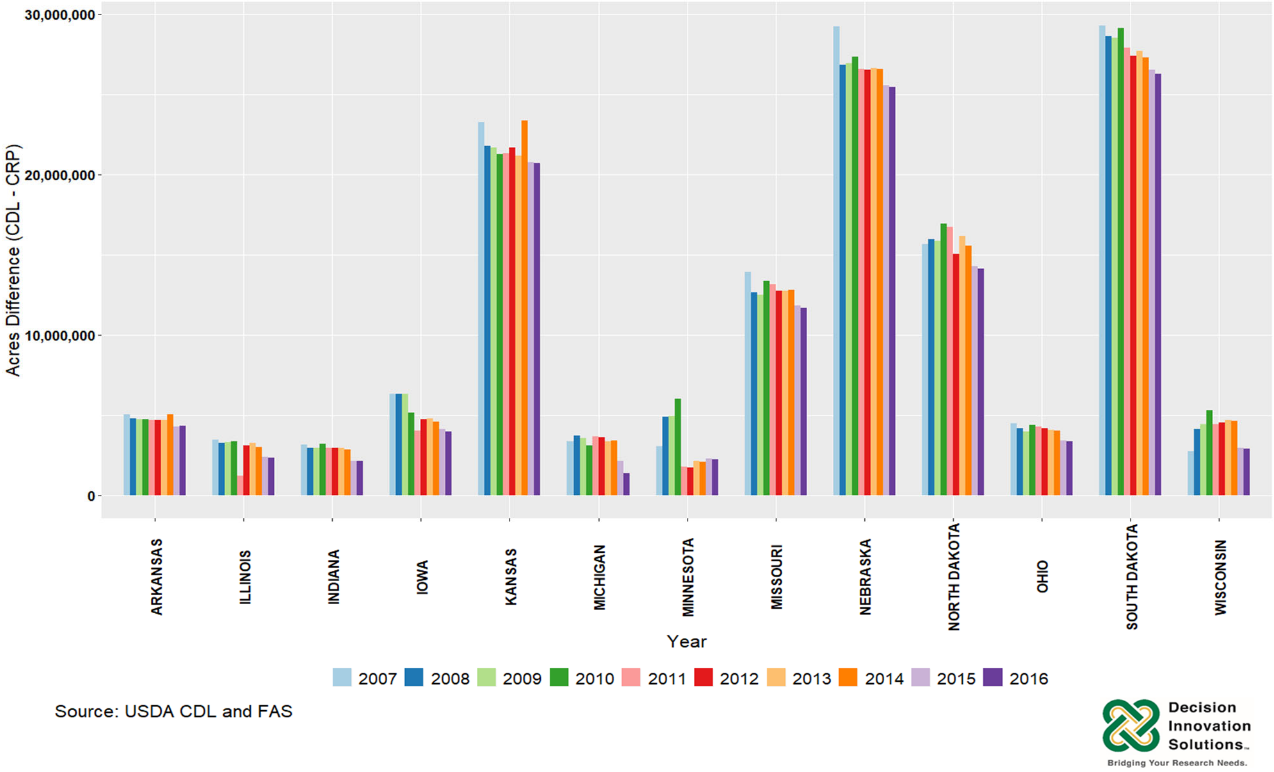
Figure 3. Crops Acreage Differences between CDL and NASS for All States, 2007–16.

Figure 4 shows the acreage difference between CDL grassy habitat and Conservation Reserve Program[1] (CRP) acres (the summation of general CRP acres and continuous CRP acres). For all states, the grassy habitat acres from CDL were higher than the CRP acres. The higher difference in “grassy habitat” acres relative to CRP is expected, given the categories included in it. CRP is a subset of all “grassy acres.” Grassy areas in the CDL data would include CRP acres, pasture areas, some rangeland, possibly some hay acres, and other grassy areas such as roadsides, grassy waterways, etc.



Source: USDA CDL and FAS

Figure 4. Grassy Habitat Acreage Differences between CDL and CRP for All States, 2007–16

Econometric Analysis

To aid in the econometric analysis component of the study, annual data were summarized at the three endpoint years, i.e., 2007, 2012 and 2016, rather than establishing the “changes” on a year-to-year basis. Consequently, the acreage data from CDL was aggregated into the seven categories, and the total acreage for each category was determined by county in each state for given years from 2007 to 2016.

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[1] All CRP data was from USDA Farm Service Agency (USDA/FSA).

The key factor for the econometric analysis is the corresponding crops and the grassy habitat profitability ratios, i.e., net operating revenue (NOR) ratios. The profitability, or NOR, of cropland is affected by price, yield and production costs. To calculate a crop's NOR, yield (county data), price (state data) and cost (used as the "operating cost", region data[2]) were used for a given crop, for each of the 13 states. To calculate grassy NOR, weighted average CRP payment rate [county data, weighted by signup type (i.e., general CRP or continuous CRP)], and maintenance cost[3] were included. Since there is land use diversity across the study area, one would expect results that were as varied as the states themselves.

A statistical software, R, was used to standardize data and apply linear models on crops and grassy habitat NOR ratios for a given state. (R Core Team, 2021) Type one error was set as 0.05 ($\alpha = 0.05$).

Methodology and Data for Comparison of GM Crops Versus Non-GM Crops

Major data sources for this section were USDA/NASS, USDA/ERS and USDA Agricultural Marketing Service (USDA/AMS) for the production, yield, price and cost data for both GM and non-GM crops.

USDA/NASS published organic corn and soybean production data for the years of 2008, 2011, 2014, 2015 and 2016. Organic corn and soybean planted acreage data were available for the years of 2007, 2008, 2010 and 2011. This data was used to calculate the yield for organic crops. By using the ratio of organic and GM crop yields, for those years for which data were available, and information from Cox and et al. (2017) planted acreage were estimated for organic crops for the entire study period. Since the total non-GM planted acreage was known (as shown in Figure 2), estimates of the non-GM planted acres for crops were calculated.

Organic corn and soybean feed and food consumption prices were obtained from USDA/ERS, with missing value imputation. It was assumed that non-GM corn price was about 7.51% for Region 1, and 0.61% for Region 2, premium per bushel than the GM corn price, and non-GM

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[2] USDA/ERS defined a set of regions depicting geographic specialization in production of U.S farmed commodities, called Farm Resource Regions. Total Operating Costs were used to calculate net operating margin for a given crop, it does not include allocated overhead costs or fixed costs. The regions are conducted by counties, which means that the cost for each county in a given region can be allocated. Within each region, the crops' costs are the same.

[3] Maintenance costs for CRP for a given county was calculated as 2% to 3% of the corresponding CRP payment rate.

soybean price was 14.27% in Region 1, and 10.6% in Region 2, premium per bushel higher than the price of GM soybeans[4].

From USDA reports (Greene et al., 2016; McBride et al., 2015) it was assumed that the production costs[5] of organic corn and non-GM corn were 0.71 times and 0.97 times the GM corn cost, respectively; and the costs of organic soybeans and non-GM soybeans were 1.12 times and 0.98 times the GM soybeans cost, respectively. The weighted average NOR was then calculated for total non-GM corn and soybeans devoted to organic and non-GM planted acreage for corn and soybeans, respectively.

The indicator for this section is the difference between the weighted average NOR for total non-GM crops (i.e., corn and soybeans) for each of the 12 or 13 states (Arkansas excluded for non-GM corn due to the lack of data), and the corresponding NOR of GM program crops that were obtained from previous econometric analysis. The statistical software, R, was used to standardize data and apply linear models. Type one error was set as 0.05 ($\alpha = 0.05$).

Results

Because of the variety of agricultural crops grown across the 13-state area, land use is very diverse. For instance, Iowa, Illinois and Missouri have a larger proportion of acreage utilized for grains and oilseeds. While for Michigan, which is one of the most agricultural diverse states in U.S., fruits, vegetables, row and tree crops, etc. are planted.

This section began with an overview of land use net change from grassy habitat to program crops for the 13-state region during three time periods. This is followed by the land use change and econometric analysis results for each of the 13 states, shown in a similar format. Finally, the land usage for GM and non-GM crops and econometric analysis will be presented.

13-State Land Use Change

The bar charts in Figure 5, Figure 6. 13-State Net Aggregated Change from Grassy Habitat to Program Crops (2012-16) and Figure 7 show the estimated aggregated land use change by state (in units of acres, reflected on the left-hand axis) for the time periods 2007–12, 2012–16 and 2007–16, respectively. Dots with data labels (there are two per figure) mark the 13-state total net change acres for a given category (right-hand axis units). To account for land use changes both from and to grassy habitat, all land use change estimates are shown on a net

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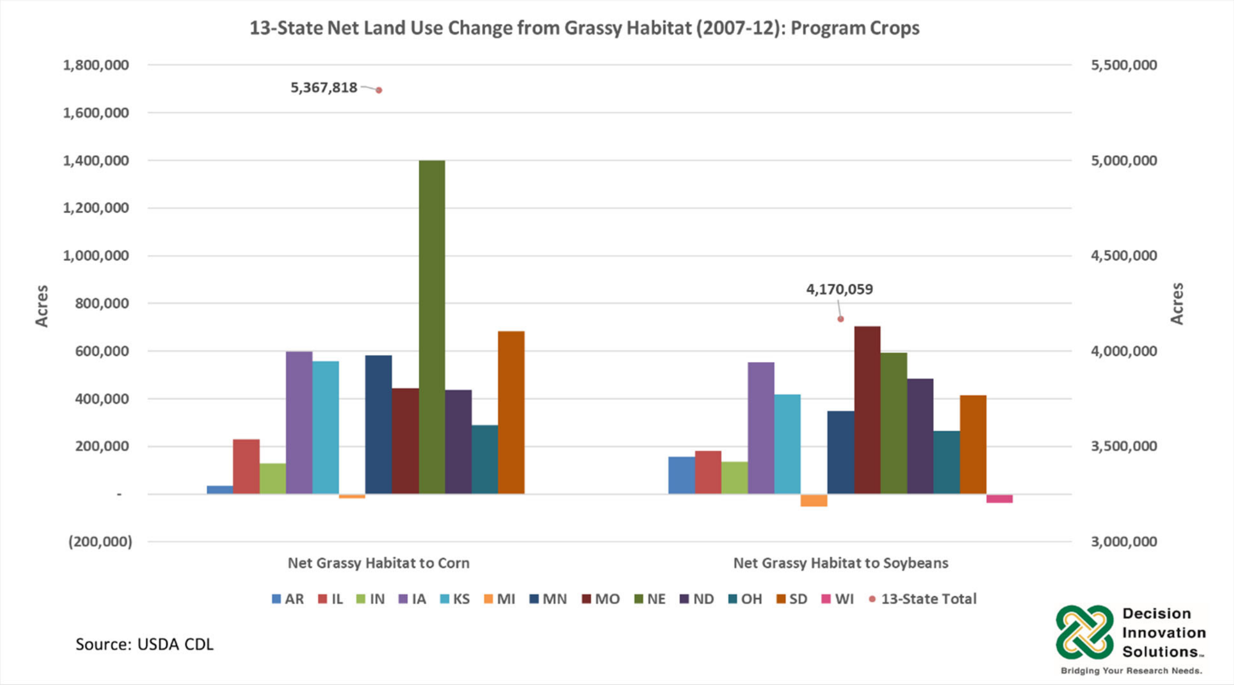
[4] From USDA non-GM price data (Report: National Weekly Non-GMO/GE Grain Report), Region 1 includes states east of the Mississippi River (Eastern Corn Belt) and Region 2 includes states west of the Mississippi (Western Corn Belt).

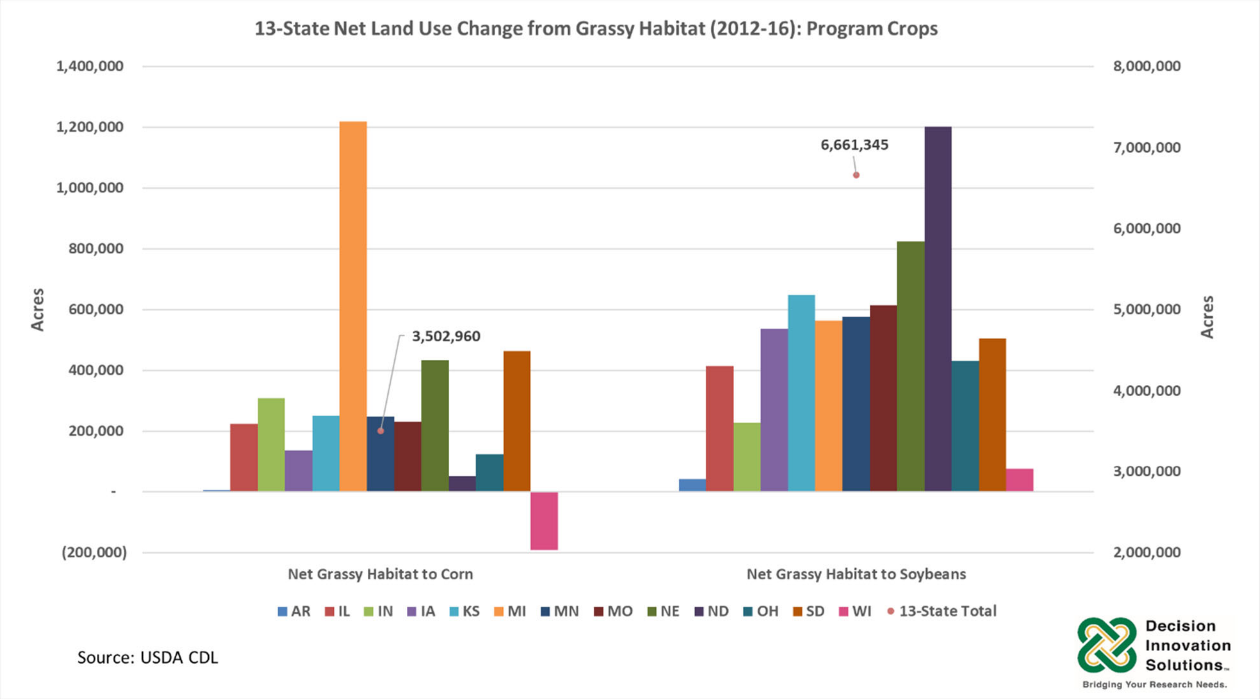
[5] The costs are operating costs, as the costs in the Econometric Analysis section.

basis. A negative number is interpreted as a net movement to a grassy habitat. For instance, in Figure 5, for Michigan, there were 69,029 acres movement from program crops (i.e., corn and soybeans) to grassy habitat, within the study period 2007–12, on a net basis.



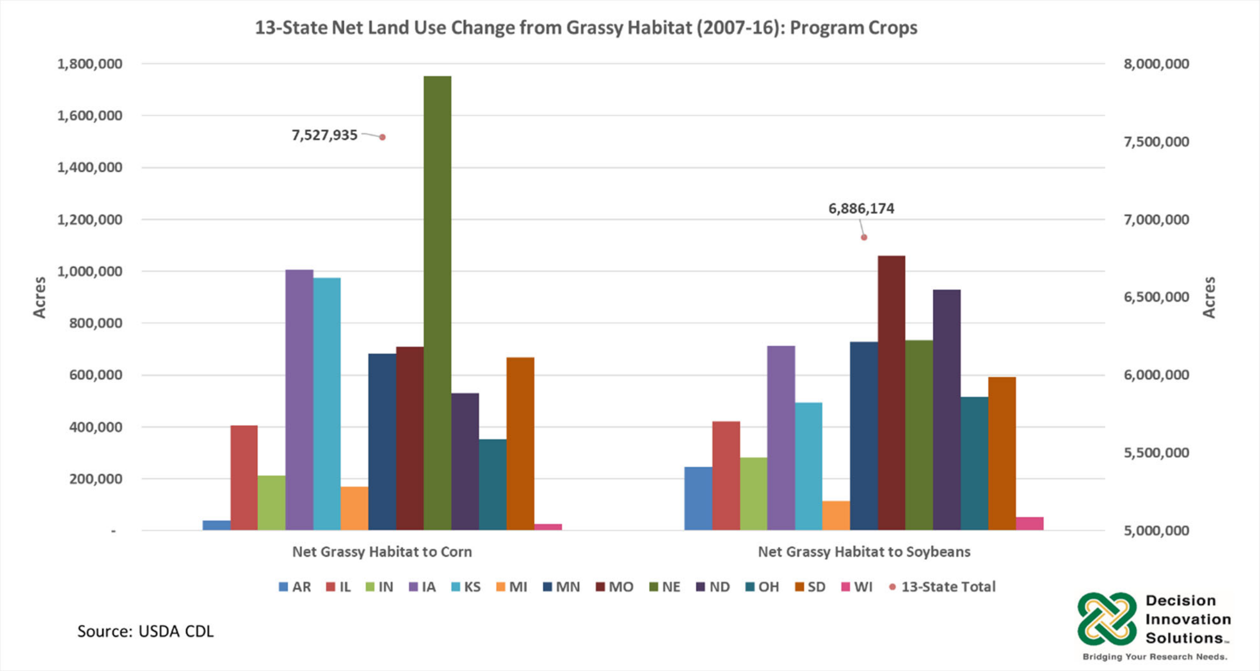
Source: USDA CDL

Figure 5. 13-State Net Aggregated Change from Grassy Habitat to Program Crops (2007-12)



Source: USDA CDL

Figure 6. 13-State Net Aggregated Change from Grassy Habitat to Program Crops (2012-16)



Source: USDA CDL

Figure 7. 13-State Net Change of Land Use from Grassy Habitat to Program Crops (2007-16)

Figure 8, Figure 9 and Figure 10 are gradient county level maps that show the estimated total net change (in acres) from grassy habitat to program crops (i.e., corn and soybeans) within the 13 study states, for the time periods 2007–12, 2012–16 and 2007–16, respectively. A positive number (shown in green color) is interpreted as a net movement from a grassy habitat to program crops. A negative number (shown in red color) is interpreted as a net movement to a grassy habitat.

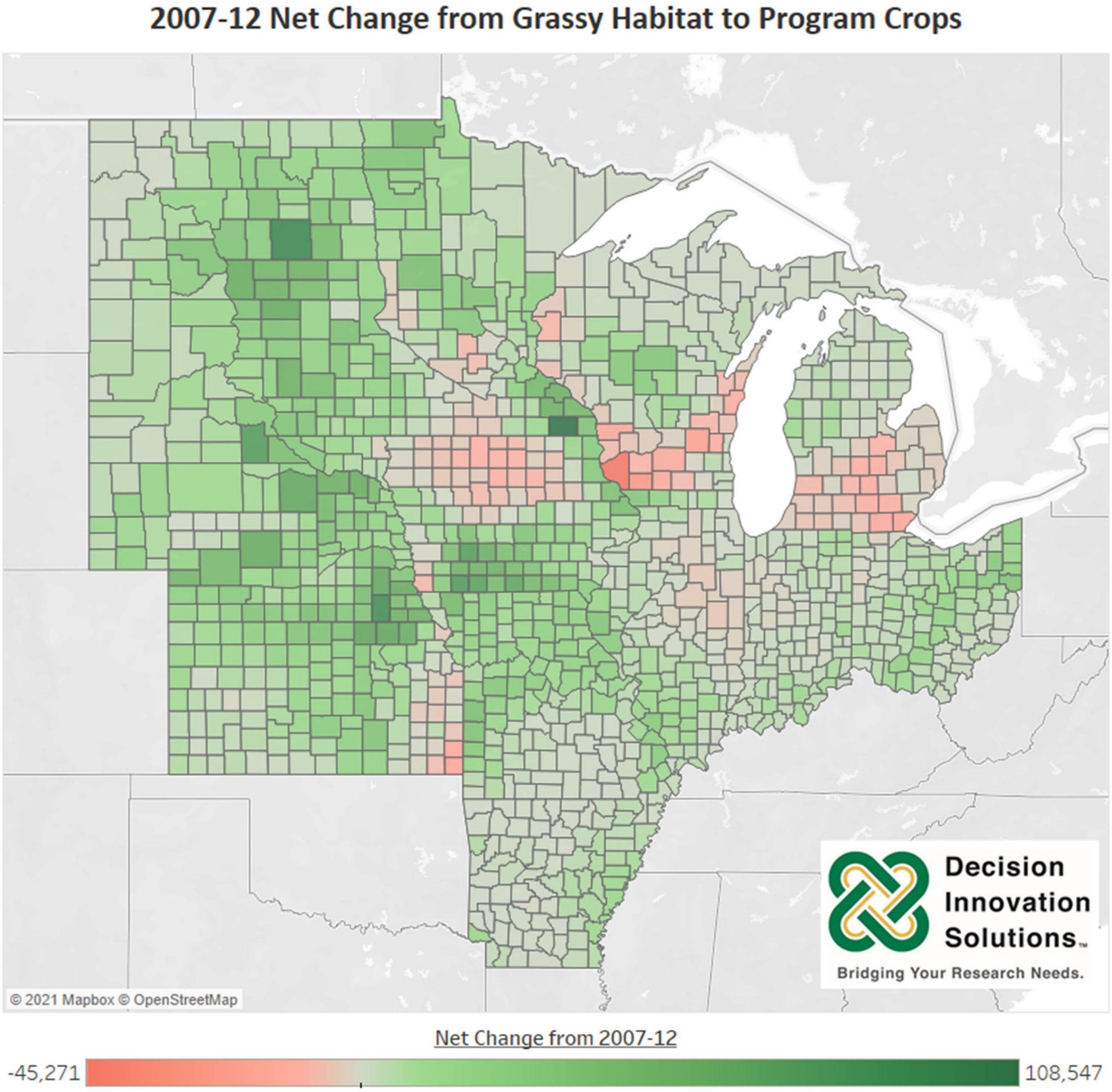


Figure 8. 2007-12 Net Change from Grassy Habitat to Program Crops

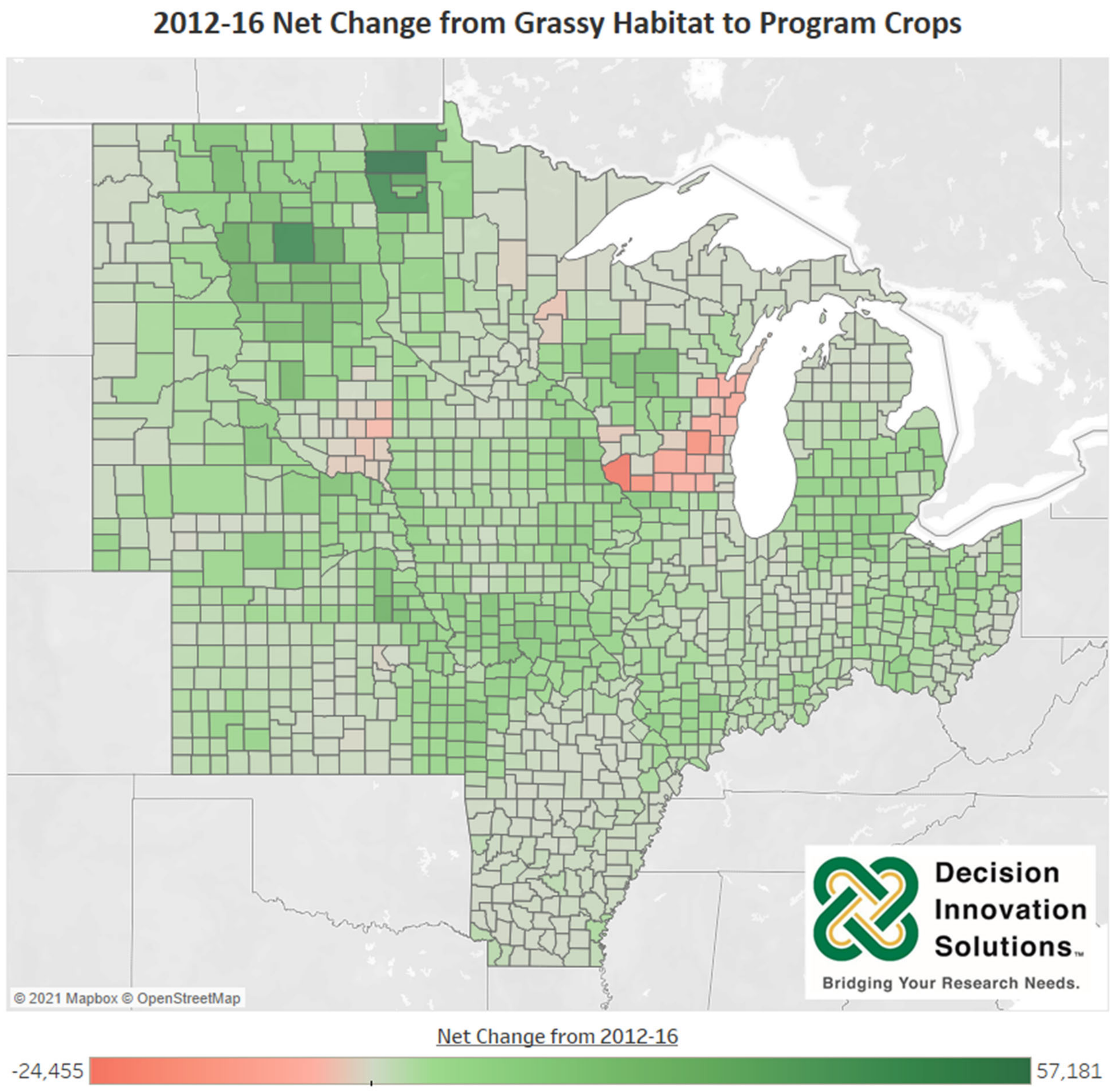


Figure 9. 2012-16 Net Change from Grassy Habitat to Program Crops

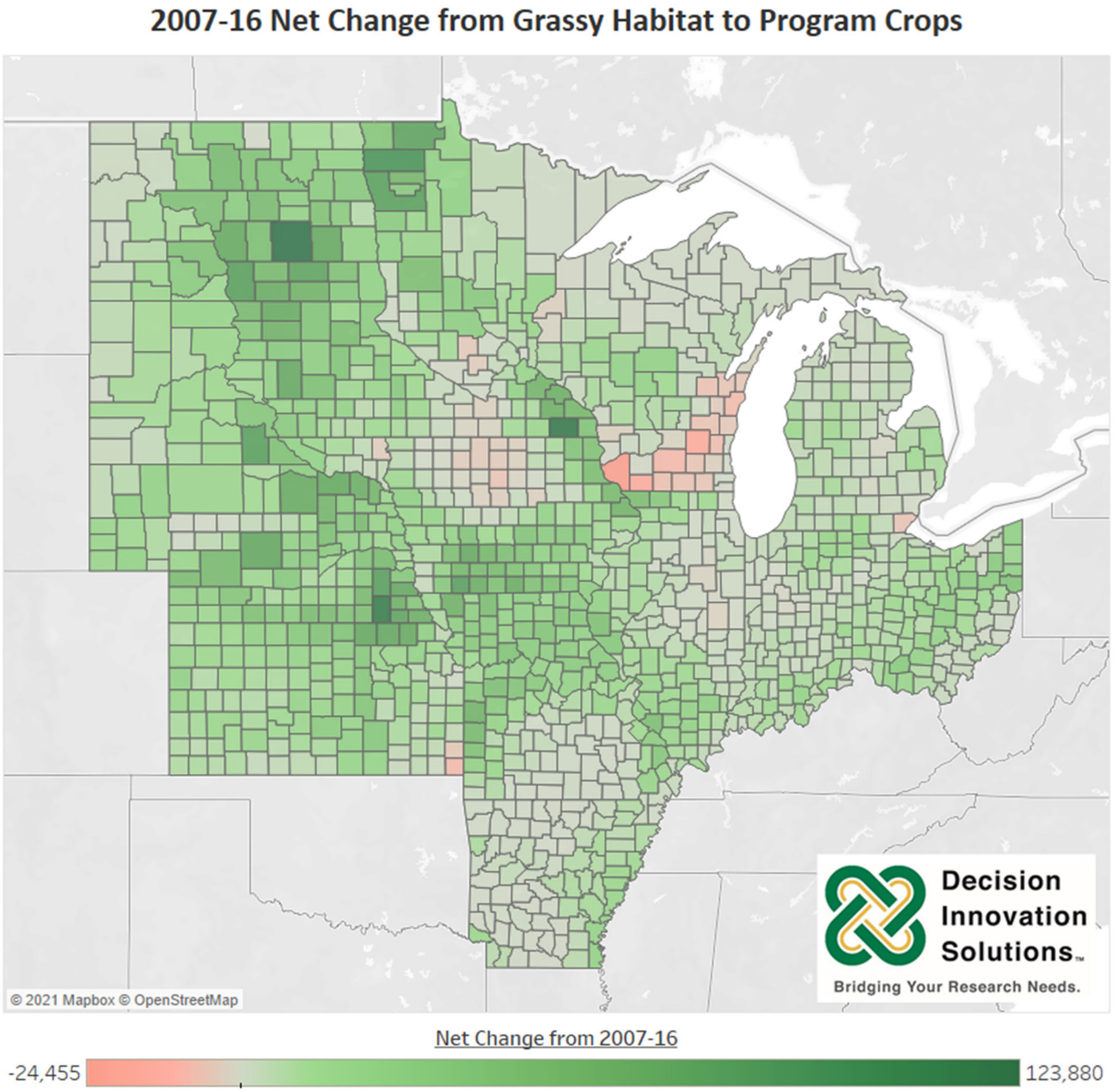


Figure 10. 2007-16 Net Change from Grassy Habitat to Program Crops

Land Sparing Effects of GM Feed Crops

One consideration in the discussion of policy options affecting use of GM crops is the amount of land sparing that can occur due to higher yields from GM crops versus non-GM crops. A meta-analysis conducted by Pellegrino and colleagues (2018) found strong evidence that GM maize increases yields in a range of 5.6% to 24.5% compared with its near isogenic line. Over the period of 2007-16, a net total of 7.5 million acres were converted from grassy habitat to corn production. This occurred as the adoption rate of GM corn rose from 73% to 92%. Assuming just a 5% yield advantage for GM corn versus non-GM corn, to reach the same level of corn production in 2016, there would have been a need for 4.1 million more acres of corn. It is likely that all this additional corn acreage would have resulted in additional conversion of grassy habitat to corn. This suggests that the amount of grassy habitat that would have been converted to corn in the absence of GM corn production would have been 11.6 million acres. Thus, the use of GM corn resulted in 4.9% fewer total acres being devoted to corn than if all non-GM corn were planted and 35.2% fewer acres of land being converted from grassy habitat to corn production.

If the mean yield advantage reported by Pellegrino (a 15% yield advantage for GM corn) were used, the use of GM corn resulted in 13.7 million fewer acres of corn being planted (a land sparing of 16.4% and a reduction in conversion of grassy habitat to corn of 64.5%).

For soybeans, a net total of 6.9 million acres of grassy habitat were converted to soybean production from 2007-16. By 2016, 94% of all soybeans planted were GM soybeans. Assuming a 3% yield advantage for GM soybeans, by 2016, the use of GM soybeans spared the use of 2.2 million acres for soybean production and assuming all these additional acres would have had to come from lands converted from grassy habitat to soybeans, the use of GM seed reduced the conversion of grassy habitat to soybean production by 24.2%.

Land Use Change and Econometric Results by State

Under this section, relationships between the changes in acreage from grassy habitat to crops were examined year by year, and the profitability of grassy habitat and of the corresponding crops for a given state. Land use across the 13-state region is very diverse. For a particular state, different crop NOR combinations and grassy NOR ratios were involved. For instance, only corn, soybeans and wheat NOR, to grassy habitat NOR ratios were applied on the Iowa; while in Missouri, corn, soybeans, wheat, sorghum, rice and cotton NOR, and grassy NOR ratios were applied. As a result of this diversity across the study area, one would expect results that were as varied as the states themselves. Therefore, similar content is provided for each of the individual 13 states.

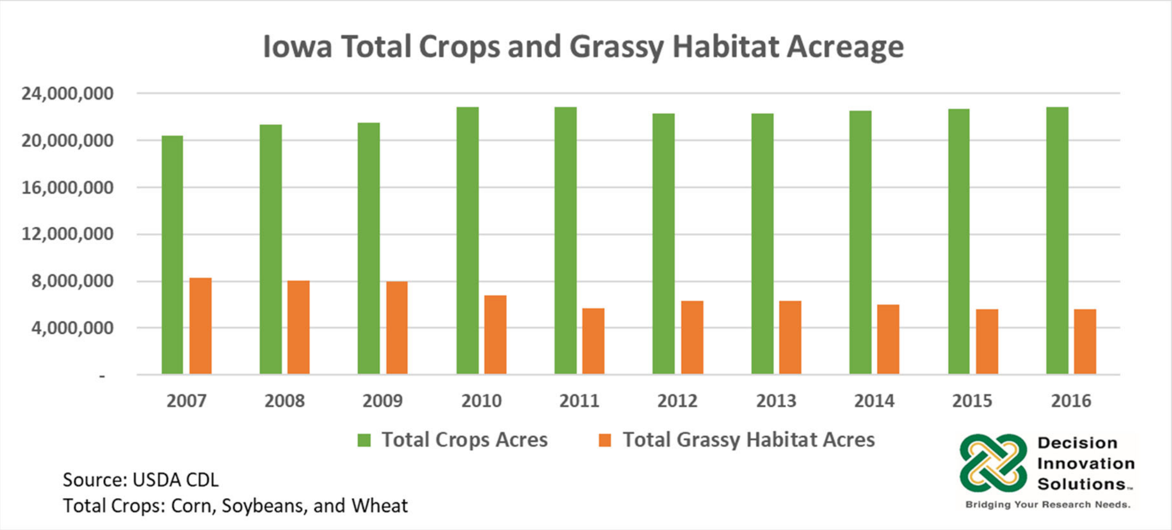
For all the estimation of coefficient tables (from **Error! Reference source not found.** to Table 17) the mark signs, such as asterisk(s), “*” or a dot, “.” next to a p-value, are explained below:

- One asterisk (*): the corresponding variable has a significant effect, and its p-value is less than 0.05 and larger than 0.01.
- Two asterisks (**): the corresponding variable has a strong significant effect, and its p-value is less than 0.01 and larger than 0.001.
- Three asterisks (***): the corresponding variable has a stronger significant effect, and its p-value is less than 0.001.

- A dot (.): the corresponding variable may have a significant effect, if the type one error was set at 0.1 ($\alpha = 0.1$), and its p-value is less than 0.1 and larger than 0.05.
- No sign: the corresponding variable has no significant effect.

Iowa

Land use in Iowa is shown in Figure 11. Total Crops and Grassy Habitat Acreage in Iowa (2007-16), from 2007 to 2016. Total crop acres planted ranged from a low of 20.45 million acres in 2007 to a high of 22.89 million acres in 2011. The total crops for Iowa refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 5.6 million acres in 2015 to 8.26 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 11. Total Crops and Grassy Habitat Acreage in Iowa (2007-16)

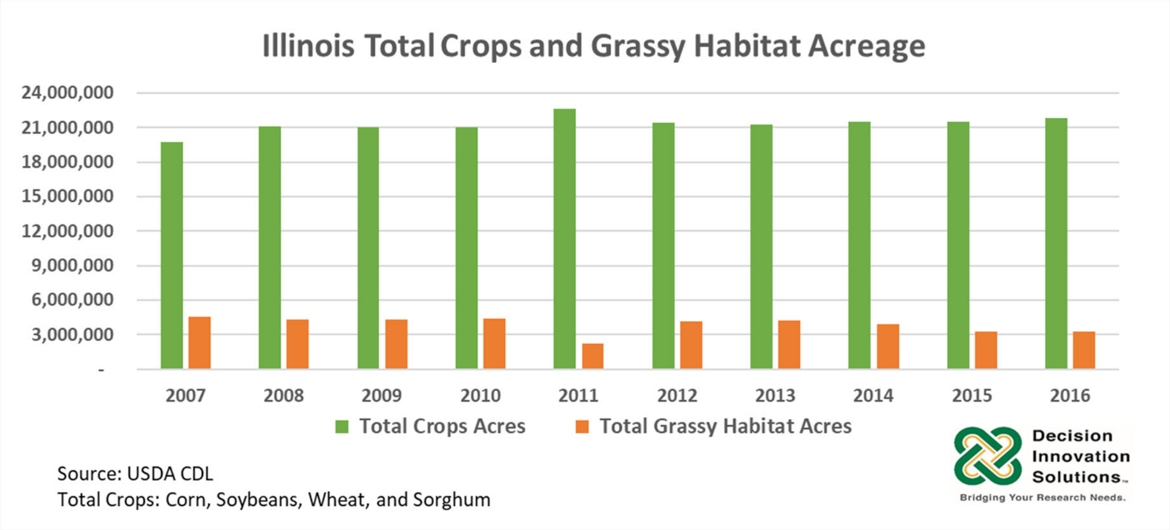
Table 1 provides results for Iowa. A summary of econometric results with regard to the explanatory variables for Iowa is provided below. Both corn NOR/grassy NOR ratio and soybean NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two ratios represent that with a higher NOR of corn or soybeans compared with that of grassy habitat, it will increase the change from grassy habitat to crops. In other words, when crops had a higher NOR, more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for corn and soybeans. Wheat NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 1. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Iowa

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	3508327	0.3806
Year	-1812	0.3609
Corn NOR/Grassy NOR Ratio	6550	0.0244 *
Soybean NOR/Grassy NOR Ratio	13576	0.0168 *
Wheat NOR/Grassy NOR Ratio	2976	0.7467

Illinois

Land use in Illinois is shown in Figure 12, from 2007 to 2016. Total crop acres planted ranged from a low of 19.76 million acres in 2007 to a high of 22.60 million acres in 2011. The total crops for Illinois refer to corn, soybeans, wheat and sorghum. Total grassy habitat acreage ranged from 2.25 million acres in 2011 to 4.55 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, and Sorghum

Figure 12. Total Crops and Grassy Habitat Acreage in Illinois (2007-16)

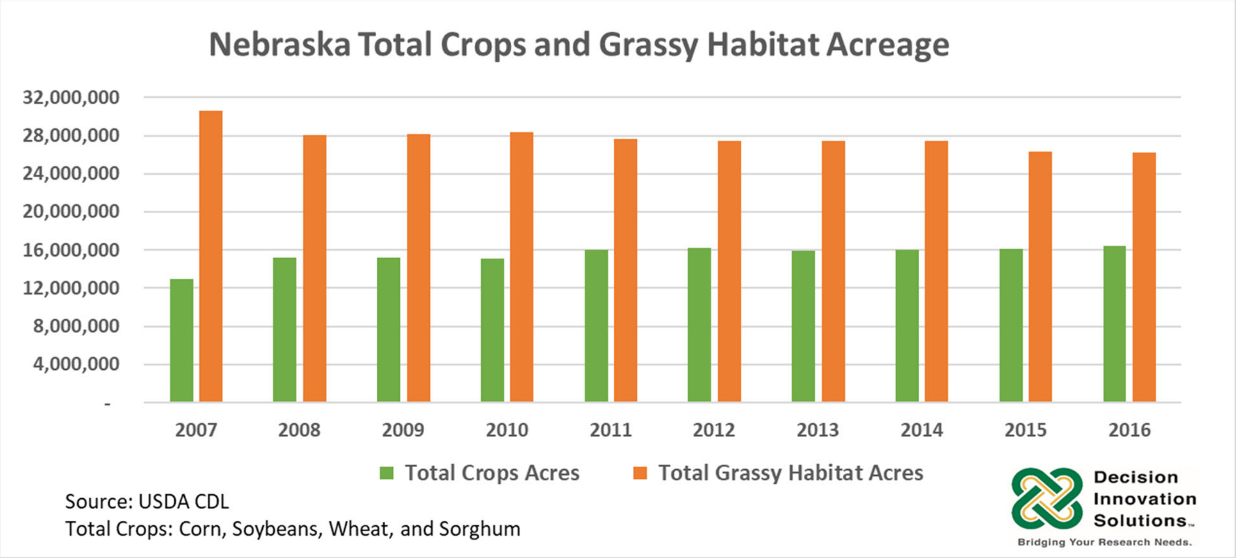
Table 2 provides a summary of econometric results with regard to the explanatory variables for Illinois. Corn NOR/grassy NOR ratio, soybean NOR/grassy NOR ratio and sorghum NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these ratios represent that with a higher NOR of corn or soybeans, or sorghum compared with that of grassy habitat, more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were for corn, soybeans and sorghum. Wheat NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 2. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Illinois

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	3475709	0.1547
Year	-1816	0.1341
Corn NOR/Grassy NOR Ratio	3776	0.0163 *
Soybean NOR/Grassy NOR Ratio	6685	0.0450 *
Wheat NOR/Grassy NOR Ratio	6861	0.1795
Sorghum NOR/Grassy NOR Ratio	7130	0.0081 **

Nebraska

Land use in Nebraska is shown in Figure 13, from 2007 to 2016. Total crop acres planted ranged from a low of 12.99 million acres in 2007 to a high of 16.48 million acres in 2016. The total crops for Nebraska refer to corn, soybeans, wheat and sorghum. Total grassy habitat acreage ranged from 26.24 million acres in 2016 to 30.56 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, and Sorghum

Figure 13. Total Crops and Grassy Habitat Acreage in Nebraska (2007-16)

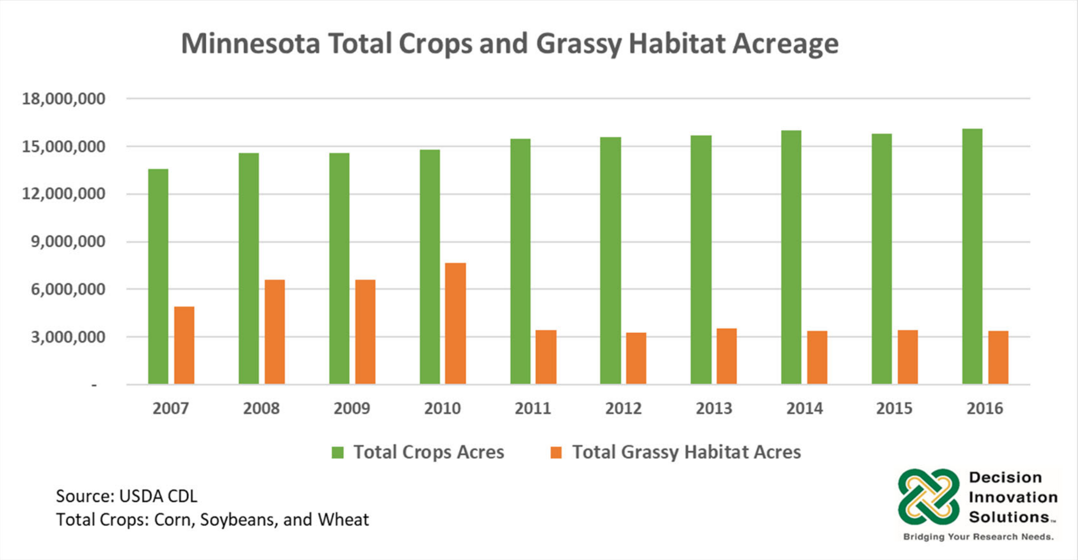
Table 3 provides a summary of econometric results with regard to the explanatory variables for Nebraska. Corn NOR/grassy NOR ratio, soybean NOR/grassy NOR ratio and wheat NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these ratios represent that with a higher NOR of corn, soybeans or wheat compared with that of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for soybeans, followed by wheat and corn. Sorghum NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 3. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Nebraska

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-3564639	0.5887
Year	1660	0.6118
Corn NOR/Grassy NOR Ratio	6992	0.0462 *
Soybean NOR/Grassy NOR Ratio	55144	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	12881	0.0108 *
Sorghum NOR/Grassy NOR Ratio	-7586	0.1912

Minnesota

Land use in Minnesota is shown in Figure 14, from 2007 to 2016. Total crop acres planted ranged from a low of 13.57 million acres in 2007 to a high of 16.12 million acres in 2016. The total crops for Minnesota refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 3.27 million acres in 2012 to 7.65 million acres in 2010. Part of the significant drop in grassy habitat acreage from 2010 to 2011 was a classification change of some grassy habitat to woody habitat in the CDL database.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

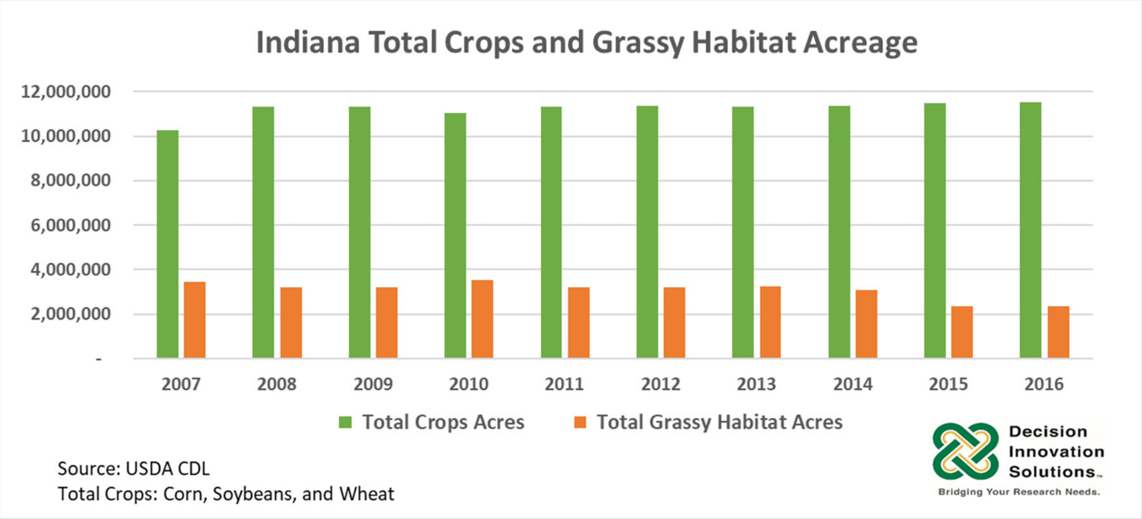
Figure 14. Total Crops and Grassy Habitat Acreage in Minnesota (2007-16)Table 4Table 4 provides a summary of econometric results with regard to the explanatory variables for Minnesota. Corn NOR/grassy NOR ratio, soybean NOR/grassy NOR ratio and wheat NOR/grassy NOR ratio had significant and positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these ratios represent that with a higher NOR of corn or soybeans, or wheat compared with that of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for soybeans, followed by corn and wheat.

Table 4. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Minnesota

Coefficient	Estimate	P-value (Prob >|t|)
Intercept	1926764	0.4911
Year	-1101	0.4282
Corn NOR/Grassy NOR Ratio	8699	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	16771	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	9369	0.0013 **

Indiana

Land use in Indiana is shown in Figure 15, from 2007 to 2016. Total crop acres planted ranged from a low of 10.27 million acres in 2007 to a high of 11.53 million acres in 2016. The total crops for Indiana refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 2.34 million acres in 2015 to 3.51 million acres in 2010.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 15. Total Crops and Grassy Habitat Acreage in Indiana (2007-16)

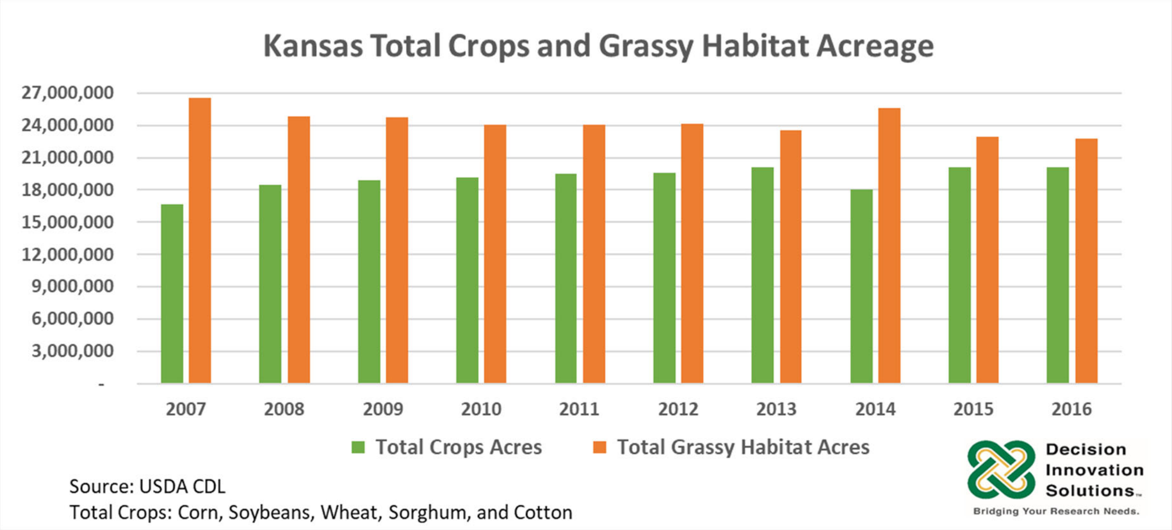
Table 5 provides a summary of econometric results with regard to the explanatory variables for Indiana. Corn NOR/grassy NOR ratio and soybean NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two ratios represent that with a higher NOR of corn or soybeans compared with that of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for corn and soybeans. Since the type one error was set to 0.05, the wheat NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 5. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Indiana

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	397986.7	0.7773
Year	-263.3	0.7057
Corn NOR/Grassy NOR Ratio	7202.8	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	7650.9	0.0006 **
Wheat NOR/Grassy NOR Ratio	-6706.6	0.0509 .

Kansas

Land use in Kansas from 2007 to 2016 is shown in Figure 16. Total crop acres planted ranged from a low of 16.67 million acres in 2007 to a high of 20.13 million acres in 2013. The total crops for Kansas refer to corn, soybeans, wheat, sorghum and cotton. Total grassy habitat acreage ranged from 22.81 million acres in 2016 to 26.51 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, Sorghum, and Cotton

Figure 16. Total Crops and Grassy Habitat Acreage in Kansas (2007-16)

Table 6 provides a summary of econometric results with regard to the explanatory variables for Kansas. Soybean NOR/grassy NOR ratio, wheat NOR/grassy NOR ratio and year had significantly negative effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two NOR ratios suggest that as the NOR of soybeans or wheat increased compared with the NOR of grassy habitat, less acreage changed from grassy habitat to crops. This would suggest that there are other factors besides NORs of crops that are affecting land use in Kansas during this period. The estimated coefficient of the year variable represents that with time moving forward from 2007 to 2016, there was less acreage changed from grassy habitat to crops. Referring to Figure 16, the differences between total grassy habitat acres (shown as orange bar) and total crops acres (green bar) decreased nearly every year from 2007 to 2016.

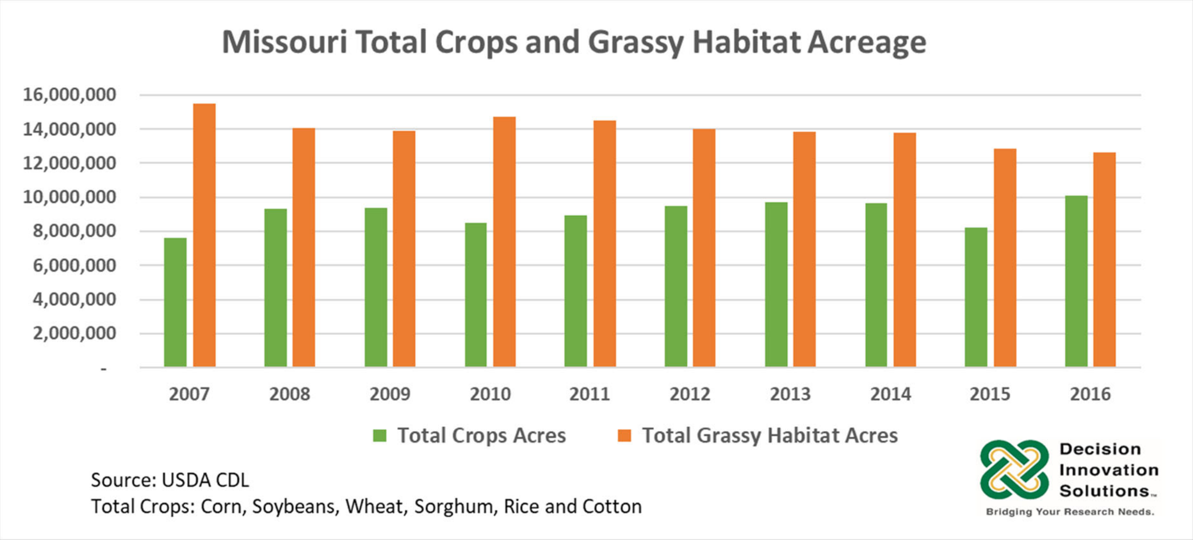
On the other hand, cotton NOR/grassy NOR ratio had a significant positive effect on the acreage change from grassy habitat to crops. This estimated coefficient represents that with a higher NOR of cotton compared with that of grassy habitat, there will be more acreage changed from grassy habitat to crops. Corn NOR/grassy NOR ratio and sorghum NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 6. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Kansas

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	12629641	0.0045 **
Year	-6229	0.0048 **
Corn NOR/Grassy NOR Ratio	-484	0.7135
Soybean NOR/Grassy NOR Ratio	-5062	0.0117 *
Wheat NOR/Grassy NOR Ratio	-20000	<0.0000 ***
Sorghum NOR/Grassy NOR Ratio	-187	0.9470
Cotton NOR/Grassy NOR Ratio	7500	0.0109 *

Missouri

Land use in Missouri is shown in Figure 17, from 2007 to 2016. Total crop acres planted ranged from a low of 7.61 million acres in 2007 to a high of 10.09 million acres in 2016. The total crops for Missouri refer to corn, soybeans, wheat, sorghum, rice and cotton. Total grassy habitat acreage ranged from 12.57 million acres in 2016 to 15.50 million acres in 2007.


Missouri Total Crops and Grassy Habitat Acreage

Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, Sorghum, Rice and Cotton

Figure 17. Total Crops and Grassy Habitat Acreage in Missouri (2007-16)

Table 7 provides a summary of econometric results with regard to the explanatory variables for Missouri. Corn NOR/grassy NOR ratio and rice NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two ratios indicate that with a higher NOR of corn or rice compared with NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for corn and rice.

On the other hand, cotton NOR/grassy NOR ratio had a significant negative effect on the acreage change from grassy habitat to crops. This estimated coefficient represents that with a higher NOR of cotton compared with that of grassy habitat, there will be less acreage changed from grassy habitat to crops. Soybean NOR/grassy NOR ratio, wheat NOR/grassy NOR ratio and sorghum NOR/grassy NOR ratio had no significant effect on the acreage changing.

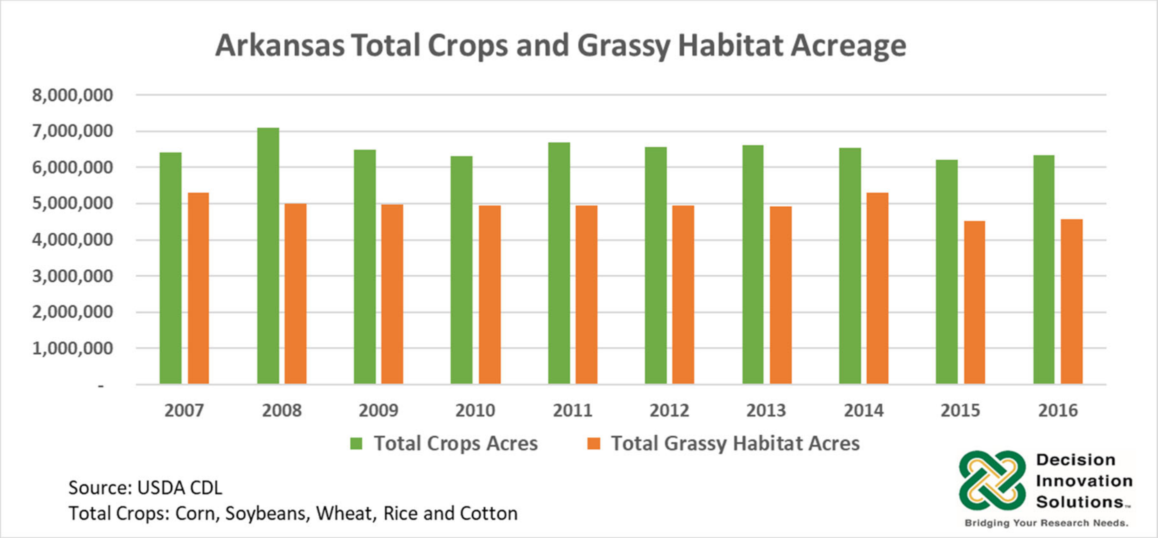
Table 7. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Missouri

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-13023768	0.1903
Year	6285	0.2026
Corn NOR/Grassy NOR Ratio	10680	0.0262 *

Soybean NOR/Grassy NOR Ratio	-1406	0.9054
Wheat NOR/Grassy NOR Ratio	26296	0.1545
Sorghum NOR/Grassy NOR Ratio	8275	0.3750
Rice NOR/Grassy NOR Ratio	21702	0.0090 **
Cotton NOR/Grassy NOR Ratio	-20471	0.0445 *

Arkansas

Land use in Arkansas is shown in Figure 18, from 2007 to 2016. Total crop acres planted ranged from a low of 6.21 million acres in 2015 to a high of 7.10 million acres in 2008. The total crops for Arkansas refer to corn, soybeans, wheat, rice and cotton. Total grassy habitat acreage ranged from 4.51 million acres in 2015 to 5.30 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, Rice and Cotton

Figure 18. Total Crops and Grassy Habitat Acreage in Arkansas (2007-16)

Table 8 summarizes econometric results with regard to the explanatory variables for Arkansas. No crop NOR ratios showed significant explanatory effects on the changes of acreage from grassy habitat to crops. This would indicate that a different model might be more appropriate for explaining these changes in Arkansas. An alternative model specified for Arkansas used only the NOR ratios for principal crops (i.e., corn, soybeans and wheat) to grassy habitat (Table 9). In this case, the NOR ratio of wheat to grassy habitat is significant, which may indicate that grassy habitat did not readily switch to cotton or rice acreage in Arkansas, but that higher NOR for wheat (relative to grassy habitat) may have triggered a switch from grassy habitat to wheat.

Table 8. Estimation of Coefficients on Acreage Changing from Grassy Habitat to Crops – Arkansas

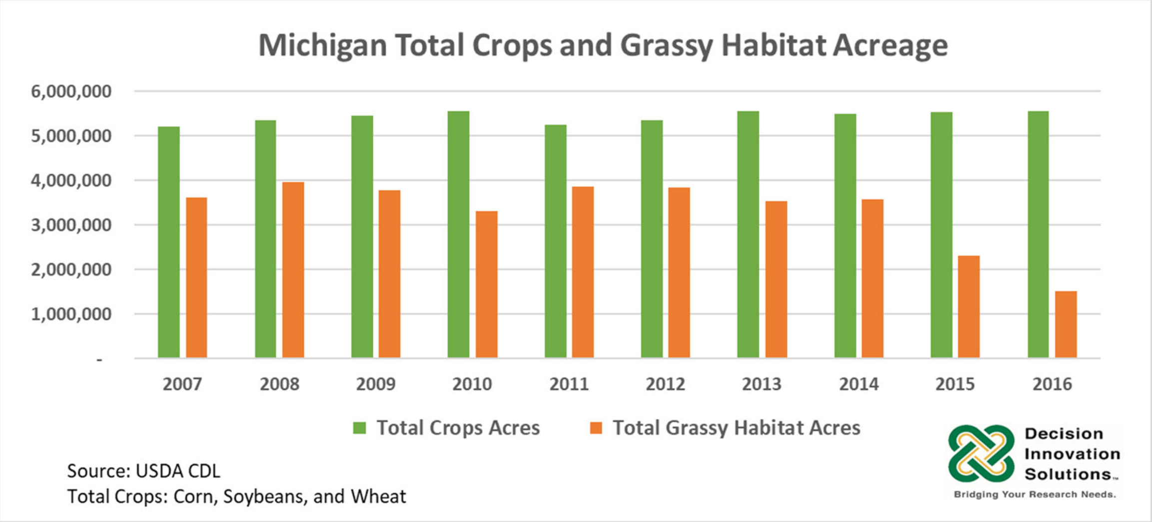
Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-5070432	0.3525
Year	2395	0.3762
Corn NOR/Grassy NOR Ratio	1570	0.4586
Soybean NOR/Grassy NOR Ratio	-2677	0.5891
Wheat NOR/Grassy NOR Ratio	12497	0.0901 .
Rice NOR/Grassy NOR Ratio	4788	0.1406
Cotton NOR/Grassy NOR Ratio	-2034	0.6376

Table 9. Alternative Model Estimation of Coefficients on Acreage Changing from Grassy Habitat to Crops – Arkansas

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-2405784.7	0.603
Year	1065	0.643
Corn NOR/Grassy NOR Ratio	-375.6	0.840
Soybean NOR/Grassy NOR Ratio	3615.7	0.360
Wheat NOR/Grassy NOR Ratio	52352.4	<0.0000 ***

Michigan

Land use in Michigan is shown in Figure 19, from 2007 to 2016. Total crop acres planted ranged from a low of 5.22 million acres in 2007 to a high of 5.57 million acres in 2013. The total crops for Michigan refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 1.52 million acres in 2016 to 3.97 million acres in 2008.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 19. Total Crops and Grassy Habitat Acreage in Michigan (2007-16)

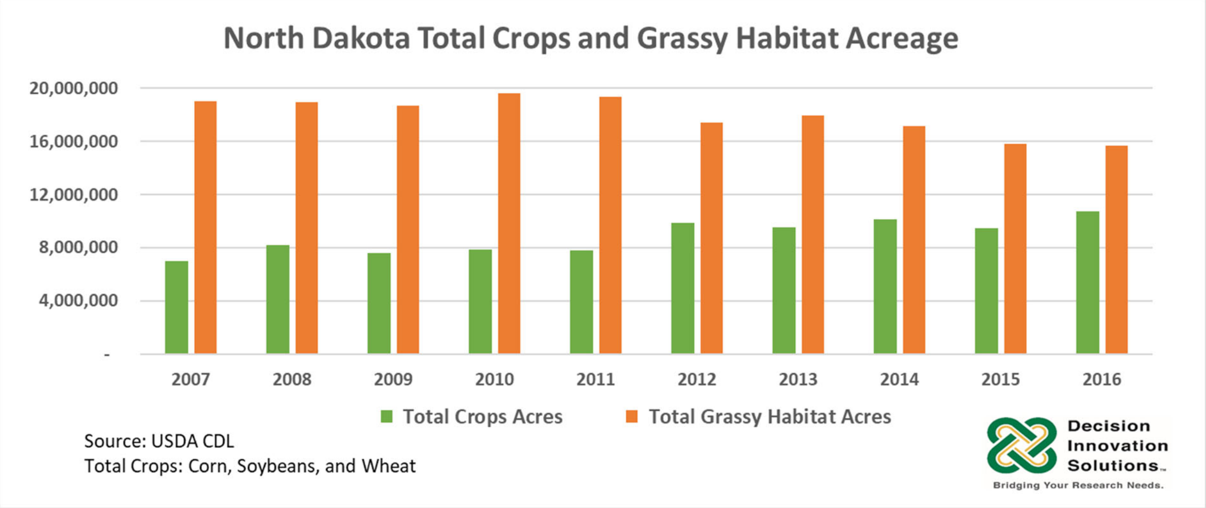
Table 10 provides a summary of econometric results with regard to the explanatory variables for Michigan. Corn NOR/grassy NOR ratio and soybean NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two ratios represent that with a higher NOR of corn or soybeans compared with the NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changing to crops are mainly for corn and soybeans. With the type one error was set to 0.05 the wheat NOR/grassy NOR ratio has no significant effect on the acreage changing.

Table 10. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Michigan

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	2092135.2	0.2173
Year	-1096.3	0.1930
Corn NOR/Grassy NOR Ratio	3051.2	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	6470.6	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	3321.9	0.0693 .

North Dakota

Land use in North Dakota is shown in Figure 20, from 2007 to 2016. Total crop acres planted ranged from a low of 6.98 million acres in 2007 to a high of 10.73 million acres in 2016. The total crops for North Dakota refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 15.26 million acres in 2016 to 19.61 million acres in 2010.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 20. Total Crops and Grassy Habitat Acreage in North Dakota (2007-16)

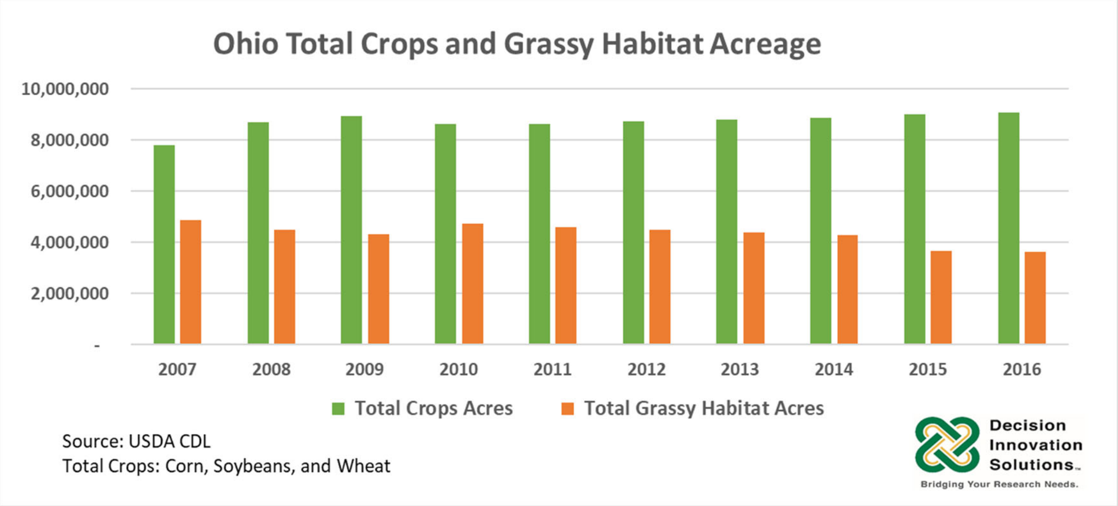
Table 11 provides a summary of econometric results with regard to the explanatory variables for North Dakota. Corn NOR/grassy NOR ratio and soybean NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these two ratios suggest that with a higher NOR of corn or soybeans compared with the NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for corn and soybeans. Wheat NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 11. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – North Dakota

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	7107916	0.366
Year	-3612	0.355
Corn NOR/Grassy NOR Ratio	7843	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	35281	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	-2029	0.777

Ohio

Land use in Ohio is shown in Figure 21, from 2007 to 2016. Total crop acres planted ranged from a low of 7.79 million acres in 2007 to a high of 9.07 million acres in 2016. The total crops for Ohio refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 3.62 million acres in 2016 to 4.85 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 21. Total Crops and Grassy Habitat Acreage in Ohio (2007-16)

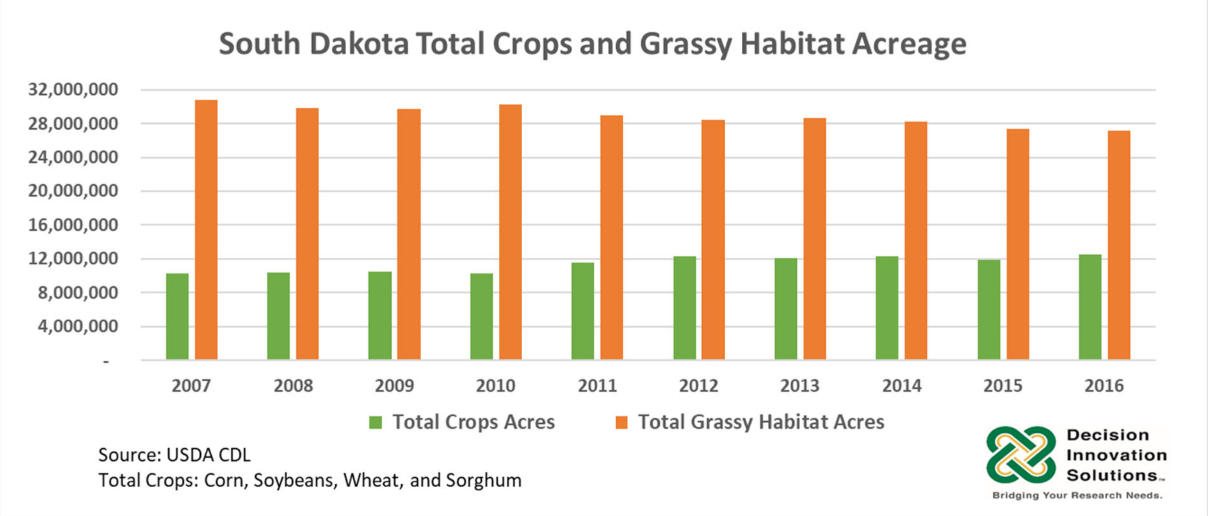
Table 12 provides a summary of econometric results with regard to the explanatory variables for Ohio. Corn NOR/grassy NOR ratio, soybean NOR/grassy NOR ratio and wheat NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these ratios represent that with a higher NOR of corn or soybeans, or wheat compared with the NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for soybeans, followed by corn and wheat.

Table 12. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Ohio

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-2144760.9	0.2001
Year	969.6	0.2434
Corn NOR/Grassy NOR Ratio	4877.6	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	22073.7	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	8554.5	0.0040 **

South Dakota

Land use in South Dakota is shown in Figure 22, from 2007 to 2016. Total crop acres planted ranged from a low of 10.31 million acres in 2010 to a high of 12.46 million acres in 2016. The total crops for South Dakota refer to corn, soybeans, wheat and sorghum. Total grassy habitat acreage ranged from 27.21 million acres in 2016 to 30.85 million acres in 2007.



Source: USDA CDL
Total Crops: Corn, Soybeans, Wheat, and Sorghum

Figure 22. Total Crops and Grassy Habitat Acreage in South Dakota (2007-16)

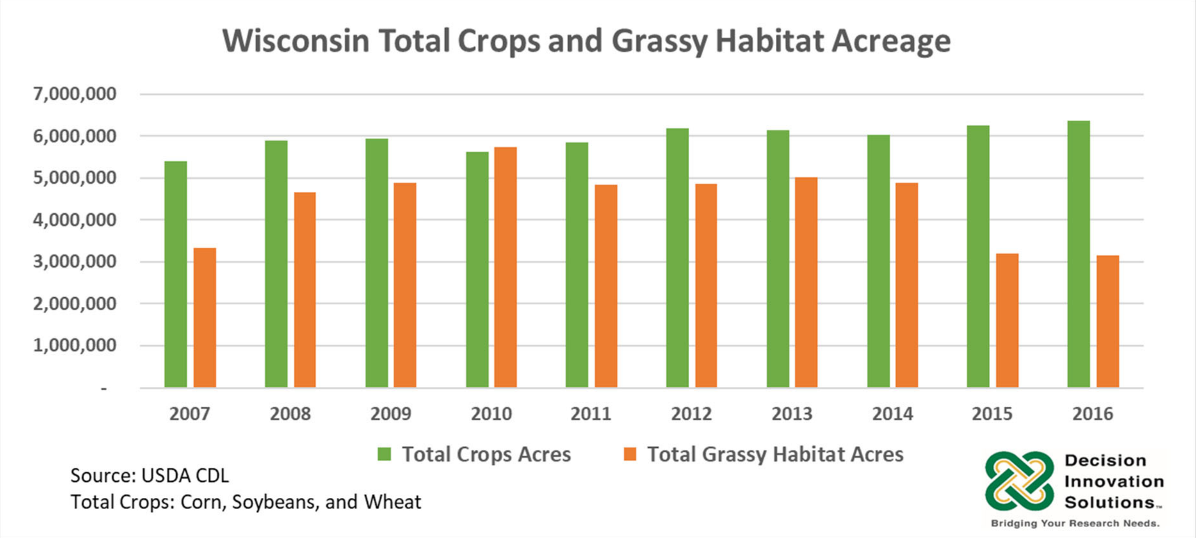
Table 13 provides a summary of econometric results with regard to the explanatory variables for South Dakota. Corn NOR/grassy NOR ratio, soybean NOR/grassy NOR ratio and wheat NOR/grassy NOR ratio had significant positive effects on the acreage change from grassy habitat to crops. The estimated coefficients of these ratios represent that with a higher NOR of corn, soybeans or wheat compared with the NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for soybeans, followed by corn and wheat. Sorghum NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 13. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – South Dakota

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-33691743	0.0009 ***
Year	6644	0.2010
Corn NOR/Grassy NOR Ratio	9511	<0.0000 ***
Soybean NOR/Grassy NOR Ratio	30554	<0.0000 ***
Wheat NOR/Grassy NOR Ratio	45606	<0.0000 ***
Sorghum NOR/Grassy NOR Ratio	-2124	0.7369

Wisconsin

Land use in Wisconsin is shown in Figure 23, from 2007 to 2016. Total crop acres planted ranged from a low of 5.39 million acres in 2007 to a high of 6.36 million acres in 2016. The total crops for Wisconsin refer to corn, soybeans and wheat. Total grassy habitat acreage ranged from 3.15 million acres in 2016 to 5.73 million acres in 2010.



Source: USDA CDL
Total Crops: Corn, Soybeans, and Wheat

Figure 23. Total Crops and Grassy Habitat Acreage in Wisconsin (2007-16)

Table 14 provides a summary of econometric results with regard to the explanatory variables for Wisconsin. Only corn NOR/grassy NOR ratio, among all the NOR ratio variables, had a significant positive effect on the acreage change from grassy habitat to crops. The estimated coefficient represents that with a higher NOR of corn compared with the NOR of grassy habitat, there will be more acreage changed from grassy habitat to crops. In this case, the acres changed to crops were mainly for corn. Soybean NOR/grassy NOR ratio and wheat NOR/grassy NOR ratio had no significant effect on the acreage changing.

Table 14. Estimation of Coefficient on Acreage Changing from Grassy Habitat to Crops – Wisconsin

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	5132002.1	0.0014 **
Year	-1577.1	0.1019
Corn NOR/Grassy NOR Ratio	1898.2	0.0027 **
Soybean NOR/Grassy NOR Ratio	2563.8	0.0669 .
Wheat NOR/Grassy NOR Ratio	-2191	0.2713

Economic Factors Influencing the planting of GM Crops versus Non-GM Crops

The purpose of this part of the analysis was to estimate the impact of econometric factors on non-GM corn and soybeans planted acreage. To have a better view of non-GM crops, non-GM crops and organic crops were treated separately. Since there are many data gaps on non-GM and organic crops systems, primary challenges were making assumptions appropriately and the imputation of missing values. Moreover, as only annual data by state level was available during the study period, the econometric analysis of GM and non-GM crops would be analyzed regardless of the states for this section.

Corn

Figure 24 and Figure 25 use pie charts to show the estimated GM corn (green color) and total non-GM corn (yellow color, organic and non-GM corn) planted acreage for the 12 states (Arkansas excluded) in the years of 2007 and 2016, respectively.

In 2007, Illinois planted the most non-GM corn acreage among all 12 states, with 3.04 million acres that occupied 26% of total Illinois corn planted acres. North Dakota planted the least non-GM corn acreage among all 12 states, with 0.29 million acres that occupied 12% of total North Dakota corn planted acres.

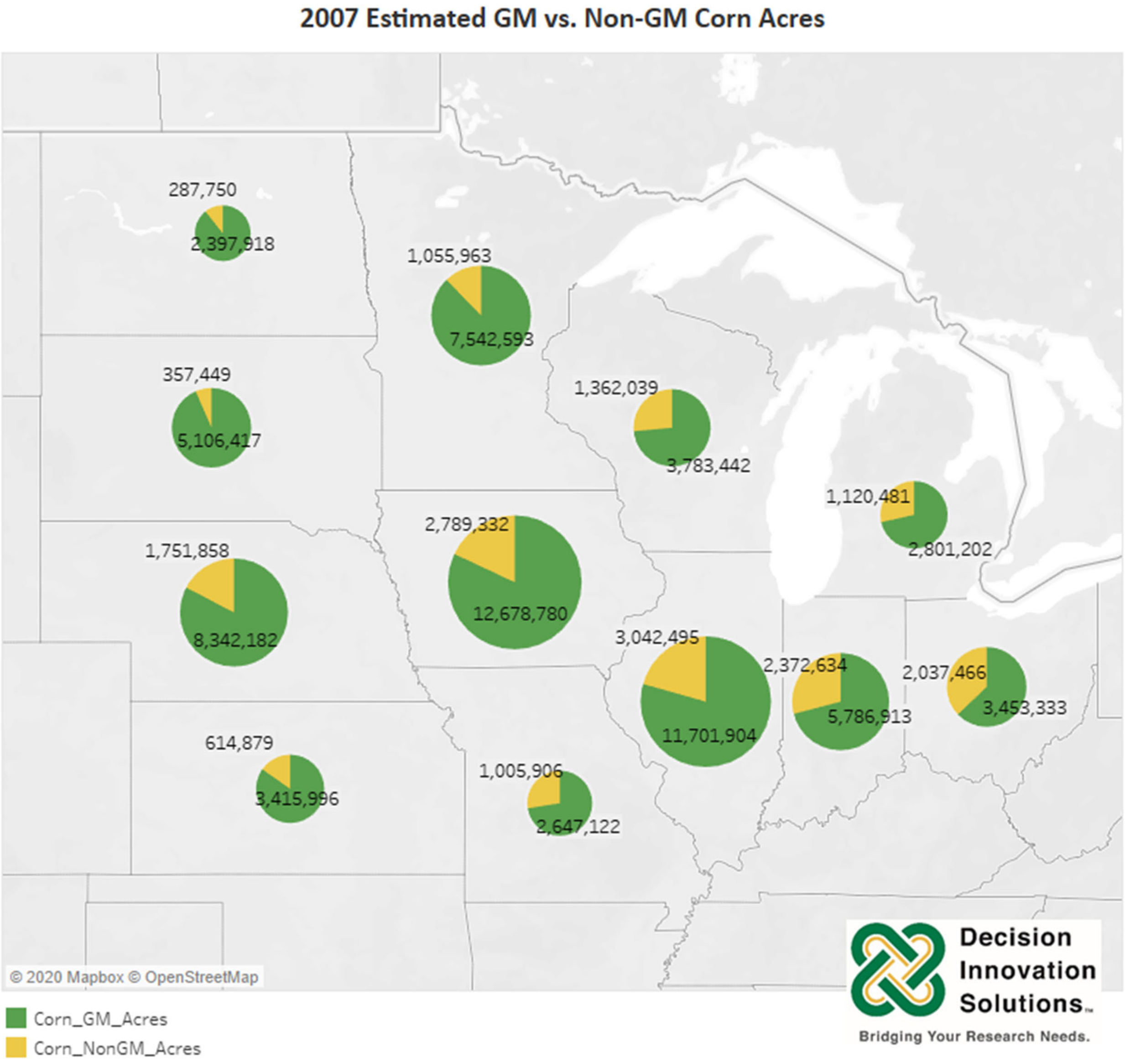


Figure 24. 2007 Estimated GM vs. Non-GM Corn Acres

In 2016, Iowa planted the most non-GM corn acreage among all 12 states, with 1.09 million acres that occupied 8% of acres planted to corn. South Dakota planted the least non-GM corn acres among all 12 states, with 0.11 million acres that occupied 2% of total South Dakota corn planted acres.

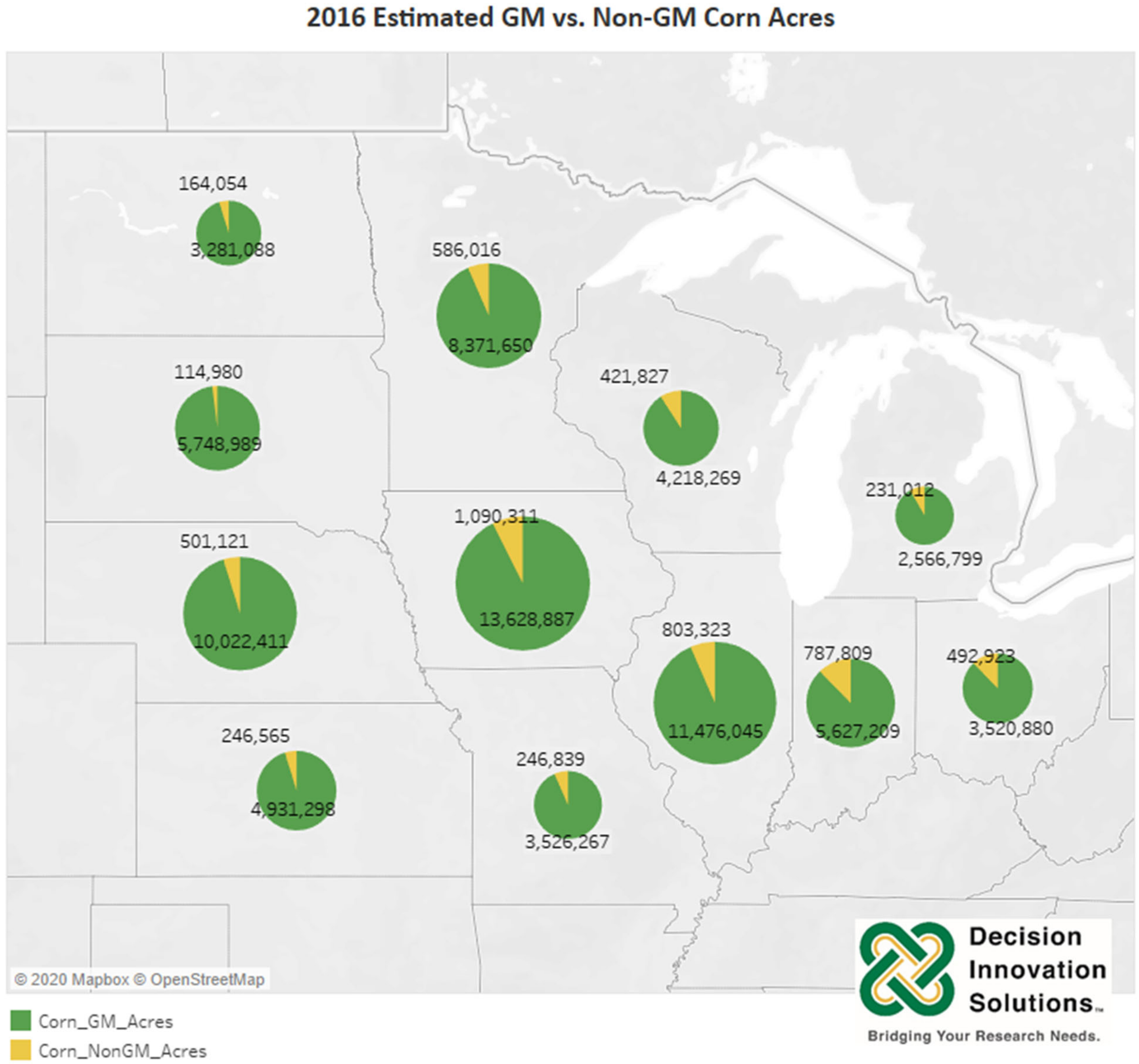


Figure 25. 2016 Estimated GM vs. Non-GM Corn Acres

Figure 26 shows the relationships between the planted acreage and the NOR for GM, non-GM, and organic corn for all study states from 2007 to 2016. The bar charts represent planted acres, and the lines represent net operating revenues above variable costs. The yellow color represents the numbers for non-GM variables, the green color represents the information for GM variables, and the purple color represents the information for organic variable. Since organic planted acreage was small compare with other planted acres, so the organic planted acre was combined with not organic and non-GM planted acres as the corn total non-GM acres shown in Figure 26. For all 12 states, the GM corn NORs were higher than non-GM corn NOR during the study period (2007 to 2016). Figure 2 demonstrates that at the national level, the share of non-GM planted acres after 2013 declined from more than 10% to around 8%.

Source: USDA CDL, NASS and ERS

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Figure 26. GM Corn vs Non-GM Corn Acreage and Net Return from 2007–16

Table 15 provides a summary of linear regression results with regard to the explanatory variables on the total non-GM corn planted acreage. The Year variable had a significantly negative effect on the total non-GM corn planted acres indicating that there was a significant time trend for reductions in total non-GM corn acres.

The estimated coefficient of the log term of organic corn/GM corn NOR ratio had a significantly positive effect, which demonstrates higher organic corn NOR could lead to higher total non-GM corn planted acreage. Increase 1% of organic corn NOR will increase 127,231 of total non-GM corn planted acres. On the other hand, the estimated coefficient of the log term of non-GM corn/GM corn NOR ratio had no significant effect on total non-GM corn planted acreage.

Table 15. Estimation of Coefficient on Total Non-GM Corn Acreage (2007–16)

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	223048714	<0.0000 ***
Year	-110531	<0.0000 ***
Log (Organic corn NOR/GM corn NOR Ratio)	127231	0.0107 *
Log (non-GM corn NOR/GM corn NOR Ratio)	16289	0.9300

Table 16 provides a summary of linear regression results with regard to the explanatory variables on the organic corn planted acreage. The estimated coefficient of the log term of organic corn/GM corn NOR ratio had a significantly positive effect (at $\alpha = 0.1$ level), which demonstrates higher organic corn NOR could lead to higher organic corn planted acreage. Increase 1% of organic corn NOR will increase 1,987 of organic corn planted acres.

Table 16. Estimation of Coefficient on Organic Corn Acreage (2007-16)

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-736663.8	0.3225
Year	372.9	0.3139
Log (Organic corn NOR/GM corn NOR Ratio)	1986.5	0.0616 .

Soybeans

Figure 27 and Figure 28 use pie charts to show the estimated GM soybeans (green color) and total non-GM soybeans (yellow color, organic and non-GM soybeans) planted acres for the 13 states in the years of 2007 and 2016, respectively. In 2007, Illinois planted the most non-GM soybeans acres among all 13 states, with 0.88 million acres, occupying 12% of total Illinois soybeans planted acres. South Dakota planted the least non-GM soybeans acres among all 13 states, with 98,052 acres, occupying 3% of total South Dakota soybeans planted acreage.

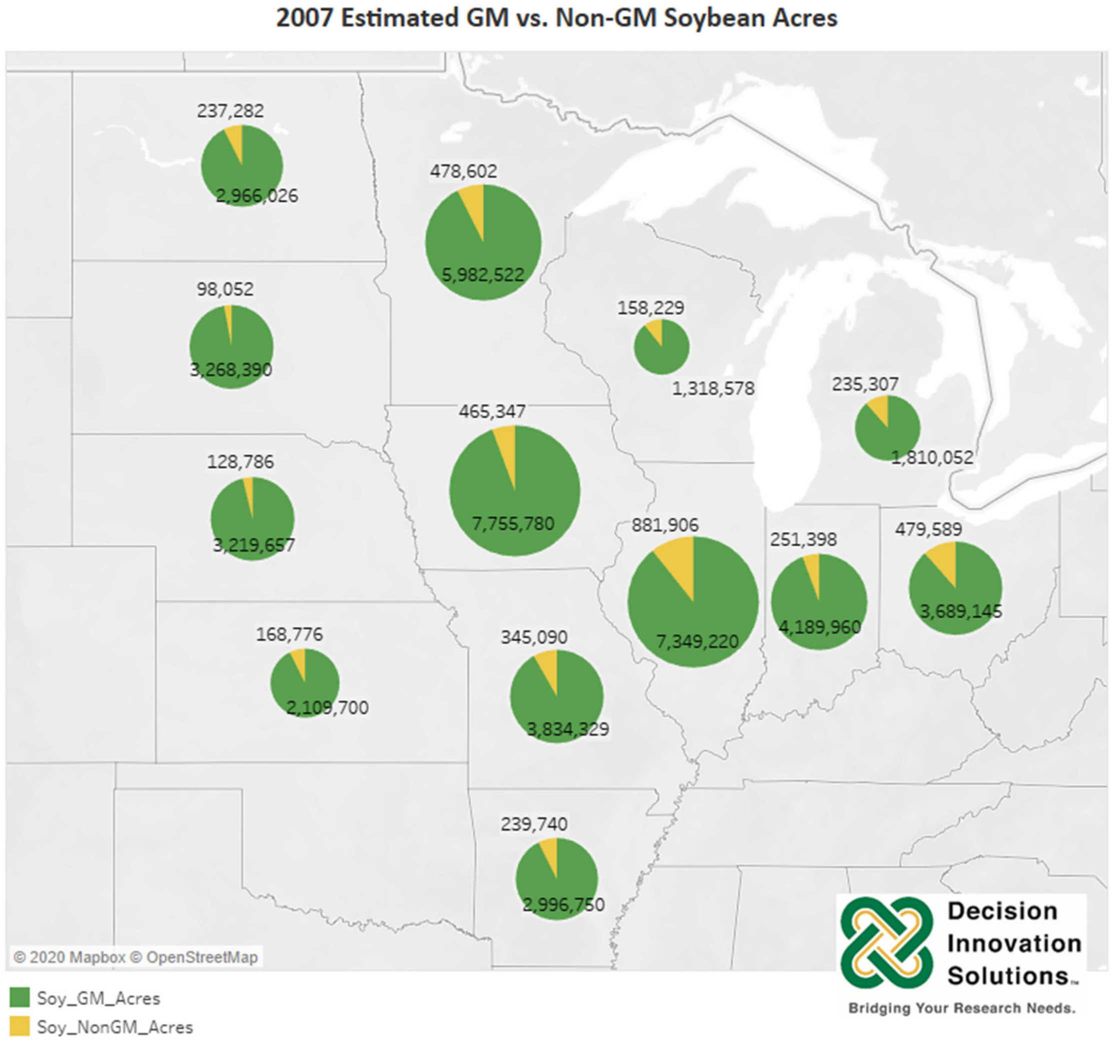


Figure 27. 2007 Estimated GM vs. Non-GM Soybean Acres

In 2016, Missouri planted the most non-GM soybeans acres among all 13 states, with 0.61 million acres occupying 11% of total Missouri soybeans planted acres. Wisconsin planted the least non-GM soybean acres among all 13 states, with 0.11 million acres occupying 6% of total Wisconsin soybean planted acres.

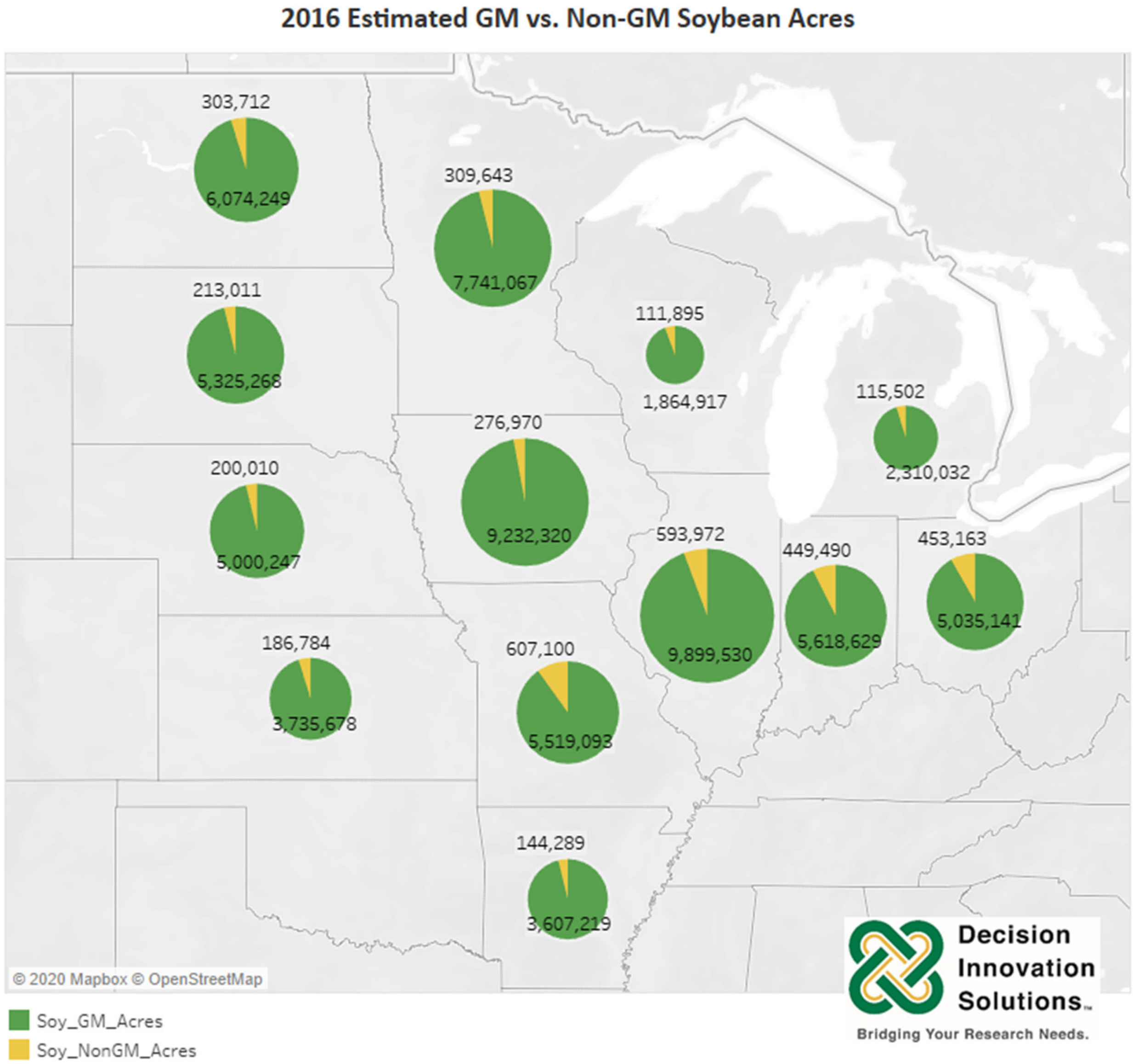
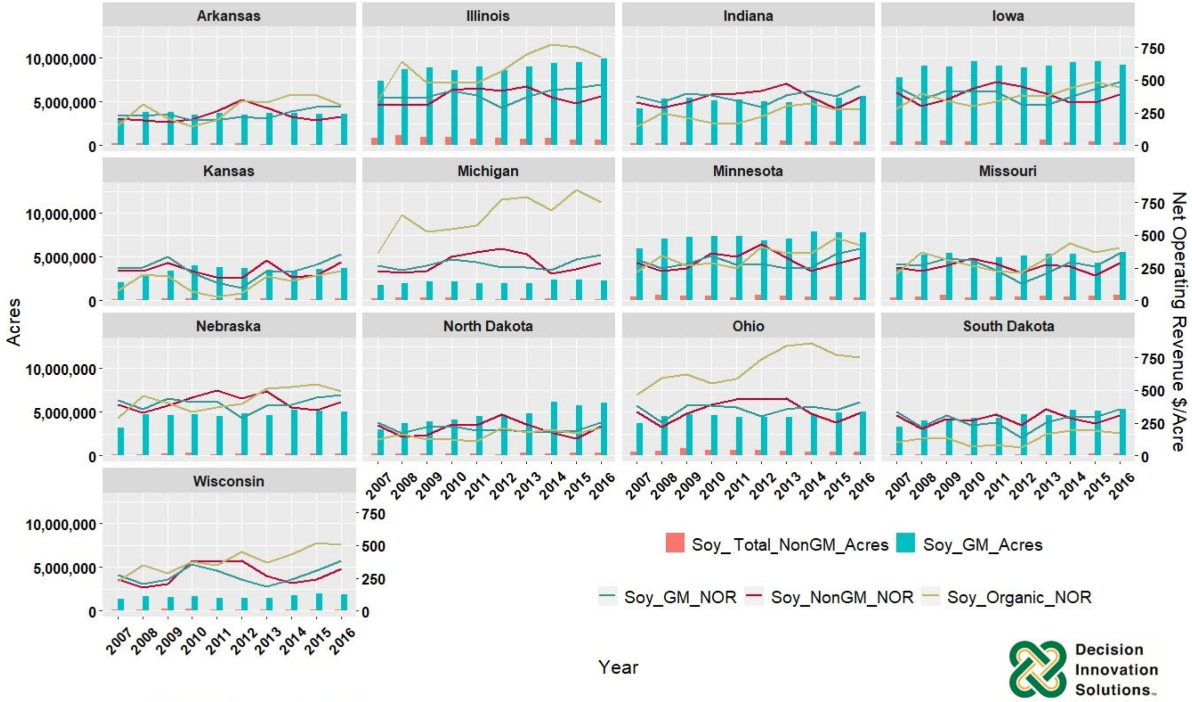


Figure 28. 2016 Estimated GM vs. Non-GM Soybean Acres

Figure 29 shows the relationships between the planted acres and the NOR for GM, non-GM and organic soybeans for all study states from 2007 to 2016. The bar charts represent planted acres and the lines represent NOR. The red color represents the numbers for non-GM variables, and the blue color represents the information for GM variables, the khaki color represents the information for organic variable. For all 13 states, the non-GM soybean NORs were higher than GM soybean NOR during 2010 to 2013. Before 2010 and after 2014, the GM soybean NORs were higher. After 2014, the share of non-GM soybean planted acres dropped down a little, from 7% to 6%, at the national level. But overall, the share of non-GM soybean planted acres were stable within the range of 6% to 9%, which was much smaller than the range of non-GM corn planted acres, which varied from 8% to 27%.



Source: USDA CDL, NASS and ERS

Figure 29. GM Soybeans vs Non-GM Soybeans Acreage and Net Return from 2007–16

Table 17 summarizes linear regression results with regard to the explanatory variables on the total non-GM soybean planted acreage. Similar to corn, the Year variable had a significantly negative effect on the total non-GM soybean planted acres indicating that there was a significant time trend for reductions in total non-GM soybean acres (at α = 0.1 level).

The estimated coefficient of the log term of organic soybean/GM soybean NOR ratio had a significantly positive effect, which demonstrates higher organic soybean NOR could lead to higher total non-GM soybean planted acreage. Increase 1% of organic soybean NOR will increase 149,646 of total non-GM soybean planted acres. On the other hand, the estimated coefficient of the log term of non-GM soybean/GM soybean NOR ratio had no significant effect on total non-GM soybean planted acreage.

Table 17. Estimation of Coefficient on Total Non-GM Soybean Acreage for All States (2007–16)

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	25117535	0.0575 .
Year	-12320	0.0609 .
Log (Organic soybean NOR/GM soybean NOR Ratio)	149646	<0.0000 ***
Log (non-GM soybean NOR/GM soybean NOR Ratio)	-29256	0.6921

Table 18 provides a summary of linear regression results with regard to the explanatory variables on the organic soybean planted acreage. The estimated coefficient of the log term of organic soybean/GM soybean NOR ratio had no effect.

Table 18. Estimation of Coefficient on Organic Soybean Acreage (2007-16)

Coefficients	Estimate	P-value (Prob >|t|)
Intercept	-565248	0.183
Year	285	0.178
Log (Organic corn NOR/GM corn NOR Ratio)	1174	0.239

Conclusions

Spatial Implications

- Land use change results support the perception that land use continues to evolve in the 13 states. The assumption, by some, regarding the large degree to which net land use changed away from grassy habitat to crops is accurate, for the study period from 2007 to 2016. When looking at the other two study periods, i.e., 2007–12 and 2012–16, most of the states exhibited net land use change away from grassy habitat except for

Michigan and Wisconsin. It can be concluded that, within the 10-year period, a significant portion of the 13-state study area suffered net losses in grassy habitat.

- The percent of non-GM corn planted acreage has decreased for all 12 states (Arkansas excluded) from 2007-2016. At the national level, the share of non-GM planted corn acres after 2013 declined from more than 10% to around 8% (Figure 2). Ohio had the highest percentage of acreage planted to non-GM corn ranging from 14% (in 2014 and 2016) to 59% (in 2007); while South Dakota had the lowest planted acreage for non-GM corn ranging from 2% (in 2016) to 7% (in 2007). The percent of non-GM soybean planted acreage remained stable, ranging from 6% to 9% at the national level.
- Other key findings of this spatial research with regard to spatial implications was the degree of value gained from using CDL data for decision-making. While the data have been improving over time and continues to increase its ability to guide the policy decision-making process, there still were some differences between CDL and USDA/NASS survey data, mainly because of how certain types of land covers were identified, particularly those which were either comparatively observed less frequently or were more grassy in nature.

Econometric Implications

- For the first part of econometric analysis, the land use change from grassy habitat to crops for a given state was studied. A summary results table (Table 19) is shown below. Due to the diversity of each state's planting scenarios, different crops' NOR/grassy NOR ratio combinations were involved. Corn, soybeans and wheat were the three most common crops among the 13-states examined. Rice NOR/grassy NOR ratio was only used for Missouri.
- Not surprisingly, all signs of the variables were positive, because when a crop NOR/grassy NOR ratio increase, there would be more acreage change from grassy habitat to the corresponding crop to gain a better profit. **Corn NOR/grassy NOR ratio (11 out of the 13 states) and soybean NOR/grassy NOR ratio (10 out of the 13 states) showed a significant effect.** These two ratios represented that with a higher NOR of corn or soybeans compared with that of grassy habitat, it will increase the change from grassy habitat to crops. Neither of these two ratios had a significant effect for Arkansas, instead, wheat NOR/grassy NOR ratio was the dominant variable on acreage change from grassy habitat to crops.

Table 19. Sign and Significance of Estimated Coefficients for Each Variable of Each State

State	Parameter	Corn NOR / Grassy NOR	Soybean NOR / Grassy NOR	Wheat NOR / Grassy NOR	Sorghum NOR / Grassy NOR	Cotton NOR / Grassy NOR	Rice NOR / Grassy NOR
Iowa	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	NO			
Illinois	Sign	Positive	Positive	Positive	Positive		
	Significance	**YES**	**YES**	NO	**YES**		
Nebraska	Sign	Positive	Positive	Positive	Positive		
	Significance	**YES**	**YES**	NO	NO		
Minnesota	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	**YES**			
Indiana	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	NO			
Kansas	Sign	Positive	Positive	Positive	Positive	Positive	
	Significance	NO	**YES**	**YES**	NO	**YES**	
Missouri	Sign	Positive	Positive	Positive	Positive	Positive	Positive
	Significance	**YES**	NO	NO	NO	**YES**	**YES**
Arkansas	Sign	Positive	Positive	Positive			
	Significance	NO	NO	**YES**			
Michigan	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	NO			
North Dakot	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	NO			
Ohio	Sign	Positive	Positive	Positive			
	Significance	**YES**	**YES**	**YES**			
South Dakot	Sign	Positive	Positive	Positive	Positive		
	Significance	**YES**	**YES**	**YES**	NO		
Wisconsin	Sign	Positive	Positive	Positive			
	Significance	**YES**	NO	NO			

For the second part of the econometric analysis, the dominant factor that led to the total non-GM corn, organic corn planted acre changes, and total non-GM soybean, organic soybean planted acre changes (decreases for not organic and non-GM crop planted acres and increases for organic crop planted acres, generally speaking) from the study period from 2007 to 2016 was examined. It was found that:

1. In all cases, the time variable had a significantly negative effect on both non-GM corn and non-GM soybean planted acreage.
2. Higher organic corn NOR and organic soybean NOR contribute to increases in total non-GM corn AND total non-GM soybean planted acreage.
3. Higher organic corn NOR leads to the larger organic corn planted acreage, but the organic soybean NOR did not have a similar impact on organic soybean planted acres.
4. For non-GM (non-organic) corn planted acreage and non-GM (non-organic) soybean planted acreage, the net operating revenues did not show any significant influences on non-GM acreage. This suggests that those planting non-GM (non-organic) corn and soybeans, in aggregate, are doing so for reasons beyond year-to-year changes in NOR.

5. The highly significant time variable indicates that there are strong non-economic factors beyond NOR that are driving adoption of GM crop technologies.

Therefore, it is concluded that organic corn NOR and organic soybean NOR are significant drivers for overall non-GM crop production acreage and are significant drivers for organic production acres, but differences in the premiums of NOR of non-organic, non-GM crops versus GM crops has not exerted significant influence on overall non-GM crop acreage. In most cases, corn is the driver for a farmer's production methodology preference (either GM or non-GM).

Environmental implications of GM versus non-GM crop selection (Priority 2)

Introduction

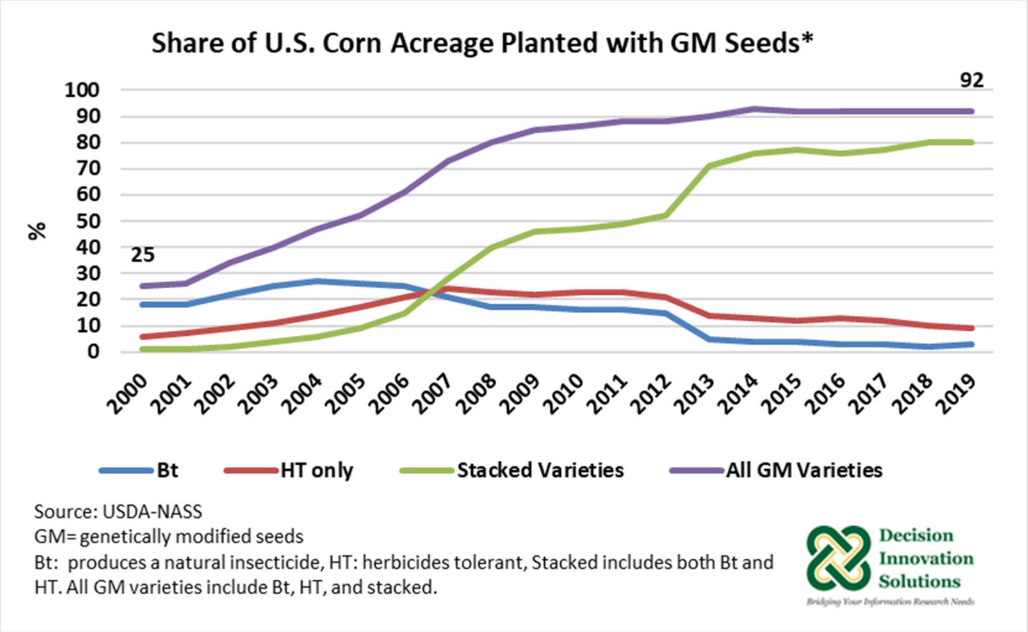
The selection of crops (non-GM vs. GM crops) would impact the environment in several ways. GM crops with enhanced nitrogen use efficiency could help reduce nitrate runoff. Also, the environmental literature indicates low-till/no-till agriculture enabled by herbicide tolerant (HT) GM crops can contribute to the reduction in GHG emissions and generate other environmental benefits. Farmers have resorted to till the fields in order to disrupt weeds; however, tilling can cause erosion as well as soil compaction which, in turn reduces the soil capacity to absorb water causing runoff that can pollute rivers with residual chemicals (National Research Council, 2010). Research indicates that GM HT crop adoption reduces farmers' dependence on tillage for weed management. By reducing tillage activities, farmers benefit in terms of fuel, equipment and labor costs (Fernandez-Cornejo et al., 2013). Fuel reduction leads to lower CO_2 emissions, which benefits the environment. Research by Wade, Kurkalova and Secchi (2016) indicates that conservation tillage, which leaves at least 30% of crop residue on the soil surface at the time of planting, benefits soil structure, lowers soil temperature and evaporation, increases infiltration, and reduces soil erosion and nutrient runoff. Conservation tillage reduces the carbon footprint of agriculture (Fernandez-Cornejo et al., 2013). Improved soil quality and reduced soil erosion means more carbon remains in the soil, resulting in lower GHG emissions.

Authors Brookes and Barfoot (2018) conducted an evaluation of the key environmental impacts associated with the U.S. adoption of GM HT technology, which provides tolerance to specific herbicides, mainly glyphosate, in corn and soybeans. The authors assessed the impact of GM crop use on GHG emissions, mainly based on fuel use and tillage systems in crop production processes. GM HT technology facilitates no-till and reduced-tillage farming compared to non-GM crop production commonly employing traditional tillage systems. The significant shift from a plow-based to reduced/no-tillage cropping system has resulted in a reduction in total fuel and energy use. Based on their findings, 416 million kilograms of CO_2 were saved as a result of 156 million liters lower fuel use in the production of HT corn in the U.S. in 2016 alone. An even more impactful result was found related to the adoption of GM HT soybeans in 2016 in the U.S., with a reduction in fuel use of 202 million liters, which translated to a savings of 533 million kilograms of CO_2 emissions. In addition, the authors argue that the adoption and maintenance of reduced till/no-till production systems in North America, aided by GM HT crops (especially in soybeans), has enhanced farmers' ability to control competing weeds, which lowers the dependence on soil cultivation and seed-bed preparation, resulting in improved of soil quality and reduction in soil erosion.

Temporal Trends and Planting of GM Corn and Soybeans in the U.S.

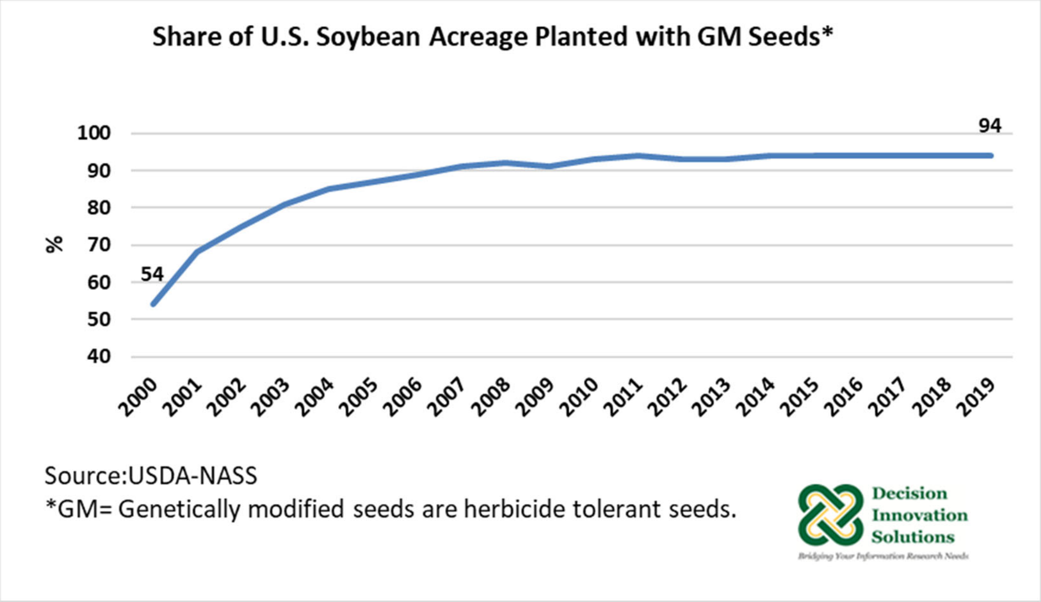
Part of the information in this section is based on several USDA/NASS Agricultural Chemical Use Surveys of corn and soybean producers. Some of the data collected in the surveys includes nitrogen used and pest management practices. The years selected were 1995, which is the year before GM seeds were available in the U.S., and 2018, a year when 92% of U.S. corn planted acres and 94% of U.S. soybean planted acres were planted using GM seeds (see Figure 30 and Figure 31). Based on data availability, three other years between these two periods were included.

GM seeds have been widely adopted by U.S. corn and soybean farmers. Roughly 24% of corn acres planted in the U.S. were HT seeds in 2007; while the percentage of seeds with HT declined to 9% by 2019, the prevalence of stacked trait corn hybrids, which include HT and insect resistance (Bt) traits has now reached 80%. Overall, 92% of U.S. corn acres were planted with GM seeds in 2018 and 2019 (including the combination of Bt only, HT only and stacked) (see Figure 30). In the case of soybeans, the share of U.S. soybean acres planted to HT seeds grew from 54% in 2000 to 94% in 2018 and 2019, respectively (Figure 31).



Source: USDA-NASS
GM= genetically modified seeds
Bt: produces a natural insecticide, HT: herbicides tolerant, Stacked includes both Bt and HT. All GM varieties include Bt, HT, and stacked.

Figure 30. Share of U.S. Corn Acreage Planted with GM Seeds

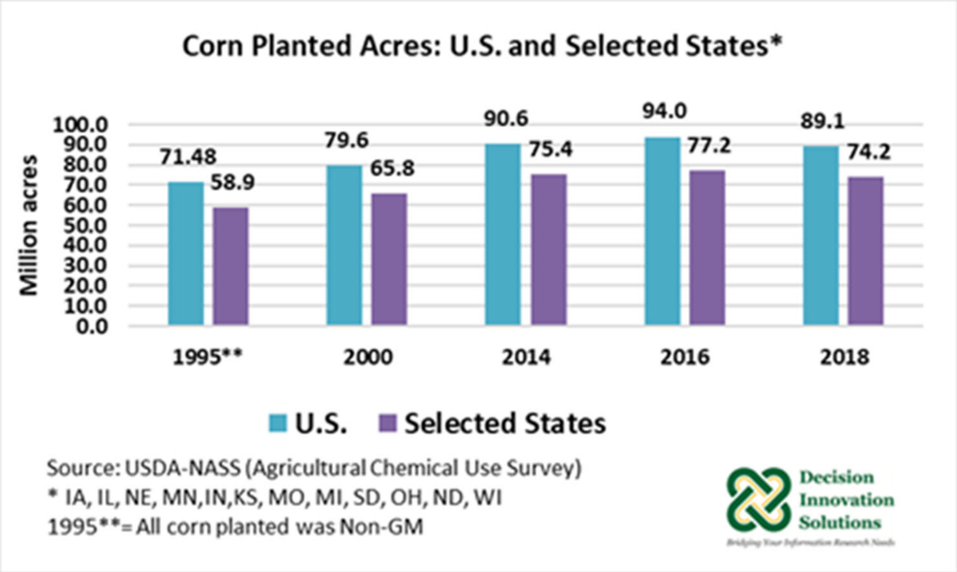


Source:USDA-NASS

*GM= Genetically modified seeds are herbicide tolerant seeds.

Figure 31. Share of U.S. Soybean Acreage Planted with GM Seeds

Corn data is presented for 12 states (Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, Missouri, Michigan, South Dakota, Ohio, North Dakota and Wisconsin). Arkansas was not included due to lack of data. These 12 states accounted for 82% of the 58.9 million acres planted to corn in 1995 and 83% of the 89.1 million acres planted to corn in 2018 (see Figure 32). Soybean data presented includes the same states as corn plus Arkansas. These 13 states accounted for 84% of the 62.5 million acres planted to soybeans in 1995 and 85% of the 89.2 million acres planted in 2018 (see Figure 33).

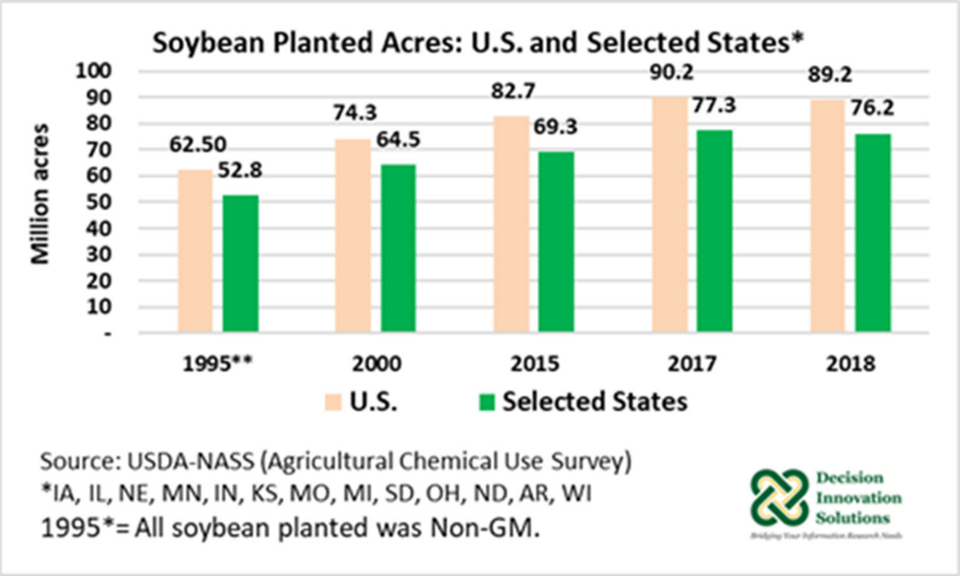


Source: USDA-NASS (Agricultural Chemical Use Survey)

* IA, IL, NE, MN, IN, KS, MO, MI, SD, OH, ND, WI

1995**= All corn planted was Non-GM

Figure 32. Corn Planted Acres: U.S. and Selected States



Source: USDA-NASS (Agricultural Chemical Use Survey)
*IA, IL, NE, MN, IN, KS, MO, MI, SD, OH, ND, AR, WI
1995*= All soybean planted was Non-GM.

Figure 33. Soybean Planted Acres: U.S. and Selected States

Nitrogen Use Efficiency

Percentages of corn planted acres treated with Nitrogen (N) has remained about the same from 1995 (97%) to 2018 (98%), as shown in Figure 34; however, the rate of nitrogen efficiency has improved during the expansion period of GM seed use. The average number of nitrogen pounds used per bushel of production declined 26% from 1.2 pounds of nitrogen per bushel of corn in 1995, to 0.90 pounds in 2018 among all 12 states selected (see Figure 35). Among the top three corn producers – Iowa, Illinois and Nebraska – nitrogen use declined even further. For Iowa and Illinois, nitrogen use per bushel of corn fell 30% and 43%, respectively, from 1995 to 2018. Nebraska's use of nitrogen per bushel of corn declined 31% during this period (see Figure 36). GM crops with enhanced nitrogen use efficiency could help reduce nitrate runoff, while contributing to increased yield. As shown in Figure 37, on average, among the selected states, corn yield increased from 109 bushels/acre in 1995 to 172 bushels/acre in 2018.

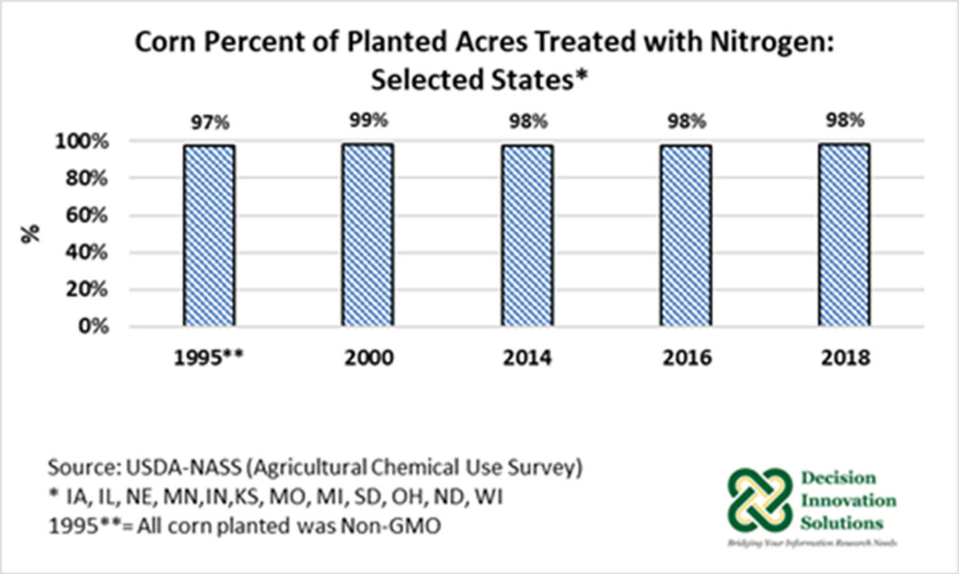


Figure 34. Corn Percent of Planted Acres Treated with Fertilizers: Selected States

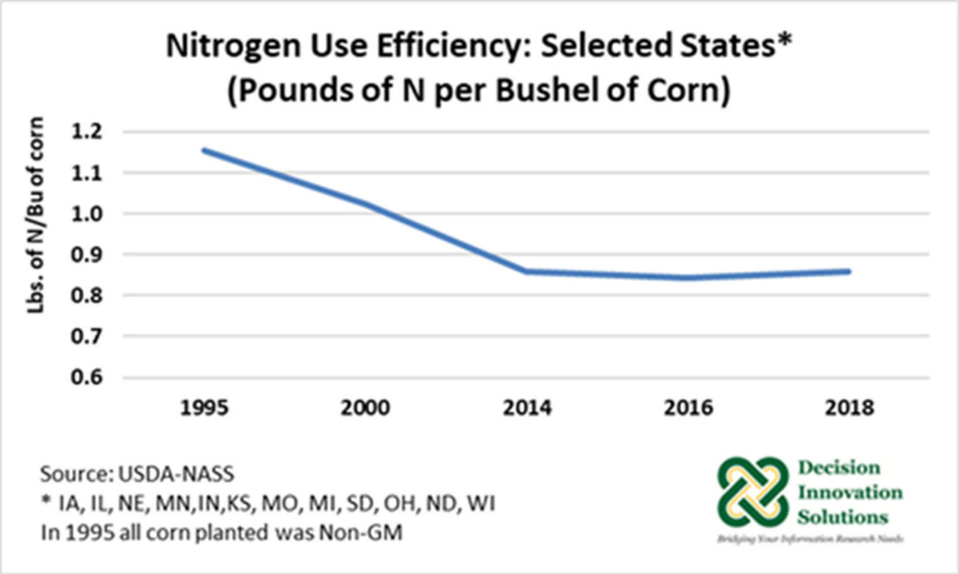


Figure 35. Nitrogen Use Efficiency: Selected States (Pounds of N per Bushel of Corn)

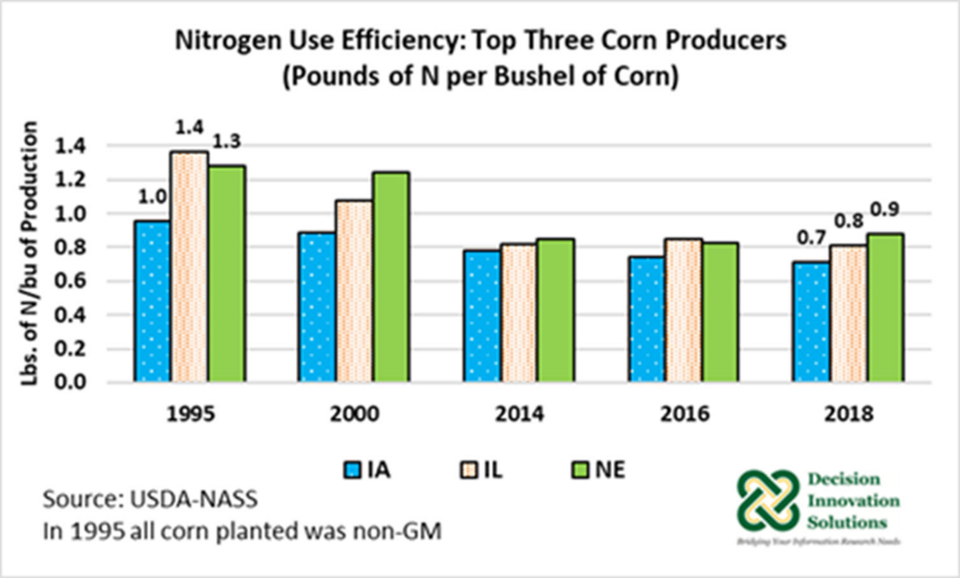


Figure 36. Nitrogen Use Efficiency: Top Three Corn Producers (Pounds of N per Bushel of Corn)

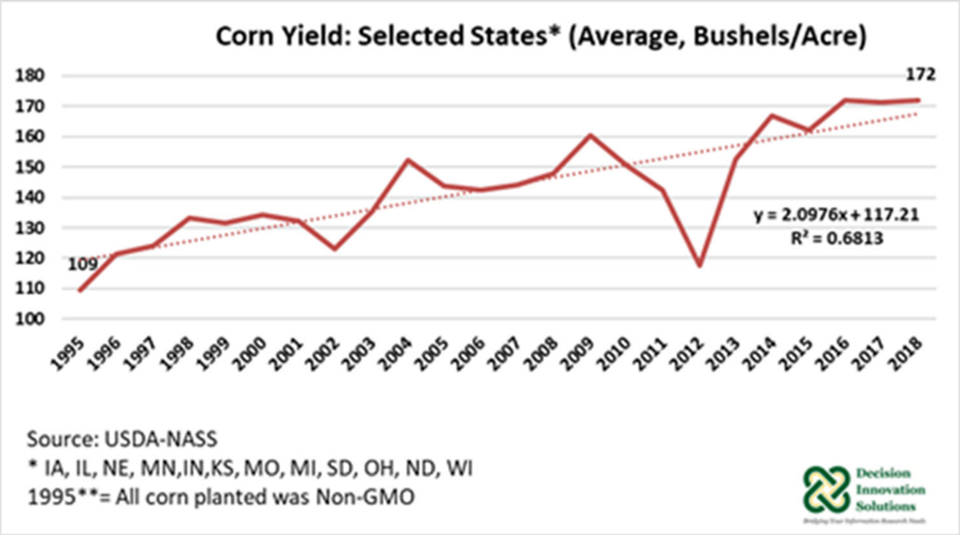


Figure 37. Corn Yield: Selected States (Average, Bushels/Acre)*

Nitrogen Emissions in Corn Production

Three of the primary environmental issues for nitrogen use in corn production result from volatilization of N at application, N leaching in drainage, and N releases through denitrification.

Volatilization

Volatilized ammonia loss from fertilizer is related to the type of N fertilizer, application method, soil pH, and timing of rainfall after application (Meisinger & Randall, 1991). The amount and type of surface residue can also impact volatilization from surface applied urea/urea-based products, products which, in general, can be subject to large volatilization losses. Soil type can influence such losses with coarse textured soils losing a greater percentage of applied anhydrous ammonia N than fine textured soils (Stanley & Smith, 1956). Losses can be minimal with use of ammonia-based fertilizers if placement is at least 15 cm in depth and if application occurs when soil moisture conditions are optimal (Stanley & Smith, 1956). However, such application under “optimal soil conditions” can be challenging due to the precipitation events. Generally, the reported range of percent of fertilizer lost through volatilization in the Midwest is 0 to 15% (Burkart et al., 2005; Burkart & James, 1999; Jordan & Weller, 1996; Puckett et al., 1999; Stanley & Smith, 1956). More specifically, volatilization losses from anhydrous ammonia and N solutions/UAN have been listed at 1 to 4% and 2.5%, respectively, of the soil inorganic N content (Bouwman et al., 1997; Libra et al., 2004). Burkart and James (1999) and Goolsby et al. (1999) described this output as ranging from 2 to 6 kg N/ha (1.8 to 5.4 lb N/ac) in Iowa. Properly injected anhydrous ammonia typically makes volatilization losses negligible unless soil moisture conditions are not optimal (Bouwman et al., 1997). Similar to other gaseous N outputs from the soil, fertilizer N volatilization is difficult to quantify, highly variable, and is associated with high uncertainty (Castellano et al., 2012).

Castellano et al. (2012) report volatilization rates for three different application rates in corn-soybean rotations in Iowa with 2.4 lbs N volatilized when the application rate was 123 lbs N applied per acre; 2.6 lbs N volatilized when 135 lbs N was applied per acre; and 2.8 lbs N volatilized when 147 lbs N applied per acre. Under the rational assumption that farmers planting non-GM corn that has a 5% yield disadvantage to GM corn would apply approximately 5% less N per acre of corn planted, it should be expected that N volatilization would be about 2.1% less per acre than would be expected in GM corn. If, however, it takes 4.9% more corn acres to yield the same level of production with non-GM corn as would be expected with GM corn, then total N volatilization under all non-GM corn production would be expected to be 2.7% higher than with all GM corn production.

N Leaching

Leaching of N in drainage, predominantly in nitrate form, can be a major output from the soil system in Midwest cropping systems. Typical loads range from 18 to 31 lbs of N per acre (David et al., 1997; Gentry et al., 2000; Jaynes et al., 2001; Kalita et al., 2006). While there are many “controllable” and “uncontrollable” factors affecting N leaching through drainage, precipitation (amount of precipitation, timing of precipitation, and extreme precipitation events) if one of the most important uncontrollable factors influencing nitrogen losses through drainage and leaching (Randall & Goss, 2008). Castellano et al. (2012) report N losses through drainage of 20 lbs N per acre at application rates of 123 lbs N per acre, 21 lbs of N leaching at application rates of 135 lbs per acre, and 28 lbs of N leaching at application rates of 147 lbs N per acre.

Under the rational assumption that farmers planting non-GM corn that has a 5% yield disadvantage to GM corn would apply approximately 5% less N per acre of corn planted, it should be expected that N leaching would be about 0.56% less per acre than would be expected in GM corn. If, however, it takes 4.9% more corn acres to yield the same level of production with non-GM corn as would be expected with GM corn, then total N volatilization under all non-GM corn production would be expected to be 4.3% higher than with all GM corn production.

Denitrification

Denitrification is the microbial transformation of nitrate to gaseous nitric oxide, nitrous oxide and dinitrogen gas (NO, N_2O, and N_2) and is typically the predominant N loss pathway from the soil to the atmosphere. In nature, the vast majority of these gaseous denitrification emissions are in the form of N_2O and N_2 rather than NO. In agricultural production systems with high nitrate concentration, such as corn, denitrification is typically controlled by soil water content (oxygen availability) and dissolved organic carbon availability. Thus, soil organic matter and drainage class can provide an estimate of potential denitrification (Meisinger & Randall, 1991) (Table 20). Based on an assumed organic matter content of 3.5% for Iowa soils, Goolsby et al. (1999) estimated denitrification losses were 20% of available N inputs. For an Illinois N budget, David and Gentry (2000) assumed 10% of the fertilizer application was lost. Modeling estimates of denitrification losses in the Midwest region range from 5.4 to 27 lbs N per acre (Burkart & James, 1999; Goolsby et al., 1999; Seitzinger et al., 2006). Others have reported findings of N losses of 36-41 lbs N per acre for poorly drained soils and 22-26 lbs N per acre for well drained soils. In a comparison of five denitrification simulation models, David et al. (2009) reported annual denitrification loss rates ranging from 2.9 to 30 lbs N loss per acre per year with an average loss of 12.9 lbs N per acre per year for an Illinois watershed. Castellano et al. (2012) reported denitrification losses for the corn phase of a corn soybean rotation in Iowa of 5.9 lbs N per acre per year for N application rates of 123 lbs N per acre; 6.5 lbs N per acre per year loss at an N application rate of 135 lbs N per acre, and 7.1 lbs N loss per acre per year at an N application rate of 147 lbs N per acre.

Under the rational assumption that farmers planting non-GM corn that has a 5% yield disadvantage to GM corn would apply approximately 5% less N per acre of corn planted, it should be expected that N losses from denitrification would be about 5.2% less per acre than would be expected in GM corn. If, however, it takes 4.9% more corn acres to yield the same level of production with non-GM corn as would be expected with GM corn, then total N denitrification losses under all non-GM corn production would be expected to be 0.55% less than with all GM corn production.

Table 20. Nitrogen Emissions in Corn

Nitrogen Emissions in Corn			
Nitrogen Application Rate (Lbs N/Acre/Year)	Fertilizer Volatilization (Lbs N/Acre/Year)	Drainage Leaching (Lbs N/Acre/Year)	Denitrification (Lbs N/Acre/Year)
123	2.4	20	5.9
135	2.6	21	6.5
147	2.8	28	7.1
Percent Change with All Non-GM Corn:	+2.7%	+4.3%	-0.6%
Based on Christianson et al., (2012) emission rates, and assumption of a 5% decrease in N applied for Non-GM corn and an increase in acreage of 4.9% to achieve equivalent production as when 92% of planted corn is GM.			

Influence of Tillage Practices on Greenhouse Gas Emissions

Data Source**:** Information about the prevalence of production practices, such as no-till or minimum-till, comes from USDA/NASS Agricultural Chemical Use Surveys of corn and soybean producers. The quantification of the environmental implications of employing alternative production practices related to no-till vs. conventional tillage corn production was based on 2020 corn budget information published by the University of Nebraska-Lincoln, 2020.

Data limitations**:** Of the several crop production budgets collected for this analysis, none included information on water use and the effect of erosion related to alternative production practices employed while using GM vs non-GM seeds. Therefore, quantification of the environmental (water use/quality and erosion) implications of employing alternative production practices in producing GM vs non-GM corn and soybeans were not included in this analysis.

Prevalence of No-Till/Minimum-Till Practices

Based on USDA/NASS Agricultural Chemical Use Surveys of corn[6] and soybean producers[7], on average, about 65% of corn planted acres during 2014, 2016 and 2018 were planted using no-

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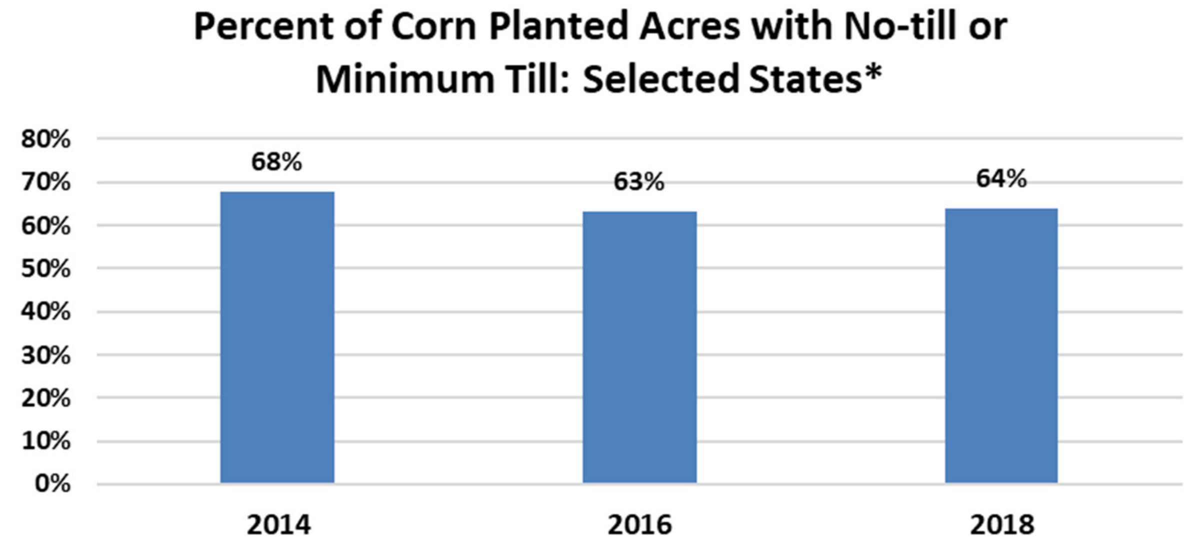
[6] States selected from USDA/NASS Agricultural Chemical Use Surveys include: Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, Missouri, Michigan, South Dakota, Ohio, North Dakota and Wisconsin. Arkansas was not included due to a lack of data. These 12 states accounted for 82% of the 71.5 million acres planted to corn in 1995 and 83% of the 88.9 million acres planted to corn in 2018.

[7] States selected from USDA/NASS Agricultural Chemical Use Surveys include: Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, Missouri, Michigan, South Dakota, Ohio, North Dakota, Wisconsin and Arkansas. These 13 states accounted for 84% of the 62.5 million acres planted to soybeans in 1995 and 85% of the 89.2 million acres planted in 2018.

till or minimum-till cropping systems (see Figure 38). During those three years, on average, 92% of acres were planted with GM corn seeds in the selected states. In the case of soybeans, 69% of soybean acres were planted using no-till or minimum-till during the 2015, 2017 and 2018 years, on average (see Figure 39). For soybeans, 94% of planted acres were GM soybean seeds during those three years.



Source: USDA-NASS (Agricultural Chemical Use Survey)
* IA, IL, NE, MN,IN,KS, MO, MI, SD, OH, ND, WI.
No data available for 1995.

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Figure 38. Percent of Corn Planted Acres with No-till or Minimum-till: Selected States

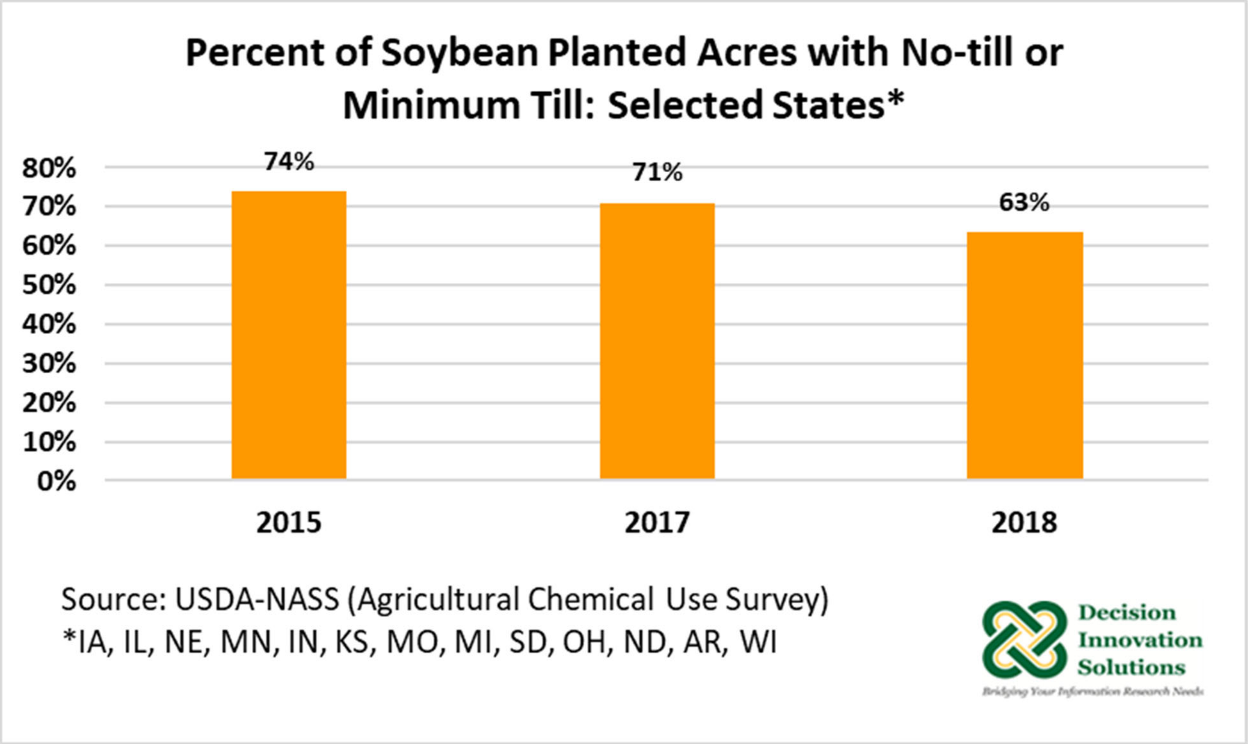

Figure 39. Percent of Soybean Planted Acres with No-till or Minimum-till: Selected States

Results

Impact of a 5% Increase in Non-GM Corn Acres on CO_2 Emissions

Corn production budgets for 2020 (published by the University of Nebraska-Lincoln) were used to estimate the CO_2 emitted in diesel combusted during field operations on a metric ton/acre basis. Table 21 shows the four different production systems considered: GM No-till (GM-NT), GM conventional till (GM-CT), non-GM No-till (non-GM-NT) and non-GM conventional till (non-GM-CT).

The fuel cost per acre under these systems varies from $10.05 for non-GM-CT to $5.75 for GM-NT. In general, fuel costs are greater for conventional till (CT) than for no-till (NT) ($9.95/acre vs $5.80/acre).

Overall, the lowest fuel cost per acre corresponds to GM-NT ($5.75/acre). Likewise, there is more diesel usage under the CT system than under the NT system, and more so under non-GM-CT (4.43 gallons/acre). As more gallons of diesel are used under the CT system (4.38 gallons/acre, on average) compared with the NT system (2.56 gallons/acre, on average) more CO_2 emitted in diesel combusted under the CT system (0.045 metric tons/acre, on average) in comparison with the NT system (0.026 MT/acre, on average). On a per acre basis, the GM-NT system emits the least CO_2 in the diesel combusted in field operations (0.0258 MT/acre), which is closely followed by non-GM-NT (0.0262 MT/acre).

Table 21. Eastern Nebraska 2020 All Field Operations Fuel Usage and CO_2 Emissions: GM, Non-GM Seeds, No-Till and Conventional Tillage Practices.

Production System	Fuel Cost ($/acre)	Diesel Usage (gallons/acre)	CO2 emitted in diesel combusted (MT/acre)
GM-NT	**$5.75**	**2.53**	**0.0258**
GM-CT	**$9.84**	**4.33**	**0.0441**
Non GM-NT	**$5.85**	**2.58**	**0.0262**
Non GM-CT	**$10.05**	**4.43**	**0.0451**
Difference CT minus NT	**$4.12**	**1.82**	**0.0185**
Difference Non GM minus GM	**$1.92**	0.84	**0.0086**

Source: GM,Non-GM, No-till and conventional till data: University of Nebraska-Lincoln. Diesel CO2 emissions: EPA greenhouse gas equivalencies calculator.
Diesel price= $2.27/galllon.
There are 0.01018 MT of CO2 emitted per gallon of diesel combusted.
NT= No-till, CT= Conventional till.

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For the national level environmental (GHG) impact, the analysis assumed a 5% increase in non-GM corn acres. To estimate the national level impact on the environment (CO_2 emissions) of an increase in non-GM corn seed planting related to the different field operations, the following <u>baseline</u> (2018 data) estimates were considered:

- Total corn planted acres in 2018: 88,871,000 acres (USDA data).
- No-till %= 64% (56,877,440 acres) of total acres in 2018 (USDA data, (See Figure 32).
    - Assumed: 62% are GM-NT (55,100,020) and 2% non-GM NT (1,777,420 acres).
- Conventional till %= 36% (100%-64%) (31,993,560 acres) of total acres in 2018.
    - Assumed: 30% are GM-CT (26,661,300) and 6% are non-GM CT (5,332,260 acres).

Note that, GM % of planted acres= 92% (81,761,320 acres) of total acres in 2018 (USDA data, see Figure 30) and Non-GM % of planted acres= 8% (7,109,680 acres) of total acres in 2018.

A 5% increase in non-GM seed planting would decrease the GM-NT acres from 55.100 million to 52.105 million acres, and GM-CT would go down from 26.661 million acres to 25.213 million acres. Non-GM NT acreage would increase from 1.777 million acres to 2.88 million. At the same time, the non-GM-CT acreage would grow from 5.332 million acres to 8.665 million acres. The 5% increase in non-GM seed, would bring down GHG emissions by 150,260 MT of CO_2 in the case on GM NT, and 124,375 MT of CO_2 in the case of GM CT due to fewer acres in these categories. At the same time, GHG emissions from non-GM NT would increase from 46,630 MT CO_2 to 123,133 MT CO_2 (up 76,503 MT CO_2) and GHG emissions would increase the most for non-GM-CT as this combination of seeds and tillage systems uses the most fuel during the field operations. Overall, a 5% expansion in non-GM seeds acres planted would increase total GHG emissions by 7% (196,151 MT CO_2) (see Table 22).

Table 22. U.S. 2020 Corn All Field Operations CO2 Emissions (MT) and Impact of a 5% Increase in Non-GM Acres Planted

Production System	Acres Baseline	Acres with 5% increase in Non-GM	GHG Baseline (Metric Tons CO2 Equivalent)	GHG Difference from 5% increase in Non-GM (Metric Tons CO2 Equivalent)	Net GHG with a 5% increase in Non-GM (Metric Tons CO2 Equivalent)
GM - NT	55,100,020	52,105,067	1,420,828	(150,260)	1,270,568
GM-CT	26,661,300	25,212,703	1,176,517	(124,375)	1,052,142
Non GM-NT	1,777,420	2,888,308	46,630	76,503	123,133
Non GM-CT	5,332,260	8,664,923	240,325	394,284	634,609
Total	88,871,000	88,871,000	2,884,301	196,151	3,080,452

Source: DIS estimates based on production budgets from University of Nebraska-Lincoln. Diesel CO2 emissions: EPA greenhouse gas equivalencies calculator.

Diesel price= $2.27/galllon.
There are 0.01018 MT of CO2 emitted per gallon of diesel combusted.
NT= No-till, CT= Conventional till.

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Conclusions

Environment Analysis Highlights: The GM, No-till Advantage

GM corn and soybeans have been used in the U.S. for over 20 years and currently, more than 90% of acres are planted with these seeds. The environmental literature indicates no-till agriculture, enabled by HT GM crops, can benefit the environment through a reduction in GHG emissions.

Based on the selected budgets, the implication for the environment on a per acre basis are:

- **GM corn production emits 0.0086 MT/acre CO_2 less than non-GM production.**
- **GM corn production emits 21.3% less CO_2 per acre than non-GM production.**
- **NT corn production emits 0.0185 MT/acre CO_2 less than CT corn production.**
- **NT corn production emits 41.7% less CO_2 per acre than CT corn production.**

Based on an 5% increase in corn planted from GM corn to non-GM, GHG emissions would increase by 196,151 MT CO_2 annually, a 7% increase from current levels.

If all corn were produced with non-GM technology, nitrogen emissions from fertilizer volatilization would be expected to increase by 2.7%; nitrogen emissions from drainage leaching would be expected to increase 4.3% and nitrogen emissions from denitrification would be expected to decrease by 0.6%.

Note: All data sources used in the analyses presented in this section were disclosed. Conclusions and generalizations should not be made beyond the scope of the data presented.

Use of Inputs (Priority 3)

Introduction

Crop production costs were selected based on the availability of production budgets for corn and soybeans using GM and non-GM seeds to determine production cost differences between the two types of seeds and production practices. For many state level crop budgets there were no separate budgets for non-GM crops. Many land-grant universities create "average" crop production budgets for crops of significance for their particular state and since GM technology is the predominant technology for corn and soybean production in many of these states, the state universities only publish a budget that would be assumed to be applicable to GM corn or soybean production. Crop producers, lenders, researchers and others use these budgets to better understand the cost to produce a given crop. Budgets containing specific variables for non-GM scenarios are not available in all states.

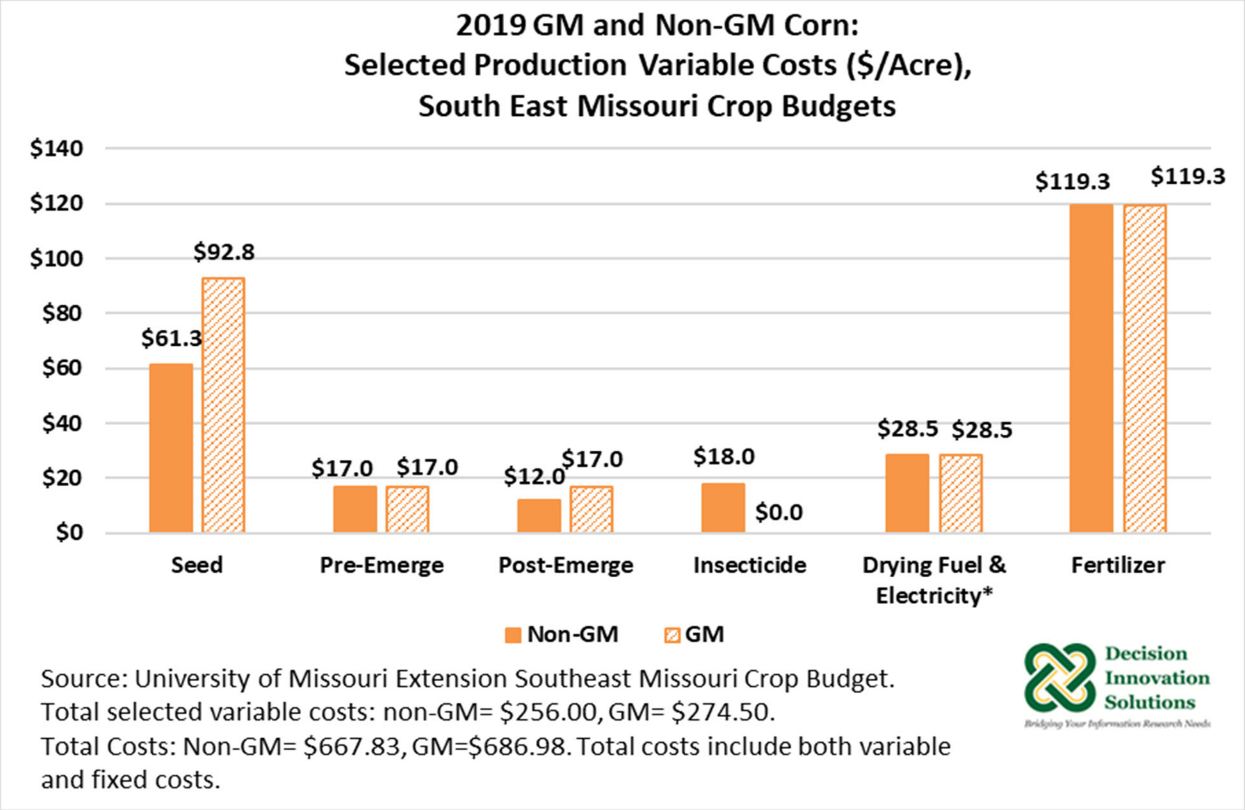
Methods

Data Sources**:** Data for this section of the report was obtained from 2019 crop budgets for Southeast Missouri (SEMO) published by the University of Missouri Extension, 2019 crop budgets for Iowa published by Iowa State University (ISU) Extension and Outreach, and 2020 corn budget data published by the University of Nebraska-Lincoln. Analysis of input costs for soybean production (GM vs. non-GM) was more limited than for corn. Most of the production budgets for soybeans are based on seeds with GM traits. Data from these three sources vary in the level of detail, the selection of budget included, and locations; therefore, comparisons among the budgets were avoided. For these reasons results are presented in separate subsections.

Results

Production Costs Based on SEMO Crop Budget Data

In the SEMO corn production budgets, yields for GM and non-GM are both modeled on an expected yield of 150 bushels per acre. Thus, fertilizer costs are the same for both budgets. On a dollars-per-acre basis, when comparing selected inputs used in corn production, SEMO 2019 crop budgets indicate that because of the lower cost of non-GM corn seeds, there is a savings of $32/acre compared with GM seeds. According to the published reference budget, post-



Source: University of Missouri Extension Southeast Missouri Crop Budget.
Total selected variable costs: non-GM= $256.00, GM= $274.50.
Total Costs: Non-GM= $667.83, GM=$686.98. Total costs include both variable and fixed costs.

Figure 40. 2019 GM and Non-GM Corn: Selected Production Variable Costs ($/Acre), Southeast Missouri Crop Budgets

emergent[8] herbicide programs are $5/acre greater for GM corn production relative to non-GM corn production[9]. There was no difference in the budget for drying fuel and electricity using either type of seed. In 2019, 92% of U.S. corn acreage was planted using biotechnology seed varieties. Biotechnology seed includes traits for insect resistance (e.g., Bt), herbicide resistance

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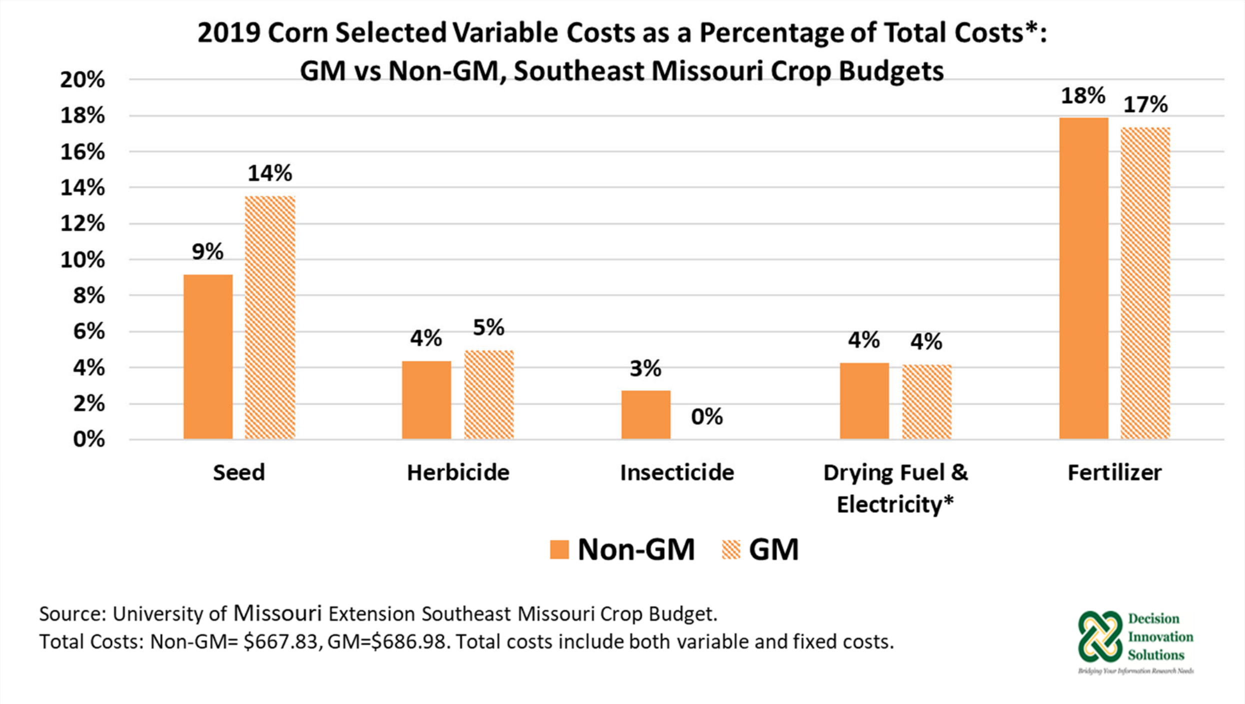
[8] Post-emergent herbicides: herbicides applied after the crop has emerged and can control weeds that have already emerged (i.e., adult weeds are attacked through absorption into the plant tissue) and, depending on the herbicidal action, can provide residual weed control.

Pre-emergent herbicides: Are applied prior to emergence of the crop (can be either pre-plant or post-planting, but before the crop emerges). These herbicides typically are used to control emerged weeds and depending on the herbicidal action can provide residual weed control.

[9] While the SEMO crop budget indicates a higher cost for post-emerge herbicide for GM crops compared to non-GM crops, any herbicide combination used for non-GM corn could be used for GM corn, but less expensive herbicides that can be used post-emerge on GM corn (such as glyphosate) cannot be used in non-GM corn production. What is presented here is data from the listed budgets, the authors assume that the herbicide costs for non-GM corn production should be at least equal to herbicide costs for GM corn production and likely higher in the aggregate.

or stacked genes hybrids, which contain traits for both herbicide and insect resistance. Under this budget, the insect resistance offered by GM corn seeds saves farmers $18/acre in insecticide use when compared with non-GM corn seeds (***Error! Reference source not found.***).

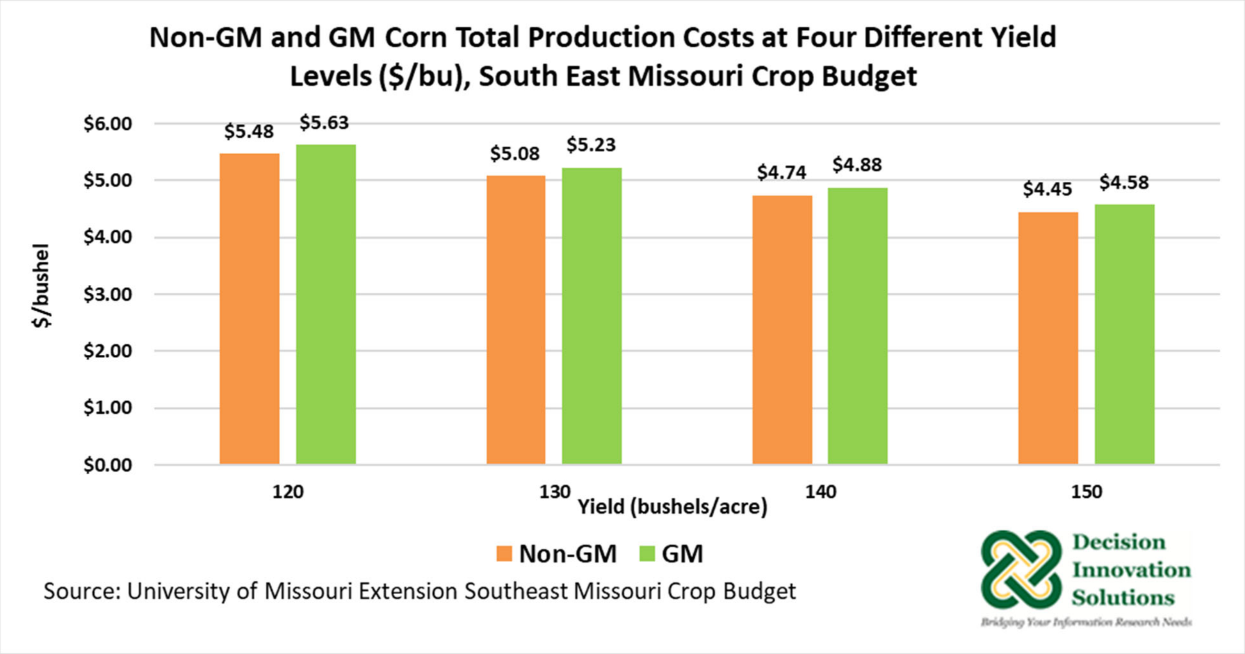
Figure 41 shows the relative percentage change when variable costs for seed, fertilizer, herbicide, insecticide, and drying fuel are compared to total costs of producing corn in southeast Missouri. When all costs are considered (variable and fixed costs), there is a 3% increase in total production costs when comparing the budgets for GM corn versus non-GM corn production. Seed cost as a percentage of total costs rises from 9% of total cost to 14% of total cost when GM seed is used. Herbicide costs rise from 4% of total costs (non-GM) to 5% of total costs (GM), insecticide costs drop from 3% of total costs (non-GM) to zero (GM), drying costs remain the same, and fertilizer costs drop from 18% of total cost (non-GM) to 17% of total cost (GM).



Source: University of Missouri Extension Southeast Missouri Crop Budget.
Total Costs: Non-GM= $667.83, GM=$686.98. Total costs include both variable and fixed costs.

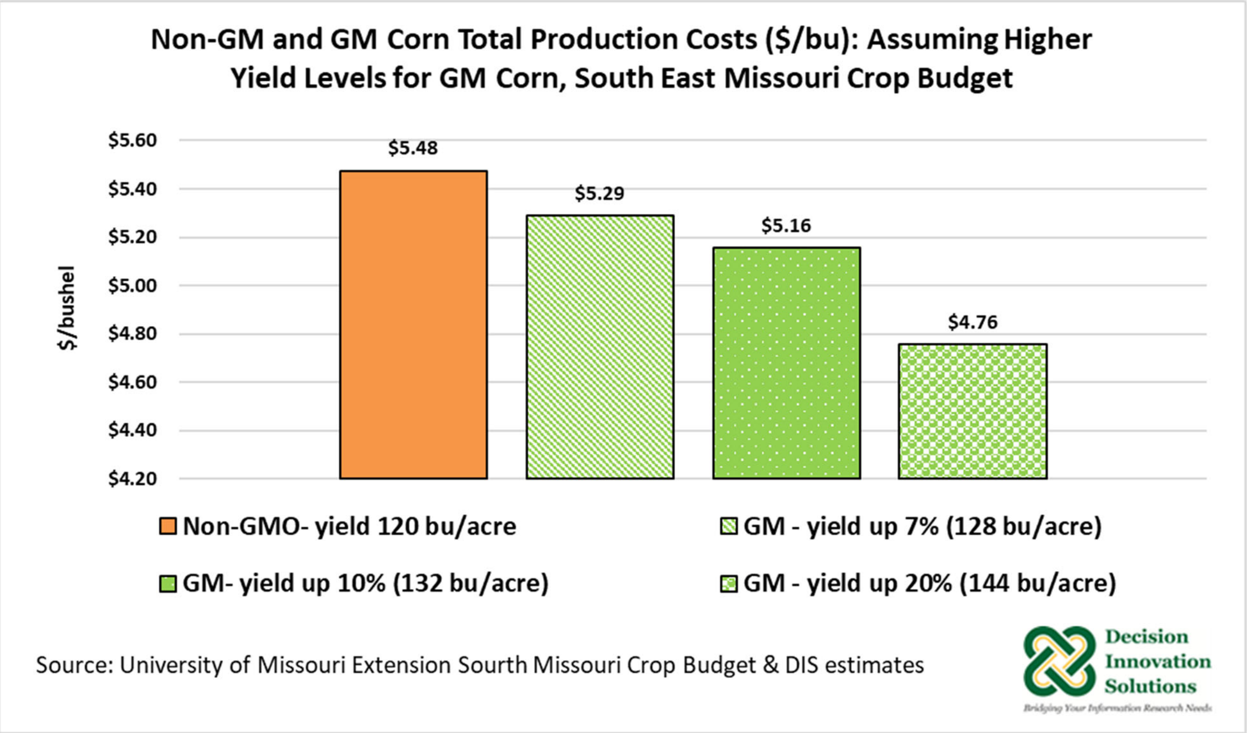
Figure 41. 2019 SEMO Corn Selected Variable Cost as a Percentage of Total Costs: GM vs Non-GM, Southeast Missouri Crop Budgets (Selected Variables)

If both types of seeds yield the same volume of corn per acre, based on total productions costs per acre, GM corn is more costly to produce than non-GM corn (see Figure 42). The cost difference ranges from $0.16/bushel at 120 bushels/acre to $0.13/bushel at 150 bushels/acre. However, GM trait adoption has had a strong positive impact on maize yield according to Xu et al. (2013). In addition, a meta-analysis study which analyzed peer-reviewed literature from 1996 to 2016 on maize yields and other attributes, found strong evidence that GM maize increases yields in a range of 5.6% to 24.5% compared with its near isogenic line (Pellegrino et al., 2018). Using these findings, Figure 43 shows that if GM corn yield is up 7%, 10% or 20% from the baseline yield of 120 bushels/acre for non-GM corn, then GM corn production costs ($/bushel) would be less than non-GM production costs on a per bushel basis with the cost advantage to GM corn ranging from $0.19/bushel at 128 bushels/acre to $0.72/bushel at 144 bushels/acre.



Source: University of Missouri Extension Southeast Missouri Crop Budget

Figure 42. Non-GM and GM Corn Total Production Cost at Four Different Yield Levels, Southeast Missouri Crop Budget


Non-GM and GM Corn Total Production Costs ($/bu): Assuming Higher Yield Levels for GM Corn, South East Missouri Crop Budget

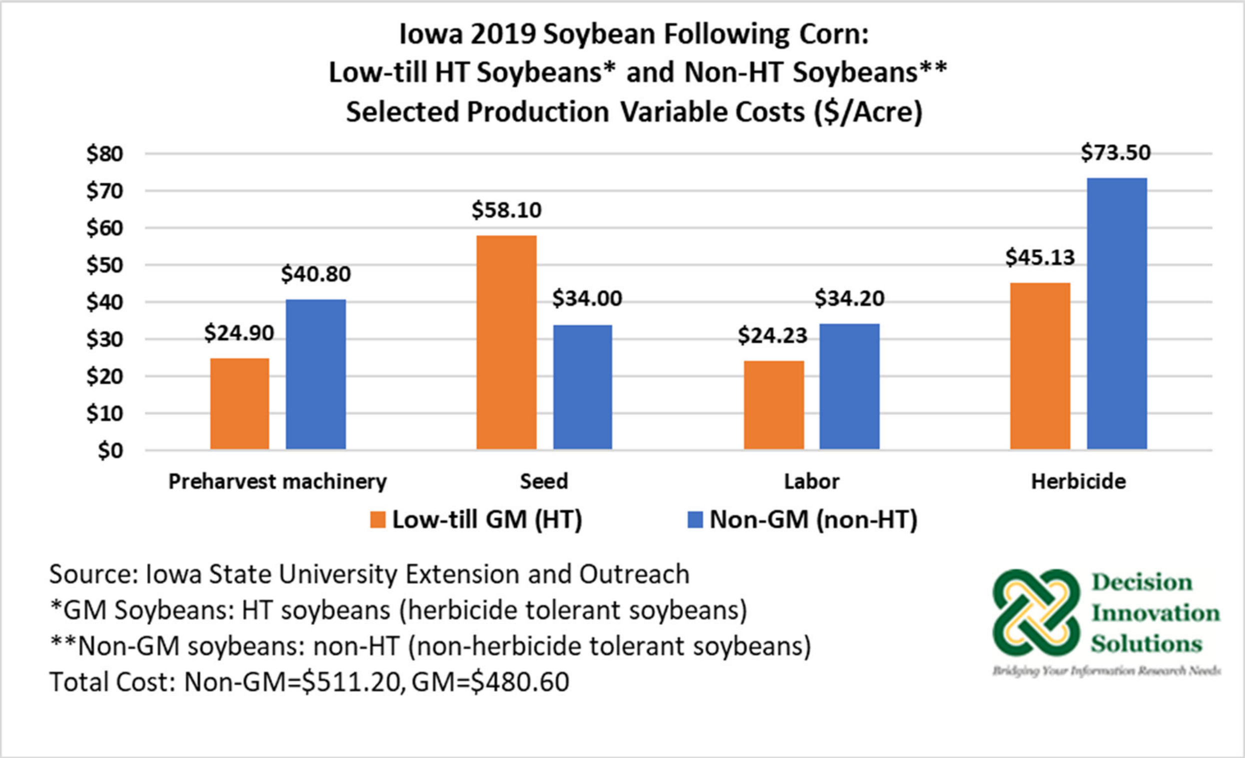
Source: University of Missouri Extension Sourth Missouri Crop Budget & DIS estimates

Figure 43. Non-GM and GM Corn Total Production Costs: Assuming Higher Yield Levels for GM Corn, Southeast Missouri Budget

Production Costs Based on ISU Crop Budget Data

According to ISU Extension and Outreach, currently all corn is GM in the budgets they prepare for the State of Iowa and there is no explicit differentiation between traits. Budgets reflect expected expenses using the most demanded trait each season (based on a survey of ISU agronomists). The lack of current crop production budgets for non-GM corn limits the cost comparison between GM and non-GM seeds.

In the case of soybeans, ISU Extension and Outreach includes budgets for soybeans following corn non-herbicide tolerant (non-HT soybeans), a non-GM soybean seed variety and low-till soybeans following corn herbicide tolerant (low-till HT soybeans), a GM soybean seed variety. GM HT technology facilitates environmentally beneficial reduced tillage in farming, and as shown in Figure 44 and Figure 45, using low-till HT soybeans reduces preharvest machinery costs by $15.90/acre (39%), labor by $9.97/acre (29%), and herbicide costs by $28.37 (39%) compared with non-GM soybeans. Using GM soybeans increases the costs of seeds by $24.10/acre (up 71%). In general, total production costs decreases 6% per acre in the case of GM soybeans compared with non-GM soybeans. Note that ISU budgets did not include energy use or water use, therefore no comparison was possible for these two important variables for GM and non-GM seeds.



Source: Iowa State University Extension and Outreach
*GM Soybeans: HT soybeans (herbicide tolerant soybeans)
**Non-GM soybeans: non-HT (non-herbicide tolerant soybeans)
Total Cost: Non-GM=$511.20, GM=$480.60

Figure 44. Iowa 2019 Soybean Following Corn: Low-till HT Soybeans and Non-HT Soybeans, Selected Production Variable Costs ($/Acre)

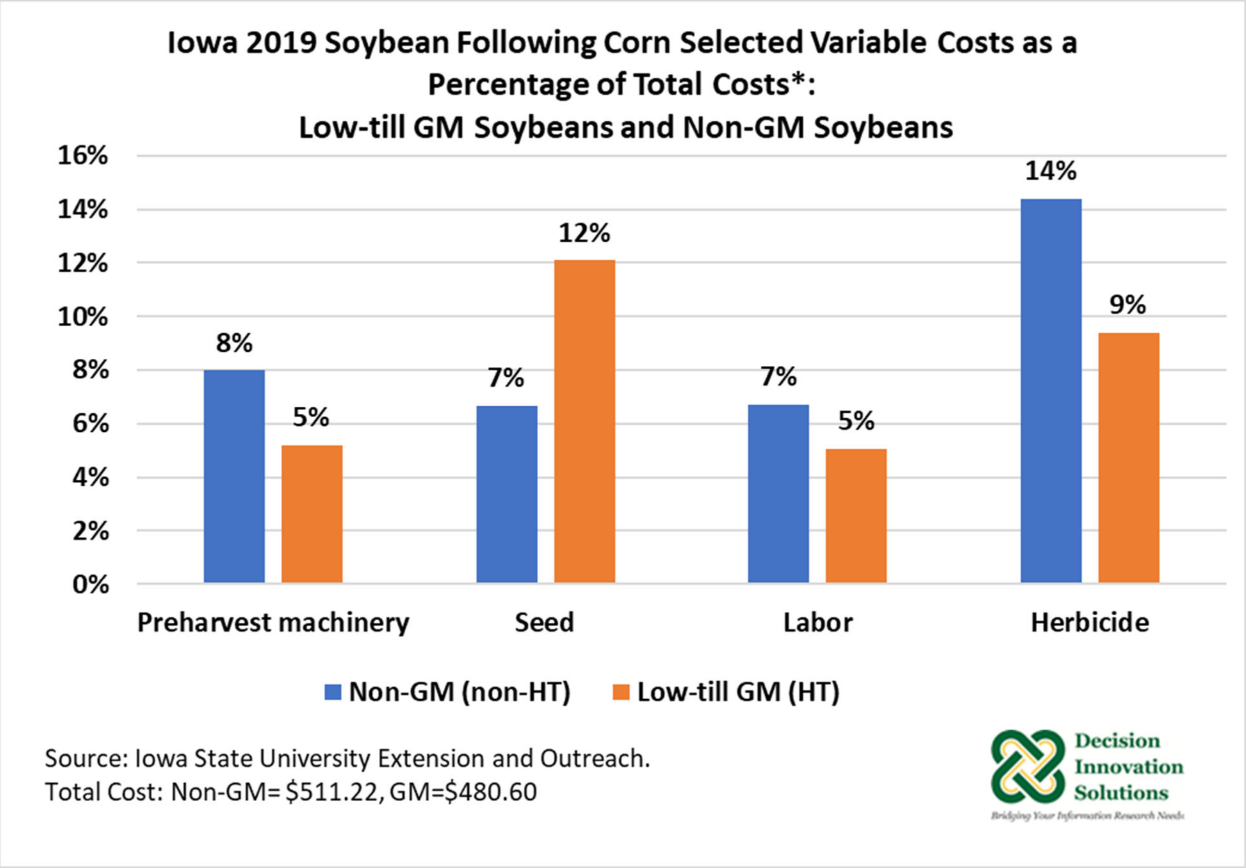
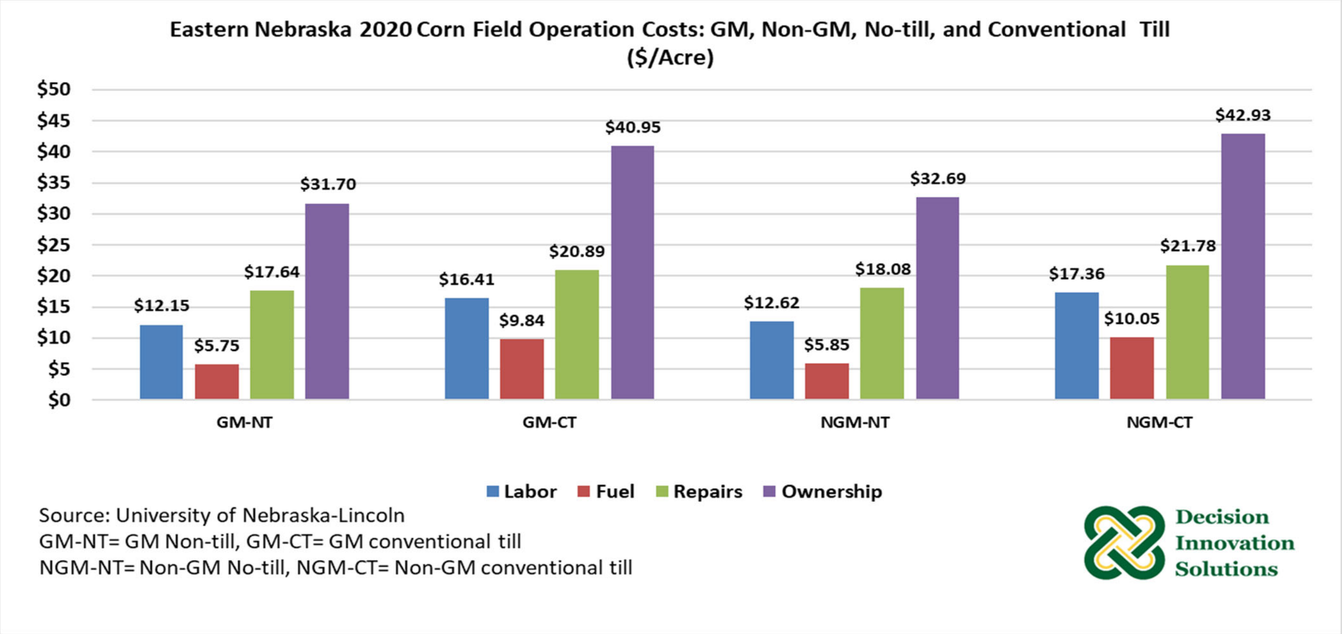


Figure 45. Iowa 2019 Soybean Following Selected Corn Selected Variable Cost as a Percentage of Total Costs: Low-till HT Soybeans vs non-HT Soybeans

Production Costs Based on University of Nebraska-Lincoln Crop Budget Data

As mentioned in the introduction to the environment section, savings in terms of fuel, equipment and labor costs can be achieved by reducing tillage activities, which have been facilitated by GM HT crops. Using 2020 selected crop budgets from the University of Nebraska-Lincoln, corn field operation (e.g., labor, fuel, repairs and ownership) costs were compared for different types of seeds (GM and non-GM) and production practices (no-till [NT] and conventional till [CT] systems). For all field operations, CT is more expensive than NT. Labor increases $4.26/acre when comparing GM-CT versus GM-NT, and labor is up $4.74/acre in the case of non-GM CT versus non-GM NT. Fuel is up $4.09/acre under GM-CT versus GM-NT, and fuel is up $4.20/acre under non-GM CT in contrast with non-GM NT. The cost of repairs for CT increases $3.25/acre under GM and is up $3.70 under Non-GM. Finally, the cost of ownership for CT grows $9.25/acre and $10.24/acre under GM and Non-GM respectively (see Figure 46). In general, field operations are more expensive under CT compared with NT, and field operations costs for non-GM crops is more expensive relative to GM.



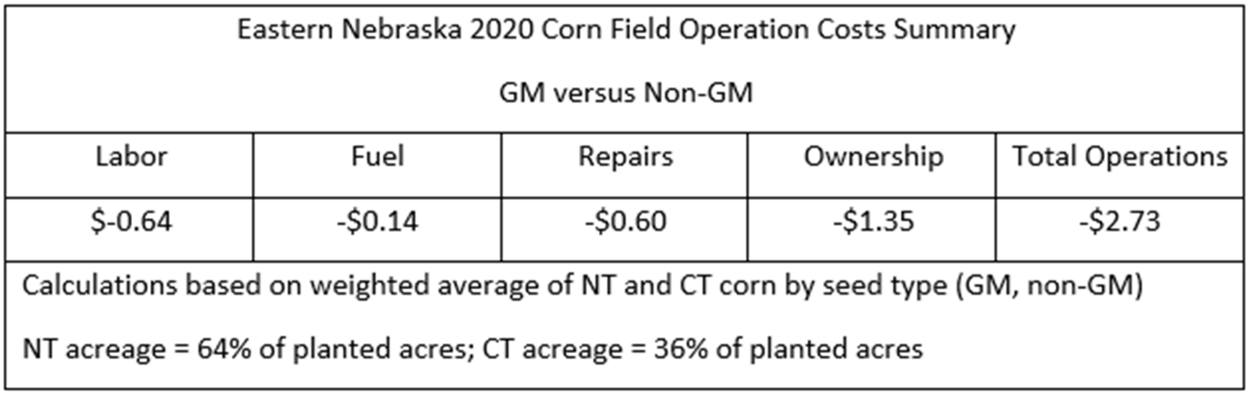
Eastern Nebraska 2020 Corn Field Operation Costs: GM, Non-GM, No-till, and Conventional Till ($/Acre)

Source: University of Nebraska-Lincoln
GM-NT= GM Non-till, GM-CT= GM conventional till
NGM-NT= Non-GM No-till, NGM-CT= Non-GM conventional till

Figure 46. Eastern Nebraska 2020 Corn Field Operation Costs: GM, Non-GM, No-till and Conventional Till ($/Acre)

To summarize the field operation costs for corn production in Eastern Nebraska by seed type (GM and Non-GM), a weighted average of the cost differentials shown in Figure 46 was calculated based on 64% of the acreage being NT and 36% of the acreage being CT and is shown in Table 23.

Table 23. Eastern Nebraska 2020 Corn Field Operations Costs Summary, GM versus Non-GM



Eastern Nebraska 2020 Corn Field Operation Costs Summary

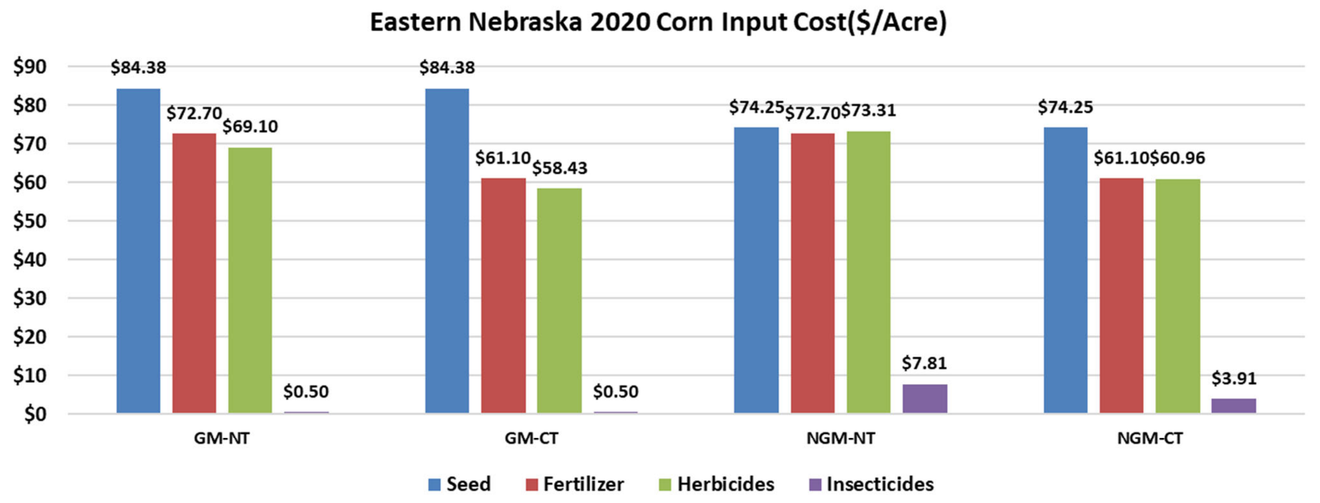
GM versus Non-GM

Labor	Fuel	Repairs	Ownership	Total Operations
$-0.64	-$0.14	-$0.60	-$1.35	-$2.73

Calculations based on weighted average of NT and CT corn by seed type (GM, non-GM)

NT acreage = 64% of planted acres; CT acreage = 36% of planted acres

Input costs (Figure 47) vary by type of input. GM seeds are more expensive (about $10.13/acre) than non-GM seeds due to the added traits in the GM seeds. For fertilizer costs, NT is more costly than CT because anhydrous, which is used in these budgets for CT, is cheaper than liquid forms of nitrogen fertilizer, which is what is used for NT[10]. The cost of fertilizer increases about 16% per acre when comparing NT with CT. Herbicides under NT is also more expensive than CT because there is an initial burndown performed under NT. The cost of herbicides is up $10.67/acre for GM no-till compared with GM conventional tillage. The cost of herbicide rises $12.35/acre under non-GM not-till relative to non-GM conventional till. In the case of insecticide costs, regardless of tillage system, using GM corn seeds is less expensive than non-GM, based on the seeds that are used; GM seeds have the traits that protect the plant against insects. Insecticide costs are down $7.31/acre and $3.41/acre when comparing GM seeds versus non-GM NT and non-GM CT, respectively. Non-GM no-till is likely more costly than non-GM CT because in general, there would be more residues that harbor insects in the non-GM no-till, and the Non-GM seeds do not have the gene protection against insects.


Eastern Nebraska 2020 Corn Input Cost($/Acre)

Source: University of Nebraska-Lincoln
GM-NT= GM Non-till, GM-CT= GM conventional till
NGM-NT= Non-GM No-till, NGM-CT= Non-GM conventional till

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Figure 47. Eastern Nebraska 2020 Corn Input Cost ($/Acre)

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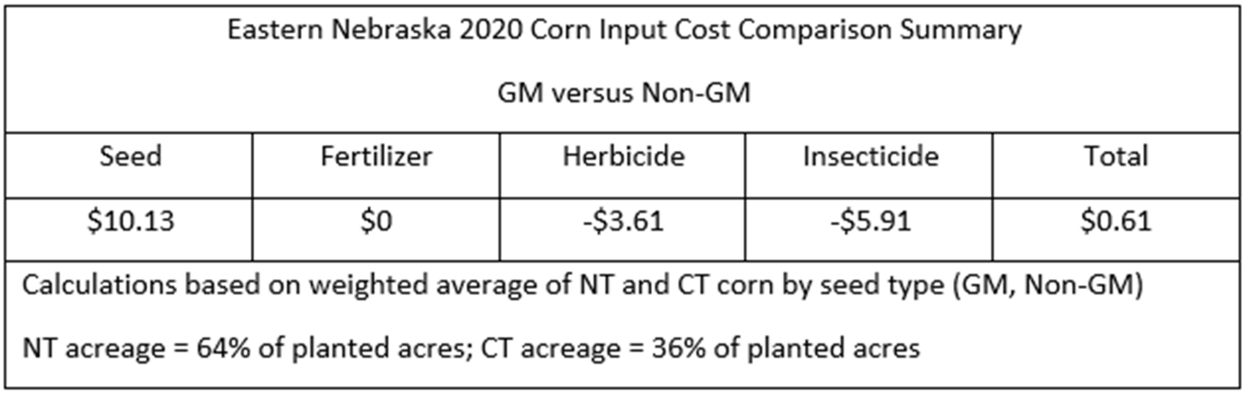
[10] Anhydrous ammonia is “knifed in” to the soil and causes some level of soil disturbance. In some characterizations of no-till, no soil disturbance is allowed beyond that which occurs with the placement of the seed. Thus, in some instances, anhydrous ammonia application may be excluded from no-till production. Others, however, allow for anhydrous ammonia application under their definitions of no-till, in which case, the cost of N fertilizer for NT would be the same as for CT.

To summarize the input costs for corn production in Eastern Nebraska by seed type (GM and Non-GM), a weighted average of the cost differentials shown in Figure 47 was calculated based on 64% of the acreage being NT and 36% of the acreage being CT and is shown in Table 24. When combined field operations and input costs are considered for Eastern Nebraska corn, costs for GM corn are $2.12 per acre less than non-GM corn.

Table 24. Eastern Nebraska 2020 Corn Input Cost Comparison, GM versus Non-GM



Eastern Nebraska 2020 Corn Input Cost Comparison Summary

GM versus Non-GM

Seed	Fertilizer	Herbicide	Insecticide	Total
$10.13	$0	-$3.61	-$5.91	$0.61

Calculations based on weighted average of NT and CT corn by seed type (GM, Non-GM)

NT acreage = 64% of planted acres; CT acreage = 36% of planted acres

Conclusions

Highlights about Inputs and Energy Data

- *Based on SEMO budget data for 2019*, total costs per acre are higher for producing GM corn, primarily due to the additional cost of the traited seeds. The SEMO budget, however, does not adjust for yield or fertilizer differences between GM and non-GM. Additionally, the cost of herbicides is higher for GM corn in the SEMO budget, which may no longer be true due to advancements in herbicide technology.
- When adjusted for likely yield differences, the cost of producing corn in southeast Missouri using GM technology may be as much as 13% less than producing corn with Non-GM technology. Using SEMO budget data and assuming a GM corn yield advantage of 7%, 10% and 20% from a baseline of 120/acre for non-GM corn, GM corn production costs would accrue a cost reduction for GM corn ranging from $0.19/bushel at 128 bushels/acre to $0.72/bushel at 144 bushels/acre.
- *Budget data (2019) from ISU,* shows that using low-till HT soybeans reduces the total cost of producing soybeans by $30.60 per acre, a 6% reduction.
- While seed costs are higher for GM production, this is more than offset by lower costs for preharvest machinery costs, reduced herbicide costs and lower labor costs.
- At equivalent yields, the savings by using GM technology are $0.55 per bushel. If GM soybeans yield greater than non-GM soybeans by an average of 3%, then the cost advantage for GM soybeans is $0.83 per bushel.

- ***Based on the four budgets analyzed from the University of Nebraska-Lincoln:***
    - Production using GM technology is slightly more expensive per acre ($0.61) than non-GM technology. However, if even a 1% yield advantage is realized for GM production, then GM corn production costs less per bushel than non-GM corn production.
    - No-till corn production systems that use only surface-applied nitrogen sources are more expensive than corn production systems that use anhydrous ammonia. This is regardless of whether the crop is GM or non-GM.
    - Herbicide and insecticide costs are lower in GM corn production systems than in non-GM corn production systems. The cost savings realized with lower herbicide and insecticide costs essentially offsets the higher seed costs associated with GM production.
- **Overall, conventional till is more expensive than no-till for all field operations. The most expensive among the four corn production budgets is non-GM conventional till at $92.12/acre, which includes all field operations. While the lowest production budget corresponds to GM corn no-till at $67.24/acre for all the field operations included.**
- **For no-till, herbicide costs are higher relative to conventional till because of the initial burndown implemented under NT.**
    - The cost of herbicides is up an additional $10.67/acre for GM no-till compared with GM conventional tillage.
    - The cost of herbicide is up an additional $12.35/acre under non-GM no-till in contrast with non-GM conventional till.
    - Notwithstanding the tillage system, GM corn seeds required less insecticide compared with non-GM seeds.
    - There is a reduction of $5.36/acre, on average, when using GM seeds relative to non-GM seeds.

Note: All data sources used in the analyses presented in this section were disclosed. Conclusions and generalizations should not be made beyond the scope of the data presented.

Objective 2: Assess physical and logistical changes likely to be adopted within grain and feed industries to accommodate increasing demand for non-GM ingredients and products. (IFEEDER priorities 4 and 6)

Introduction

With a continuing interest from consumers in non-GM foods, detection and isolation of GM grain is important. The U.S. grain supply chain evolved over time to produce, harvest, process, store and transport a large amount of commodity products efficiently and rapidly.

Grain elevators, processors and feed mills have been designed to handle large quantities of a small number of products. When these facilities handle additional product categories, existing equipment may not be well suited to this task, presenting the risk of commingling of grain. Unintentional commingling of GM grain in non-GM grain loads can contribute to "adventitious presence" (AP), the unintended presence of a small amount of transgenic material in seed, grain, or feed and food products. To regulate AP in the segregated product stream, tolerance levels dictate how much AP is allowed in a given non-GM load. Accordingly, processes and procedures must be implemented to avoid AP in the segregated product stream. Segregating grain and grain co-products at a commodity grain facility adds more labor and capital costs than at a facility where no segregation is required.

In this case, physical and logistical changes assessed were those likely to be adopted within the grain and grain co-product supply chains to accommodate demand for non-GM ingredients. Based on the literature, several points in the supply chain where commingling of grain is most likely to occur were identified. Costs and relevant risk factors were considered for existing handling, conveying and processing equipment. In some instances, the purchase of additional equipment to accommodate dual ingredient production was considered.

Methods

A review of the literature on commingling and AP in the supply chains for grain handled at grain elevators, processors and feed mills was undertaken. From the literature, key points in the handling, processing and storage equipment in a typical current (i.e., non-segregated) supply chain that will need to be made in order to mitigate AP in incoming product streams were identified. Both the costs of such changes, where they could be found in the literature, and the risk levels of commingling associated with each step were identified.

While this project is limited to considering the segregation of GM and non-GM corn and soybeans, the literature has much to say about other factors for which segregation may be desirable such as high/low oil soybeans and corn, levels of dockage, protein content and other grains (e.g., canola and wheat). Where appropriate, these studies have helped inform the key points where AP may take place. While the facilities and processes in the farm-to-table supply chain are many, the focus of this research was with on-farm grain storage, grain elevators, grain processors and feed mills.

<u>Results</u>

Key areas in the supply chain where commingling commonly occurs were identified along with potential mitigation methods. Several common industry practices are already in place to help avoid commingling, such as equipment, transportation and storage cleanout.

Farm

Handling and Storage

Proper handling and segregation on the farm are essential to minimize AP. Even if all mitigation procedures are practiced downstream, the exercise will not mitigate grain that is already over the posted tolerance level.

In the U.S., on-farm grain storage capacity surpasses that of off-farm commercial grain storage (13.5 billion bushels and 11.6 billion bushels, respectively), according to USDA/NASS data from 2020. In addition to this trend, individual grain bins are also larger, facilitating more storage space, but at the expense of flexibility. With the rise of larger, but fewer, grain storage bins, grain elevators, processors and feed mills have found it challenging to segregate smaller lots of non-GM grain. In addition, as more categories of grain and grain products are handled, the effective storage capacity of a facility is reduced (Baumel, 1999).

If a producer wishes to grow GM and non-GM grain, it is essential to have multiple storage bins dedicated for each product type. If a bin is to be “swapped” and used for another product, a meticulous cleanout, including sweeping, vacuuming and ensuring no grain is “hung up” on the beams and supports of the bin, should be performed. Although the capital cost is not great, the actions take a considerable amount of time and resources to adequately complete the job. For this reason, dedicated storage bins for non-GM grain storage are advised.

For transportation, unless there is a large enough non-GM crop to which a truck or grain cart may be dedicated, existing trucks and grain carts are likely to be used for both GM and non-GM grain. Thus, close inspection of the truck or grain cart should be undertaken to ensure no carryover of GM grain. If feasible, harvesting and transporting of non-GM grain first will ensure that if any commingling does occur, it is not detrimental to the non-GM grain.

If these precautions for storage and transportation are taken, AP in non-GM grain that is attributable to equipment and procedures taken on-farm are unlikely.

Grain Elevators and Processors

Receiving

The receiving step is one of the most important steps to prevent AP of non-GM grain at a grain elevator. An elevator handling non-GM grain should not assume the purity of an incoming load of non-GM grain and should therefore have procedures in place for testing for GM grain.

The type of test to be used should be deliberated carefully. Consideration should be given to the cost of the initial test and the time it takes to perform the test. Staff should be well-trained not only on the use of the test, but on sampling procedures. Several opportunities for variance occur throughout the sampling process, so proper staff training is critical (Freese et al., 2015). The modeling work reported in section 3b of this report accounts for labor, equipment capital investments, as well as test strips and other consumable costs. In addition to the cost for test strips, the test strip reader for these particular rapid tests cost $3,750.00. The modeling work reported in section 3b of this report accounts for labor, equipment capital investments, as well as test strips and other consumable costs.

Table 25 shows a cost comparison between several types of GM tests performed at different locations in the supply chain. The cost of the tests largely depends on the type of test - strip test or polymerase chain reaction (PCR) - and the level of tolerance required. While this table was adapted from a 2002 publication (Wilson & Dahl, 2002), current authors updated the price to reflect recent rapid testing costs relevant for corn and soybeans. As of August 2021, a rapid test for corn was quoted at $47.03 per test while $14.41 per test was quoted for soybeans. GM rapid strip tests had increased in cost due to the need to account for the increasing number of marketed GM traits. The discrepancy between the corn and soybean prices is a result of the greater number of GM traits in corn that must be accounted for in the test compared with soybeans. In addition to the cost for test strips, the test strip reader for these particular rapid tests cost $3,750.00. The modeling work reported in section 3b of this report accounts for labor, equipment capital investments, as well as test strips and other consumable costs.

Table 25. Cost of GM Testing by Supply Chain Location

Location	Test Type	Tolerance (+/- %)	Confidence Interval (%)	Cost ($/test)	Lot Size (bushel)	Cost (cents/bushel)
Farm Bin	Strip Test	1	95	14.41-47.03	5,000	0.28-0.94
Country Elevator (Receiving)	Strip Test	1	95	14.41-47.03	800	1.8-5.9
Country Elevator (Loading)	Strip Test	1	95	14.41-47.03	3,300	0.44-1.43
Domestic User Receiving	PCR	1	99	120	3,300	3.64
		0.1	95	300	3,300	9.10
		0.1	99	400	3,300	12.12
Export Elevator Receiving	PCR	1	99	120	3,300	3.64
		0.1	95	300	3,300	9.10
		0.1	99	400	3,300	12.12
Export Elevator Loading	PCR	1	99	120	33,000	0.36
		0.1	95	300	33,000	0.90
		0.1	99	400	33,000	1.21
Importer Receiving	PCR	1	99	120	33,000	0.36
		0.1	95	300	33,000	0.90
		0.1	99	400	33,000	1.21

*Adapted from Wilson and Dahl (2002)

Quick strip tests are typically less expensive than PCR tests and require less sample preparation and a lower level of technical skills to perform, but the tradeoff is a less precise result. A major advantage of quick tests, whether for GM presence or any other test, is that the wait time for driver unloading the grain is shorter. Long wait times can result in logistical problems (e.g., traffic jams) or the opportunity cost as other drivers choose to take their grain elsewhere.

Depending on how long it takes to get test results back and the adequacy of bin space available on-site, trucks may dump grain into a smaller, temporary storage. Once the test results are back, this grain may be put into long-term storage. This reduces waiting time for the driver and is another helpful measure to mitigate contamination.

If an elevator is handling both GM and non-GM grain, it is helpful, when possible, to implement a temporal segregation strategy, scheduling deliveries for all like-product receiving for a certain day or time period. This reduces the times the handling equipment must switch back and forth between product types, thus reducing the likelihood of commingling. Berruto and Maier (2001) completed simulations comparing a typical first-in-first-out (FIFO) receiving method and a “batching” method of queue management. They found the batch method reduced average waiting times up to 27% per customer. Scheduling receiving in this way also gives a pre-determined buffer so that cleanout or flushing can happen before receiving non-GM grain. It also allows personnel to sweep up any grain in the receiving area that may have bounced out of the receiving pit.

Due to the relatively high rate of sampling errors and uncertainty about being able to schedule receiving to such a degree during a busy harvest season, chances of AP in non-GM grain at the receiving step is moderately likely and could have disastrous results if a load gets diverted to the wrong bin, due to the sheer size of the load.

Conveying

Conveying equipment, especially older equipment designed with little consideration for sanitation (i.e., self-cleaning and ease-of-access), has the potential for considerable commingling. It may be possible to have a dedicated receiving pit for only non-GM grain; however, because the vast majority of corn and soybeans grown in the U.S. are GM, the relatively small amount of non-GM grain received makes this option unappealing due to opportunity costs, and often, multiple receiving pits are serviced by the same elevator leg.

Several studies investigated the amount of grain commingling in various grain handling equipment at grain elevators (

Table 26). In study 1, most of the commingling occurred in the grain cleaner, scale and pit/elevator boot. The cumulative effect of commingling in this case may result in an overall value of 0.65%. Ingles et al. (2003) observed a larger amount of “instantaneous commingling” in that the first few samples of a subsequent load of grain had a higher AP than at the end of the load. No two elevators have the exact same layout, equipment configuration, spout angles and degree of maintenance, which may explain the apparent discrepancies between the amount of contaminated grain found.

In study 2, trials were performed with two types of receiving pits (gravity and drag take-away) and one investigating the amount of commingling in the bucket elevator.

Table 26. Grain Commingling in Grain Handling Equipment

Study	Equipment	Total Load (ton)	Feed Rate (tons/hour)	% Commingling
1[a]	Pit and Boot	8.49	47.3	0.18
	Scale	8.28	49.6	0.22
	Grain Cleaner	6.93	48.4	0.24
	Grain Scalper	6.11	43.3	0.01
2[b]	Gravity Pit	5.80	39.9	1.31
	Pit w/drag conveyor	8.10	50.7	0.30
	Bucket Elevator	8.22	52.4	0.23
[a]Ingles et al. (2003), [b]Ingles et al. (2006)				

Residual Grain

In study 1 (above), Ingles et al. (2003) also inspected equipment after the grain handling trials for residual grain. They found that the majority of residual grain remained in the boot and receiving dump pit (1.41% and 0.24% of total load, respectively) compared to the scale above the grain cleaner, grain scalper and grain cleaner (0.01%, 0.004% and 0.008%, respectively). Residual grain is another possible source of AP in subsequent loads. If not cleaned often, the boot of bucket elevators can become filled with grain, which can then commingle with subsequent grain loads. With rigorous cleaning and sanitation, commingling is less likely to occur (albeit at a higher labor cost).

Feed Mill

The receiving, testing, conveying and storage steps for grain elevators, processors of grain co-products and feed mills are largely alike. Scheduling deliveries, proper training on sampling and testing methods and proper conveying and storage should follow the same protocols. However, the receiving step at the feed mill is more complicated due to the greater variety of ingredients received. Depending on ingredient pricing, a feed mill may obtain a number of different ingredients from several different suppliers. Some of the ingredients would carry no additional risk of AP if commingled (e.g., limestone) but others, such as bakery by-product meal, could if they included GM corn. For this reason, the receiving analysis matrix should be updated to reflect this potential risk.

For a mill that produces medicated feeds, the risks and hazards of contaminated feed should already be well understood. The protocols should already be in place to prevent the interaction of certain product streams. Sequencing products is a practice commonly performed at feed mills to organize feed batch production in such a way that feed which may contain ingredients hazardous to certain animals is produced in sequence with other, non-hazardous feeds to minimize the potential for hazard carryover into the batch of feed for the sensitive species. Since such practices are already in place at many facilities for biological, chemical and/or physical hazards, this would not be difficult to implement to minimize the monetary risk posed by AP in a non-GM feed batch, nor add significant costs above their current procedures.

When sequencing cannot be done or is impractical, “flushing” equipment is another option. After a GM feed has been made, a sufficient quantity of a non-GM ingredient is moved through the system using the same equipment. This small quantity is sacrificed, assumed to be GM, and “flushes” out any residue left behind. This is another method that is already used commonly in feed mills. For example, mixers can retain residue of previous batches and flushing is often used to clean them before making a subsequent feed batch to make sure there is no hazard or unwanted material.

Storage and Transportation

The risks of commingling in a feed mill are similar to an elevator in that there is a chance that finished feed may be put into the wrong bin or loaded into the wrong truck. However, unlike most country elevators, many modern feed mills use automated software to operate and monitor equipment, record batching logs, sequence rations and bag and load-out finished feed. A very useful benefit of such a system is the lockout feature. Once a ration is finished, the system is programmed to convey the finished feed only to the correct bin and load-out only into the correct truck (usually equipped with an RFID sensor). This largely minimizes or removes altogether the human error from commingling the finished non-GM feed with GM feed. This is another process that is already in widespread use in the feed industry, so it would not be difficult nor costly to implement in a non-GM segregation situation.

Costs of Segregation

Table 27 shows various costs associated with segregating product streams across a variety of grain types and quality/end-use factors as gathered from previous literature. Across these studies, the costs considered were not uniform; some studies included opportunity costs, transportation costs and costs applied further down the supply chain than others. For corn, the cost of segregation ranged from $0.06/bushel (GM/non-GM) to $0.37/bushel (high oil/regular). For soybeans, the cost of segregation ranged from $0.04/bushel (high oil/regular) to $0.72/bushel (GM/non-GM, cost accounting method). The average cost for segregating corn and soybeans was approximately $0.21 and $0.39/bushel, respectively. Section 3b of this report provides a thorough analysis of segregation costs throughout feed supply chains for swine, broilers, layers, and beef and dairy cattle.

Conclusions

The risk factors identified here are included in the risk assessment models described elsewhere in this report (most prominently, the modeling work done to determine costs and feasibility of segregation along feed supply chains, section 3b). Incoming grain commingling can be mitigated with carefully structured procedures and properly trained staff who consistently adhere to these procedures. Maintaining the skill level and cross-training employees can help reduce errors in sampling and analysis.

Residual GM grain found in conveying, processing and storage equipment contributes to increased grain commingling. The more equipment with residual grain, the greater the cumulative effect of commingling. Even with proper sequencing, flushing and well-organized truck receiving patterns, unwanted grain will still accumulate, so regular clean-out and housekeeping must be a priority to mitigate AP of GM grain in non-GM grain.

Transportation and storage concerns are alleviated by meticulous and regular sanitation/housekeeping. Inspection of empty (cleaned) bins and transportation should be a regular task.

Purchasing new equipment dedicated for handling and processing non-GM grain is likely not cost-effective. However, if the situation allows, dedicated grain bins (even if temporary) may be used to offset any delays that additional testing for GM grain would cause. As storage is usually at a premium, this may or not be feasible depending on the situation.

Table 27. Cost of Segregation for Various Commodities and Scope of Analysis

Researcher	Estimated Cost of Segregation or Identity Preservation	Methodology	Scope of Analysis
Askin (1988)	13 c/mt (wheat)	Econometric	Segregating to increase wheat 2 grades.
Jirik (1994)	11-15 c/bu	Survey	Segregating grain at elevators and processors.
Hurburgh et al. (1994)	3.7 c/bu (soybeans)	Economic Engineering Model	Segregating high oil and regular soybeans. Includes cost of testing.
Herrman et al. (1999)	1.9-6.4 c/bu (two grades) 1.9-5.6 c/bu (three grades)	Simulation	Cost of segregating two or three product grade ranges.
Maltsbarger and Kalaitzandonakes (2000)	16.4-36.6 c/bu (corn)	Simulation	Segregating high oil and regular corn. Includes opportunity costs (inability to grind and blend grains).
Nelson et al. (1999)	6 c/bu (corn) 18 c/bu (soybeans)	Survey	Segregating GM and non-GM corn and soybeans.
Bullock and Desquilbet (2002)	30-40 c/bu (soybeans)	Cost Accounting	Segregating GM and non-GM. Includes costs from seed to market.
Dahl and Wilson (2002)	25-50 c/bu (wheat)	Survey	Segregating identity preserved (IP) wheat.
Wilson and Dahl (2001)	15 c/bu (wheat)	Survey	Segregating for dockage in wheat.
USDA-ERS (Lin et al. (2000))	22 c/bu (corn) 54 c/bu (soybeans)	Survey	Cost accounting of survey results of specialty grain handlers.
Smyth and Philips (2001)	21-27 c/bu (canola)	Analysis	Implementing IP for canola in Canada.
Gosnell (2001)	15-42 c/bu (high throughput) 23-28 c/bu (wood elevators)	Survey	Additional transportation and segregation costs for dedicated GM elevators.
Sparks Companies (2000)	38-45 c/bu (canola) 63-72 c/bu (soybeans)	Cost Accounting	Segregating GM and non-GM canola and soybeans.
Bender et al. (1999)	22 c/bu (corn) 18-54 c/bu (soybeans)	Survey	Segregating GM and non-GM corn and soybeans from country elevators to export elevators.

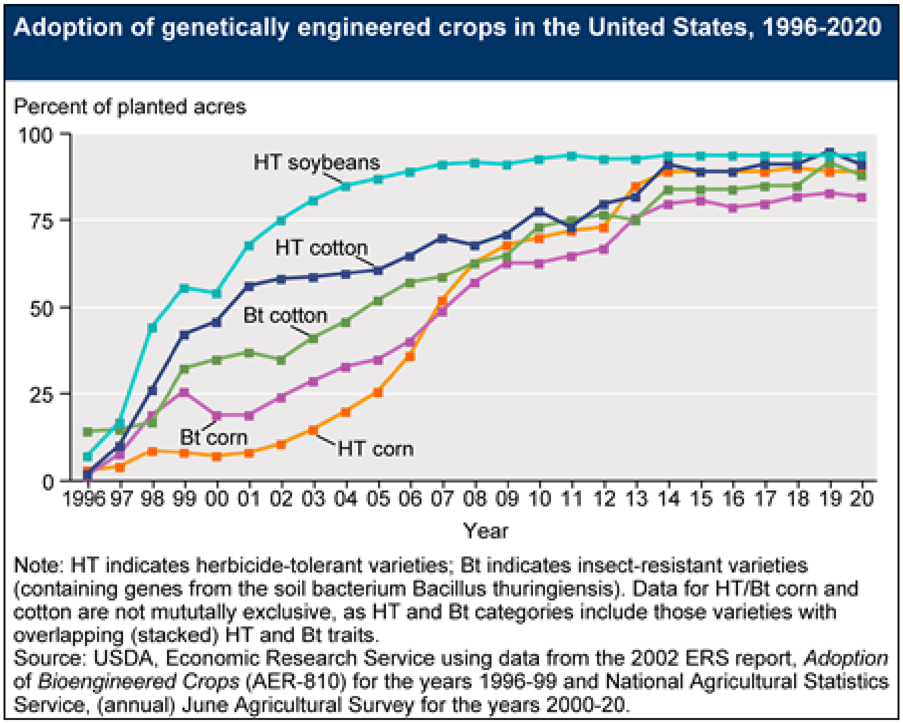
Objective 3: Assess changes to operational, feed cost, and costs to consumers as the proportion of non-GM feed increases relative to the percentage of total feed production (IFEEDER priorities 7, 8, and 9)

Cost considerations for GM and non-GM grains as feed ingredients, and for feed mill operations (IFEEDER Priority 7)

Introduction

The U.S. livestock feed industry depends on grains and grain-based coproducts as ingredients for a large percentage of the feed rations used today. Corn grain and soybean meal are commonly utilized as principal ration components for livestock and poultry to provide complete proteins for muscle development and carbohydrates and fats for energy and desirable meat quality. Grain production and feed milling are spread across the country to meet the needs of livestock producers and minimize transportation costs. Prices for commodity grains are determined by the Chicago Board of Trade and prices are adjusted in local markets considering the supply, demand, and transportation distance which represent the determination of “basis”.

More than 90 million U.S. acres were planted for corn grain production and nearly 84 million acres were planted for soybeans in 2020. (United States Department of Agriculture National Agricultural Statistics Service, 2021) Of these acres, about 93% were genetically modified for agronomic benefits, such as weed and pest control, and for plant vigor to withstand climate extremes, such as drought, wind, excess rain and heat stress. Some genetic modifications in corn and soybeans have allowed increased production on the same land area. Some corn hybrids and soybean varieties are bred for special nutrient characteristics, but these varieties are usually developed through traditional breeding practices. Figure 48 shows the adoption of genetically engineered crops in the United States over the last 25 years.



Adoption of genetically engineered crops in the United States, 1996-2020

Note: HT indicates herbicide-tolerant varieties; Bt indicates insect-resistant varieties (containing genes from the soil bacterium Bacillus thuringiensis). Data for HT/Bt corn and cotton are not mututally exclusive, as HT and Bt categories include those varieties with overlapping (stacked) HT and Bt traits.

Source: USDA, Economic Research Service using data from the 2002 ERS report, *Adoption of Bioengineered Crops* (AER-810) for the years 1996-99 and National Agricultural Statistics Service, (annual) June Agricultural Survey for the years 2000-20.

Figure 48. Adoption of genetically engineered crops in the United States, 1996-2020

Corn and soybeans are key ingredients used in livestock feed rations and are counted among the few GM crops that are used widely (Hasell & Stroud, 2020). No studies have confirmed that any of the genetic modifications are harmful or detrimental in animal and human food products, yet some American consumers have mixed views about GM food. (Hasell & Stroud, 2020)

Non-GM grains are contracted directly with grain producers and handlers for specific markets, so their prices take into consideration the cost to transport the non-GM grains to the feed mill and/or processing facility. The commodity system has evolved to minimize transportation cost, but the production of specialty grains (such as non-GM) is not as well aligned with processors, thus incurring additional cost. In addition, non-GM prices include a risk factor for the farmer, as production of any specialty grain likely includes a reduction in yield (“yield drag”) as well as some risk that the harvested grain will pass all necessary tests to qualify as non-GM grain and thus receive the contracted price. These factors, in addition to any increased production cost for the farmer, are accounted for when determining the contracted prices for non-GM grain.

USDA corn and soybean non-GM price data over a three-year period was collected for production east of the Mississippi (Region 1) and west of the Mississippi (Region 2) and compared to Chicago Board of Trade prices for each month. Premiums were determined as the difference of the monthly average price of non-GM and commodity grain and expressed as percentages. These percentage premiums were highly variable, reflecting not only production cost and risk, but the sometimes the comparatively high cost of transportation to get the grain to a feed mill that processes non-GM feed. In general, premiums were higher for soybeans than for corn, and premiums were higher in Region 1 than Region 2. Understandably, specialty grain production and specialty feed mills are not perfectly positioned with each other, therefore adding cost to provide these feed ingredients.

Overview of the U.S. Animal Food Industry

A general overview of the livestock feed processing industry was obtained from industry and market research by IBIS World's reports, "Farm Animal Feed Production in the U.S.," and, "IBIS World Business Environment Profile – Price of Feed." The IBIS World reports are based on five-year increments of historical data to estimate the size of the industry and identify the key drivers that influence its growth or decline. Those drivers are identified as:

- price of feed;
- demand for wholesale farm supplies;
- per capita meat consumption; and
- trade-weighted index.

This research was primarily concerned with the prices of feed inputs and the relative change in operating costs that could be triggered by a change in ingredients. Yet, it was also important to acknowledge larger factors that influence supply and demand and the price of feed. The IBIS World report serves as a comprehensive view of what is happening in the feed industry, aside from the current issue of consumer demand for non-GM inputs in the food supply.

According to IBIS World's 2020 Specialized Industry Report for Farm Animal Feed Production in the U.S., demand for meat will continue to grow as global population increases and more countries incorporate meat into human diets. Although U.S. per capita meat consumption grew only slightly in the five-year period, the demand for animal feed remained steady. The report noted a large number of dairy farmers went out of business in 2018-2019, however, consolidations in that sector helped maintain the number of dairy cattle on feed. Such consolidations, paired with an increase in global demand for dairy products, exemplify a mechanism by which domestic demand for feed is maintained.

Feed industry revenue declined by 3.4% over the period 2014-2019, following record high prices of grain inputs prior to 2014 that translated into high feed prices. Following that period, corn and soybean supply reached record levels, thus reducing grain prices and feed prices. Consequently, during the five-year period prior to 2019, the feed industry experienced an annualized decline of 3.4% to a total revenue of $32.6 billion. Major players such as Purina Mills LLC and Cargill Inc., represent nearly 20% of revenue, with $3.6 billion and $2.7 billion, respectively. The remaining industry players together represent $26.3 billion.

IBIS World forecasts industry revenue to increase at an annualized rate of 1.0% over the five-year period 2019-24, citing the global demand for meat in developing countries. This new demand would spur livestock producers to increase their herd/flock sizes and, thus, increase demand for feed products. Feed producers will also become more export-oriented in response to global demand by livestock producers in other countries. The average profit margin of 3.9% in 2019 may be threatened by higher wage costs and lagging feed prices due to low grain prices. Consolidation in the industry over the next five years will likely reduce the number of firms by 1.0%.

A study commissioned by IFEEDER entitled, “The U.S. Animal Feed and Pet Food Manufacturing Industry Economic Contribution Study,” showed that, in 2017, there were 5,715 livestock feed mills in the US and 517 pet food companies. Most of these facilities are in the midwestern, southern and eastern regions (Decision Innovation Solutions, 2017). More than 9.2 billion food producing animals are raised annually, and the feed mills that serve them are located to minimize transportation costs both to the sources of feed inputs and to the animals consuming the feed.

In Iowa, for example, there are 448 feed mills that make medicated and non-medicated feeds. The mills are positioned so there is usually a feed mill within a 20-minute drive from a livestock producer. Iowa is also a major producer of corn and soybean meal. Figure 49 shows the concentration of licensed feed in Iowa mills by zip code. It is conceivable that in areas with many feed mills serving local livestock production and a soybean processor nearby, grain producers could be incentivized to grow non-GM corn and soybeans for feed production without incurring increases in transportation costs. It would also be important for the mills and soybean meal processors to segregate the non-GM ingredients.

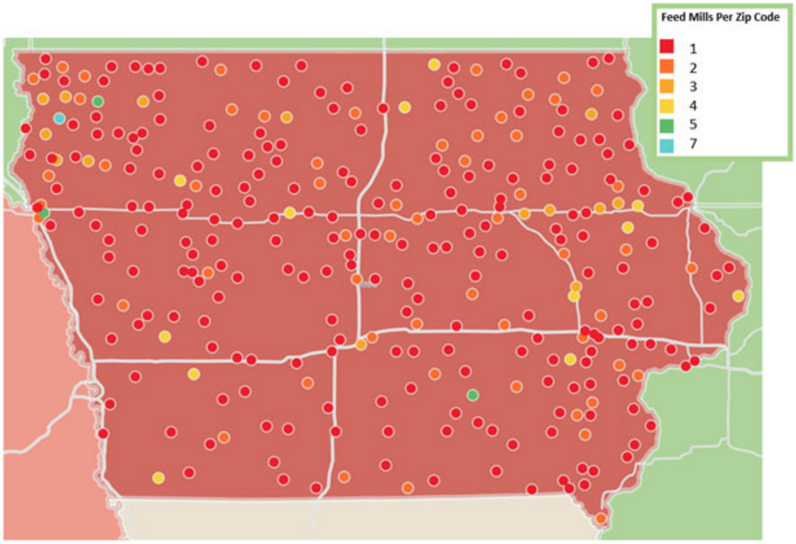


Figure 49. Iowa Feed Mill Concentration, source: Decision Innovation Solutions for Iowa Farm Bureau, Preston Lyman. 2017

Most U.S. feed mills either make a variety of feeds for many animal species or they are designed to make large quantities of feed for one species. Newer mills are usually in the latter category, catering to large single species animal populations, such as swine, poultry, and beef and dairy cattle. The current breakdown of the U.S. total feed production is: 24.6% beef and dairy cattle feed; 43.9% poultry feed; 12.0% swine feed; and 19.5% feed for other species (Curran, 2020).

Feed Milling Operations Cost

Profit/Loss comparisons among U.S. feed mills were examined in BizMiner and IndustriUS. Both are subscription services that support business financial analysis. BizMiner analyzed financial data from 48 livestock and/or poultry feed manufacturing plants (2015-18) and 51 plants in 2019 and found that the Cost of Sales were 76.28-77.03% of revenue over the five-year period. Similarly, IndustriUS analyzed financial data from 432 feed manufacturing plants (2017-19) and found the Cost of Sales to be 76.1-78.7% of revenue in that period. IndustriUS data also showed that materials costs ranged from 50.1% of revenue in 2018 to a high of 54.5% of revenue in 2019. Gross profit margins for these operations ranged from a high of 26% in 2016 to 21% in 2019. From this data, it can be estimated that the cost of ingredients represents about 50% of revenues for a feed mill. Increases in ingredient costs directly translate into increased prices of mixed feed. For the feed mill, increased prices of feed will bolster sales revenue if the livestock producers are able and willing to pay.

For most life stages, more than 90% of a swine diet is comprised of corn and soybean meal, both of which come from U.S. corn and soybeans that are genetically modified. Similarly, with poultry diets in the U.S., the major ingredients are corn and soybean meal, although some regions might use wheat or sorghum instead of corn as an energy source and use a variety of oilseed meals for protein.

For the livestock producer, 60% of all costs in a farrow-to-finish swine operation is the cost of feed (U.S. Pork Center of Excellence, 2016). Similarly, 65-75% of live production costs in poultry operations are the feed costs (Poultry Hub Australia). Therefore, changes in the costs of feed to the livestock producer can be significant to the operational costs.

Price comparison for GM (Conventional) and non-GM corn and soybeans

The major feed grains in the U.S. are corn, soybeans and wheat. Coproducts from these grains (e.g., soybean meal, wheat middlings, corn gluten meal, etc...) are also included among major feed ingredients, and the prices of the coproducts usually track with the price of the grain from which they were derived. Therefore, it is most useful to compare the prices of the raw grain as these are recorded publicly by the USDA. There is no GM wheat, so only prices of corn and soybeans were compared to determine the impact on the cost of mixed feed rations if more non-GM ingredients were used.

Prices for these conventional crops are set daily by the Chicago Board of Trade (CBOT) and adjusted by local traders to account for regional demand, transportation costs and other factors known commonly as “basis.” This study uses the CBOT average monthly prices over the recent three-year period (January 2017-March 2020) without adjustments for basis (USDA).

Some non-GM corn and soybean cultivars have always been grown for human food production. These specific varieties have a particular flavor or processing quality (i.e., flint corn for cereals and snacks, large-seeded, clear-hilum soybeans for tofu and soy milk) and are usually contracted for a particular buyer at an agreed-upon price. These prices were not regularly recorded as the terms of the contracts differed widely and were privately bid.

As GM seeds entered the market in the late 1990s, organic and specialty livestock producers demanded feed ingredients that did not contain genetic modifications. Grain producers were incentivized to grow non-GM cultivars that are, and historically had been, used in livestock feed. As production of non-GM feed grains increased to meet demand, the USDA began to collect and record weekly prices for non-GM corn and soybeans, differentiated as “food-grade” and “feed-grade.” For this study, prices for “feed-grade” non-GM corn and soybeans were obtained by request from the USDA and were used to compare with prices of conventional corn and soybeans. “Food-grade” corn and soybeans continue to be grown specifically for human food production and are unlikely to be sold as animal feed ingredients, so those prices were not considered.

CBOT pricing for conventional crops is applicable across the U.S., whereas the USDA price data for non-GM crops is divided into Regions 1 and 2. Region 1 includes states east of the Mississippi River (Eastern Corn Belt) and Region 2 includes states west of the Mississippi (Western Corn Belt). The Western Corn Belt produces about 53% more corn and about 23% more soybeans than the Eastern Corn Belt. Figure 50 and Figure 51 show monthly price comparisons in both regions for corn for the period January 2017-March 2020. Figure 52 and Figure 53 show the same information for soybeans. Also included in each figure is a percentage premium (relative percentage difference between Non-GM and GM prices) and a related trend line.

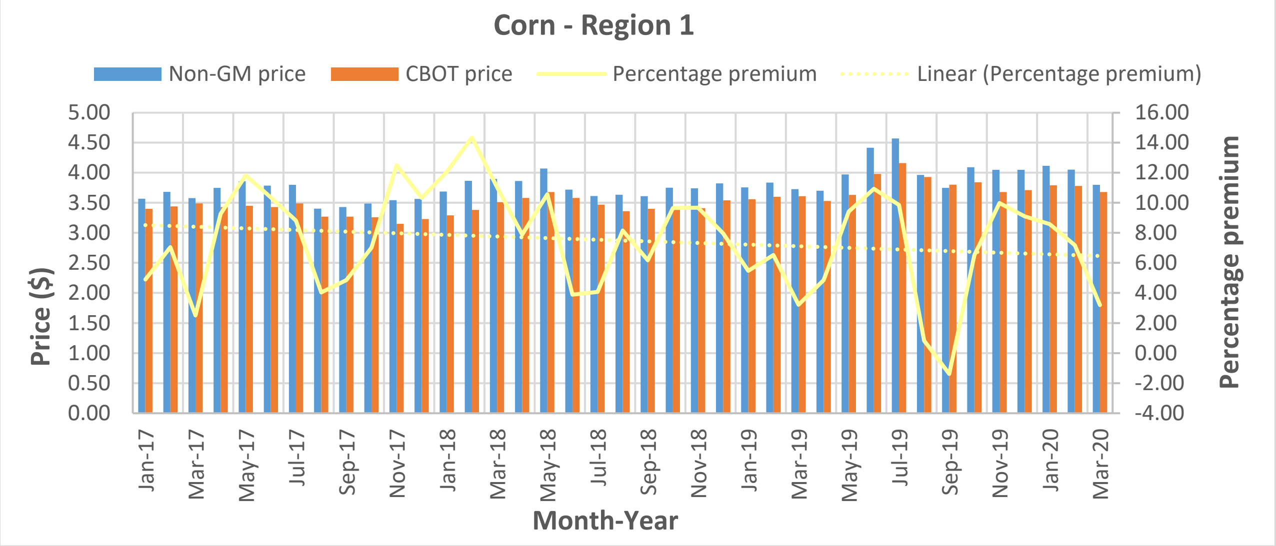


Figure 50. Corn price comparison - Region 1 includes states east of the Mississippi River (Eastern Corn Belt)

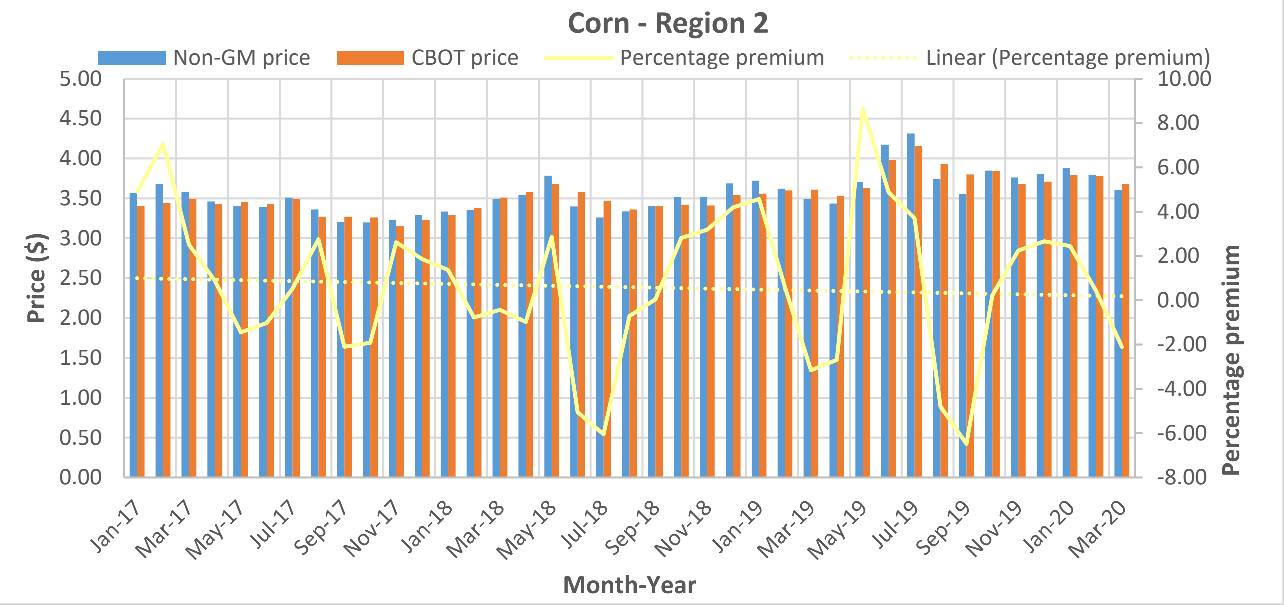


Figure 51. Corn price comparison – Region 2 includes states west of the Mississippi (Western Corn Belt)

Premiums for non-GM corn were erratic over the three-year period shown, and they generally decreased over time. Non-GM corn in Region 1 commanded higher premiums than in Region 2, and only once reached a negative premium (where conventional corn price was higher) in September 2019. Percentage premiums in Region 1 decreased from about 8% in 2017 to nearly 6% in 2020. In Region 2, non-GM percentage premium ranged, on average, between 1% and zero. There were several months where non-GM corn was priced lower than conventional corn, yet it hit significant percentage premiums (4–8%) in early 2017 and in early-to-mid 2019.

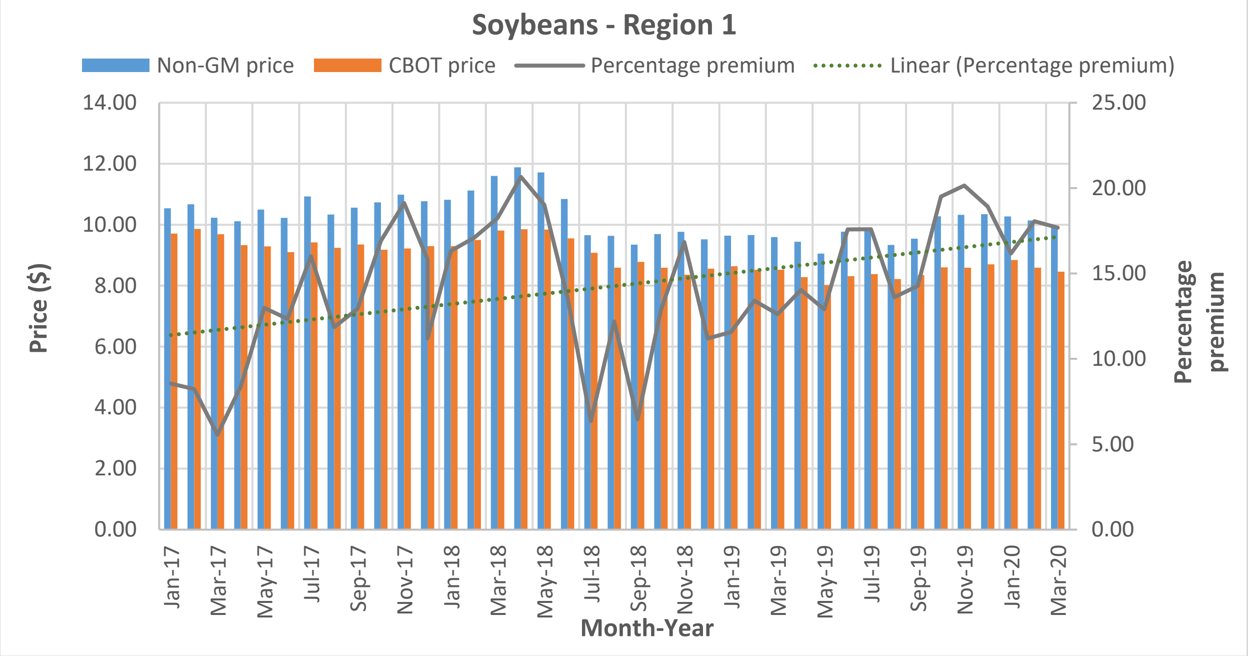


Figure 52. Soybean price comparison – Region 1 includes states east of the Mississippi River (Eastern Corn Belt)

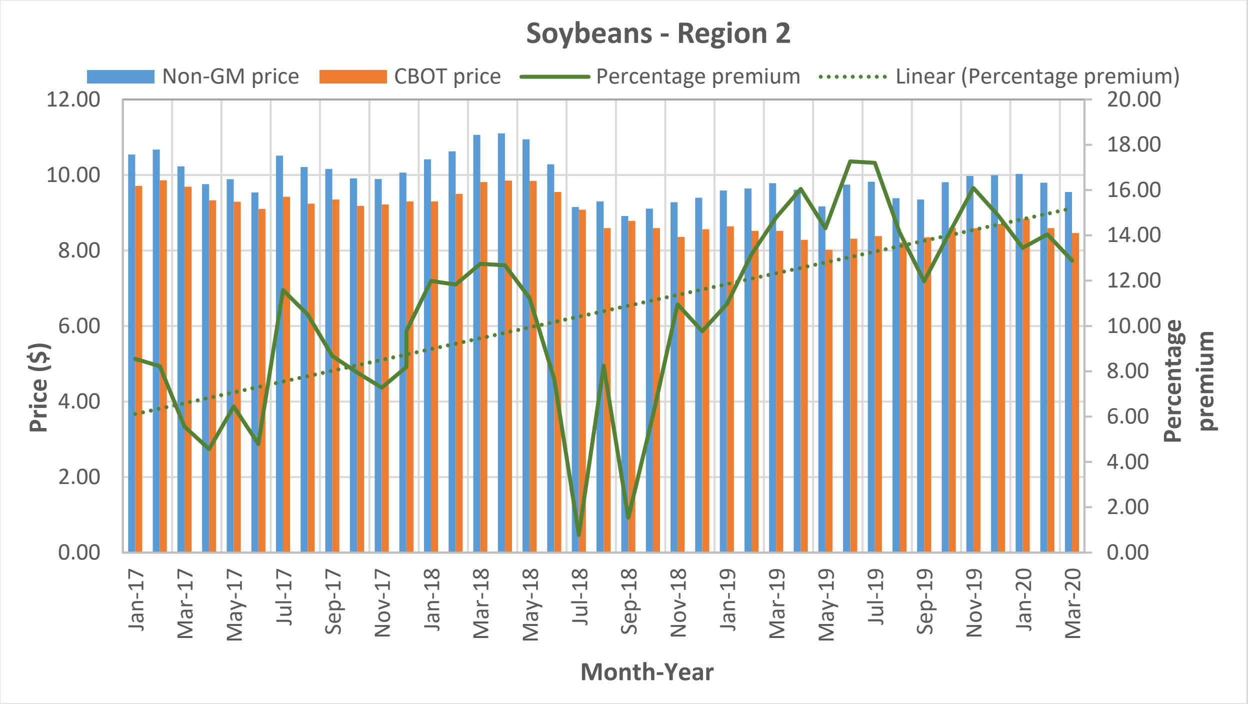
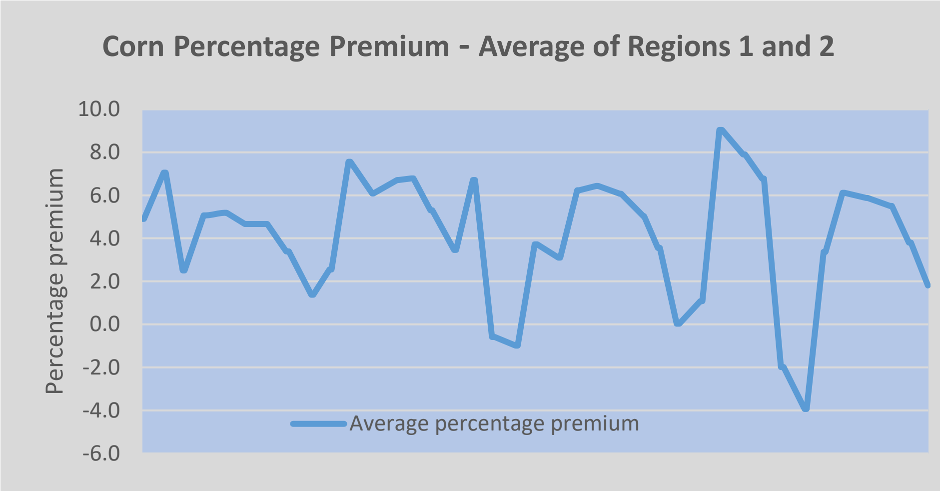


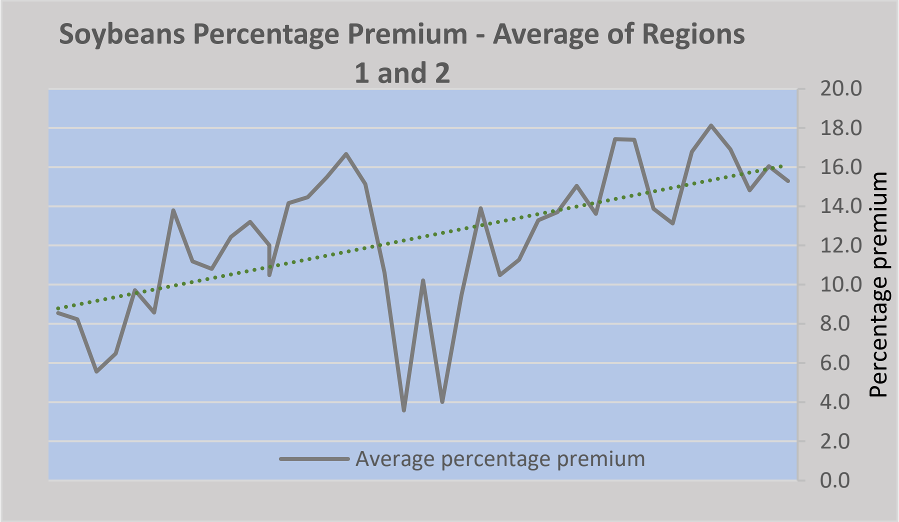
Figure 53. Soybean price comparison – Region 2 includes states west of the Mississippi (Western Corn Belt)

There may be some value in averaging the percentage premium across Regions 1 and 2, and those averages are shown in Figure 54 and Figure 55. Because non-GM grain is currently treated as a “specialty” grain (where there is a buyer demanding it), the price of non-GM grain is more dependent on transportation and logistics than is conventional grain. Conventional corn, for example, can be purchased via grain handling network, but it is considered “fungible” or interchangeable with corn from a different location that is less expensive to transport. This is not usually true for specialty grains, where the grain is purchased as a specific type from a specific source. So, determining a “national” percentage premium would be more useful under a scenario where significantly more non-GM grain is grown for livestock markets across the U.S. For corn, the average percentage premium across the three-year period shown is 7.51% in Region 1 and 0.61% in Region 2, and the average premium across both regions is 4.06%. For soybeans, the average percentage premium across the three-year period shown is 14.27% in Region 1, 10.60% in Region 2 and 12.43% across both regions. Between the two regions, price variability is less for non-GM soybeans than it is for corn. This may be because soybeans are contracted directly by the soybean meal processors who need consistent supply and therefore attempt to maintain contracts for specialty soybeans within their trade areas. Corn, on the other hand, is “processed” at the feed mill and accessed directly from many individual growers or grain handlers at various locations, so transportation costs may play a larger role in specialty corn price.



Corn
January 2017-March 2020
Average Percentage
Premium
Region 1 = **7.51**
Region 2 = **0.61**
Combined = **4.06**

Figure 54. Average percentage premium for non-GM corn in Regions 1 and 2



Soybeans
January 2017-March 2020
Average Percentage
Premium
Region 1 = **14.27**
Region 2 = **10.60**
Combined = **12.43**

Figure 55. Average percentage premium for non-GM soybeans in Regions 1 and 2

The highest percentage premium (14.35%) for corn occurred in February 2018 in Region 1 when the monthly average for non-GM was $0.49 above the conventional price of $3.38 per bushel. The highest percentage premium for soybeans (20.66%) occurred in April 2018 in Region 1 when the monthly average for non-GM was $2.04 above the conventional price of $9.85 per bushel. Across the period January 2017-March 2020, the average premium price for non-GM corn is $0.12 per bushel and for non-GM soybeans is $1.11 per bushel.

Conclusions

Using the feed industry's financial data compiled by BizMiner and IndustriUS over a five-year period, the Cost of Sales in livestock feed manufacturing is typically approximately 77% of Revenue, and the Cost of Materials to manufacture feed is typically 50% of Revenue. Feed prices are mostly influenced by the cost of feed ingredients, so potential premiums for ingredients that are not as readily available as commodity grains will boost the costs of feed.

This component of the study also intended to determine how prices were set in markets that were already seeing a demand for non-GM feed corn and soybeans. The following conclusions can be made from the data compiled by the USDA between January 2017 and March 2020:

- Premiums for non-GM corn and soybeans are erratic and depend on a combination of factors, such as contract requirements, local demand and transportation costs.
- Premiums in Region 1 are usually higher than in Region 2.
- Highest percentage premiums occurred in February 2018 for corn (14.35% in Region 1) and November 2019 for soybeans (18.12% in Region 1).
- Average premiums for corn across both regions was $0.12 per bushel and for soybeans, $1.11. Averaging both regions, however, tends to level the real premium potential that occurs especially in Region 1.

Understandably, premiums for non-GM corn and soybeans would be inconsistent when compared to commodity prices for same grains because they are determined by contract requirements as well as local demand and transportation costs. At this time, non-GM grains are not fungible, as commodity grains are, so transportation costs can be significant to move the desired grain to the processors' locations. Also, pricing for demand that is relatively new (non-GM) is being compared with an established system (CBOT) that governs the larger pool of bulk commodity trade. As non-GM demand grows, its pricing system could become more uniform and those trades would represent a larger part of the market.

This price data was used in other sections of this report in order to maintain consistency in determining price elasticities of feedstuffs and in estimating production costs for broilers, layers, cattle, and swine, which would ultimately estimate the costs to consumers for meat, milk, and eggs from livestock and chickens fed only non-GM feed ingredients.

Costs of achieving segregation goals in feed supply chains (IFEEDER Priority 8)

Introduction

A large proportion of animal feed is composed of corn and soybeans or their derivatives. For more than 20 years, the industry has been using GM ingredients. In the United States, more than 90% of corn and soybean production is GM. Although there are no risks to human or animal health related to these ingredients, consumer demand exists for non-GM products. Enabling consumer choice requires understanding and assessing production costs along the supply chain. Changes throughout the supply chain must occur to ensure the purity of the final product is within the acceptable tolerance limits. The changes relevant to grain industry stakeholders are in equipment and processes for the purposes of ensuring proper segregation of non-GM ingredients and products. The present study undertook to create an economic model to calculate added costs of non-GM animal feed (for swine, broiler, layer and cattle feeds) compared to feed made from conventional GM grains.

Table 28. Summary of previous studies on costs of segregation and identity preservation

Researcher	Estimated Cost of Segregation	Methodology
Hurburgh (1994)	$0.04 / bushel	Economic Engineering Model
Krueger et al. (2000)	$ 3.04 / truck	Simulation
Bullock et al. (2000)	$0.03 / bushel	Cleaning and testing
Lin et al. (2000)	$0.22 to $0.54 / bushel	Survey and Estimations
Wilson and Dahl (2002)	$0.25 to $0.50 / bushel	Survey
Askin (1988)	$0.13 / metric ton	Econometric
Herrman et al. (1999)	$0.02 to $0.07 / bushel	Simulation
Reichert and Vachal (2000)	$0.33 / bushel	Economic Decision Model
Maltsbarger and Kalaitzandonakes (2000)	$0.16 to $0.36 / bushel	Simulation
Lentz and Akridge (1997)	$0.07 / bushel	Simulation Budget Model

Table 28, from Schlecht et al. (2004), presents several works on logistical costs and strategies for segregation. There is significant variability among the studies due to the variability of different regions, products and facilities considered in each analysis. Each model had several important parameters that contributed to the models built as part of this study. The current model took typical U.S. corn and supply chain stakeholder production patterns for swine, broiler and layer hens. Various scenarios were constructed to represent possible configurations of the supply chain and its participants and potential process changes that could be adopted to accommodate non-GM handling and/or production. For each of these facilities, a set of parameters with a range of values was determined, resulting in a range of additional costs calculated for each supply chain step. The same economic model was applied to corn and soybeans, with each crop's appropriate adjustments.

Methods

A stochastic model was developed in Microsoft Excel with the Palisade @Risk software add-in (Palisade, Ithaca, NY, USA). This software makes it possible to run a Monte Carlo simulation on multiple formulas at the same time. Each variable in these formulas can receive a specific statistical distribution of values. Several scenarios were constructed, representing possible configurations of the supply chain participants and potential process adaptations that could be adopted to accommodate non-GM handling and/or production. Each scenario was subjected to an independent simulation. Thus, final distribution of costs for each scenario was determined and will be presented for each case.

The cost models are based on corn and soybean supply chains. The supply chain participants included in the models were the farm, grain elevator and feed mill. The assumption was that feed mills purchased ingredients directly from the farm or a grain elevator. Grain processing facilities, such as ethanol plants, were not included, as there was not an economic justification for this type of facility to use non-GM ingredients. While there are some beverage production facilities that use non-GM grain, these companies are typically minor, more regionally specific ingredient producers. These facilities, therefore, were not considered suppliers of feed ingredients for the purposes of this study.

The model scenarios account for the fact that each of the supply chain participants (farm, grain elevator, feed mill) carry out non-GM segregation using different methods. For example, the feed mill can work exclusively with non-GM feed. Or it can produce both GM and non-GM feed and segregate them through temporal means, in which it receives and processes the two types of ingredients on different days. It can also perform a spatial separation, receiving and processing the two kinds of grains simultaneously, but using a dedicated processing line for non-GM ingredients. Likewise, the elevator can segregate temporally or spatially, or dedicate the entire facility to non-GM grain handling. Although the farm potentially could also work with spatial segregation (reserving specific land lots for special seeds), the assumption was that the farm that opted to plant non-GM seed will only employ a single production methodology. This is supported by the Objective 1 observation that there was a significant, positive correlation between non-GM soybean planted acres and non-GM corn planted acres. An assumption of the model was that the farm will plant all corn or all soybeans on the given land lot.

Cost categories will be described more fully in each of the farm, grain elevator and feed mill sections below. In general, all facilities received similar values concerning interest rates, the equipment's useful life, insurance premium rates and labor costs. Other generic parameters applied are bushels represented by testing and tons of grain processed per year. Each of these parameters receives not just a single, point estimate but rather a distribution of values. The distribution assigned to a given parameter may follow the normal distribution, where an average and standard deviation are attributed. In other cases, the distribution is triangular, defined by a three-point estimate: minimum, most likely and maximum. The triangular distribution is essential to represent values that are not evenly distributed around the mean. An example for which the triangular distribution was used was the purchase price for new equipment, obtained from the manufacturer's quotes. Information about crop production and market prices for grains was obtained from USDA publications, such as the Crop Report for 2019 and Ag Decision Maker tools developed by Iowa State University Extension. Data that are collected routinely (such as grain market prices) are represented by a normal distribution in this model. More specific parameters were found in previous models, specifically from the (Hurburgh Jr. et al., 1994) engineering economic model simulation.

In total, there were 83 independent scenarios (18 for the farm, 18 for the grain elevator, 45 for the feed mill, and two additional that consider feed produced in the farm), which will be described in more detail below. The @Risk software performed 10,000 iterations for each scenario.

In the cases of beef and dairy feeding, there was a particularity that there are some beef and dairy farms also producing the feed to be used. In this case, the cost to obtain the ingredients follows the modeling of the costs found for the Farm scenarios. After the ingredient costs, segregation costs in feed processing and production were added. It is assumed that a farm that chooses to feed its animals with non-GM feed will do so for the entire production cycle. That is, there will not be a section of animals with differentiated feeding, but all will receive the same category of feed. Thus, the main cost of producing non-GM feed on the farm is the production of the ingredients, namely corn and soybeans.

Farm

The first set of scenarios was developed by separating the farm between corn and soybeans. Each scenario was subjected to a simulation, and the variance obtained from each parameter determined the creation of additional scenarios. The most significant variance was in the 'isolation distance' parameter because corn is an open-pollinated crop. Thus, four additional scenarios were created for corn with isolation distances of 0, 50, 100, 150 and 200 feet. After simulating these new scenarios, the variance was still high due to the distribution in the parameter "total planting area". The scenarios were then divided into three more each, according to the acreage of 200, 350 and 500 acres. The next most significant contributor to the variance was the premium price paid for the non-GM grain. As this is a variable controlled by the market, alternative scenarios varying this parameter were not created.

In the end, 18 farm scenarios were examined as shown in Table 29 with three scenarios referring to soybean production without isolation distance, three scenarios for corn without isolation distance, and another 12 scenarios on corn with select combinations of isolation distance and crop area in acreage.

Table 29. Scenarios for Farm

Farm Costs		
Product	***Isolation Distance (ft)***	***Crop Area (ac)***
Soybeans	0	200
Soybeans	0	350
Soybeans	0	500
Corn	0	200
Corn	0	350
Corn	0	500
Corn	50	200
Corn	50	350
Corn	50	500
Corn	100	200
Corn	100	350
Corn	100	500
Corn	150	200
Corn	150	350
Corn	150	500
Corn	200	200
Corn	200	350
Corn	200	500

Farm Cost Categories

The farm cost categories are listed in

Table 30. The isolation distance (C1) has a cost associated because a fraction of the premium product is assumed to have cross-pollinated with GM crops and is sold at a commodity price. Field geometry also influences cross-pollination and, subsequently, the proportion of the yield to be sold as GM. The other expenses come from special preparation of equipment for planting, harvesting, and storage when a GM farm decides to produce non-GM grains. There was also the production cost comparison per hectare, yield comparison and seed price comparison between

GM and non-GM. Time and consumables to set up equipment and labor costs are parameters associated with costs 2, 3 and 4, as shown in

Table 30. The result is expressed in dollars per bushel of grain produced.

Table 30. Cost Categories for Farm

Farm Cost Categories	
C1	Isolation Distance
C2	Planting
C3	Harvesting
C4	Storage

The values found are strictly related to the operational costs of isolation and segregation. Comparisons of profitability between GM and non-GM are not being considered.

Grain Elevators

The grain elevator model was initiated with six scenarios: segregation by time, segregation by space and a dedicated facility for both corn and soybeans. Each scenario was subjected to one simulation, and the variance obtained from each parameter determined the creation of additional scenarios. The component that contributed most to the variance was the premium paid for non-GM grain. As in the farm case, no scenarios were created to vary this parameter as it is something defined by the market at the time of sale. Thus, each scenario was divided into three processing scales: one-half million, one million and two million bushels per year. The biggest difference for the scale was the price of new equipment, which resulted in a more significant differentiation in the case of spatial segregation than in the others.

Table 31 below displays all the scenarios assessed.

Table 31. Scenarios for Grain Elevators

Elevator Scenarios			
#	***Product***	***Segregation***	***Volume (bu/y)***
E1	Soybeans	Space	500000
E2	Soybeans	Space	1000000
E3	Soybeans	Space	2000000
E4	Soybeans	Time	500000
E5	Soybeans	Time	1000000
E6	Soybeans	Time	2000000
E7	Soybeans	Dedicated	500000
E8	Soybeans	Dedicated	1000000
E9	Soybeans	Dedicated	2000000
E10	Corn	Space	500000
E11	Corn	Space	1000000
E12	Corn	Space	2000000
E13	Corn	Time	500000
E14	Corn	Time	1000000
E15	Corn	Time	2000000
E16	Corn	Dedicated	500000
E17	Corn	Dedicated	1000000
E18	Corn	Dedicated	2000000

Grain Elevator Cost Categories

The grain elevator model's cost categories (

Table 32) include tester, test operation, waiting time, receiving, sample storage, standardization, grain storage, risk of mis-quantification of GM adventitious presence (AP) in non-GM grain (resulting in undeserved premium payment), ingredients and conveyors. When segregating by time, these pieces of equipment need to be setup. In the case of spatial segregation, their acquisition and maintenance costs were considered. The sum of all these costs is the additional processing cost in deciding whether to work with non-GM feed. The result here is expressed in dollars per bushel of non-GM grain handled.

Table 32. Cost Categories for Grain Elevators

Elevators Cost Categories	
C1	Tester
C2	Test Operation
C3	Waiting Time
C4	Receiving
C5	Sample Storage
C6	Grain Storage
C7	Standardization
C8	Disputes
C9	Misgrading Risk
C10	Ingredients
C11	Conveyors

Feed Mills

The Feed Mill model started with 15 scenarios, the result of the combination of three methods of segregation and five types of feed (swine, broiler, layer, beef and dairy). Each scenario was subjected to a simulation and the variance obtained from each parameter determined the creation of additional scenarios. The most significant contributors to the variance were, again, the market prices paid for grains and their respective premiums. As the market delimits these values, there will be no separation of scenarios representing different price ranges. Iowa is estimated to have 600 Feed Mills and produce 15 million tons per year. So, the average production per facility is approximately 25,000 tons per year. Three scales were considered: 10,000 tons, 25,000 tons and 50,000 tons per year. Thus, the 15 scenarios were divided into three each, representing different production scales. Table 33 shows these scenarios:

Table 33. Scenarios for Feed Mills

Feed Mill Costs			
Scenario	***Product***	***Segregation***	***Capacity (tons/year)***
M1	Swine	Space	10,000
M2	Swine	Space	25,000
M3	Swine	Space	50,000
M4	Swine	Time	10,000
M5	Swine	Time	25,000
M6	Swine	Time	50,000
M7	Swine	Dedicated	10,000
M8	Swine	Dedicated	25,000
M9	Swine	Dedicated	50,000
M10	Broiler	Space	10,000
M11	Broiler	Space	25,000
M12	Broiler	Space	50,000
M13	Broiler	Time	10,000
M14	Broiler	Time	25,000
M15	Broiler	Time	50,000
M16	Broiler	Dedicated	10,000
M17	Broiler	Dedicated	25,000
M18	Broiler	Dedicated	50,000
M19	Layer	Space	10,000
M20	Layer	Space	25,000
M21	Layer	Space	50,000
M22	Layer	Time	10,000
M23	Layer	Time	25,000
M24	Layer	Time	50,000

M25	Layer	Dedicated	10,000
M26	Layer	Dedicated	25,000
M27	Layer	Dedicated	50,000
M28	Beef	Space	10,000
M29	Beef	Space	25,000
M30	Beef	Space	50,000
M31	Beef	Time	10,000
M32	Beef	Time	25,000
M33	Beef	Time	50,000
M34	Beef	Dedicated	10,000
M35	Beef	Dedicated	25,000
M36	Beef	Dedicated	50,000
M37	Dairy	Space	10,000
M38	Dairy	Space	25,000
M39	Dairy	Space	50,000
M40	Dairy	Time	10,000
M41	Dairy	Time	25,000
M42	Dairy	Time	50,000
M43	Dairy	Dedicated	10,000
M44	Dairy	Dedicated	25,000
M45	Dairy	Dedicated	50,000

Feed Mill Cost Categories

The feed mill model's cost categories (shown in Table 34) were tester, test operation, waiting time, receiving, sample storage, standardization, grain storage, risk of AP mis-quantification (resulting in undeserved premium payment), ingredients, conveyors, millers, mixers, pelletizers and baggers. When segregating by time, all the processing equipment must be set-up. In the case of spatial segregation, their acquisition and maintenance costs were considered. The sum of all these costs was the additional processing costs to produce non-GM feed. The results are expressed in dollars per ton of feed produced.

As is typical for the formulation of animal feed, soybean meal was used instead of the whole grain, therefore, a constant percentage in the premium for soybean meal as for soybeans was assumed and the same percentage increase of processing as for whole soybeans. This means that testing and handling costs have been included twice, once for whole grains in a processor and once for the meal at the feed mill.

Table 34. Cost Categories for Feed Mills

Feed Mills Cost Categories	
C1	Tester
C2	Test Operation
C3	Waiting Time
C4	Receiving
C5	Sample Storage
C6	Grain Storage
C7	Standardization
C8	Disputes
C9	Misgrading Risk
C10	Ingredients
C11	Conveyors
C12	Miller
C13	Mixer
C14	Pelletizer
C15	Bagger

Supplement for Grazing

The USDA reports show a cattle inventory in the U.S. of 96.6 million head, with 14.6 million head on feed. The majority of cattle are fed mainly by grazing. (Barnhart & Duffy, 2012; Ellis et al., 2007; Schulte & Tranel) Approximately 14% of beef cattle and 34% of dairy cattle are on feed. Nevertheless, grazing cattle still consume nutritional supplements with ingredients that should be replaced in a non-GM diet. The model to calculate the additional operating costs and replacement of ingredients for producing grazing beef and dairy was an integrated version of the farm and feed mill scenarios. The farm was the processor of feed ingredients, planting corn to be used in animal feed and buying soybean meal from a processor, as in the case of feed mills. Consequently, two scenarios were created, one for beef cattle feed and one for dairy cattle feed.

Grazing Cost Categories

Since production and operating costs for farm and feed mills have been calculated, cost categories can be simplified in this model, taking advantage of scenario results. Therefore, two categories of costs for grazing were included: farm costs (mainly for the corn proportion) and ingredients costs (mainly for soybean mean proportion).

Other Considerations

For spatial segregation scenarios in Grain Elevators and Feed Mills, the major cost factor was the acquisition of equipment for the construction of an exclusive line. In this case, the facility's structure for processing non-GM ingredients continued to function and the costs presented were for processing an additional volume. In the other two cases, the processed volume of non-GM replaced the processing of GM ingredients. Thus, the cost of spatial segregation presented will be higher, and there will be no compensation with the general cost of production.

Results

Farm

Table 35. Segregation Costs on Farm Scenarios

Farm Costs				
Product	***Isolation Distance (ft)***	***Crop Area (ac)***	***Mean ($/bu)***	***Std Deviation***
Soybeans	0	200	$ 0.0137	$ 0.0003
Soybeans	0	350	$ 0.0078	$ 0.0002
Soybeans	0	500	$ 0.0055	$ 0.0001
Corn	0	200	$ 0.0026	$ 0.0000
Corn	0	350	$ 0.0015	$ 0.0000
Corn	0	500	$ 0.0010	$ 0.0000
Corn	50	200	$ 0.0138	$ 0.0073
Corn	50	350	$ 0.0100	$ 0.0055
Corn	50	500	$ 0.0082	$ 0.0047
Corn	100	200	$ 0.0246	$ 0.0144
Corn	100	350	$ 0.0182	$ 0.0109
Corn	100	500	$ 0.0151	$ 0.0092
Corn	150	200	$ 0.0351	$ 0.0212
Corn	150	350	$ 0.0263	$ 0.0162
Corn	150	500	$ 0.0219	$ 0.0136
Corn	200	200	$ 0.0452	$ 0.0278
Corn	200	350	$ 0.0342	$ 0.0214
Corn	200	500	$ 0.0286	$ 0.0180

For better visualization, Figure 56 depicts the difference in the segregation costs per bushel of soybeans and corn harvested, depending on the planting area. With corn, four isolation distances were considered, ranging from 0 to 200 feet. This isolation distance is a decision that the farmer must make according to the degree of purity desired for the crop. To reduce isolation distance, the farmer may check which crop the neighbors are planting. If neighbors also plant non-GM seeds, the isolation distance may not be necessary.

It was expected that with the volume of crop produced, costs would fall as fixed costs would be more diluted. However, there is a very small drop in the costs of segregation as the planted area increases. For the field sizes examined, increased planting area reduces the additional costs per bushel, with the most significant differences in costs seen at greater isolation distances.

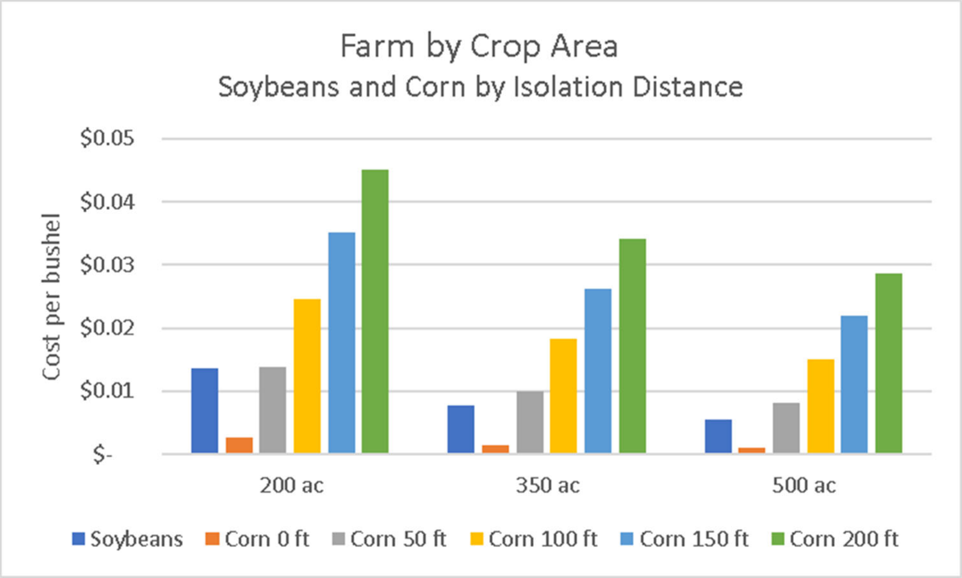


Figure 56. Segregation Costs on Farm

Cost category C1, isolation distance, when it occurs, comprises the majority of total segregation costs on the farm. Other variables like time and consumables to clean equipment and storage systems have very small contributions to the total additional cost. Labor costs would not differ from the processing of GM crops.

Elevator

Table 36. Costs for Elevator

Elevator Costs				
Product	***Segregation***	***Volume (bu/y)***	***Mean ($/bu)***	***Std Deviation***
Soybeans	Space	500000	$ 0.0690	$ 0.0095
Soybeans	Space	1000000	$ 0.0649	$ 0.0096
Soybeans	Space	2000000	$ 0.0619	$ 0.0095
Soybeans	Time	500000	$ 0.0583	$ 0.0096
Soybeans	Time	1000000	$ 0.0559	$ 0.0096
Soybeans	Time	2000000	$ 0.0547	$ 0.0095
Soybeans	Dedicated	500000	$ 0.0579	$ 0.0095
Soybeans	Dedicated	1000000	$ 0.0557	$ 0.0094
Soybeans	Dedicated	2000000	$ 0.0546	$ 0.0095
Corn	Space	500000	$ 0.0867	$ 0.0031
Corn	Space	1000000	$ 0.0824	$ 0.0031
Corn	Space	2000000	$ 0.0795	$ 0.0031
Corn	Time	500000	$ 0.0760	$ 0.0030
Corn	Time	1000000	$ 0.0736	$ 0.0030
Corn	Time	2000000	$ 0.0724	$ 0.0030
Corn	Dedicated	500000	$ 0.0756	$ 0.0030
Corn	Dedicated	1000000	$ 0.0734	$ 0.0030
Corn	Dedicated	2000000	$ 0.0723	$ 0.0030

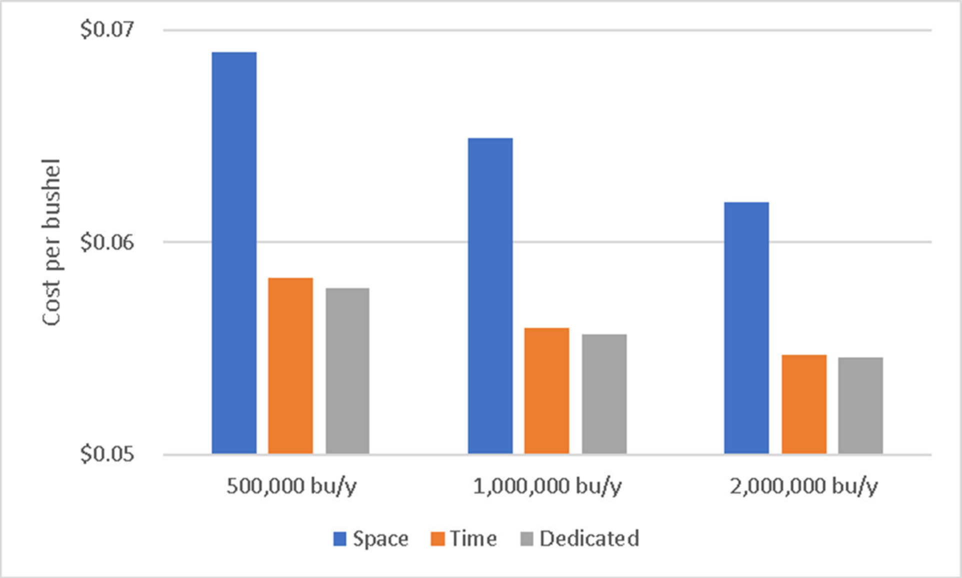


Figure 57 and Figure 58 compare the costs of processing soybeans or corn on three production scales. The cost of segregation does not fall much as the scale of processing increases. This fact is explained by the variable costs being more impactful than the fixed costs.

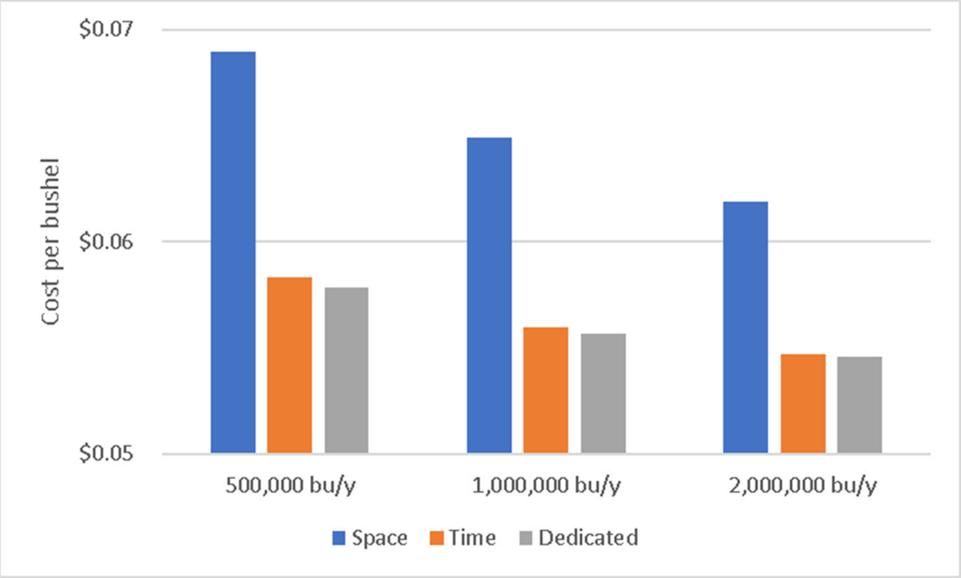


Figure 57. Soybeans on Elevator – Segregation Cost by Volume Handled and Segregation Method

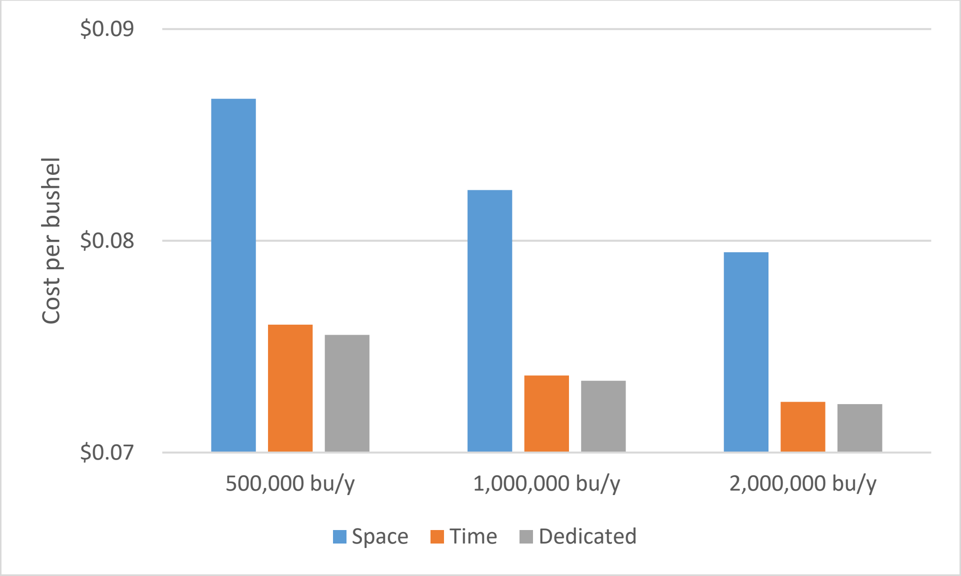


Figure 58. Corn on Elevator – Segregation Costs by Volume Handled and Segregation Method

The category contributing the greatest amount to the final price is the test on receiving (C2). The test for corn is more expensive because there are many more GM traits for corn than for soybeans.

Category C10 (ingredients) considers the disbursement related to the premium price paid for the non-GM product. It is an opportunity cost, compared to an application in an average savings account. For example, to process 500,000 bushels per year of non-GM corn, the amount disbursed on the purchase is $75,000 above the purchase of GM corn. The same volume of soybeans would represent a disbursement of more than $500,000 per year. The facility recovers this investment in the sale of the product at a premium price, but it is worth noting that the facility needs to be prepared for the potential temporary decrease of cash flow.

Feed Mill

Table 37. Costs on Feed Mill Scenarios

Feed Mill Costs					
#	***Product***	***Segregation***	***Capacity (tons/year)***	***Mean ($/ton)***	***Std Deviation***
M1	Swine	Space	10,000 tons/y	$ 7.1587	$ 0.1336
M2	Swine	Space	25,000 tons/y	$ 6.5339	$ 0.1169
M3	Swine	Space	50, 000 tons/y	$ 6.0698	$ 0.1099
M4	Swine	Time	10,000	$ 5.2590	$ 0.1038
M5	Swine	Time	25,000	$ 5.0235	$ 0.1024
M6	Swine	Time	50,000	$ 4.9462	$ 0.1025
M7	Swine	Dedicated	10,000	$ 5.2910	$ 0.1089
M8	Swine	Dedicated	25,000	$ 4.9546	$ 0.1017
M9	Swine	Dedicated	50,000	$ 4.9118	$ 0.1020
M10	Broiler	Space	10,000	$ 7.1832	$ 0.2769
M11	Broiler	Space	25,000	$ 6.5575	$ 0.2695
M12	Broiler	Space	50,000	$ 6.0924	$ 0.2685
M13	Broiler	Time	10,000	$ 5.4875	$ 0.2697
M14	Broiler	Time	25,000	$ 5.0473	$ 0.2642
M15	Broiler	Time	50,000	$ 4.9684	$ 0.2637
M16	Broiler	Dedicated	10,000	$ 5.3159	$ 0.2685
M17	Broiler	Dedicated	25,000	$ 4.9785	$ 0.2639
M18	Broiler	Dedicated	50,000	$ 4.9342	$ 0.2641
M19	Layer	Space	10,000	$ 7.3938	$ 0.1379
M20	Layer	Space	25,000	$ 6.7663	$ 0.1200
M21	Layer	Space	50,000	$ 6.2996	$ 0.1147
M22	Layer	Time	10,000	$ 5.6978	$ 0.1132
M23	Layer	Time	25,000	$ 5.2559	$ 0.1056
M24	Layer	Time	50,000	$ 5.1757	$ 0.1064
M25	Layer	Dedicated	10,000	$ 5.5261	$ 0.1124
M26	Layer	Dedicated	25,000	$ 5.1871	$ 0.1047
M27	Layer	Dedicated	50,000	$ 5.1413	$ 0.1059
M28	Beef	Space	10,000	$ 3.0774	$ 0.0901
M29	Beef	Space	25,000	$ 2.4562	$ 0.0603
M30	Beef	Space	50,000	$ 1.9926	$ 0.0480
M31	Beef	Time	10,000	$ 1.1777	$ 0.0257
M32	Beef	Time	25,000	$ 0.9460	$ 0.0203
M33	Beef	Time	50,000	$ 0.8687	$ 0.0193
M34	Beef	Dedicated	10,000	$ 1.2097	$ 0.0423
M35	Beef	Dedicated	25,000	$ 0.8772	$ 0.0201
M36	Beef	Dedicated	50,000	$ 0.8344	$ 0.0194
M37	Dairy	Space	10,000	$ 3.5740	$ 0.0919
M38	Dairy	Space	25,000	$ 2.9433	$ 0.0639
M39	Dairy	Space	50,000	$ 2.4789	$ 0.0523
M40	Dairy	Time	10,000	$ 1.8784	$ 0.0473
M41	Dairy	Time	25,000	$ 1.4331	$ 0.0288
M42	Dairy	Time	50,000	$ 1.3550	$ 0.0285
M43	Dairy	Dedicated	10,000	$ 1.7063	$ 0.0471
M44	Dairy	Dedicated	25,000	$ 1.3642	$ 0.0289
M45	Dairy	Dedicated	50,000	$ 1.3206	$ 0.0286

As before, the same data are presented in a graphical format in Figure 59 throughFigure 62. Feed Mill – Segregation Cost for Beef Feed Figure 63. In all three types of feed, the costs of manufacturing the feed using non-GM grains are compared. Each type of feed has a different proportion of corn and soybean meal.

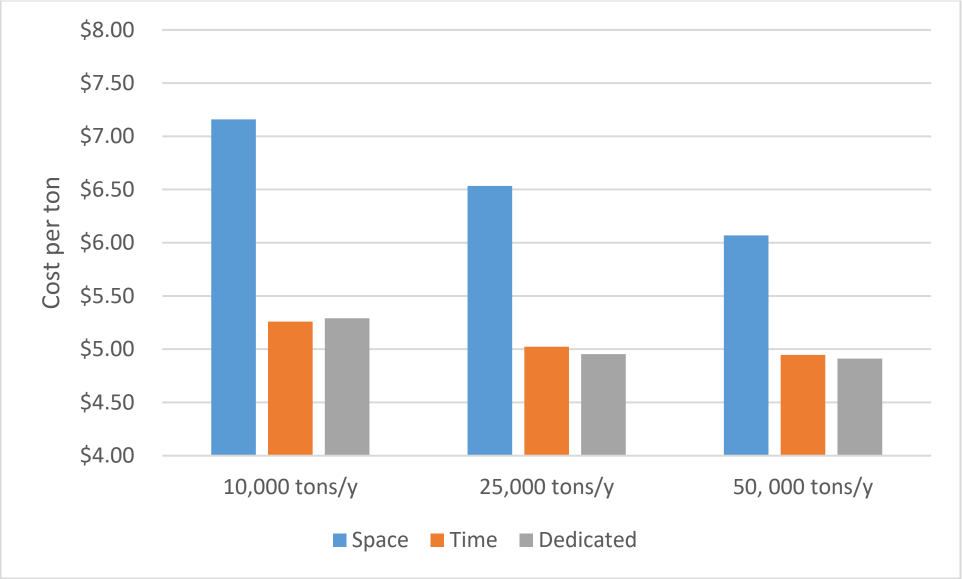


Figure 59. Feed Mill – Segregation Cost for Swine Feed

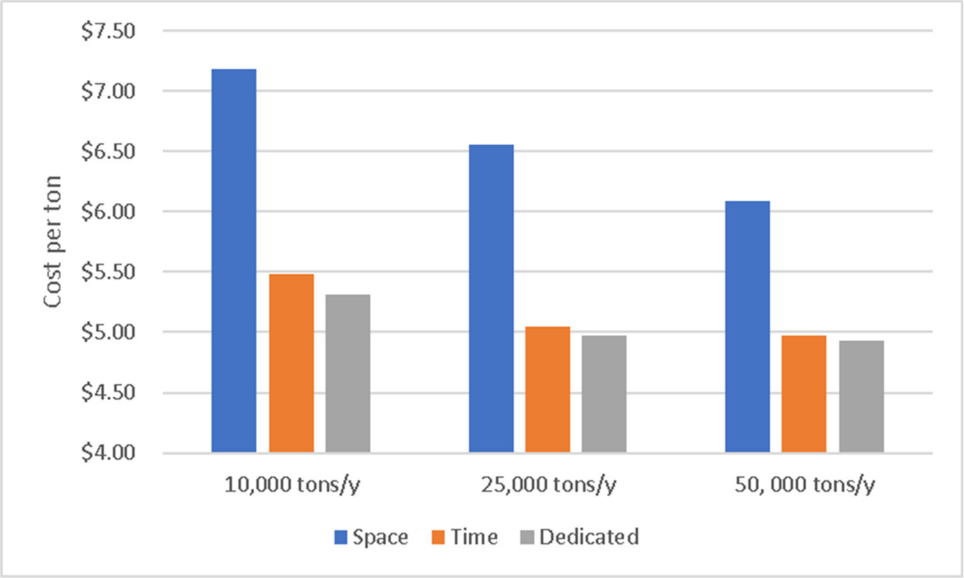


Figure 60. Feed Mill – Segregation Cost for Broiler Feed

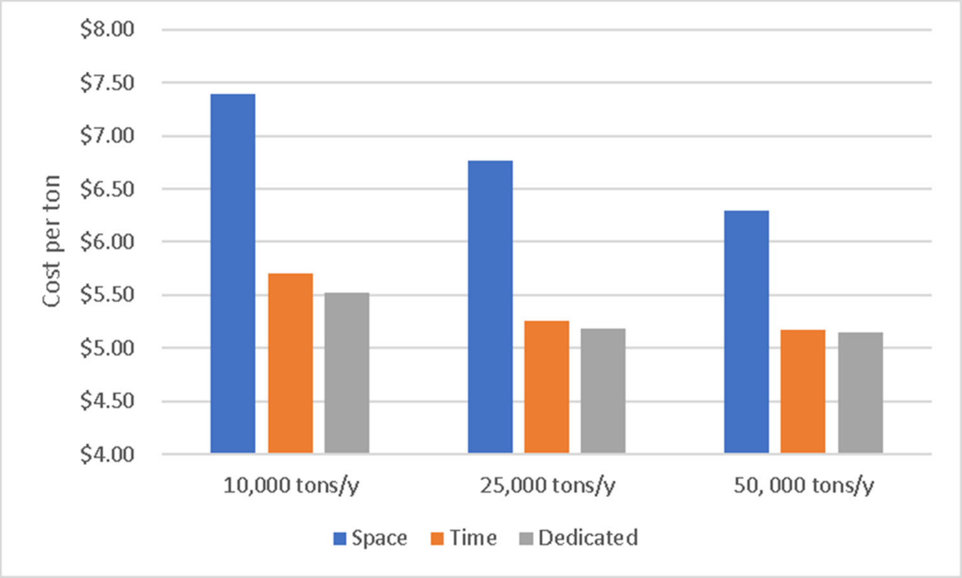


Figure 61. Feed Mill – Segregation Cost for Layer Feed

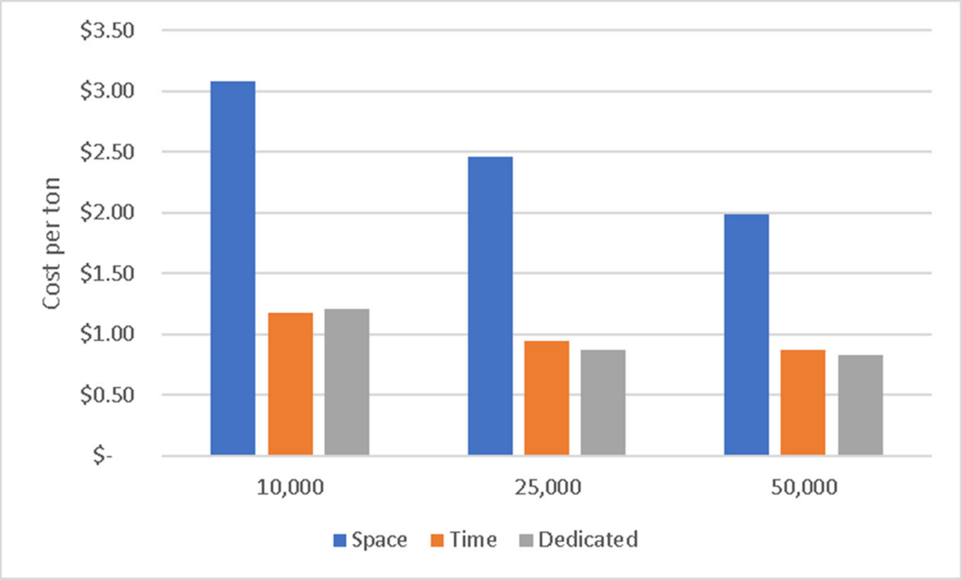


Figure 62. Feed Mill – Segregation Cost for Beef Feed

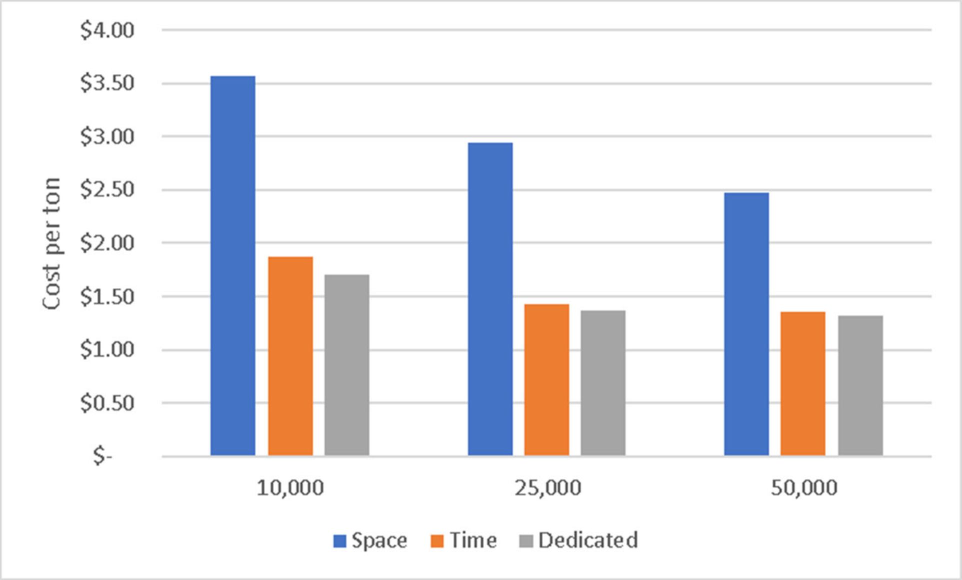


Figure 63. Feed Mill – Segregation Cost for Dairy Feed

The scale of production at the feed mill has a more significant effect on the segregation cost than for grain elevators. This is because there are more fixed costs, especially in spatial segregation, because of the need for the purchase of several pieces of equipment. For example, some costs per ton on the scale of 50,000 tons per year are greater than 25,000 tons per year because of the equipment's size for processing. Again, the category with the greatest contribution to the final price is testing costs at receiving (C2).

Grazing

The diet of beef cattle consists of 14% feed and the rest grazing. For the grazing portion, the cost per ton of material intake is 1.2 cents. The diet of dairy cows consists of 34% feed. For the remaining 66%, the calculated additional cost is 82 cents per ton of grazing intake. This difference is mainly because there is no soybean meal in the diet of beef cattle.

Conclusions

All participants in the non-GM feed production supply chain will have additional costs related to segregation and isolation. The costs of segregation on the farm are very small. Even with the largest isolation range considered, the cost of on-farm segregation is less than $0.05 per bushel. Therefore, the costs of operationalizing segregation on the farm will likely not be a major factor guiding the decision to produce or not produce non-GM grain. It is expected that the farmer will continue to reconcile productivity and final price as part of the decision choice.

As an intermediary, the grain elevator not only buys non-GM grain at a premium price but also sells it at a higher price. Therefore, clarity and transparency on costs of segregation and isolation are critical for grain elevator decisions on whether or not to handle non-GM grain. Depending on the sale date to a feed mill, the grain elevator is able to negotiate a better value for its grain, but it is always conditioned to the market value. The elevator will spend an additional $0.05 to $0.07 per bushel to handle and segregate non-GM soybeans, compared with regular soybeans, and $0.07 to $0.09 per bushel for non-GM corn.

The feed mill, at the end of the feed production chain, marks the largest increase in the price of the final product, which has direct bearing on the price of meat, milk, and eggs derived from animals fed with non-GM feed. The additional cost of segregating non-GM ingredients ranges from $4.91 to $9.08 per ton for swine feed, $4.93 to $9.11 per ton for broiler feed, $5.14 to $9.32 per ton for the layer feed, $0.44 to $2.68 per ton for beef feed, and $1.32 to 3.57 for dairy feed. For the feed mill, the choice of the segregation strategy has greater weight in the final additional cost. Spatial segregation entails higher costs, especially for smaller facilities.

When calculating the final cost for beef and dairy cattle, it is worth remembering that most of these animals are not on feed throughout the year. Yet, even when grazing, there are costs concerning the replacements of ingredients used as a supplementary diet.

These calculations and research do not consider levels of purity in the final product. Different countries and third-party certification bodies recognize varying levels of AP as "acceptable" for a product to be considered non-GM. Obviously, the smaller the acceptable level of AP, the more expensive it is to achieve. The costs shown are for standard segregation and isolation operations. In the future, this work may serve as a basis for determining segregation costs by the degree of AP.

These costs were used to determine the feed industry's economic impact from the increased demand for non-GM feed in the market. With the costs found in this study, future work may examine the supply chain to predict the increase in the price of meat, milk and eggs price from animals fed with this feed.

Key Takeaways from Priority 8 – Cost Estimates:

- An economic model was developed to analyze the operational costs to produce non-GM feed and segregate feed ingredients on farms, grain elevators and feed mills.
- On farms, average operational costs to produce non-GM soybeans are $0.01 per bushel and to produce non-GM corn is $0.02 per bushel.
- At grain elevators and feed mills, three segregation methods were compared: time, space and dedicated facilities. Costs on segregation methods are higher for dedicated

facilities, considering the purchase of new equipment to process only non-GM ingredients.

- At grain elevators, average operational costs to segregate non-GM soybeans are $0.06 per bushel and to segregate non-GM corn is $ 0.08 per bushel.
- Average operational costs for feed mills to produce non-GM feed are: $5.57 per ton of swine feed; $5.62 per ton of broiler feed; $5.83 per ton of layer feed; $1.49 per ton of beef cattle feed; and $2.00 per ton of dairy feed.
- Costs to supplement grazing with non-GM ingredients were calculated for beef and dairy. On average, the cost is $0.012 per ton of grazing in the diet for beef cattle and $0.82 per ton of grazing in the diet for dairy cows.
- Tests administered at receiving are the cost category with the biggest impact on operational costs to segregate non-GM ingredients.
- For the final cost of feed, the operational costs must be added to ingredient replacement costs, showed on the next section of this report.

Feasibility: Development of a probabilistic model for segregation at an elevator and feed mill (IFEEDER Priority 8, continued)

Introduction

Several practices and actions at the grain elevator and the feed mill can potentially contribute to the AP of GM grain in non-GM loads. This makes meeting varying tolerance levels (usually ranging from 0.9% - 5%) challenging. Robust segregation strategies are necessary while handling and processing non-GM products to maintain AP within limits. In this study, a probabilistic model to analyze the capability of the grain elevator and feed mill to segregate non-GM grain and feed at three tolerance levels (0.9%, 3% and 5%) is presented. The model evaluates existing practices and patterns at the elevator and feed mill and predicts the probability of successful segregation. The model utilizes the Monte Carlo simulation technique to simulate several hypothetical but realistic segregation scenarios to determine practices and decisions that characterize successful outcomes. The model was created using Palisade @Risk software - a Microsoft Excel add-in - and each scenario included 50,000 iterations. This model's predictions provide useful insights into the effectiveness of different segregation decisions that can be taken during grain handling and feed production.

Methods

Grain Elevator

The grain elevator model was created to assess the capability of the elevator to segregate non-GM grain at three tolerance levels: 0.9%, 3% and 5%. The model was created for three different country elevator configurations: (1) elevator with one receiving pit and one leg (bucket elevator), (2) elevator with two receiving pits and one leg, and (3) elevator with two receiving pits and two legs (Figure 64, Figure 65, and Figure 66). The reason for categorizing the grain elevators into different configurations was to consider the impact of the elevator's design and configuration on its segregation capability.

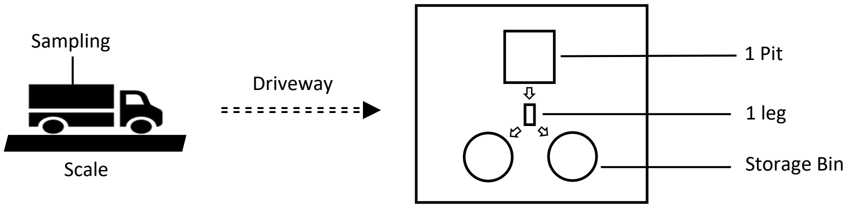


Figure 64. Elevator with one receiving pit and one leg (1pit-1leg)

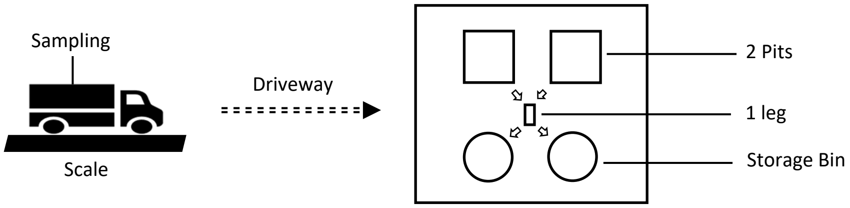


Figure 65. Elevator with two receiving pits and one leg (2pits-1leg)

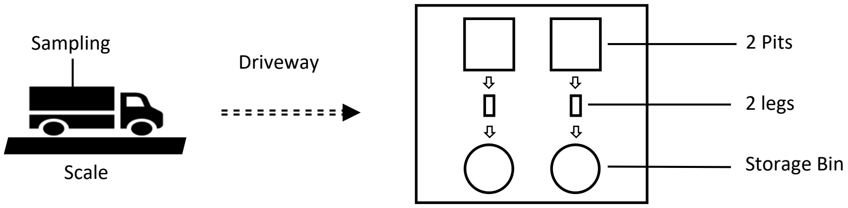


Figure 66. Elevator with two receiving pits and two legs (2pits-2legs)

The model simulates the physical flow of grain (GM and non-GM) at the elevators with the three configurations above. It accounts for the possibilities of AP at each step, beginning with the receipt of grain and ending with the load out. The key parameters potentially contributing to AP considered in the model were: grain impurity, receiving pit, leg, conveyor and handling error. These are the parameters that have been identified as important contributors to AP by previous studies (Hurburgh Jr. et al., 1994; Ingles et al., 2003; Ingles et al., 2006; Maier, 2006).

The model assesses the effectiveness of three common segregation decisions in managing the level of AP contributed by identified parameters: dedication, spatial segregation and temporal segregation. In the case of dedication, the entire facility is dedicated to non-GM handling. In spatial segregation, the non-GM variety is physically segregated from other varieties in the same facility by reserving a non-GM grain path. In temporal segregation, the same flow path is used for non-GM grain and other varieties at different times.

In total, 24 scenarios were created based on the combinations of facility configurations (1pit-1leg, 2pits-1leg and 2pits-2legs), segregation decisions (dedicate, spatial and temporal), and AP contributing parameters (grain impurity, receiving pit, leg, conveyor and handling error).

Table 38 represents the scenarios created. Six scenarios were created for the grain elevator with 1pit-1leg, six for 2pits-1leg, and 12 for 2pits-2legs. Scenarios are discussed in detail in the next section below.

Table 38. Segregation Scenarios at the Grain Elevator

Elevator Category	Segregation Decision	Scenario No.	Grain Impurity	Receiving Pit	Leg	Conveyor	Handling Error
1pit-1leg	Dedicate	E1	Level 1	Dedicate	Dedicate	Dedicate	NA
		E2	Level 2	Dedicate	Dedicate	Dedicate	NA
	Temporal	E3	Level 1	Self-clean	Self-clean	Self-clean	Applicable
		E4		Full-clean	Full-clean	Full-clean	Applicable
		E5	Level 2	Self-clean	Self-clean	Self-clean	Applicable
		E6		Full-clean	Full-clean	Full-clean	Applicable
2pits-1leg	Dedicate	E7	Level 1	Dedicate	Dedicate	Dedicate	NA
		E8	Level 2	Dedicate	Dedicate	Dedicate	NA
	Temporal	E9	Level 1	Dedicate	Self-clean	Self-clean	Applicable
		E10		Dedicate	Full-clean	Full-clean	Applicable
		E11	Level 2	Dedicate	Self-clean	Self-clean	Applicable
		E12		Dedicate	Full-clean	Full-clean	Applicable
2pits-2legs	Dedicate	E13	Level 1	Dedicate	Dedicate	Dedicate	NA
		E14	Level 2	Dedicate	Dedicate	Dedicate	NA
	Spatial	E15	Level 1	Dedicate	Dedicate	Dedicate	Applicable
		E16	Level 2	Dedicate	Dedicate	Dedicate	Applicable
	Temporal	E17	Level 1	Dedicate	Self-clean	Self-clean	Applicable
		E18		Dedicate	Full-clean	Full-clean	Applicable
		E19		Self-clean	Dedicate	Dedicate	Applicable
		E20		Full-clean	Dedicate	Dedicate	Applicable
		E21	Level 2	Dedicate	Self-clean	Self-clean	Applicable
		E22		Dedicate	Full-clean	Full-clean	Applicable
		E23		Self-clean	Dedicate	Dedicate	Applicable
		E24		Full-clean	Dedicate	Dedicate	Applicable

Description of scenarios, input data and distributions

The scenarios were created based on the capability of elevators with different configurations to apply segregation decisions. In the case of an elevator with 1pit-1leg, it is not possible to apply spatial segregation while receiving and handling both GM and non-GM grain simultaneously in the same facility. The possible way to segregate is by either dedicating the entire facility to non-GM grain or applying temporal segregation.

Similarly, in an elevator with 2pits-1leg, it is possible to receive two different varieties of grain at the same time and dedicate pits, but it is not possible to dedicate the conveying system. The segregation requires using the conveying system at different times by cleaning it between the loads (temporal segregation). However, in an elevator with 2pits-2legs, it is possible to receive and handle grains of two different varieties simultaneously by applying spatial segregation.

Dedicating the facility is an option for segregation in all three elevator categories, but economic feasibility is also a point of concern. This study does not consider economic feasibility as a limiting factor in the model. Similarly, in the case of spatial and temporal segregation, time is not considered a limiting factor. The model focused on analyzing practically possible ways of segregation that can reduce cumulative AP in the final product.

The input data and distribution used in the model are summarized in Table 39. The first parameter contributing to AP considered in the model was grain impurity. The level of grain impurity in the incoming lot can vary depending on-farm practices and cannot be assumed to begin at zero percent. The two average levels of grain impurity simulated in the model were 0.2% (Level 1) and 0.5% (Level 2).

GM testing at the time of delivery is a checkpoint to reject non-GM grain with higher AP. Uncertainties in the testing procedures can arise due to diagnostic errors and sampling errors. To consider the uncertainty in the incoming load's impurity due to testing error, the parameter (grain impurity) was modeled as a lognormal distribution (Lecroart et al., 2012).

AP due to the receiving pit and leg were modeled as an exponential distribution. The exponential distributions account for the system in which AP levels are high at the start of operation and decline with the volume of grain passing through it (Dolphin et al., 2020). AP due to conveyor was modeled as extreme distribution (Dolphin et al., 2020). In the case of dedication and spatial segregation, the scenarios were created by dedicating receiving pit, leg and conveyor for non-GM grain.

In the case of temporal segregation, cleaning was considered as an essential aspect. Scenarios were created based on the choice of cleaning procedures: self-cleaning (running the receiving and conveying system free of grain in between loads) and full cleaning (cleaning receiving and conveying systems by disassembling the equipment and cleaning with vacuum and air blowers). Self-cleaning relies on the capability of the equipment to clean itself. There may be some grain that accumulates in the equipment even after self-cleaning. The average AP levels contributed by the receiving pit, leg and conveyor after self-cleaning were derived from the previous studies (Ingles et al., 2006; Maier, 2006). Other pieces of equipment such as the grain cleaner, grain scalper and weighing scale were not considered in this model because they have better self-cleaning properties and contribute negligibly to overall AP (Ingles et al., 2003). Full cleaning was assumed to be a thorough cleaning approach. The study from Hanna and Jarboe (2011) on combine clean-out was referred to derive the input data. Equipment at the elevator was assumed to follow similar cleaning behavior as the combine harvester. Thorough cleaning of pit, leg and conveyor was assumed to bring down AP to as low as 0.01% each. Flushing the line with the non-GM grain can also be an effective strategy to manage AP, but it was not considered in this study due to the lack of available data.

Handling error (grain mishandling, ineffective cleaning and erroneous data entry) was also considered as an AP contributing parameter. Handling error was simulated using triangular distribution to account for three levels of AP due to handling error: 0.01 for minimum, 0.1 for most likely, and 0.5 for maximum level (Hurburgh, 1999; Wilson & Dahl, 2005).

For dedicated facilities, handling error was considered 'not-applicable' because of the low likelihood; in spatial and temporal segregation, handling errors can potentially contribute to AP. Facilities were assumed to have designated bins for storing non-GM raw materials and finished products. This excluded the possibilities of AP due to storage. Table 39 below shows the input data and distributions used in the model.

Table 39. Input Data and Distributions Assigned to Parameters at the Grain Elevator

Parameter	Distribution Type	Model Input Value (%AP by Weight) Mean (SD)
Grain impurity	Lognormal	Level 1: 0.2 (0.05) Level 2: 0.5 (0.05)
Receiving pit	Exponential	Self-Clean: 1.3 (0.58) Full Clean: 0.01 (0.007)
Leg (bucket elevator)	Exponential	Self-Clean: 0.23 (0.10) Full Clean: 0.01 (0.007)
Conveyor	Extreme	Self-Clean: 0.30 (0.1) Full Clean: 0.01 (0.007)
Handling Error	Triangular	0.2 (SD: 0.10) Min: 0.01, Most likely: 0.1, Max: 0.5

Feed Mill

The feed mill model was created to assess the capability of the feed mill to manufacture non-GM feed at three tolerance levels: 0.9%, 3% and 5%. The model was created for two commercial feed mill configurations: (1) single-species feed mills with a single processing line and (2) multiple-species feed mills with multiple processing lines (Figure 67 and Figure 68).

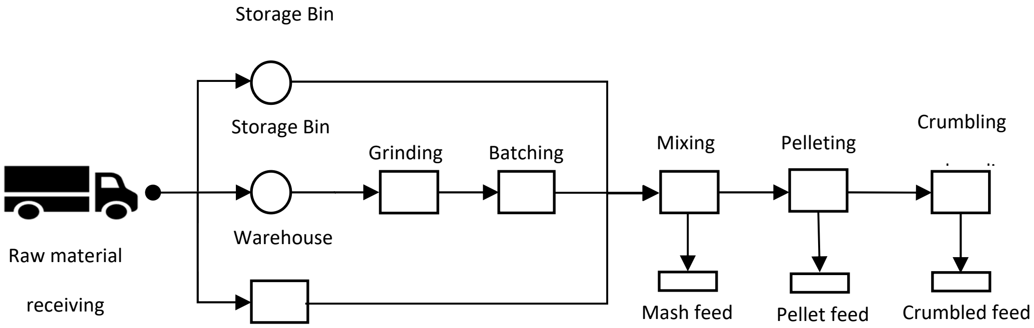


Figure 67. Single-species Feed Mill with Single Processing Line

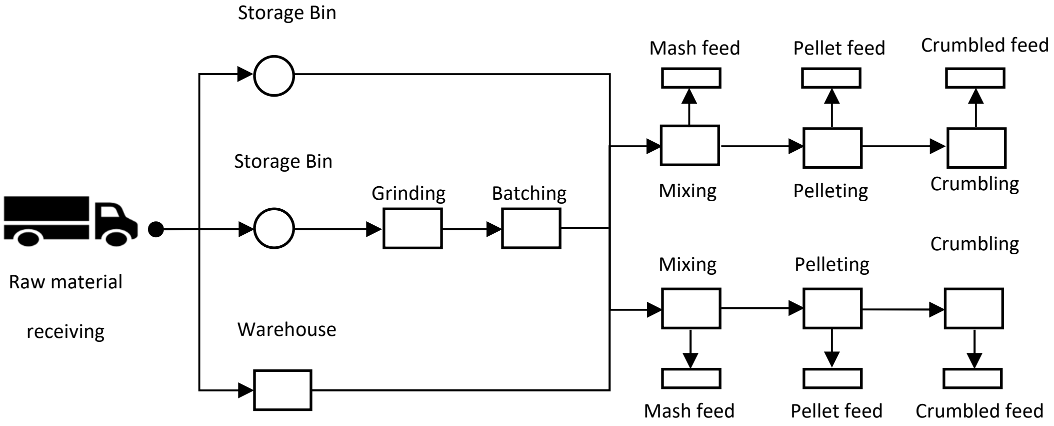


Figure 68. Multiple-species Feed Mill with Multiple Processing Lines

The key parameters potentially contributing to AP at the feed mill included in the model were: ingredient impurity, receiving and conveying system, processing line and handling error. The model assesses the capability of the facility to segregate non-GM feed by either dedicating the facility for non-GM production or segregating spatially and temporally while handling both GM and non-GM feed in the same facility.

In total, 22 scenarios were created based on combinations of facility configurations (single processing line and multiple processing lines), segregation decisions (dedicated, spatial and temporal), and AP contributing parameters (ingredient impurity, receiving and conveying system, processing line and handling error) (Table 40). Scenarios are discussed in detail in the next section below.

Table 40. Segregation Scenarios at the Feed Mill

Feed Mill Category	Segregation Decision	Scenario No.	Ingredient Impurity	Receiving and Conveying System	Processing Line	Handling Error
Single process line	Dedicate	FM1	Level 1	Dedicate	Dedicate	NA
		FM2	Level 2	Dedicate	Dedicate	NA
	Temporal	FM3	Level 1	Self-clean	Self-clean	Applicable
		FM4		Full-clean	Full-clean	Applicable
		FM5	Level 2	Self-clean	Self-clean	Applicable
		FM6		Full-clean	Full-clean	Applicable
Multiple process lines	Dedicate	FM7	Level 1	Dedicate	Dedicate	NA
		FM8	Level 2	Dedicate	Dedicate	NA
	Spatial	FM9	Level 1	Dedicate	Dedicate	Applicable
		FM10	Level 2	Dedicate	Dedicate	Applicable
	Temporal	FM11	Level 1	Self-clean	Self-clean	Applicable
		FM12		Self-clean	Dedicate	Applicable
		FM13		Dedicate	Self-clean	Applicable
		FM14		Full-clean	Full-clean	Applicable
		FM15		Full-clean	Dedicate	Applicable
		FM16		Dedicate	Full-clean	Applicable
		FM17	Level 2	Self-clean	Self-clean	Applicable
		FM18		Self-clean	Dedicate	Applicable
		FM19		Dedicate	Self-clean	Applicable
		FM20		Full-clean	Full-clean	Applicable
		FM21		Full-clean	Dedicate	Applicable
		FM22		Dedicate	Full-clean	Applicable

Description of Scenarios, Input data and Distributions

Table 41 summarizes the input data and distributions assigned to AP contributing parameters at the feed mill. The first source of AP considered in the model was ingredient impurity. Apart from grain and grain-based ingredients, various other ingredients such as limestones, phosphates, vitamins and amino acids are also used in feed production. In this study, the grain and grain-based ingredients were assumed to be the main contributors to AP. The two average levels of AP contributed by ingredient impurity taken in this model were 0.2 % (level 1) and 0.5% (level 2).

Compared to whole grains, testing GM content in grain-based ingredients is complicated because processing degrades genetic material to a certain extent. Also, the presence of multiple ingredients in the product increases the technical complexity of detecting low AP levels. This adds to the uncertainty in GM testing at the time of receiving. To reflect the uncertainties in testing, the ingredient's impurity was simulated using lognormal distribution.

Table 41. Input Data and Distributions Assigned to Parameters at Feed Mills

Parameter	**Distribution Type**	**Model Input Value (% AP by Weight)** **Mean (SD)**
Ingredient impurity	Lognormal	Level 1: 0.2 (0.05) Level 2: 0.5 (0.05)
Receiving and conveying system	Exponential	Self-Clean: 1.5 (0.15) Full Clean: 0.01 (0.007)
Processing line	Exponential	Self-Clean: 0.5 (0.05) Full Clean: 0.01 (0.007)
Handling error	Triangular	0.2 (SD: 0.10) Min: 0.01, Most likely: 0.1, Max: 0.5

AP due to receiving and conveying system was simulated using an exponential distribution. The facility with a single processing line was assumed to have a single receiving and conveying system (receiving pit, leg and conveyor). In such a facility, it is not possible to implement spatial segregation at the time of receiving GM and non-GM ingredients simultaneously. The facility with multiple processing lines was assumed to have multiple receiving and conveying systems. In such a facility, it is possible to apply spatial segregation at the time of receiving.

The variations during temporal segregation were simulated in the model by considering two cleaning approaches: self-cleaning and full cleaning. Full cleaning was assumed to be thorough, and AP level after full cleaning was simulated as 0.01% (Hanna & Jarboe, 2011). In the case of self-cleaning, the average level of AP contributed by receiving and conveying system was taken as 1.5% due to the combined effect of the pit, leg and conveyor (Ingles et al., 2006).

The next source of AP considered in the model was the processing line. The processing line for feed production includes milling systems (to grind whole grain), batching and mixing systems (to mix ingredients to form mash or meal feed), conditioning and pelleting systems (to form pellet feed), drying and cooling systems (to reduce moisture and temperature), crumbling systems (to form crumbled feed) and bagging systems (to package feed). Processing equipment such as grinders, mixers, pellet mills, coolers and dryers potentially contribute to AP.

Sufficient data was not available to simulate the levels of AP contributed by each piece of equipment individually. The overall AP contributed by the processing line was simulated using an exponential distribution. The exponential distribution accounts for the high level of AP at the start of the operation and declines with the volume of product passing through the line (Dolphin et al., 2020).

A facility with multiple processing lines was assumed to have the capability of dedicating one line for non-GM production. In that case, the level of AP contributed by the processing line was considered to be negligible. In the case of self-cleaning, the average level of AP contributed by the processing line was assumed to be 0.5%. The value was based on the study conducted by (Lecroart et al., 2012).

Another AP contributing parameter considered in the model was handling error. Grain mishandling, ineffective cleaning and erroneous data entry can lead to AP. Handling error was simulated using triangular distribution to account for three levels of AP due to handling error: 0.01 for minimum, 0.1 for most likely and 0.5 for maximum level (Hurburgh, 1999; Wilson & Dahl, 2005).

In the case of dedication, handling error was considered 'not-applicable' because of the low likelihood of AP due to handling in a dedicated facility. In spatial and temporal segregation, handling errors can potentially contribute to AP. Facilities were assumed to have designated bins and space for storing non-GM raw material and finished product. This excluded the possibilities of AP due to storage.

Results

Monte Carlo simulation was used to determine the total AP levels for different segregation scenarios created at the grain elevator and feed mill. Figure 69 shows an example of the output graph generated after simulating 50,000 iterations for one scenario. The x-axis represents the percent cumulative AP, and the y-axis represents the relative frequency. The outputs graph after simulating each scenario was analyzed to identify the probability of testing at or below 0.9%, 3% and 5% tolerance levels.

The graphs were also analyzed to identify tolerance levels required to ensure 75%, 95% and 99% feasibility of meeting the tolerance. For a tolerance level representing 75% feasibility, 37,500 outputs out of 50,000 iterations were equal to or less than the given tolerance level. For example, in the graph shown below, the tolerance level required to ensure 75% feasibility

(37,500 output values) was 2.861%. Similarly, tolerance levels to ensure 95% feasibility (47,500 outputs) and 99% feasibility (49,500 outputs) were identified and compared with the three tolerance levels of interest, 0.9%, 3% and 5%.

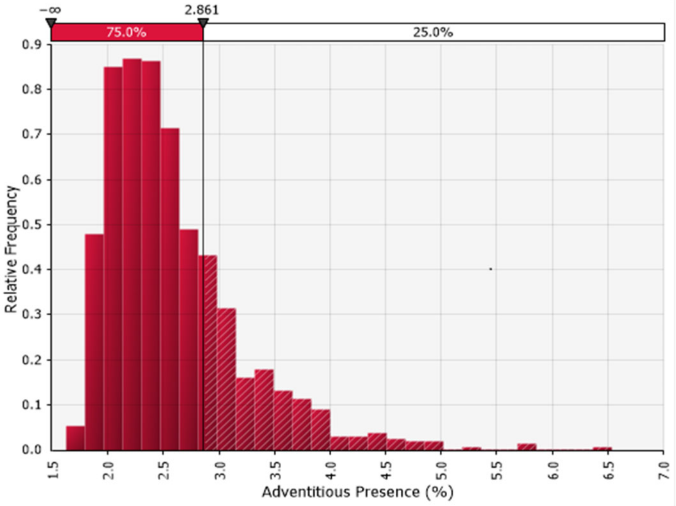


Figure 69. Monte Carlo simulation output distribution

Grain Elevator

The model was created to assess the capability of the grain elevator to segregate non-GM grain. Twenty-four scenarios were simulated based on combinations of facility configurations, segregation decisions and AP contributing parameters.

Table 42 below shows the mean AP (%) and standard deviations determined in each scenario. It also summarizes the probability of meeting three tolerance levels of interest: 0.9%, 3% and 5%.

Table 42. Summary of Simulation Outcomes at the Grain Elevator

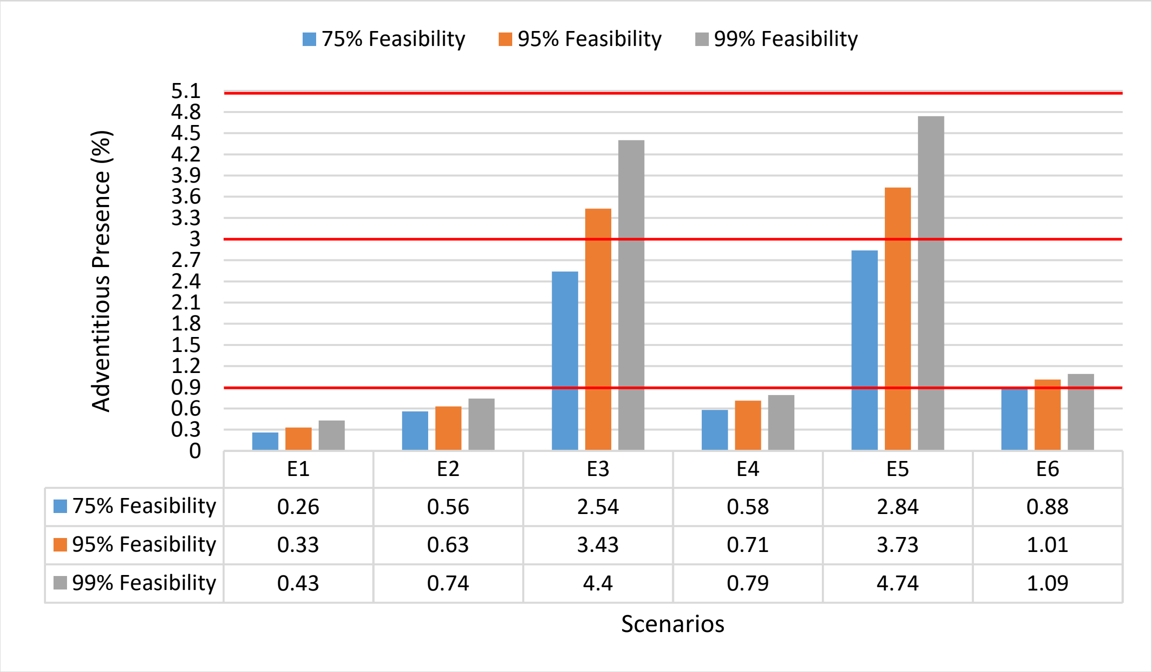
Elevator Category	**Segregation Decision**	**Scenario No.**	**Grain Impurity**	**Receiving Pit**	**Leg**	**Conveyor**	**Handling Error**	**Mean AP% (SD)**	**Probability of Meeting Tolerance Level**		
									0.9%	**3%**	**5%**
1pit-1leg	Dedicate	E1	Level 1	Dedicate	Dedicate	Dedicate	NA	0.25 (0.050)	100%	100%	100%
		E2	Level 2	Dedicate	Dedicate	Dedicate	NA	0.55 (0.049)	100%	100%	100%
	Temporal	E3	Level 1	Self-clean	Self-clean	Self-clean	Applicable	2.28 (0.608)	0%	88.5%	100%
		E4		Full-clean	Full-clean	Full-clean	Applicable	0.50 (0.118)	100%	100%	100%
		E5	Level 2	Self-clean	Self-clean	Self-clean	Applicable	2.58 (0.608)	0%	80.8%	100%
		E6		Full-clean	Full-clean	Full-clean	Applicable	0.80 (0.118)	78.6%	100%	100%
2pits-1leg	Dedicate	E7	Level 1	Dedicate	Dedicate	Dedicate	NA	0.25 (0.050)	100%	100%	100%
		E8	Level 2	Dedicate	Dedicate	Dedicate	NA	0.55 (0.049)	100%	100%	100%
	Temporal	E9	Level 1	Dedicate	Self-clean	Self-clean	Applicable	0.98 (0.186)	34.6%	100%	100%
		E10		Dedicate	Full-clean	Full-clean	Applicable	0.48 (0.117)	100%	100%	100%
		E11	Level 2	Dedicate	Self-clean	Self-clean	Applicable	1.28 (0.186)	0.2%	100%	100%
		E12		Dedicate	Full-clean	Full-clean	Applicable	0.78 (0.117)	81.8%	100%	100%
2pits-2legs	Dedicate	E13	Level 1	Dedicate	Dedicate	Dedicate	NA	0.24 (0.235)	100%	100%	100%
		E14	Level 2	Dedicate	Dedicate	Dedicate	NA	0.55 (0.535)	100%	100%	100%
	Spatial	E15	Level 1	Dedicate	Dedicate	Dedicate	Applicable	0.45 (0.117)	100%	100%	100%
		E16	Level 2	Dedicate	Dedicate	Dedicate	Applicable	0.75 (0.117)	88.1%	100%	100%
	Temporal	E17	Level 1	Dedicate	Self-clean	Self-clean	Applicable	0.98 (0.186)	35.3%	100%	100%
		E18		Dedicate	Full-clean	Full-clean	Applicable	0.48 (0.117)	100%	100%	100%
		E19		Self-clean	Dedicate	Dedicate	Applicable	1.75 (0.591)	0%	100%	100%
		E20		Full-clean	Dedicate	Dedicate	Applicable	0.47 (0.117)	100%	100%	100%
		E21	Level 2	Dedicate	Self-clean	Self-clean	Applicable	1.28 (0.186)	0.2%	100%	100%
		E22		Dedicate	Full-clean	Full-clean	Applicable	0.78 (0.117)	81.8%	100%	100%
		E23		Self-clean	Dedicate	Dedicate	Applicable	2.05 (0.591)	0%	100%	100%
		E24		Full-clean	Dedicate	Dedicate	Applicable	0.77 (0.117)	84.7%	100%	100%

The simulation results elucidated the impact of a facility configuration on its segregation capability. For example, in the case of an elevator with 1pit-1leg, the results show that the facility was able to successfully segregate GM and non-GM grain in some scenarios (refer to scenarios E1, E2 and E4). Dedicating the facility for non-GM grain was found to be an effective way of segregation. In the case of temporal segregation, self-cleaning and full cleaning were found to be equally effective in meeting the 5% level, but self-cleaning was not effective in meeting the 0.9% and 3% tolerance level (refer to scenarios E3 and E5).

In the case of an elevator with 2pits-1leg, while dedicating the pit at the time of receiving was an option, but it alone was ineffective in meeting the 0.9% tolerance level (refer to scenario E9). A combination of the dedicated pit with a thoroughly cleaned conveying system was found to be an effective way of segregation (refer to scenarios E10). The purity of incoming grain played an essential role in deciding overall AP levels in all scenarios. Scenarios starting with low grain impurity (0.2% as Level 1) were able to achieve a 0.9% level as compared to scenarios starting with higher grain impurity (0.5% as Level 2) (compare scenarios E10 and E12).

In the case of an elevator with 2pits-2legs, spatial segregation was an effective approach to segregate by dedicating a flow path for non-GM grain (refer to scenario E15). While handling different varieties in the same facility, human error was considered an essential parameter in deciding overall AP. In the scenarios where spatial segregation was not possible, the facility could still meet the 0.9% tolerance level by applying a combination of strategies during temporal segregation (refer to scenarios E18 and E20).

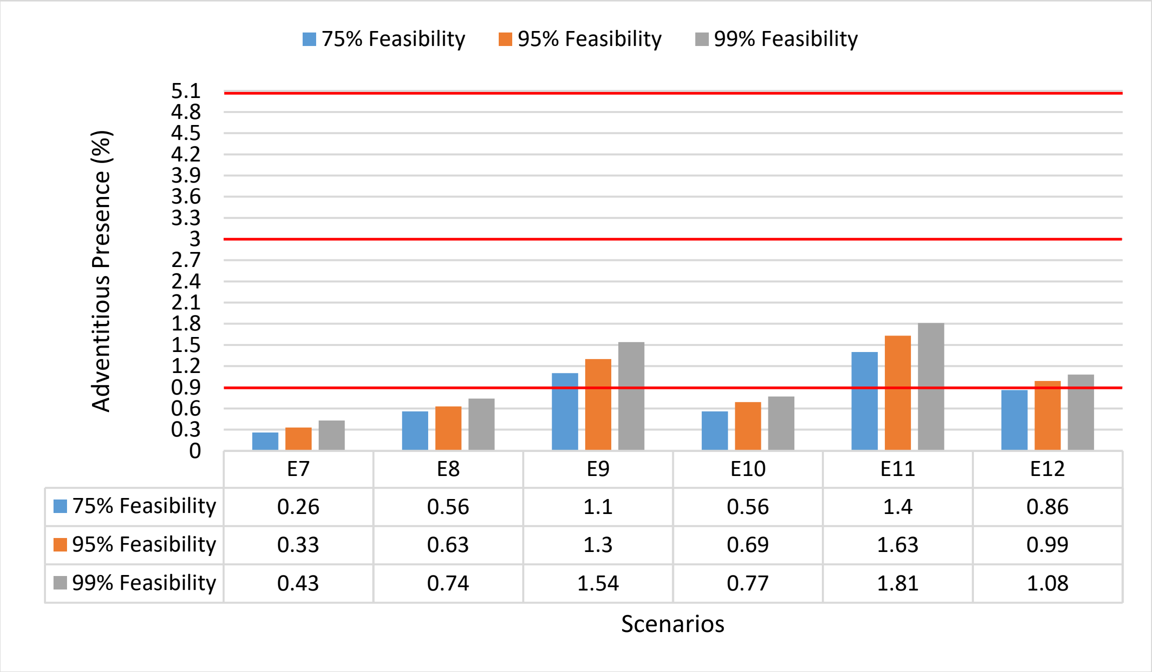
Figure 70, Figure 71, and Figure 72 below show the tolerance level needed in each elevator facility to ensure the feasibility to meet tolerances at 75%, 95% and 99%. The tolerance levels needed to meet the feasibility of 75%, 95% and 99% were compared with three tolerance levels 0.9%, 3.0% and 5%. In 1pit-1leg elevator (Figure 70), if 75% was considered an acceptable feasibility rate, testing at 0.9% yielded four successful scenarios (refer to scenarios E1, E2, E4 and E6), and testing at 3% and 5% yielded all six successful. If 95% and 99% feasibility were an acceptable rate, testing at 0.9% yielded three successful scenarios (refer to scenarios E1, E2 and E4).



	E1	E2	E3	E4	E5	E6
75% Feasibility	0.26	0.56	2.54	0.58	2.84	0.88
95% Feasibility	0.33	0.63	3.43	0.71	3.73	1.01
99% Feasibility	0.43	0.74	4.4	0.79	4.74	1.09

Figure 70. Elevator with 1pit-1leg: Tolerance Level Needed to Ensure that 75%, 95% and 99% Feasibility is Met Versus Tolerance Level of interest, 0.9%, 3% and 5% (bold red lines)

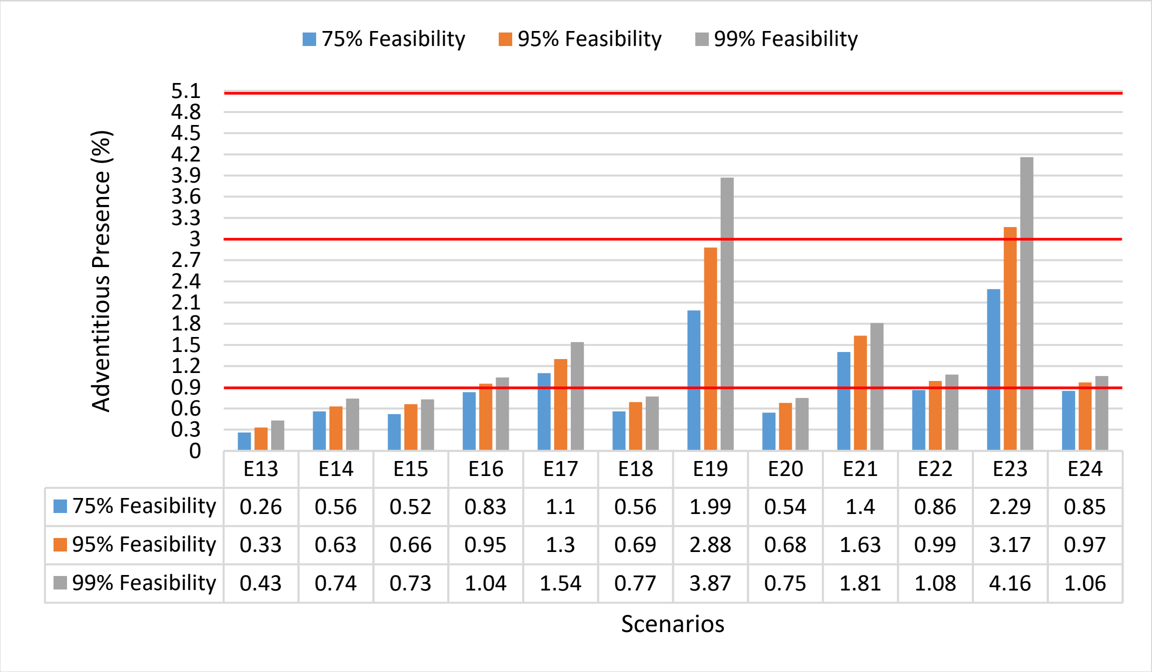
Figure 71 shows that, for a 2pits-1leg elevator, if 75% feasibility was considered acceptable, testing at 0.9% yielded four successful scenarios (refer to scenarios E7, E8, E10 and E12), and testing at 3% and 5% yielded all six successful scenarios. If 95% and 99% were acceptable feasibility rates, testing at 0.9% yielded three successful (refer to scenarios E7, E8 and E10).



	E7	E8	E9	E10	E11	E12
75% Feasibility	0.26	0.56	1.1	0.56	1.4	0.86
95% Feasibility	0.33	0.63	1.3	0.69	1.63	0.99
99% Feasibility	0.43	0.74	1.54	0.77	1.81	1.08

Figure 71. Elevator with 2pits-1leg: Tolerance Level Needed to Ensure that 75%, 95% and 99% Feasibility is Met Versus Tolerance Level of Interest, 0.9%, 3% and 5% (bold red lines)

In an elevator with 2pits-2legs, Figure 72 shows if 75% feasibility was considered acceptable, testing at 0.9% yielded seven successful scenarios (refer to scenarios E13, E14, E15, E16, E18, E20, E22 and E24), and testing at 3% and 5% yielded all successful scenarios. If 95% and 99% were acceptable rates, testing at 0.9% yielded five successful scenarios (refer to scenarios E13, E14, E15, E18 and E20).



	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24
🟦 75% Feasibility	0.26	0.56	0.52	0.83	1.1	0.56	1.99	0.54	1.4	0.86	2.29	0.85
🟧 95% Feasibility	0.33	0.63	0.66	0.95	1.3	0.69	2.88	0.68	1.63	0.99	3.17	0.97
⬜ 99% Feasibility	0.43	0.74	0.73	1.04	1.54	0.77	3.87	0.75	1.81	1.08	4.16	1.06

Figure 72. Elevator with 2pits-2legs: Tolerance Level Needed to Ensure that 75%, 95% and 99% Feasibility is Met Versus Tolerance Level of Interest, 0.9%, 3% and 5% (bold red lines)

Feed Mill

The probabilistic model was created to analyze the capability of the feed mill to segregate non-GM feed.

Table 43 below summarizes the mean AP (%) and standard deviations determined for each scenario. It also summarizes the probability of meeting three tolerance levels of interest: 0.9%, 3% and 5%.

Table 43. Summary of Simulation Outcomes at the Feed Mill

Feed Mill Category	**Segregation Decision**	**Scenario No.**	**Ingredient Impurity**	**Receiving and Conveying System**	**Processing Line**	**Handling Error**	**Mean AP% (SD)**	**Probability of Meeting Tolerance Level**		
								0.9%	**3%**	**5%**
Single processing line	Dedicate	FM1	Level 1	Dedicate	Dedicate	NA	0.25 (0.050)	100%	100%	100%
		FM2	Level 2	Dedicate	Dedicate	NA	0.55 (0.049)	100%	100%	100%
	Temporal	FM3	Level 1	Self-clean	Self-clean	Applicable	2.65 (0.196)	0%	94.4%	100%
		FM4		Full-clean	Full-clean	Applicable	0.48 (0.118)	100%	100%	100%
		FM5	Level 2	Self-clean	Self-clean	Applicable	2.95 (0.197)	0%	64.9%	100%
		FM6		Full-clean	Full-clean	Applicable	0.78 (0.118)	81.6%	100%	100%
Multiple processing lines	Dedicate	FM7	Level 1	Dedicate	Dedicate	NA	0.25 (0.050)	100%	100%	100%
		FM8	Level 2	Dedicate	Dedicate	NA	0.55 (0.049)	100%	100%	100%
	Spatial	FM9	Level 1	Dedicate	Dedicate	Applicable	0.45 (0.117)	100%	100%	100%
		FM10	Level 2	Dedicate	Dedicate	Applicable	0.75 (0.118)	87.4%	100%	100%
	Temporal	FM11	Level 1	Self-clean	Self-clean	Applicable	2.65 (0.196)	0%	94.4%	100%
		FM12		Self-clean	Dedicate	Applicable	2.10 (0.190)	0%	100%	100%
		FM13		Dedicate	Self-clean	Applicable	1.00 (0.127)	23.4%	100%	100%
		FM14		Full-clean	Full-clean	Applicable	0.48 (0.118)	100%	100%	100%
		FM15		Full-clean	Dedicate	Applicable	0.47 (0.117)	100%	100%	100%
		FM16		Dedicate	Full-clean	Applicable	0.47 (0.117)	100%	100%	100%
		FM17	Level 2	Self-clean	Self-clean	Applicable	2.95 (0.197)	0%	64.9%	100%
		FM18		Self-clean	Dedicate	Applicable	2.40 (0.190)	0%	100%	100%
		FM19		Dedicate	Self-clean	Applicable	1.30 (0.128)	0%	100%	100%
		FM20		Full-clean	Full-clean	Applicable	0.78 (0.118)	81.6%	100%	100%
		FM21		Full-clean	Dedicate	Applicable	0.77 (0.117)	84.6%	100%	100%

		FM22		Dedicate	Full-clean	Applicable	0.77 (0.118)	84.6%	100%	100%

The results show that in the feed mill with a single processing line, dedication effectively met the low AP tolerance level at 0.9% (refer to scenarios FM1 and FM2). The final AP levels in both scenarios were equivalent to the mean impurity of the incoming ingredients.

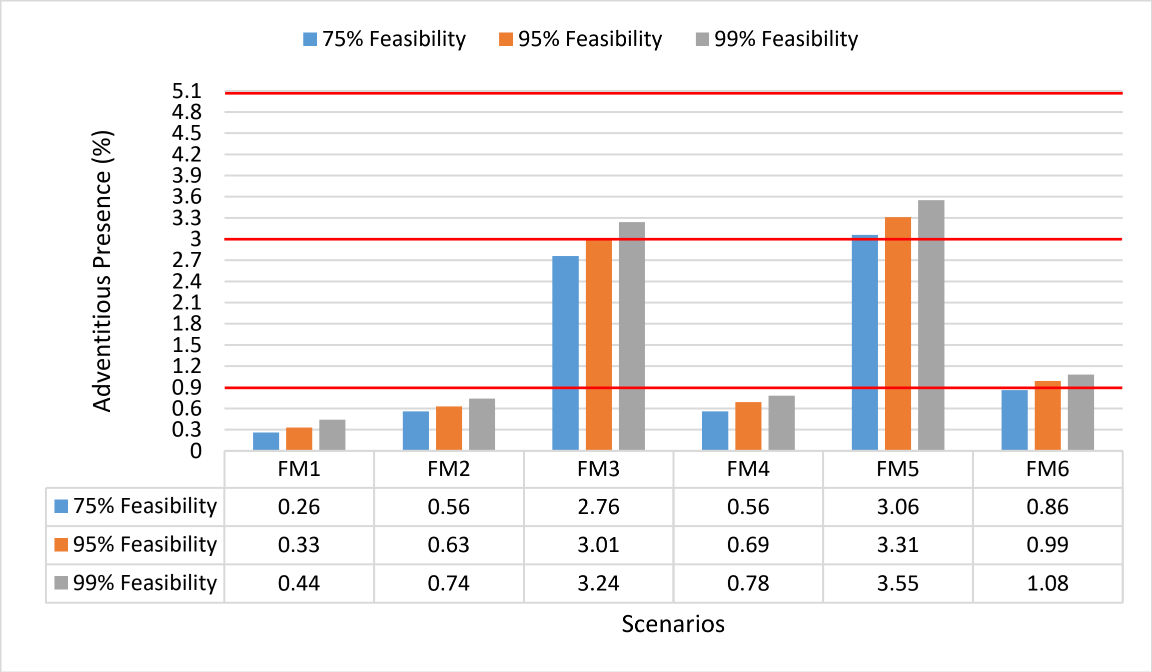
In the case of temporal isolation, scenarios starting with low ingredient impurity level (0.2% as Level 1) had a higher chance to meet 0.9% tolerance level than the scenarios starting with a high impurity level (0.5% as Level 2) (compare scenarios FM 4 and FM 6). This finding underlines the fact that ingredient impurity has a strong impact on the overall AP level in feed. Results suggest that self-cleaning may not be an effective strategy to meet the 0.9% tolerance level (see scenarios FM3 and FM5).

In the feed mill with multiple processing lines, spatial segregation effectively met the low AP tolerance level at 0.9% (refer to scenarios FM9). Initial ingredient impurity had an impact on overall AP (compare scenario FM9 and FM10). Dedicating the processing line during temporal segregation cannot fully guarantee that a 0.9% level will be met (see scenarios FM12 and FM21). A judicious combination of robust segregation strategies beginning with raw material receiving until feed production is necessary to achieve a 0.9% tolerance level.

The results indicated that some combinations of temporal strategies were effective in maintaining AP levels close to the initial impurity of incoming ingredients (see scenario FM14, FM15 and FM16). This shows that temporal isolation can be as effective as dedication in managing low AP if applied with proper planning.

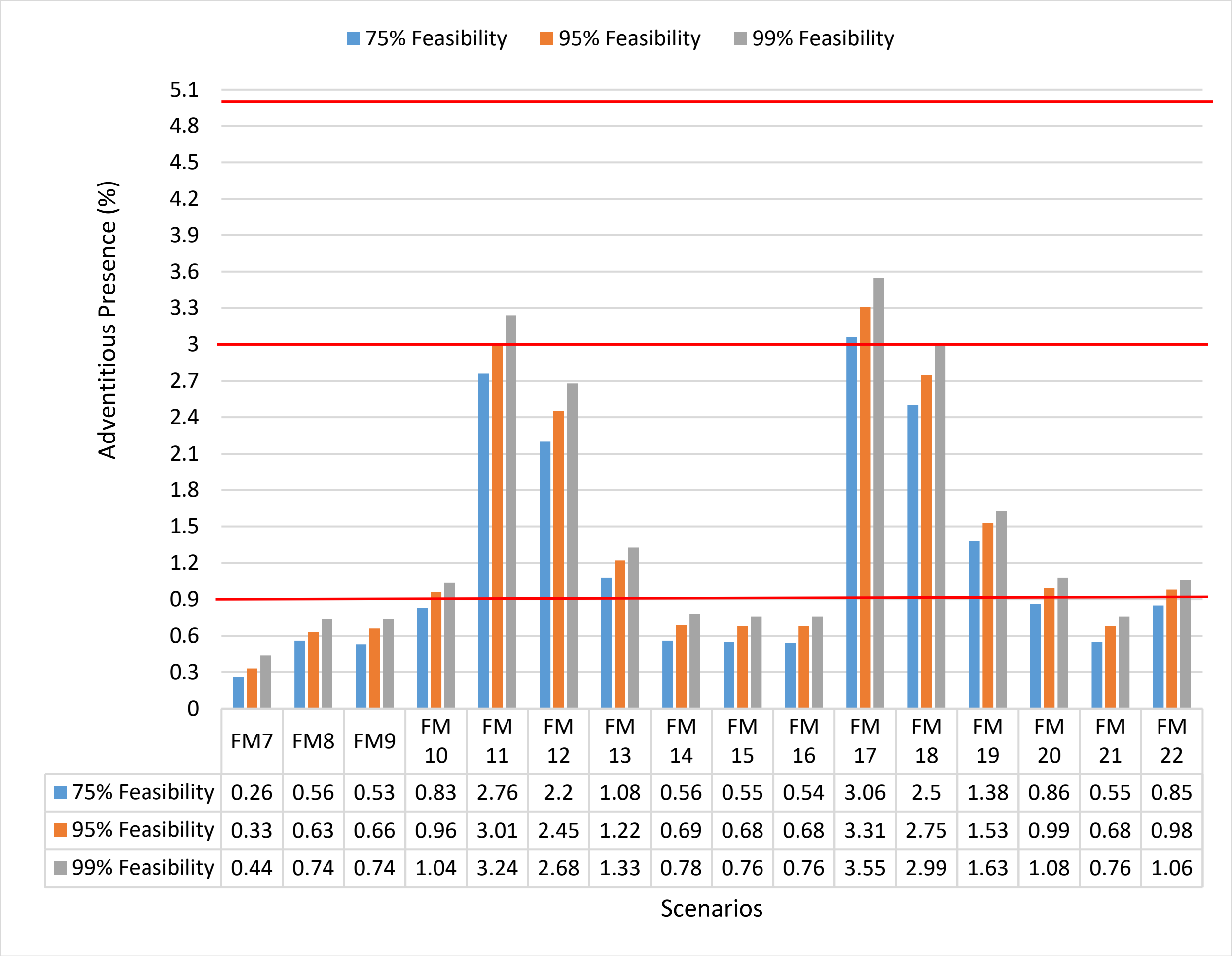
Figure 73 and Figure 74 below show the tolerance level needed to ensure the feasibility of 75%, 95% and 99% in feed mill with a single processing line and multiple processing lines, respectively. In the case of a single processing line, the tolerance levels needed to ensure 75%, 95% and 99% feasibility fell below 5%. This means that it was 100% feasible to meet 5% tolerance levels in all scenarios. However, in three out of six scenarios, tolerance levels to meet 99% feasibility were above 0.9% and ranged between 1.08% - 3.55% (see scenarios FM3, FM5 and FM6).

Similarly, in a feed mill with multiple processing lines, the tolerance levels needed to ensure 75%, 95% and 99% feasibility fell below 5%. In nine out of 16 scenarios, the tolerance levels to meet 99% feasibility were above 0.9% (see scenarios FM10, FM11, FM12, FM13, FM17, FM18, FM19, FM20 and FM22).



	FM1	FM2	FM3	FM4	FM5	FM6
🟦 75% Feasibility	0.26	0.56	2.76	0.56	3.06	0.86
🟧 95% Feasibility	0.33	0.63	3.01	0.69	3.31	0.99
▨ 99% Feasibility	0.44	0.74	3.24	0.78	3.55	1.08

Figure 73. Feed mill with single processing line: tolerance level needed to ensure that 75%, 95%, and 99% feasibility are met versus tolerance level of interest, 0.9%, 3%, and 5% (bold red lines)



	FM7	FM8	FM9	FM 10	FM 11	FM 12	FM 13	FM 14	FM 15	FM 16	FM 17	FM 18	FM 19	FM 20	FM 21	FM 22
🟦 75% Feasibility	0.26	0.56	0.53	0.83	2.76	2.2	1.08	0.56	0.55	0.54	3.06	2.5	1.38	0.86	0.55	0.85
🟧 95% Feasibility	0.33	0.63	0.66	0.96	3.01	2.45	1.22	0.69	0.68	0.68	3.31	2.75	1.53	0.99	0.68	0.98
⬜ 99% Feasibility	0.44	0.74	0.74	1.04	3.24	2.68	1.33	0.78	0.76	0.76	3.55	2.99	1.63	1.08	0.76	1.06

Figure 74. Feed mill with multiple processing lines: tolerance level needed to ensure that 75%, 95% and 99% feasibility are met versus tolerance level of interest, 0.9%, 3% and 5% (bold red lines)

Conclusions

The probabilistic model presented in this study permits an analysis of the grain elevator and feed mill's capability to segregate non-GM grain and feed at three tolerance levels: 0.9%, 3% and 5%. The modeling results shed some new light on an elevator and feed mill's capability to segregate non-GM products based on its configuration, AP contributing parameters and choice of segregation decisions. According to the model, all of the segregation scenarios simulated at both grain elevator and feed mill were effective in managing AP at 5% tolerance levels, but not all were effective in managing AP at 3% and 0.9% level.

Grain elevators with one receiving pit and one leg have limited practical methods of segregation. The model showed that despite the limited options, it is possible to segregate non-GM grain at a tolerance level of 0.9%. Dedicating the facility was found to be an effective way to meet low tolerances. In order to segregate multiple grains dumped into one pit, the model emphasized the importance of thoroughly cleaning the pit and conveying system in between loads. The model illustrated the efficacy of the self-cleaning method in meeting the 5% tolerance level but not at the 0.9% level.

The model findings conformed with the previous studies emphasizing the impact of the number of receiving pits and bucket elevators on segregation effectiveness (Herrman et al., 2001; Ingles et al., 2006; Maier, 2006). A grain elevator's segregation capability depends largely on its design and configuration. In the grain elevators with two receiving pits and one leg, it is possible to dedicate a pit for two different grains, but it is not possible to dedicate legs and conveying systems. A combination of a dedicated pit and a cleaned conveying system was identified as effective in meeting low tolerance levels. Simulations in the model showed that the mean AP could be achieved as low as 0.48% by dedicating the pit and fully cleaning the conveying system.

In the grain elevators with two receiving pits and two legs, while spatial segregation at the time of receiving was an option, dedicating the pit or leg only was found to be ineffective in meeting the 0.9% tolerance level. A combination of the dedicated pit and leg was considered as an effective way of segregation. While handling different varieties in the same facility, handling error was identified as an essential parameter contributing to AP. In the scenarios where spatial segregation was not possible, the facility could still meet the 0.9% tolerance level by applying a combination of temporal segregation strategies.

In the case of a feed mill with a single processing line, the model identified dedication and temporal segregation as an effective strategy to meet the 0.9% tolerance level. The final AP levels in both segregations were equivalent to the mean impurity of the incoming ingredients. These findings were consistent with the fact that ingredient impurity has a strong impact on the overall AP level. Scenarios starting with low ingredient impurity have a higher likelihood to achieve a 0.9% level compared to scenarios starting with high ingredient impurity.

To ensure low impurity in incoming material, it is necessary to have validated sampling and testing methods. Quantitative GM testing methods such as Polymerase Chain Reaction (PCR with 0.1% quantification limit) and Enzyme-Linked Immunosorbent Assay (ELISA with 0.2% - 0.3% quantification limit) can be effective in ensuring low AP levels in incoming materials (Demeke et al., 2006). Lateral flow, commonly known as qualitative rapid strip tests, can have a detection limit ranging from 0.1% - 1% (Grain Inspection Packers and Stockyards Administration, 2011).

In the case of a feed mill with multiple processing lines, the model suggested that dedicating the processing line cannot guarantee the capability to meet the 0.9% level. A judicious combination of robust segregation strategies beginning with the receiving of raw materials till feed production is necessary to achieve a 0.9% tolerance level. The model also suggested that with proper planning, temporal segregation can be as effective as dedication in managing low AP.

The feasibility analysis at the grain elevator and feed mills also produced some noteworthy findings. The model identified that the tolerance levels needed to meet 75%, 95% and 99% feasibility were much lower than the 5%. This means that a 5% tolerance level was feasible in all segregation scenarios analyzed in this study. However, in many scenarios, the tolerance levels needed to ensure 75%, 95% and 99% feasibility were higher than 0.9% and 3%. This means that 0.9% and 3% were not feasible tolerance levels in those scenarios.

This study elucidates the usefulness of a probabilistic model to simulate segregation scenarios and pick the right combination best suited for the business needs and desired tolerance level. The model was simulated for several scenarios in this study, but it was not limited to these only. Numerous hypothetical scenarios can be simulated, considering several other possible sources of AP and segregation decisions. The study takes a holistic view to examine how different practices and parameters together affect the overall AP in the entire process. The current model was limited due to the lack of available data. In the future, many more parameters contributing to AP and segregation decisions can be analyzed to obtain more successful segregation outcomes.

Key Takeaways from the Objective 3, Priority 8 - Feasibility:

- A probabilistic model was developed to analyze the grain elevator and feed mill's capability to segregate non-GM grain and feed at three tolerance levels: 0.9%, 3% and 5%.
- 5% tolerance level was feasible in all segregation scenarios analyzed in this study.
- 3% and 0.9% tolerance levels were not feasible in some segregation scenarios.
- For 1pit-1leg grain elevator configuration, dedication and temporal segregation (fully cleaned pit, leg and conveyor) were feasible to meet 0.9% tolerance level.
- The initial impurity of incoming grain had a strong impact on the overall AP level.
- For 2pits-1leg elevator configuration, dedication and temporal segregation (dedicated pit, fully cleaned leg and conveyor) were feasible to meet a 0.9% tolerance level.
- For 2pits-2legs elevator configuration, dedication, spatial segregation (with grain impurity 0.2%), and temporal segregation were feasible to meet 0.9% tolerance level.
- Handling error was an essential parameter contributing to AP during spatial and temporal segregation.
- For the feed mill with a single processing line, dedication and temporal segregation (fully cleaned receiving, conveying and processing line) were feasible to meet a 0.9% tolerance level.

- Scenarios starting with low ingredient impurity had a higher probability of achieving a 0.9% level than scenarios starting with high ingredient impurity.
- For a feed mill with multiple processing lines, dedicating the processing line alone was insufficient to meet the 0.9% level.
- A judicious combination of robust segregation strategies beginning with raw material receiving till feed production is necessary to achieve a 0.9% tolerance level.

Cost to Consumers (IFEEDER priority 9)

GM vs. Non-GM Elasticity Analysis

Introduction

The commonly used measure of consumers' sensitivity to price is known as "price elasticity of demand." It is simply the proportionate change in demand given a change in price. If a 1% drop in the price of a product produces a 1% increase in demand for the product, the price elasticity of demand is said to be one. A good with a price elasticity stronger than negative one is said to be "elastic;" goods with price elasticities smaller (closer to zero) than negative one are said to be "inelastic."

The above example is for own-price elasticity. The own-price elasticity of demand is often simply called the price elasticity. The relation above usually yields a negative value because of the inverse relationship between price and quantity demanded. However, economists often disregard the negative sign and report the elasticity as an absolute value.

The cross elasticity of demand is an economic concept that measures the responsiveness in the quantity demanded of one good when the price for another good changes. Cross price elasticities can be either negative or positive depending on whether the goods are substitutes or complements. Cross-price elasticity determines whether goods are complements or substitutes - if the cross-price elasticity is positive, then the goods are substitutes, and if the cross-price elasticity is negative, then the goods are complements. Two goods (A and B) are complementary if using more of good A requires the use of more good B. For example, an ink jet printer and ink cartridges are complements. Two goods (C and D) are substitutes if using more of good C replaces the use of good D. For example, Pepsi and Coca-Cola are substitutes. Complementary goods have a negative cross-price elasticity: as the price of one good increases, the demand for the second good decreases. Substitute goods have a positive cross-price elasticity: as the price of one good increases, the demand for the other good increases. Independent goods have a cross-price elasticity of zero: as the price of one good increases, the demand for the second good is unchanged. In other words, a good with a negative cross elasticity of demand means the good’s demand is increased when the price of another good is decreased. A good with a positive cross elasticity of demand means the good’s demand is increased when the price of another is increased.

Methods

The “Almost Ideal Demand System” (AIDS) was proposed by Deaton and Muellbauer (Deaton & Muellbauer, 1980). It is the most popular demand system in empirical demand analysis. Other than the studies of general household demand, the AIDS model is used to estimate the sensitivity to price changes, especially in elasticity calculations. It is a robust model because it unifies almost all theoretically and empirically desirable properties. Deriving from the original AIDS and improvising the model, Green and Alston (1990) proposed that it is common to estimate the linear approximate almost ideal demand system (LA/AIDS) instead of the AIDS. When the LA/AIDS is estimated, all the previously reported approaches to compute elasticities are theoretically incorrect. The analysis performed in the current study assumed the estimation methods of LA/AIDS elasticities proposed by Green and Alston (1990).

To study the cost to consumers, i.e., the buyers of non-GM corn and soybean feed meals, the own price and cross-price elasticities of GM and non-GM corn and soybeans are estimated. Four demand equations are used to estimate the elasticities from the LA/AIDS model:

- $w\_b = \alpha_0 + \alpha_1 lpb + \alpha_2 \, lpp + \alpha_3 \, lpc + \alpha_4 \, lpt + \alpha_5 \, lxp + \varepsilon b$ (non-GM soybean)
- $w\_p = \beta_0 + \beta_1 \, lpb + \beta_2 \, lpp + \beta_3 \, lpc + \beta_4 \, lpt + \beta_5 \, lxp + \varepsilon p$ (GM soybean)
- $w\_c = \gamma_0 + \gamma_1 \, lpb + \gamma_2 \, lpp + \gamma_3 \, lpc + \gamma_4 \, lpt + \gamma_5 \, lxp + \varepsilon c$ (non-GM corn)
- $w\_t = \delta_0 + \delta_1 \, lpb + \delta_2 \, lpp + \delta_3 \, lpc + \delta_4 \, lpt + \delta_5 \, lxp + \varepsilon t$ (GM corn)

where the dependent variables are the share of total expenditure allocated to the i^{th} good (i.e., either to non-GM or GM corn or soybeans, or the total corn and soybeans irrespective of GM or non-GM). The independent variables are the prices of the j^{th} goods, and the total expenditure normalized by the price index. A Seemingly Unrelated Regression (SUR) method was used for estimating the coefficients of prices to the market share of the crops. Then the equation for the uncompensated price elasticities for the AIDS and the LA/AIDS and the SUR coefficients were used to calculate the own price and cross-price elasticities of GM and non-GM corn and soybeans.

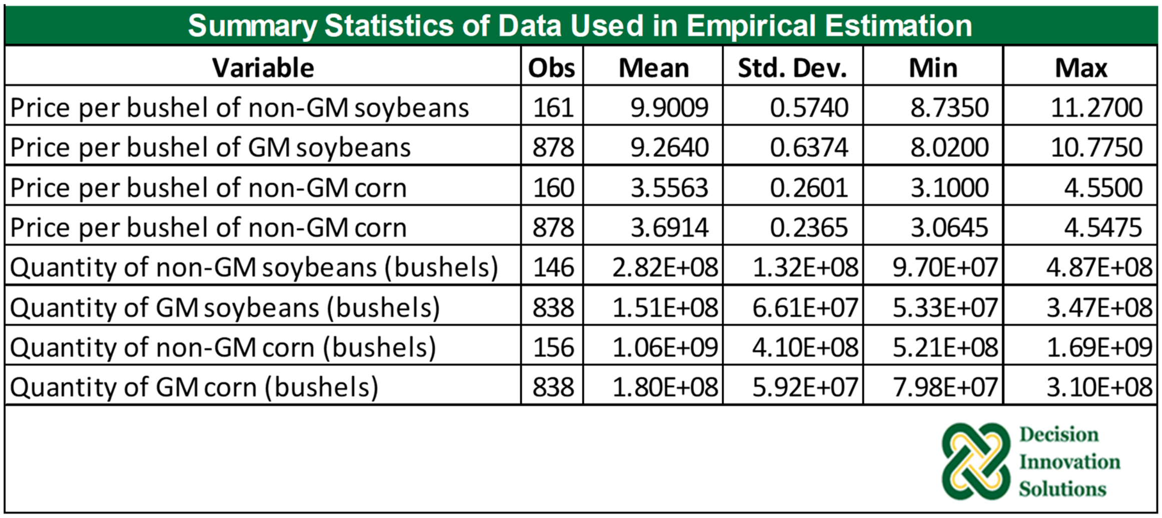
Export data of GM corn and soybeans was obtained from the USDA's Foreign Agriculture Service database. A proxy for the production of non-GM corn and soybeans was approximated from the total production of GM corn (assuming 10% of it as reported by Informa) – obtained from the USDA's dataset on crop yearbooks. From the total production data published by Informa, it is assumed that 10% of it is non-GM corn and non-GM soybean production. Prices of non-GM corn and soybeans are obtained from the 'Informa' database. Prices of GM corn and soybeans are obtained from the 'Macrotrends' database.

Analysis

In this study, it was hypothesized that the own price elasticities of GM-corn, non-GM corn, GM-soybeans, non-GM soybeans were all negative because when the price of any of these commodities increases, the demand for that commodity decreases. The results confirm this theory.

- The empirical results in Table 46 show that the cross-price elasticities of non-GM corn and non-GM soybeans are positive, i.e., a 1% increase in the price of non-GM corn increases the quantity demanded for non-GM soybeans by 1.29%. So, non-GM corn and non-GM soybeans show highly elastic results and behave as strong substitutes.
- Results also show that the cross-price elasticities of GM corn and non-GM soybeans are positive, i.e., a 1% increase in the price of GM corn increases the quantity demanded for non-GM soybeans by 1.17%. So, GM corn and non-GM soybeans also show highly elastic results and behave as strong substitutes. This means farmers can potentially use these pair of substitutes interchangeably depending on the price of the goods.
- Similarly, the cross-price elasticities of GM corn and non-GM corn are positive, i.e., a 1% increase in the price of GM corn, increases the quantity demanded for non-GM corn by 0.58%. So, non-GM corn and non-GM soybeans show elastic results and behave as weak substitutes.

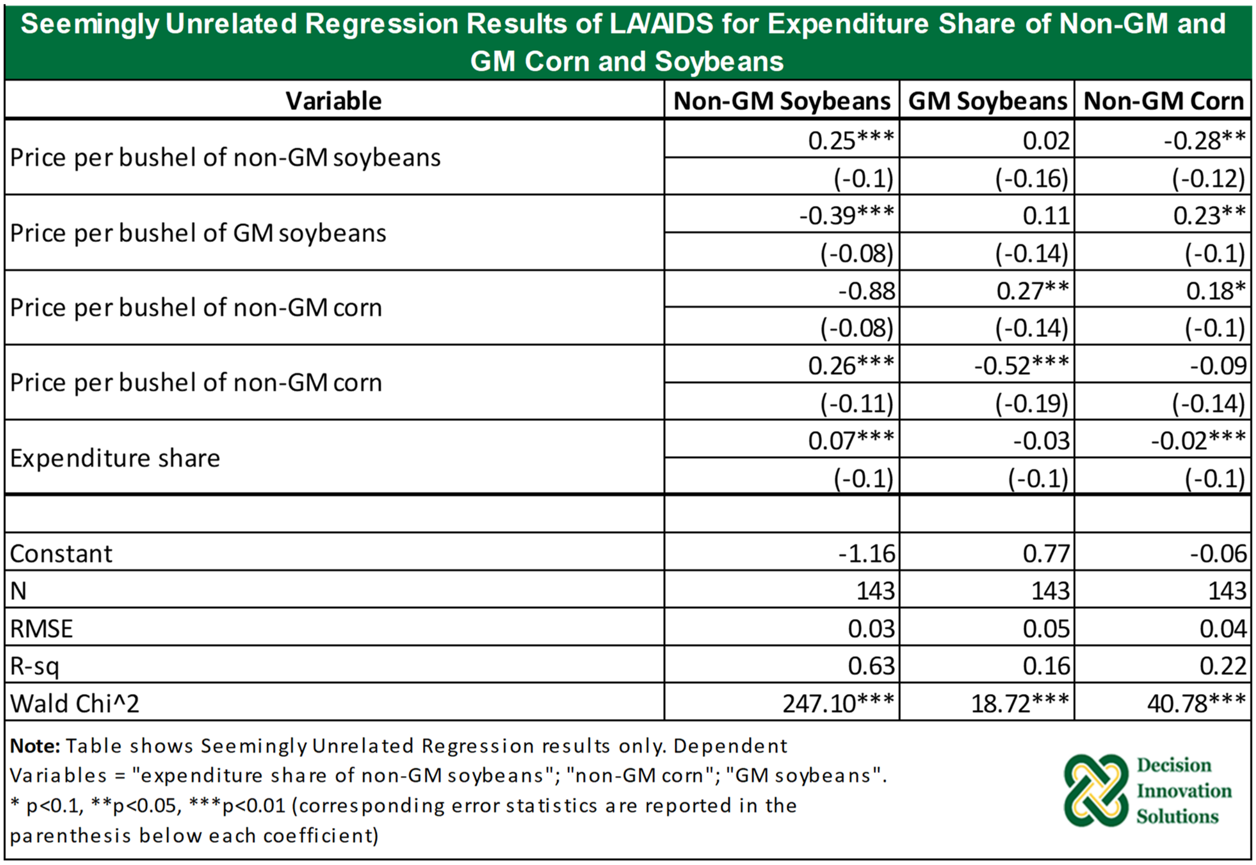
Table 44. Summary Statistics of Data Used in Empirical Estimation



Summary Statistics of Data Used in Empirical Estimation

Variable	Obs	Mean	Std. Dev.	Min	Max
Price per bushel of non-GM soybeans	161	9.9009	0.5740	8.7350	11.2700
Price per bushel of GM soybeans	878	9.2640	0.6374	8.0200	10.7750
Price per bushel of non-GM corn	160	3.5563	0.2601	3.1000	4.5500
Price per bushel of non-GM corn	878	3.6914	0.2365	3.0645	4.5475
Quantity of non-GM soybeans (bushels)	146	2.82E+08	1.32E+08	9.70E+07	4.87E+08
Quantity of GM soybeans (bushels)	838	1.51E+08	6.61E+07	5.33E+07	3.47E+08
Quantity of non-GM corn (bushels)	156	1.06E+09	4.10E+08	5.21E+08	1.69E+09
Quantity of GM corn (bushels)	838	1.80E+08	5.92E+07	7.98E+07	3.10E+08

Table 45 Seemingly Unrelated Regression Results of Linear Approximate, Almost Ideal Demand System (AIDS) for Expenditure Share of Non-GM and GM Corn and Soybeans



Seemingly Unrelated Regression Results of LA/AIDS for Expenditure Share of Non-GM and GM Corn and Soybeans

Variable	Non-GM Soybeans	GM Soybeans	Non-GM Corn
Price per bushel of non-GM soybeans	0.25***	0.02	-0.28**
	(-0.1)	(-0.16)	(-0.12)
Price per bushel of GM soybeans	-0.39***	0.11	0.23**
	(-0.08)	(-0.14)	(-0.1)
Price per bushel of non-GM corn	-0.88	0.27**	0.18*
	(-0.08)	(-0.14)	(-0.1)
Price per bushel of non-GM corn	0.26***	-0.52***	-0.09
	(-0.11)	(-0.19)	(-0.14)
Expenditure share	0.07***	-0.03	-0.02***
	(-0.1)	(-0.1)	(-0.1)
Constant	-1.16	0.77	-0.06
N	143	143	143
RMSE	0.03	0.05	0.04
R-sq	0.63	0.16	0.22
Wald Chi^2	247.10***	18.72***	40.78***

Note: Table shows Seemingly Unrelated Regression results only. Dependent Variables = "expenditure share of non-GM soybeans"; "non-GM corn"; "GM soybeans".
* p<0.1, **p<0.05, ***p<0.01 (corresponding error statistics are reported in the parenthesis below each coefficient)

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Empirical results show that there is a strong potential for consumers demanding non-GM corn in place of GM corn because non-GM corn substitutes GM corn. This is a result of interest; one could infer that there is/would be a potential demand of non-GM corn due to its substitutability with other crops that are already existing in the market. Hence, there is a good scope for profit with the adoption of non-GM corn production technology.

Table 44 shows the summary statistic of the data used in the empirical estimation. The average, minimum and maximum prices, and quantities of corn and soybeans are reported in the table.

Table 45Table 45 reports the expenditure shares of the non-GM and GM corn and soybeans, which is used in the calculation of the price elasticities reported in Table 46. To the contrary, GM corn and GM soybeans show highly inelastic relationships and behave as strong complements. A 1% increase in the price of GM corn, decreases the quantity demanded for GM soybeans by 3.47%. That means both GM corn and GM soybeans are consumed in almost equal proportions for their specific needs and a change in price of one crop affects the demand for both the crops in the same direction. GM corn and GM soybeans are not being used as a substitute for one another, rather they are used almost in the same proportions for specific needs. Similar complementary relationships are shown by GM corn and non-GM corn, non-GM corn and GM soybeans, GM soybeans and non-GM soybeans, non-GM soybeans and GM soybeans and, non-GM soybeans and non-GM corn as shown in Table 46 below.

Table 46 Elasticity Calculated from SUR Results of Linear Approximate Almost Ideal Demand System (AIDS) for Expenditure Share of Non-GM and GM Corn and Soybeans

Elasticity Calcluated from SUR Results of LA/AIDS for Expenditure Share of Non-GM and GM Corn and Soybeans

Variable	Non-GM Soybeans (qb)	GM Soybeans (qp)	Non-GM Corn (qc)
Price per bushel of non-GM soybeans (pb)	**-0.95**	-1.30	-0.60
Price per bushel of GM soybeans (pp)	-0.61	**-1.13**	0.58
Price per bushel of non-GM corn (pc)	1.29	-0.32	**-0.51**
Price per bushel of GM corn (pt)	1.17	-3.47	-0.21

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Results

To estimate the costs to consumers of GM and non-GM corn and soybeans, the prices of GM and non-GM corn and soybeans, cost of production, total production, total consumption, domestic demand, export demand, import demand and price sensitivity (Elasticity) were analyzed.

A 1% increase in the price of non-GM corn increases the quantity of non-GM soybeans demanded by 1.29%. Also, a 1% increase in the price of GM soybeans increases the quantity of non-GM corn demanded by 0.58%.

The own price elasticities are negative as hypothesized. GM corn and non-GM soybeans and non-GM corn and non-GM soybeans show highly elastic results and behave as strong substitutes, whereas GM corn and non-GM corn and non-GM soybeans and GM soybeans show highly inelastic relations and behave as strong complements.

Conclusions

The own price elasticities are negative as hypothesized. GM corn and non-GM soybeans and non-GM corn and non-GM soybeans show highly elastic results and behave as strong substitutes. GM corn and non-GM corn and non-GM soybeans and GM soybeans show highly inelastic relations and behave as strong complements. So, for the consumers of non-GM feed, it is easy to substitute GM corn with non-GM soybean. But if the demand for GM corn increases among consumers, non-GM corn demand also increases. So, both the above cases support a potential for a significant non-GM feed market in the economy.

Cost to Final Product Consumers (Retail) for Pork, Chicken, Eggs, Beef and Milk

Methods

To estimate the costs to retail consumers for non-GM corn and non-GM soybean diets (i.e., feed ingredients) for chicken, chicken egg, pork, beef and milk, an analysis was done on the costs of non-GM feed ingredients, farm value[11] of the livestock and chicken products and retail prices for the chicken, pork, eggs, beef and dairy using data from the Livestock Marketing Information Center (LMIC) database and calculations from this report regarding feed cost increases for non-GM feed ingredients. The first step in this analysis is to estimate the step up in value that occurs from feed to farm to retail. The increase in value for each of these value steps can be expressed as the ratios of 'retail' to 'farm value' and the ratios of 'farm value' to 'GM feed ingredients' for each. The ratios are calculated in the following ways:

The ratio of GM Retail Value to GM farm value (R_{RF}) is obtained by diving the GM retail prices by the GM farm values. The formula for the calculation is:

$$R_{RF} = \frac{Retail\ Prices}{Farm\ Values} \qquad (1)$$

The ratio of GM farm value to GM feed (R_{Ff}) is obtained by dividing the GM farm value by the value of GM feed ingredients. The former is obtained from the LMIC database and the latter is estimated as a part of this report. The formula for the ratio calculation is:

$$R_{Ff} = \frac{Farm\ Values}{GM\ Feed} \qquad (2)$$

The data for GM feed, farm value and retail prices are taken from the LMIC database, which reports and summarizes USDA data. The ratios mentioned above were calculated for each species (broilers, layers, swine, beef and dairy cattle) and represent the multipliers at which value is added from feed ingredients to farm value of livestock and then from farm value to retail.

The estimated cost of non-GM feed ingredients is calculated considering the price differences, substitution differences and the process differences while estimating the additional premium in the cost of non-GM feed ingredients to GM feed ingredients. The price differences come from the additional costs required to produce non-GM corn and non-GM soybeans. For non-GM corn, the premium is estimated as $0.12 per bushel and for non-GM soybeans the premium is

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[11] Farm value of a product is the market value minus the processing and selling costs (i.e., transport costs, marketing costs, etc.).

estimated as $1.11 per bushel. The substitution difference is the differences in the proportions of non-GM corn and non-GM soybean meal used with other ingredients in the non-GM feed replacing the distiller's grains, corn gluten feed and cottonseed meal since there are no non-GM substitutes for such ingredients. As reported by Baker and Hoffman (2011), DDGS replace approximately 60% corn and 40% soybean meal in the feeding of pigs and chickens in the calculations.

In a recent DIS analysis of national feed ingredient use in 2019 by species, estimates of feed composition by species are listed in Figure 75 through Figure 79. For broilers, GM ingredients include corn (59%), soybean meal (28%), corn distiller's dried grains (5%), and cottonseed meal (2%). In a non-GM ration, the GM ingredients would be replaced with more non-GM corn and soybean meal. The non-GM broiler ration would consist of corn (63%) and soybean meal (31%) with no corn distiller's grains or cottonseed meal. The price and substitution effect on non-GM broiler feed averages $17.77 per ton for the 2014-19 period.

For egg production, the GM feed ingredient ration uses corn (56%), soybean meal (16%), DDGS (8%) and cottonseed meal (1%). The non-GM feed ration would use corn (61%) and soybean meal (20%) with no distiller's dried grains or cottonseed meal. The price differential and substitution effect of non-GM feed on layer rations average $16.35 per ton for the 2014-19 period.

For swine production, the GM feed ingredient ration uses corn (60%), soybean meal (12%), corn distiller's dried grains (7%) and corn gluten feed (3%). The non-GM ration for swine would include corn (66%) and soybean meal (16%) with no distiller's dried grains or corn gluten meal. The price differential and substitution effect of non-GM ingredients on swine rations averages $20.15 per ton for the 2014-19 period.

For beef production, the GM feed ingredient ration uses corn silage (9%), distiller's dried grains (8%), Bromegrass hay (75%) and corn grain (8%). For the non-GM feed, the DDGS and corn grain proportions are replaced by non-GM corn (total of 16% in the ration). There is no use of soybean meal in both types of beef feed. Using premium for corn and soybean meal as used before to find operational costs (objective 3, priority 8), the price of substitution effect on non-GM ingredients on beef feed rations averages $1.08 per ton.

For milk production, the GM feed ingredient ration uses forage mix (64.4%), ground corn (15.32%), soybean meal (9.3%) and other grain (10.98%). For the non-GM feed, the GM corn is replaced by non-GM corn and the GM soybean meal replaced by non-GM soybean meal, using the same proportions. Using premium for corn and soybean meal as used before to find operational costs (objective 3 priority 8), the price of substitution effect on non-GM ingredients on dairy feed rations averages $4.91 per ton. Composition of feed for beef and dairy are listed in Figure 78 and Figure 79, respectively.

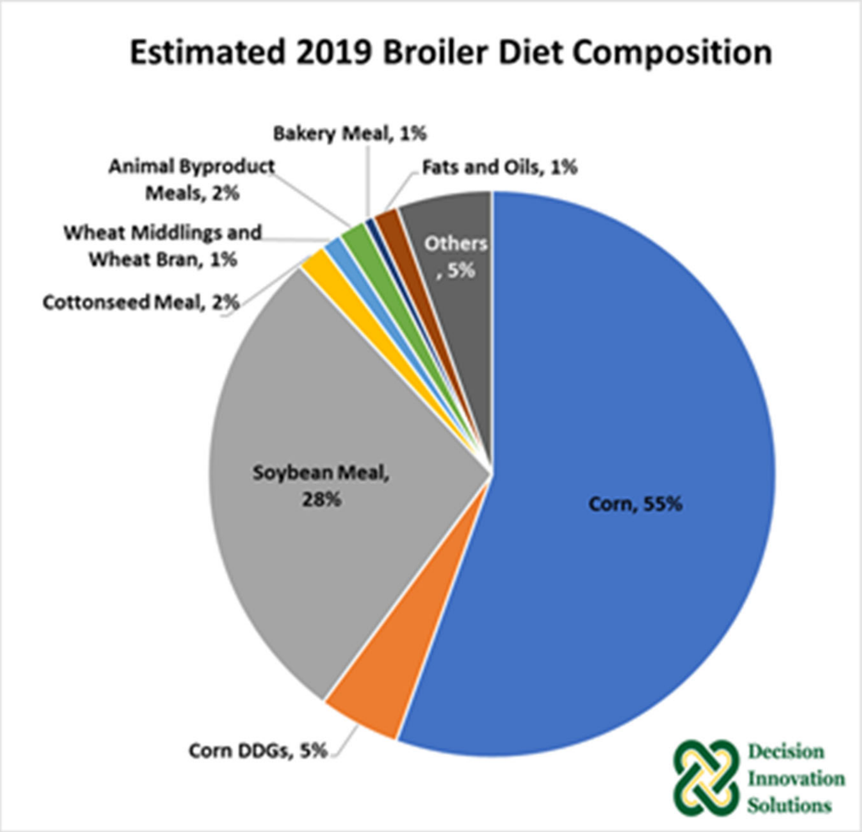

Figure 75. Estimated 2019 Broiler Diet Composition

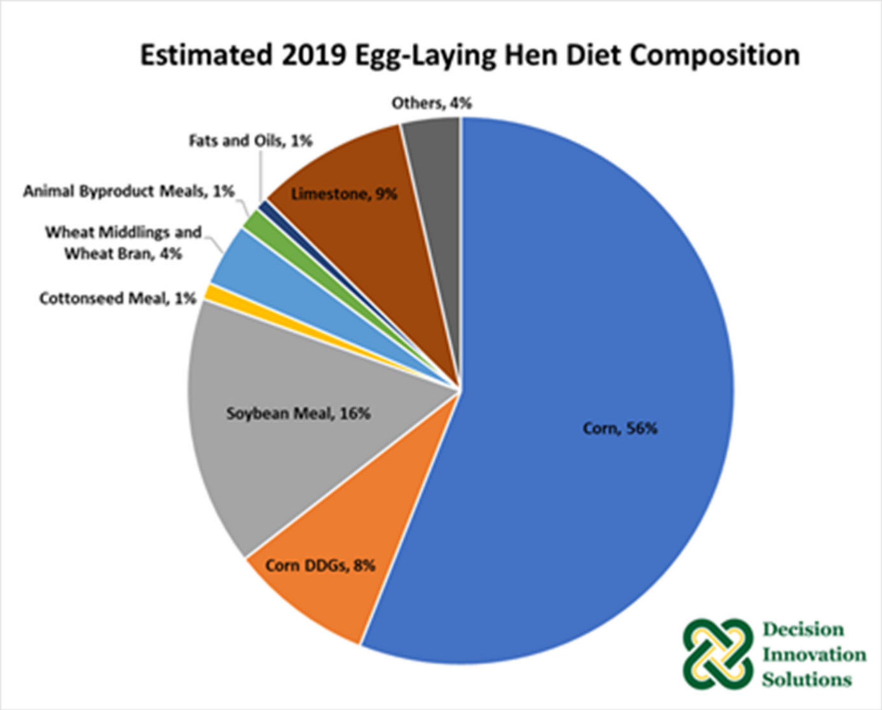

Figure 76. Estimated 2019 Egg-Laying Hen Diet Composition

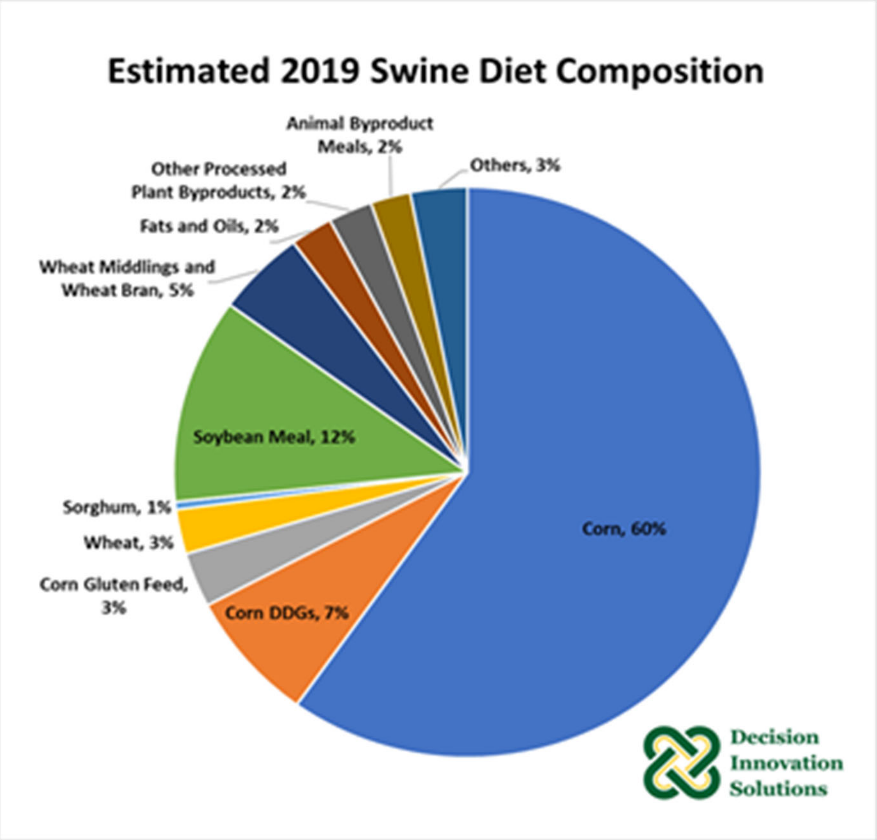

Figure 77. Estimated 2019 Swine Diet Composition

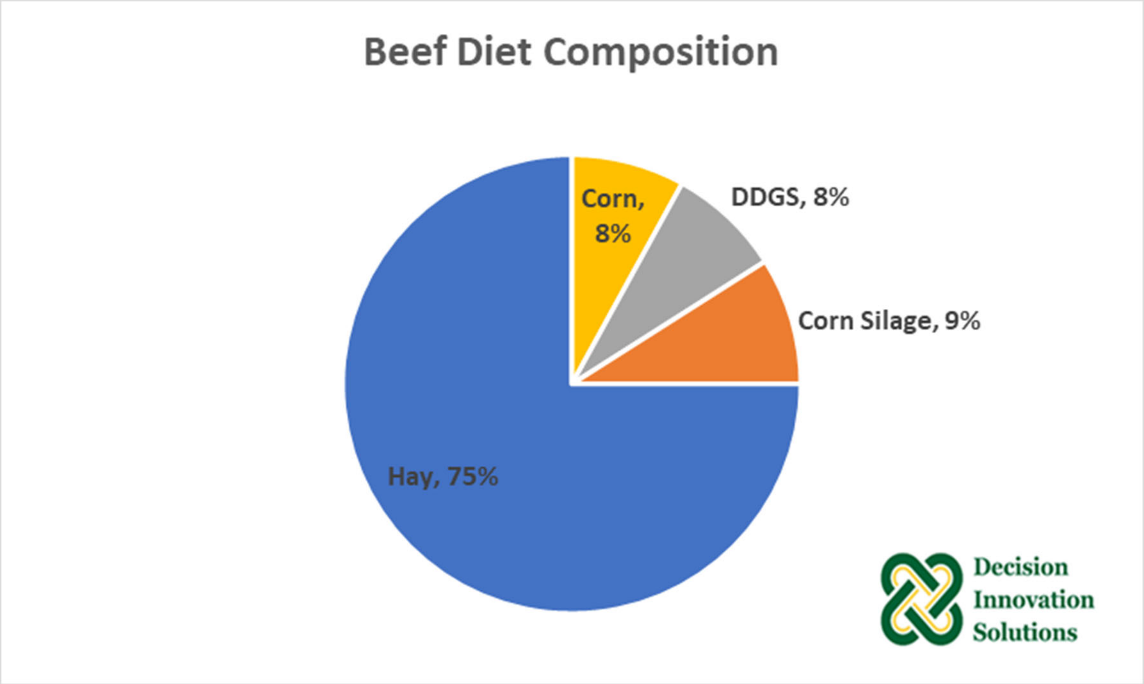

Figure 78. Beef Diet Composition

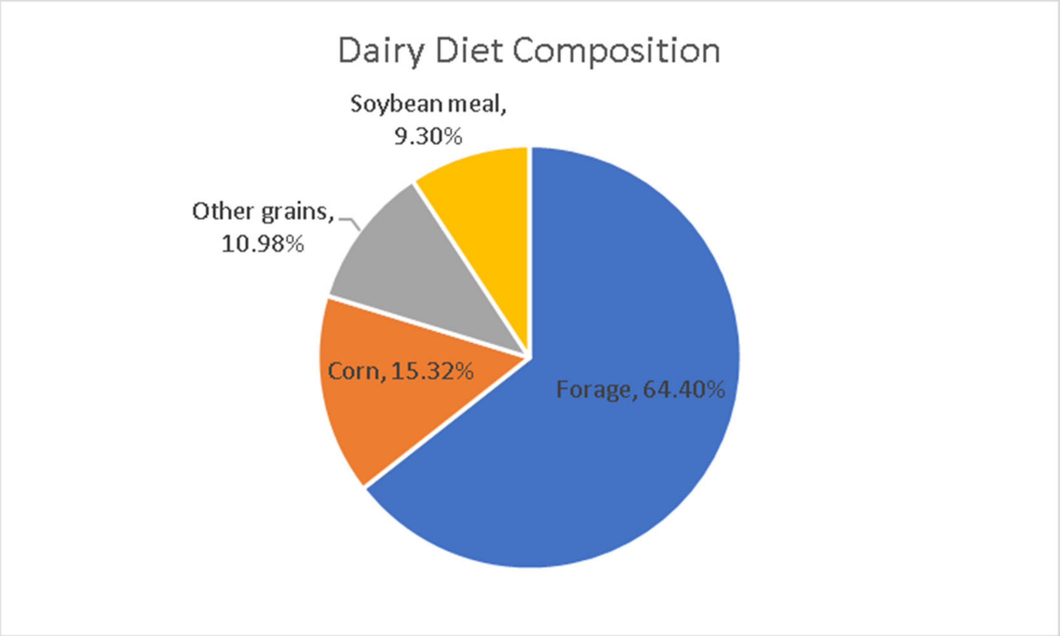

Figure 79. Dairy Diet Composition

The process difference is attributed to the differences in feed mill costs for non-GM and the elevator costs for non-GM. The feed mill costs, and the elevator cost premiums are estimated from Table 47 and Table 48, below. As shown in Table 47, process differences are calculated considering the three different scenarios,

a. Segregation by space where the facility continues to produce both kinds of feed.
b. Segregation by time where there are specific times when a facility processes GM feed and specific times when it processes non-GM feed.
c. Use of a dedicated facility.

Table 47. Elevator Costs

Elevator Costs

Product	***Segregation***	***Volume (bu/y)***	***Mean ($/bu)***	***Std Deviation***
Soybeans	Space	500,000	$ 0.0690	$ 0.0095
Soybeans	Space	1,000,000	$ 0.0649	$ 0.0096
Soybeans	Space	2,000,000	$ 0.0619	$ 0.0095
Soybeans	Time	500,000	$ 0.0583	$ 0.0096
Soybeans	Time	1,000,000	$ 0.0559	$ 0.0096
Soybeans	Time	2,000,000	$ 0.0547	$ 0.0095
Soybeans	Dedicated	500,000	$ 0.0579	$ 0.0095
Soybeans	Dedicated	1,000,000	$ 0.0557	$ 0.0094
Soybeans	Dedicated	2,000,000	$ 0.0546	$ 0.0095
Corn	Space	500,000	$ 0.0867	$ 0.0031
Corn	Space	1,000,000	$ 0.0824	$ 0.0031
Corn	Space	2,000,000	$ 0.0795	$ 0.0031
Corn	Time	500,000	$ 0.0760	$ 0.0030
Corn	Time	1,000,000	$ 0.0736	$ 0.0030
Corn	Time	2,000,000	$ 0.0724	$ 0.0030
Corn	Dedicated	500,000	$ 0.0756	$ 0.0030
Corn	Dedicated	1,000,000	$ 0.0734	$ 0.0030
Corn	Dedicated	2,000,000	$ 0.0723	$ 0.0030

Sources: DIS calculations; ISU Calculations

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Table 48. Feed Mill Costs

Feed Mill Costs					
#	***Product***	***Segregation***	***Capacity (tons/year)***	***Mean ($/ton)***	***Std Deviation***
M1	Swine	Space	10,000 tons/y	$ 7.1587	$ 0.1336
M2	Swine	Space	25,000 tons/y	$ 6.5339	$ 0.1169
M3	Swine	Space	50, 000 tons/y	$ 6.0698	$ 0.1099
M4	Swine	Time	10,000	$ 5.2590	$ 0.1038
M5	Swine	Time	25,000	$ 5.0235	$ 0.1024
M6	Swine	Time	50,000	$ 4.9462	$ 0.1025
M7	Swine	Dedicated	10,000	$ 5.2910	$ 0.1089
M8	Swine	Dedicated	25,000	$ 4.9546	$ 0.1017
M9	Swine	Dedicated	50,000	$ 4.9118	$ 0.1020
M10	Broiler	Space	10,000	$ 7.1832	$ 0.2769
M11	Broiler	Space	25,000	$ 6.5575	$ 0.2695
M12	Broiler	Space	50,000	$ 6.0924	$ 0.2685
M13	Broiler	Time	10,000	$ 5.4875	$ 0.2697
M14	Broiler	Time	25,000	$ 5.0473	$ 0.2642
M15	Broiler	Time	50,000	$ 4.9684	$ 0.2637
M16	Broiler	Dedicated	10,000	$ 5.3159	$ 0.2685
M17	Broiler	Dedicated	25,000	$ 4.9785	$ 0.2639
M18	Broiler	Dedicated	50,000	$ 4.9342	$ 0.2641
M19	Layer	Space	10,000	$ 7.3938	$ 0.1379
M20	Layer	Space	25,000	$ 6.7663	$ 0.1200
M21	Layer	Space	50,000	$ 6.2996	$ 0.1147
M22	Layer	Time	10,000	$ 5.6978	$ 0.1132
M23	Layer	Time	25,000	$ 5.2559	$ 0.1056
M24	Layer	Time	50,000	$ 5.1757	$ 0.1064
M25	Layer	Dedicated	10,000	$ 5.5261	$ 0.1124
M26	Layer	Dedicated	25,000	$ 5.1871	$ 0.1047
M27	Layer	Dedicated	50,000	$ 5.1413	$ 0.1059
M28	Beef	Space	10,000	$ 3.0774	$ 0.0901
M29	Beef	Space	25,000	$ 2.4562	$ 0.0603
M30	Beef	Space	50,000	$ 1.9926	$ 0.0480
M31	Beef	Time	10,000	$ 1.1777	$ 0.0257
M32	Beef	Time	25,000	$ 0.9460	$ 0.0203
M33	Beef	Time	50,000	$ 0.8687	$ 0.0193
M34	Beef	Dedicated	10,000	$ 1.2097	$ 0.0423
M35	Beef	Dedicated	25,000	$ 0.8772	$ 0.0201
M36	Beef	Dedicated	50,000	$ 0.8344	$ 0.0194
M37	Dairy	Space	10,000	$ 3.5740	$ 0.0919
M38	Dairy	Space	25,000	$ 2.9433	$ 0.0639
M39	Dairy	Space	50,000	$ 2.4789	$ 0.0523
M40	Dairy	Time	10,000	$ 1.8784	$ 0.0473
M41	Dairy	Time	25,000	$ 1.4331	$ 0.0288
M42	Dairy	Time	50,000	$ 1.3550	$ 0.0285
M43	Dairy	Dedicated	10,000	$ 1.7063	$ 0.0471
M44	Dairy	Dedicated	25,000	$ 1.3642	$ 0.0289
M45	Dairy	Dedicated	50,000	$ 1.3206	$ 0.0286

The processing cost differentials for non-GM feed versus GM feed ingredients is $7.73 per ton for non-GM broiler feed, $7.75 per ton for layer rations, $7.58 per ton for swine feed, $1.98 per ton of beef feed and $2.65 per ton of dairy feed.

Using the above scenarios, and the cost premiums of non-GM feed ingredients such as corn and soybean meal, the total additional costs per ton of finished feed ingredients is estimated at

$24.10 for layer feed, $27.73 for swine feed, $25.50 for broiler feed, $3.06 for beef feed and $7.56 for dairy feed on average as shown in Table 49.

Table 49. Summary of Price Differentials, Substitution Effects and Processing Differentials on Non-GM Feed Costs

Summary of Price Differentials, Substitution Effects and Processing Differentials on Non-GM Feed Costs

	Swine	Broilers	Layers	Beef	Dairy
Total cost differential	27.73	25.50	24.10	3.06	7.56
Price & substitution effect	20.15	17.77	16.35	1.08	4.91
Process differential	7.58	7.73	7.75	1.98	2.65

Sources: LMIC (USDA Data); DIS calculations; ISU calculations

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Upon estimating the GM and non-GM costs of feed for each of the species, the ratios of GM feed ingredients to GM farm value and the ratios of GM farm value to GM retail are calculated. The farm values and the retail prices for each of the species are obtained from the spreadsheets of the LMIC database. To estimate the costs to retail, the GM costs in equations (2) and (1) were used to calculate the ratio of GM farm value to GM feed and the ratio of GM retail value to GM farm value, respectively. Once the GM ratio estimates were obtained, the non-GM farm value was calculated by incorporating the new, non-GM feed value instead of GM feed values in equation (2). Then, the new non-GM farm value was used in equation (1) to obtain the alternative non-GM retail values. These calculations assume that the ratios of GM feed to GM farm value and for GM farm value to GM retail value will hold for non-GM products produced from non-GM feeds. For beef and milk, these calculations already consider the average percentage of cows on feed and grazing on pasture.

Table 50. Summary of Ratios

Product	**Ratio of Farm Value to Feed Value**	**Ratio of Retail Value to Farm Value**
Broilers	9.45	2.06
Eggs	13.12	1.57
Pork	8.98	5.22
Beef	7.49	2.65
Milk	6.91	2.04

Sources: LMIC (USDA Data); DIS calculations; ISU calculations.

Results

The non-GM retail value of pork is estimated at $4.47 per pound, the cost of non-GM retail composite chicken is estimated as $2.16 per pound, the cost of non-GM retail eggs is estimated as $2.04 per dozen, the cost of non-GM retail beef (cutout) is estimated as $8.84 per pound, and the cost of non-GM retail milk is estimated as $3.40 per gallon.

Table 51. Price Comparisons of Feed Values, Farm Values and Retail Values Using GM Versus Non-GM Feed

Summary of Feed Values, Farm Values and Retail Values Using GM and Non-GM Feed						
Product	**GM Feed Value**	**Non-GM Feed Value**	**Farm Value of Production Using GM Feed**	**Farm Value of Production Using Non-GM Feed**	**Retail Value of Product with GM Feed**	**Retail Value of Product with Non-GM Feed**
	$/ton	$/ton	$/ lb, doz, or gal	$/ lb, doz, or gal	$/ lb, doz, or gal	$/ lb, doz, or gal
Broilers	198.44	223.94	0.93	1.05	1.91	2.16
Eggs	179.66	203.76	1.18	1.34	1.80	2.04
Pork	165.87	193.60	0.75	0.87	3.83	4.47
Beef	124.23	127.29	3.32	3.34	8.81	8.85
grazing	50.00	50.012				
14%feed + 86%grazing	60.39	60.83				
Milk	160.40	167.96	1.63	1.67	3.33	3.40
grazing	50.00	50.82				
34%feed + 66%grazing	87.54	90.65				

Sources: LMIC (USDA Data); DIS calculations; ISU calculations.

To understand the change in the prices of pork, chicken, eggs beef, and milk that are fed with non-GM feed ingredients to the swine, broiler chickens, laying hens, beef and dairy cattle that are fed with GM feed ingredients, a comparative study was done using the existing prices of products using GM feed ingredients and the estimated prices of products using non-GM feed ingredients. As mentioned above, the estimated retail prices increase in all five product categories.

Conclusions

The retail price of pork produced with GM feed is $3.83 per pound whereas the estimated non-GM pork retail price is $4.47 per pound. The cost of pork increases by $0.64 per pound, which is a 16.71% increase. For retail composite chicken, the price per pound increases by $0.25 per pound, which is a 13.09% increase. The retail price of composite chicken produced with GM feed is $1.91 per pound, whereas the estimated non-GM composite chicken retail price is $2.16 per pound. The cost of eggs produced with GM feed is $1.80 per dozen. However, the estimated non-GM eggs would be $2.04 per dozen. So, there is an increase of $0.24 per dozen for GM eggs retail to non-GM eggs retail prices, which is a 13.33% increase. For retail beef cutouts, the price per pound increases by $0.04 per pound, which is a 0.40% increase. The retail price of beef produced with GM feed is $8.81 per pound, whereas the estimated non-GM beef retail price is $8.85 per pound. For retail milk, the price per pound increases by $0.08 per gallon, which is a 2.26% increase. The retail price of milk produced with GM feed is $3.33 per gallon, whereas the estimated non-GM milk retail price is $3.40 per gallon. As expected, the final cost of products is influenced to a greater degree for species with a higher content of grain in their diet. For beef and milk, the impact is reduced because grazing is responsible for a large part of the cattle's diet.

Appendix A. Land Use Types

Corn	
"001"	Corn
"225"	Double Crop Winter Wheat/Corn
"226"	Double Crop Oats/Corn
"237"	Double Crop Barley/Corn
"241"	Double Crop Corn/Soybeans
Soybeans	
"005"	Soybeans
"026"	Double Crop Winter Wheat /Soybeans
"239"	Double Crop Soybeans/Cotton
"240"	Double Crop Soybeans/Oats
"241"	Double Crop Corn/Soybeans
"254"	Double Crop Barley/Soybeans
Grassy Habitat	
"037"	Other Hay/Non-Alfalfa
"062"	Pasture/Grass
"176"	Grassland/Pasture
Wheat	
"022"	Durum Wheat
"230"	Double Crop Lettuce/Durum Wheat
"234"	Double Crop Durum Wheat/Sorghum
"024"	Winter Wheat
"026"	Double Crop Winter Wheat/Soybeans
"225"	Double Crop Winter Wheat/Corn
"236"	Double Crop Winter Wheat/Sorghum
"238"	Double Crop Winter Wheat/Cotton
Sorghum	
"004"	Sorghum
"234"	Double Crop Durum Wheat/Sorghum
"235"	Double Crop Barley/Sorghum
"236"	Double Crop Winter Wheat/Sorghum
Rice	
"003"	Rice
Cotton	
"002"	Cotton
"232"	Double Crop Lettuce/Cotton
"238"	Double Crop Winter Wheat/Cotton
"239"	Double Crop Soybeans/Cotton

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