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From the Editor's Desk

MARIA A. BOERNGEN, PH.D.

Chair, ASFMRA Editorial Task Force and Editor, *Journal of ASFMRA*

Dear ASFMRA members and professional colleagues,

On behalf of the American Society of Farm Managers and Rural Appraisers, I am pleased to present the 2024 issue of the *Journal of the ASFMRA*. Manuscript submissions continue to increase each year, and the 15 papers contained herein were selected for publication following a rigorous peer-review process. Within these pages, you will find a variety of timely topics that are relevant to the rural property professions, and I trust that you will enjoy reading them as much as I have.

Two years ago, we added a special session to the ASFMRA Annual Conference agenda featuring presentations from select *Journal* authors. Last year, we also included a *Journal* author in the appraisers' Rapid Fire session. These have now become regular features at the Annual Conference, and I look forward to selected authors from this current issue sharing their work at our 2024 Annual Conference.

The Editorial Task Force and I are also excited to announce that our inaugural special topics issue, focusing on rural appraisal, is currently in preparation. Publication is anticipated in fall 2024. This is just the first of many special topics issues of the *Journal* to come that will complement our regular annual issue.

As I conclude my third year as Editor of the *Journal of the ASFMRA*, I am thankful for the support and enthusiasm of my fellow Editorial Task Force members and the ASFMRA Executive Council as we continue to elevate the visibility and impact of the *Journal*. I hope to see you in Kansas City in November 2024 for the ASFMRA Annual Conference – be on the lookout for the *Journal* session on the conference agenda!

Thank you for your continued interest in the *Journal of the ASFMRA*. Please reach out to me any time if you are interested in sharing your work with our readership.

Maria A. Boerngen, Ph.D.
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Thank You to the 2023–24 Editorial Task Force

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Simulating Prevented Planting Coverage Factors based on Cost Reimbursement



By Christopher N. Boyer, W. Hence Duncan, and Eunchun Park

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Acknowledgments

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Abstract

The prevented planting provision in United States crop insurance reimburses producers when they are unable to plant. These indemnities are calculated by using a coverage factor (CF) of the insurance level. We simulated CFs that reimburse land rent and two payment values for inputs for corn and soybean production. Simulations were established to generate county-level distributions of CFs as well as changes in U.S. expenditures if the CFs were established to reimburse land rent and input costs. We found that the CF for corn is likely compensating claims more than the soybean CF, despite the soybean CF being higher than corn.

INTRODUCTION

U.S. crop insurance has a provision that pays producers an indemnity when they are prevented from planting due to an insurable loss such as excess moisture. While there is a short window of time during the production year for crops to be lost, prevented planting indemnity payments and the acres lost can account for substantial portions of U.S. crop insurance claims each year. In 2010, 2011, 2015, and 2019, more than 20% of all U.S. crop insurance payments were for prevented planting claims (Wu, Goodwin, and Coble, 2020; USDA-RMA, 2023a). In 2019, prevented planting claims hit a record high of 19 million acres lost and $4.3 billion in indemnity payments, followed by prevented planting claims made on 10 million acres (about 22% of total acres indemnified) in 2020 (USDA-RMA, 2023a).

Prevented planting indemnity payments were established in 1994 to offer a financial safety net for standard production expenses that occur prior to planting (USDA-RMA, 2021). These costs are considered to include machinery, pesticide, fertilizer, land rent, property taxes, and labor (USDA-RMA, 2021), but the provision is set up to pay policyholders based on their coverage level without considering their costs of production. The USDA Office of the Inspector General (OIG) investigated this provision and found that prevented planting indemnity payments can exceed pre-planting costs (USDA OIG, 2013), which researchers have suggested could be a moral hazard issue (Adkins et al., 2020; Boyer and Smith, 2019; Kim and Kim, 2018; Wu, Goodwin, and Coble, 2020).

Prevented planting moral hazard concerns are different from typical claims such as under-applying fertilizer or chemicals during production because economic losses from low yields are insured (i.e., *ex-ante* moral hazard) (Horowitz and Lichtenberg, 1993; Smith and Goodwin, 1996; Sheriff, 2005). Moral hazard in prevented planting is often referred to as an *ex-post* moral hazard because a producer's choice to not grow a crop for an insurable reason keeps them from planting (Rees and Wambach, 2008; Zweifel and Eisen, 2012). An *ex-post* moral hazard in prevented planting, which was defined by Kim and Kim (2018) and used by other researchers (Adkins et al., 2020; Boyer and Smith, 2019; Wu, Goodwin, and Coble, 2020), occurs when a producer chooses to take the prevented planting indemnity payment during the late planting window or switches to an alternative crop.

The USDA OIG (2013) report recommended changing the prevented planting provision to align indemnity payments with actual pre-plant production costs. This would require decreasing the prevented planting coverage factor (CF), i.e., the percentage of the policyholder's guaranteed revenue or yield coverage purchased in their crop insurance policy for various crops. In 2017 and 2019, the prevented planting CF was decreased by the USDA-RMA for corn and other crops, but soybeans were not adjusted. Policy analyses of these changes have found that lowering the prevented planting CF would likely reduce the moral hazard concerns for corn by incentivizing producers to switch from corn to soybeans, for example[1] (Adkins et al., 2020; Boyer and Smith, 2019; Kim and Kim, 2018).

Often, the literature focuses on regions such as the Prairie Pothole Region that are potentially overcompensated or more likely to have a moral hazard concern (Wu, Goodwin, and Coble, 2020). However, there might also be other counties and regions that are being undercompensated due to varying cost structures (such as land rent) and low yields. Currently, the prevented planting CF for a given crop is uniform across the U.S., that is, a corn producer will receive 55% of their guaranteed revenue or yield coverage purchased in their crop insurance policy if they are unable to plant. This has been speculated to be driving some disparities in prevented planting indemnity payments across regions (Agralytica Consulting, 2013; USDA OIG, 2013). Therefore, it is of interest to explore prevented planting CFs based on various region-specific factors such as land rent (pre-plant costs) and yields, then explore how these estimated prevented planting CFs might impact federal expenditures for the prevented planting provision. This analysis is also relevant given that farm input prices such as land rent have recently reached record levels (USDA-NASS, 2023). This type of investigation could provide insight into how higher costs impact the returns producers receive from prevented planting claims.

The objective of this paper is to calculate a U.S.-level prevented planting CF that considers county-level variation in land rent, yields, planted acres, and prevented planting acres for corn and soybeans. We estimated these CFs by assuming two threshold levels of \$100/acre and \$200/acre above the land rent cost to demonstrate how higher input costs could influence CFs. We developed simulation models to generate distributions of county-level prevented planting CF based on costs and yields across the U.S., then we estimated a weighted average CF based on insured crop acres and simulated U.S. federal crop insurance expenditures for prevented planting indemnities by using these CFs. Our results will be useful for producers and federal agencies to assess if the prevented planting CF is covering pre-plant costs and how higher costs might impact total prevented planting payments in the U.S. for corn and soybeans.

ECONOMIC FRAMEWORK

Producers who have insurance policies that are eligible for prevented planting have the same options if they are unable to plant within the designated window. One option is planting the insured crop during the 25-day late planting window, but if this option is chosen, the guaranteed coverage level of the policy declines 1% each day during that period. Another option is to switch from the original insured crop to a different insured crop after the late planting window expires, e.g., corn could be shifted to soybeans because the soybean planting window extends past corn for most regions. A producer could also shift to an uninsured secondary crop like an annual grass for haying and/or grazing without impacting their payment.

The most selected option is to forgo planting and take the full prevented planting indemnity (USDA OIG, 2013). This option pays a percentage (i.e., CF) of the guaranteed insured amount, but a harvestable crop cannot be planted on the field with a prevented planting claim in place, instead, the prevented planting field could be left fallow or planted to an unharvested cover crop. Returns to the full prevented planting payment option is mathematically defined as

$$NR_{ik} = p_i^G y_i^{APH} \delta_k \gamma_i - x_i - IP_{ik} \qquad (1)$$

where NR_{ik} is the net return to the full prevented planting payment (\$/acre) for the *i*th crop (*i* = corn or soybeans) with a *k*th crop insurance coverage level (*k* = 50%, 55%, 60%, 65%, 70%, 75%, 80%, and 85%);

p_i^G is the insured price; y_i^{APH} is the actual production history (APH) yield; is the coverage level of the crop insurance; is the prevented planting CF, where corn is 55%, soybeans 60%; is the pre-plant production cost ($/acre); and IP_{ik} is the producer's crop insurance premium ($/acre).

To illustrate this payment for corn, assume there is an RP policy with 75% coverage level, the APH is 190 bu/acre, and the insured price of $4.25/bu would have a guaranteed revenue minimum of $605.62/acre ($605.62 = $4.25 x 190 x 0.75). Prior to planting, assume the producer has spent $200/acre on the land rent, chemicals, insurance premium, and machinery. The full prevented planting payment would pay 55% of the guaranteed revenue minimum, which is $333.09/acre ($333.09 = $605.62 x 0.55), resulting in net returns of $133.09/acre ($333.09 - $200).

This example demonstrates how a higher coverage level, yield, or price can increase the prevented planting payment. Furthermore, land rents vary across the U.S. and are a function of cost structures, yield potential, government payments, and land use and amenities (Allen and Borchers, 2016; Kirwan, 2009), likely impacting the regional disparities in prevented planting payments. These determinants are state- and county-specific, so considering this variability in estimating a prevented planting CF would be helpful to ensure that producers are being reimbursed for their prevented planting costs. Equation (1) provides insight into how to solve for a prevented planting CF that would consider this variability. By setting (1) equal to some revenue minimum (RM) that considers land rent and input costs, we can solve for a prevented planting CF at the county level, which is expressed as

$$\gamma_{ikc}^{*} = \frac{x_i + RM_{ic}}{p_{is}^{G} y_{ic}^{APH} \delta_{ic}} \tag{2}$$

where γ_{ikc}^{*} is the CF for county *c* (*c*=1,...,*C*) and δ_{ic} is the weighted average across coverage levels (of the crop insurance. This would estimate geographic and coverage level variation in the prevented planting CF and would provide producers with a financial safety net if they were unable to plant. The producers' premium cost was not considered in this calculation since crop insurance does not reimburse the premium but the losses.

Simulation Model

Agralytica Consulting (2013) in their analysis of prevented planting provision recognized the limitation of setting a U.S.-level prevented planting CF but cited a large "administrative burden of determining appropriate CFs at the regional, state, or sub-state level" as the reason for using a U.S.-level prevented planting CF. The report also stated that providing a stable and uniform prevented planting CF is vital for producers to efficiently manage their risk. While a prevented planting CF that provides equal returns to all producers without overcompensating would likely reduce moral hazard in prevented planting, the cost would likely be higher than the savings to administer. However, these county- and policy-specific prevented planting CFs can be averaged to find a U.S. average from a distribution of prevented planting CFs. Therefore, we established a simulation model by using stochastic prices, yields, average crop insurance coverage levels, land rents, percent of acres indemnified due to prevented planting, and total acres for a commodity at the county level. First, we simulated Equation (2), which can be re-written as

$$\tilde{\gamma}_{ic}^{*} = \frac{\widetilde{LR}_c + \pi}{\tilde{p}_{is}^{G} \tilde{y}_{ic}^{APH} \tilde{\delta}_{ic}} \tag{3}$$

where "~" denotes a randomly drawn parameter from a distribution; $\widetilde{LR}_c$ is county-level land rents for cropland; and π is a set payment above land rent.

Pre-plant costs typically include land rent along with chemical and machinery costs for burndown and pre-emerge herbicides (Boyer and Smith, 2019). Land rent data are available, but county-level production costs are not recorded and are hard to estimate. Therefore, we simulated the prevented planting CF by assuming a set payment (above land rent of $100/acre and $200/acre. These values were selected to show how the prevented planting CF might vary as input costs increase.

To aggregate these values to the national level, we calculated an acre-weighted average prevented planting CF. The prevented planting CF is weighted with total insured acres within a county and expressed as

$$\tilde{\Gamma}_i^{*} = \sum_{c}^{C} \left[\frac{\tilde{\gamma}_{ic}^{*} \times TA_{ic}}{TA_{ic}}\right] \tag{4}$$

where $\tilde{\Gamma}_i^{*}$ is a weighted average prevented planting CF for commodity i and TA_{ic} is the county total insured acres of commodity i.

Next, we substituted the estimated prevented planting CFs found in (3) into (1) to calculate payments. After that, we aggregated the prevented planting payments across the counties to calculate total prevented planting expenditures with the current prevented planting CF and the hypothetical prevented planting CF that would provide a $100/acre and $200/acre payment above the land rent. This calculation required us to find the total acres lost to prevented planting in a county and the total insured acres in a county. Like Boyer, Park, and Yun (2023), we divided the total lost acres to prevented planting by county by the total insured acres (PV_{ic}). These equation are specified as

$$\widetilde{TPP}_i = \sum_c^C \square\, \tilde{p}_i^G \times \tilde{y}_i^{APH} \times \tilde{\delta}_k \times \gamma_i \times (\widetilde{PV}_{ic}\, \widetilde{\times TA}_{ic}) \tag{5}$$

where TPP_i is the total prevented planting payment and PV_{ic} is the ratio of corn and soybean acres prevented from being planted. We estimated the same payment by using the hypothetical prevented planting CF $(\tilde{\gamma}_{ic}^{*})$ at the two threshold payment levels above land rent. We note here that the model assumes the entire crop's insurance unit is indemnified. Also, we do not account for yield adjustments to policies over time due to frequent prevented planting claims.

Prices, yields, average crop insurance coverage levels, land rents, percent of acres indemnified due to prevented planting, and total acres for a commodity were randomly drawn from a PERT (Project Evaluation and Review Technique) distribution at a county level. We chose this distribution because we simulated county-level distributions individually. By aggregating counties into one distribution, the distribution could be disproportionally weighted: some counties with few acres but a higher prevented planting CF would receive equal weight as those counties with low prevented planting CF but higher acres. Therefore, we ran a simulation for each county using this distribution and weighted the prevented planting CF and expenditures by the insured acres. The PERT distribution is useful when minimal information is available because it requires only minimum, midpoint, and maximum values as the bounds for the distribution (Richardson, 2008). We used Simulation and Econometrics to Analyze Risk (SIMETAR©) to develop the distributions and perform the simulations (Richardson et al., 2008). We simulated a total of 1,000 observations for each distribution.

Data

Data were collected from USDA-RMA and USDA-NASS from 2011 to 2022 for the U.S. The USDA-RMA Summary of Business database provided data on all the sold insurance policies for corn and soybeans (USDA-RMA, 2023b). These county-level data include the number of insurance policies sold, policies indemnified, acre coverage, total premiums, subsidies, and indemnity payments by county, state, year, coverage plan, and coverage level. For example, in a specific county, there could be five observations in a year for RP policies with 50%, 55%, 65%, 75%, and 80% coverage levels, meaning there could be multiple observations within a county.

We used these data to calculate an acre-weighted average coverage level for corn and soybean insurance policies by county. They also provided each county's total number of insured acres by crop. Next, we gathered USDA-RMA cause of loss data to find county-level acres of corn and soybeans lost to prevented planting (USDA-RMA, 2023a). We divided the county-level acres lost to prevented planting by the total insured acres to calculate the ratio of acres lost to prevented planting, which matches the Boyer, Park, and Yun (2023) calculation.

Figures 1 and 2 show the average ratio of acres lost to prevented planting divided by the total insured acres by county for corn and soybeans, respectively; the ratio of insured acres of corn lost to prevented planting is higher on average than soybeans. The Mississippi River Basin has a higher intensity of corn prevented planting acres frequently designated as prevented planting acres due to excessive moisture (USDA OIG, 2013; USDA-RMA, 2023; Boyer, Park, and Yun, 2023). The Prairie Pothole Region also frequently has corn acres indemnified as prevented planting (Wu, Goodwin, and Coble 2020).

APH yield data are not publicly available, which is a challenge for researchers who analyze crop insurance policies, so studies typically use USDA-NASS yields (Kim and Kim, 2018; Seo et al., 2017). We collected county-level NASS yields for corn and soybeans for all the counties that experienced a prevented planting loss in the study period (USDA-NASS, 2023). USDA-NASS was also used to find the county-level cropland cash rent values measured in dollars per acre (USDA-NASS, 2023). Unlike the other data, land rent values were not available for 2015 and 2018 but were available for the remaining years between 2011 and 2022. Finally, the USDA-RMA Price Discovery database provided the states' projected prices set by RMA for corn and soybeans (USDA-RMA, 2022). We excluded counties for both soybean and corn that did not have at least five years of reported data within a county over the study time.

Table 1 shows the summary statistics of the input data in the simulation. The average USDA-RMA-projected price of corn during this time was $4.84 per bushel, and the yield was 149 bushels/acre. The average price for soybeans was $11.45 per bushel, and yields were 45 bushels/acre. The average land rent was $110/acre and $117/acre for the corn counties and soybean counties, respectively. On average, about 3% of the counties in this study area reported prevented planting claims on their insured acres for corn; this was about 2% for soybeans. However, the maximum for the prevented planting ratio for corn and soybeans within a county was 89% and 83%, respectively.

RESULTS

Simulation

Table 2 shows the simulated weighted average prevented planting CF for corn and soybeans, assuming a payment of $100/acre and $200/acre above land rent for a county. Currently, the prevented planting CF for corn is 0.55 and 0.60 for soybeans (USDA-RMA, 2021). Assuming a payment of $100/acre over land rent values, the prevented planting coverage level was found to be 0.49. If pre-plant costs were $200/acre above land rent, the prevented planting CF was 0.70. This means that the current prevented planting CF is likely paying more than $100/acre above land rent but probably not more than $200/acre above land rent. The soybean prevented planting CF was found to be 0.62 and 0.92 when paying $100/acre and $200/acre above land rent, respectively.

Figures 3 and 4 show the simulated prevented planting CF across the study region for corn and soybeans, respectively. The variation of these county-level CFs ranges from as low as 0.2 to over 1, which means the producer would need to be compensated more than their guaranteed coverage payment to cover their land rent. The prevented planting CF is lower in the southern states, where land rents are less the northern states and land rent is higher. Figures 3 and 4 show how geographic factors such as costs, land rent, and yields can impact prevented planting CF.

Table 3 shows the simulated U.S. federal crop insurance expenditures for prevented planting for corn and soybeans. The simulation model estimated the average annual payment for prevented planting to be around $1.1 billion for corn and $216 million for soybeans. The USDA-RMA cause of loss data reported average annual expenditures of prevented planting indemnities to be $733 million for corn and $259 million for soybeans. Therefore, our simulation model estimated higher expenditures for corn but lower expenditures for soybeans. That said, the simulated expenditures with the current CFs served as a baseline to adjusting for $100/ and $200/acre over land rent. For corn, total U.S. expenditures for prevented planting indemnities would decrease if the provision paid $100/acre plus land rent to $929 million but increase to $1.3 billion if the CF paid $200/acre plus land rent. Therefore, the current CF is likely reimbursing producers on average between $100/ and $200/acre plus their land rent. For soybeans, the total U.S. expenditures for prevented planting indemnities would increase to $404 million if the CF paid $100/acre plus land rent and $616 million if the CF paid $200/acre plus land rent. Therefore, the current CF is likely not reimbursing producers $100/acre over land rent for soybeans.

Implications

The findings of this study suggest that the producer's net returns to prevented planting are likely higher for corn than soybeans, thus the incentive to take the full prevented planting payment for corn is higher than for soybeans. This would align with what Boyer and Smith (2019) found when analyzing *ex-post* moral hazard in prevented planting for corn and soybeans. They reported that the incentive for moral hazard in the prevented planting provision is stronger for corn than soybeans. Conversely, they found *ex-post* moral hazard is unlikely to occur for soybeans.

Additionally, the USDA cause of loss data report 29.4 million corn acres indemnified as prevented planting cause of loss from 2011 to 2022. The total soybean acres during the same period (2011 to 2022) are about 15.5 million acres. Many producers who are planting corn could switch to planting soybeans in the same growing season since soybean planting extends later than corn if the herbicide program allows for it. In fact, Adkins et al. (2020) reported a corn producer would maximize their net returns by planting soybeans instead of taking their prevented planting indemnity from corn. Therefore, it is possible a portion of the $29.4 million corn acres indemnified to prevented planting could have been planted in soybeans, but prevented planting CFs for corn provide an optimal incentive to not switch to an alternative crop.

The implication of this study is that the CF for corn is compensating producers more than the soybean prevented planting CF, despite the soybean CF being higher than corn. This higher payment is likely causing more corn prevented planting acres. Our study shows that insuring both corn and soybean producers to be paid $100/acre over there land rent would mean the corn CF would need to be lowered to 0.49 and increased to 0.62 for soybeans. This would result in total expenditures decreasing for corn and increasing for soybeans. Taking the total simulated payments for corn and soybeans at the current CF was found to be $1,370,853 ($216,465,652 + $1,154,387), but if both corn and soybean producers were compensated $100/acre over land rent, the total expenditures would decrease to $1,333,990 ($404,596,475 + $929,393,541).

CONCLUSIONS

The purpose of this study was to generate a distribution of prevented planting CFs that considers county-level variation in land rent, yields, planted acres, and prevented planting acres for corn and soybeans. Simulation models were developed for corn and soybeans assuming input costs of $100/ and $200/acre plus land rent cost to show how higher input costs could influence CFs. While these two values likely do not represent all farmers, they were selected to show how the prevented planting CF might vary as input costs increase. We used these county-level CFs, USDA data to estimate a weighted average CF, and changes in U.S. federal crop insurance expenditures for prevented planting indemnities. These results will be useful for federal agencies to assess if the prevented planting CF is covering the cost thresholds for producers and how this might impact total prevented planting payments in the U.S. for corn and soybeans.

When assuming a payment of $100/ and $200/acre over land rent values, the expected prevented planting CF for corn was 0.49 and 0.70, respectively. The CF for soybeans was 0.62 and 0.92 when paying $100/ and $200 /acre above land rent, respectively. The current CF is 0.55 for corn and 0.6 for soybeans, which is within range of the simulated CF for corn and lower than the average CF for soybeans. The implication of this study is that the CF for corn is compensating producers more than the soybean prevented planting CF, despite the soybean CF being higher than corn. This would match other findings (Boyer and Smith, 2019) and align with USDA-RMA prevented planting acres.

U.S. expenditures for prevented planting indemnities would decrease corn if the CF reimbursed $100/acre plus land rent went to $929 million but increase to $1.3 billion if the CF paid $200/acre plus land rent. The corn CF appears to be reimbursing on average between $100/ and $200/acre plus land rent. U.S. expenditures for prevented planting indemnities for soybeans would increase to $404 million, with a CF paying $100/acre plus land rent and $616 million with a CF paying $200/acre plus land rent. Therefore, the current CF is likely not reimbursing producers $100/acre over land rent for soybeans.

FOOTNOTES

1 An herbicide program would need to be established to allow a producer to switch from corn to soybeans during the planting window.

2 Eligible policies include Revenue Protection (RP), RP with the Harvest Price Exclusion (RPHPE), and Yield Protection insurance plans. The insured must have been prevented to plant the lesser of 20 acres or 20% of a unit.

3 The final planting date is the last day an insured crop can be planted and remain eligible for full crop insurance coverage. After the final planting date, the late planting period begins and lasts for 25 days.

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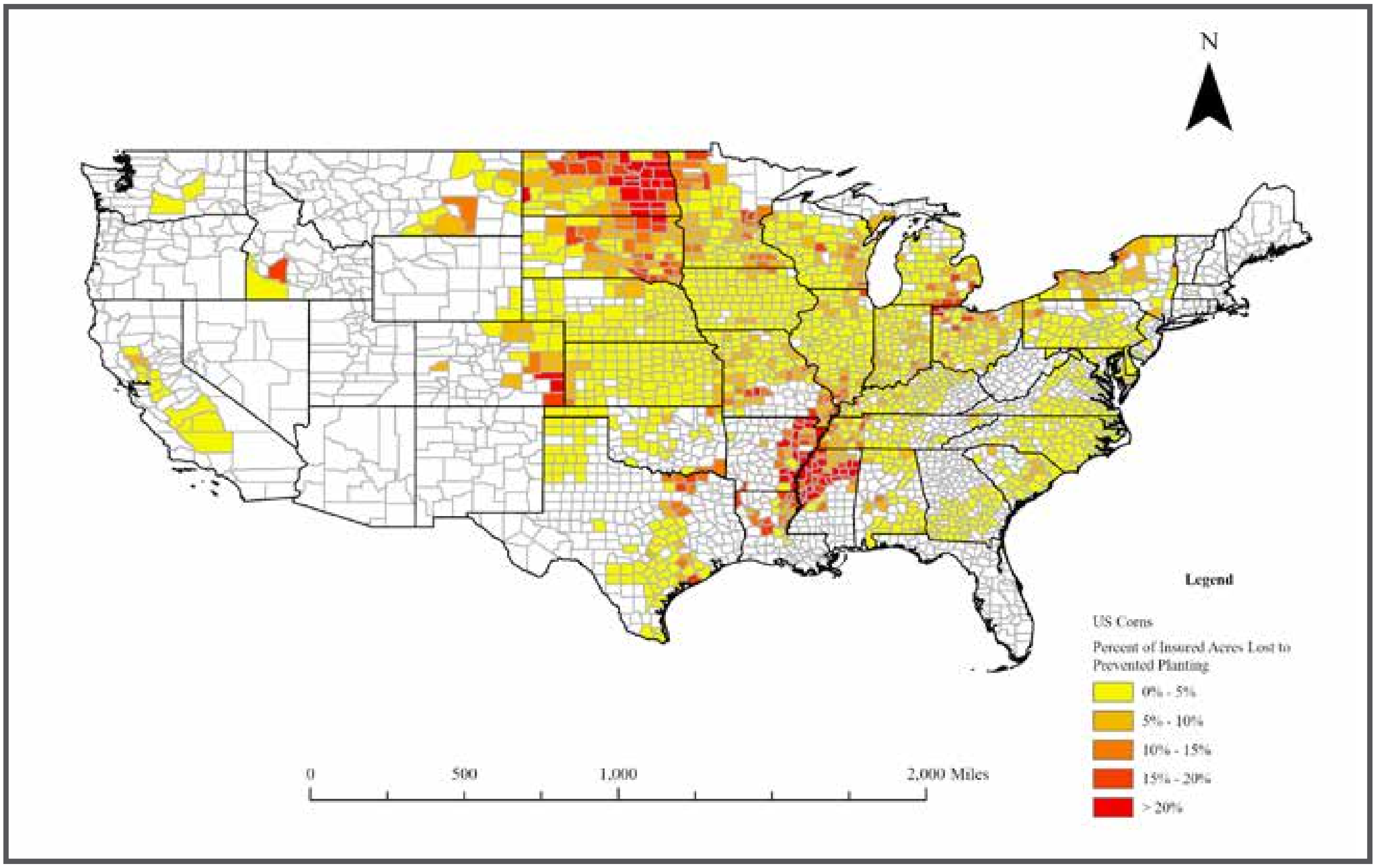

Figure 1. Ratio of prevented planted to total insured acres for corn from 2011 to 2022

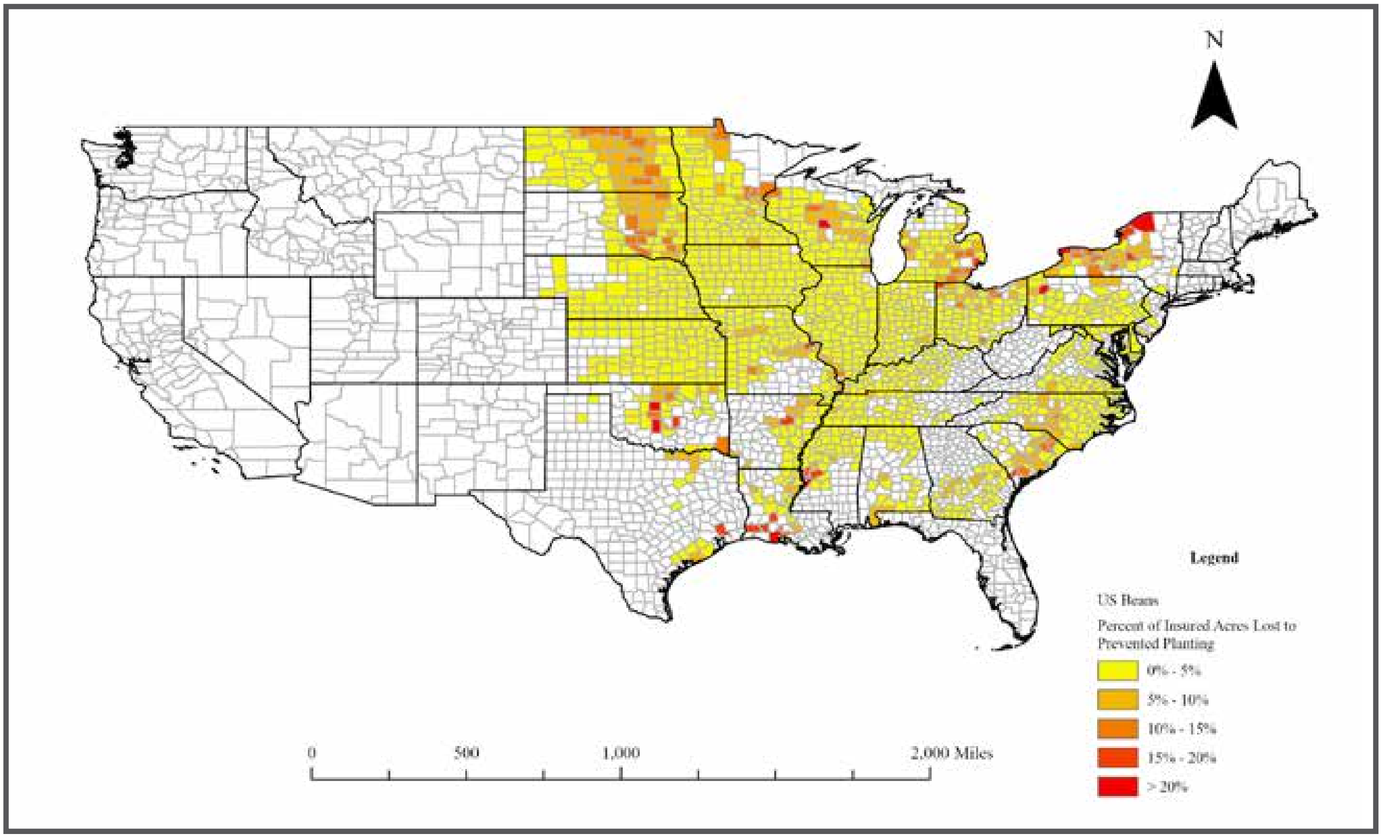

Figure 2. Ratio of prevented planted to total insured acres for soybeans from 2011 to 2022

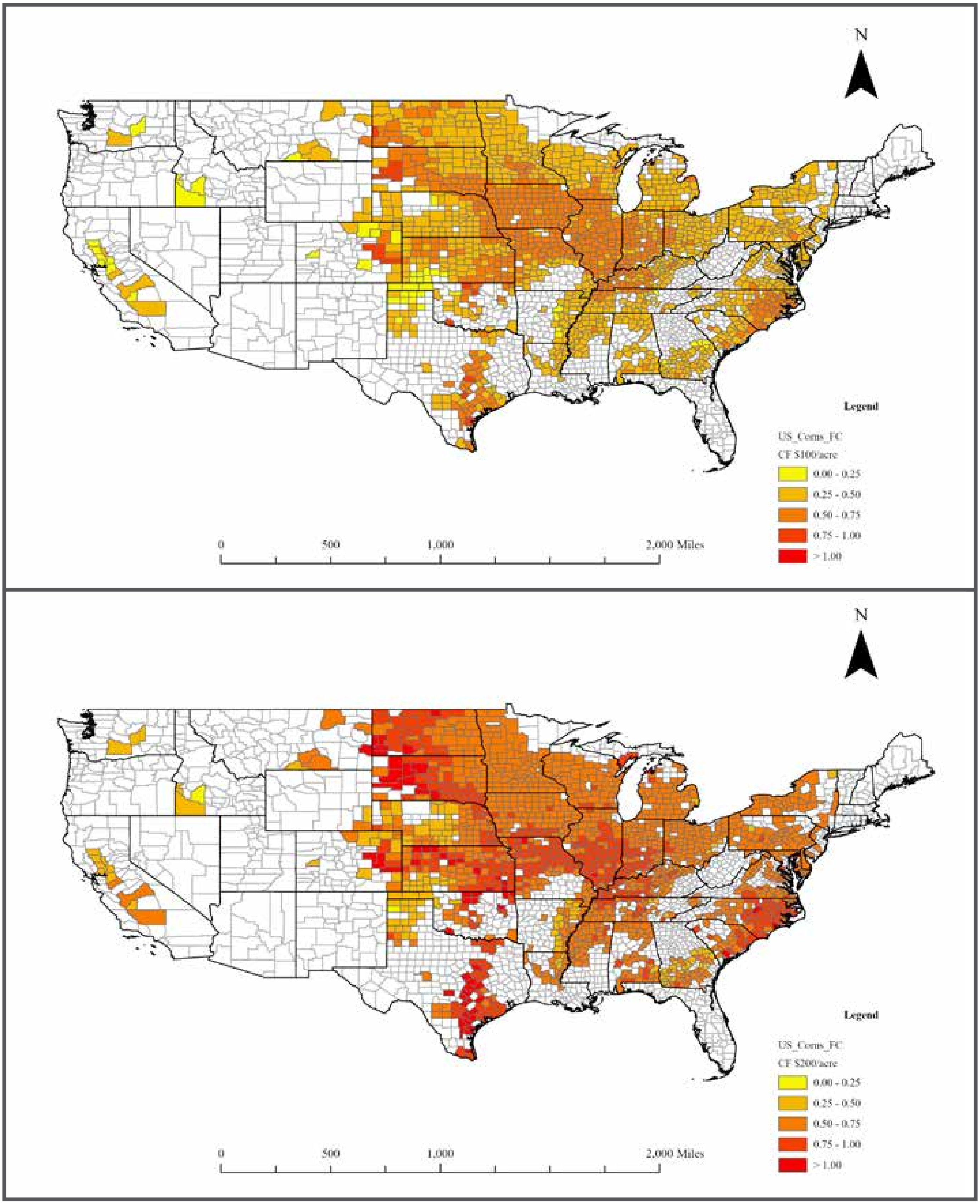

Figure 3. Expected prevented planting CF from simulation model for corn by county and payment threshold level with top map being $100/acre and bottom map being $200/acre

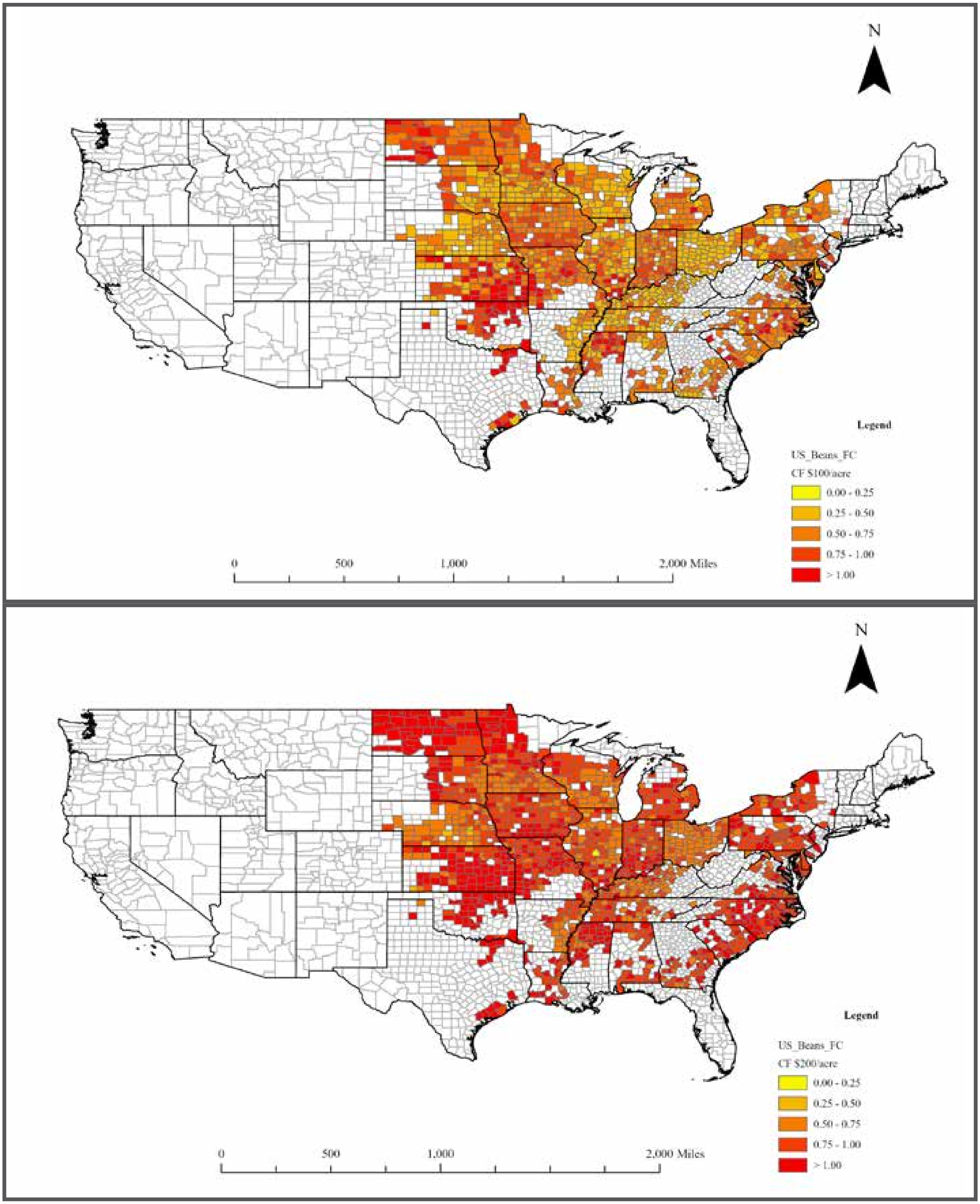

Figure 4. Expected prevented planting CF from simulation model for soybeans by county and payment threshold level with top map being $100/acre and bottom map being $200/acre

Table 1. Summary Statistics of County-Level Data Used in the Simulation Models for Corn (n = 12,782) and Soybeans (n = 11,749) from 2011 to 2022

Variable	Average	Standard Deviation	Minimum	Maximum
	Corn			
Price	$4.84	0.87	$3.81	$6.32
USDA-NASS Yield[1]	149.55	40.19	10.40	277.10
Weighted Average Coverage Level	0.67	0.03	0.50	0.80
Cropland Rent	$110.85	69.66	$10.50	$371.00
Total Insured Acres	47,807	54,299	123	336,382
Percent of Insured Acres Lost to Prevented Planting	0.03	0.09	0.00	0.89
	Soybean			
Price	$11.45	1.79	$8.85	$14.33
USDA-NASS Yield[1]	45.38	11.01	5.10	77.30
Weighted Average Coverage Level	0.67	0.03	0.54	0.80
Total Insured Acres	$117.11	68.28	$12.50	$371.00
Percent of Insured Acres Lost to Prevented Planting	47,675	51,295	339	473,921
Total Insured Acres	0.02	0.05	0.00	0.83

[1] United States Department of Agriculture National Agricultural Statistic Service.

Table 2. Simulated Weighted Average Prevented Planting Coverage Factors for Corn and Soybeans to Reimburse Producers $100/ and $200/Acre Over Land Rent

	Corn		Soybean	
CF	Mean	Standard Deviation	Mean	Standard Deviation
$100/Acre Over Land Rent	0.49	0.01	0.62	0.05
$200/Acre Over Land Rent	0.70	0.02	0.92	0.08

Table 3. Simulated Weighted Average Prevented Planting Indemnity Payment for Corn and Soybeans to Reimburse Producers $100/ and $200/acre Plus Land Rent

Prevented Planting Payment	Mean	Standard Deviation
	Corn	
Current CF	$1,154,387,804	$39,248,315
CF Paying $100/Acre Plus Land Rent	$929,393,541	$31,492,164
CF Paying $200/Acre Plus Land Rent	$1,339,041,412	$44,922,118
	Soybeans	
Current CF	$216,465,652	$9,617,786
CF Paying $100/Acre Plus Land Rent	$404,596,475	$14,211,034
CF Paying $200/Acre Plus Land Rent	$616,793,007	$21,683,207

Farmland Values in California: Pre- and Post-COVID-19 Perspectives

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Abstract

The specialty crop industry in California is still adapting to the ever-changing circumstances in the aftermath of the COVID-19 outbreak, including labor shortage and market disruptions. This article utilizes secondary data to shed light on the most recent trends in farmland values for specific fruits and tree nuts in the state, as well as the various factors that may impact farmland values. These factors encompass crop yield, production levels, and a range of macroeconomic indicators. Subsequently, we employ correlation analyses to furnish evidence indicating that the degree of association between farmland values in California and these factors differs depending on the type of commodity.

INTRODUCTION

Similar to other major fruit and vegetable areas of the world, California's specialty crop growers faced unprecedented shocks to the supply chain due to the COVID-19 outbreak. This resulted in shifts in food prices (Yu et al., 2020; Bairagi, Mishra, and Mottaleb, 2022) and labor shortages (Beatty, Martin, and Rutledge, 2020; Charlton and Castillo, 2020). The global food supply experienced disruptions to varying degrees—for example, the fresh produce supply chain remained robust in Canada during the pandemic (Richards and Richard, 2020; Chenarides, Richards, and Richard, 2021), and vegetable supply chains demonstrated resilience in Ethiopia (Hirvonen et al., 2021), but produce supply chains were severely disrupted in Senegal (Fabry et al., 2022). The economic impacts of COVID-19 on different specialty crops in the U.S. varied, such as increased production expenses and supply chain disruptions (Ridley and Devadoss, 2020; Goodrich, Kiesel and Bruno, 2021).

Understanding the trends of farmland prices is crucial for growers, as land serves as both an essential input and asset. Due to the economic shutdown during the COVID-19 pandemic, agricultural producers expect to face reduced crop returns, which is putting downward pressure on farmland values (Lawley, 2020). However, numerous prior studies exploring the impact of COVID-19 on farmland values have revealed either positive or no discernible effect in various geographic areas. For instance, Deaton (2021) conducted a survey on farmland values in Ontario and reported that nearly 60% of respondents indicated no effect of COVID-19 on the land values, with more than 80% of respondents expected farmland values in the area to remain stable or increase after 2020. Oppendahl (2021) found an average annual increase of 6% in agricultural land values in five Midwest states from 2020 to 2021. Similarly, Zhang (2020) and Zhang and

Duffy (2020) conducted a survey in Iowa and indicated that respondents anticipated stable or rising land values in the year following 2020. Additionally, Zhang and Basha (2022) used secondary data to demonstrate that the average farmland values in the state of Iowa rose by 30% in 2021. However, there is a scarcity of research regarding farmland values in California. In this research, our primary focus is on California, given its unique role in nurturing the growth of a diverse range of specialty crops. We choose to study the years 2018 to 2020, encompassing pre-pandemic (2018-2019), pandemic (2020), and post-pandemic years (2021-2022).

There are some general trends of farmland values in California compared to the U.S. between 2018 and 2020 based on the data from the USDA National Agricultural Statistics Service (USDA NASS, 2023). As shown in Table 1, farmland values in California are three times higher than the national average in the U.S. Prior to the COVID-19 outbreak, the values of both cropland and farmland including buildings were increasing in both the U.S. and California. However, as seen in Table 1, the rate of increase was significantly higher in California. In 2020, the value of California's cropland experienced a slight increase of 0.5%, despite disruptions in the specialty crop industry. Meanwhile, cropland value in the U.S. remained unchanged from the previous year. Following 2020, both cropland values and values of farmland with buildings experienced rapid growth, both in the state and nationally, with the country seeing a slightly higher growth rate. It appears that the onset of COVID-19 initially slowed down the growth of farmland values, but the increase rebounded swiftly thereafter.

Another trend of economic interest is the rent paid for farmland, which represents the net return on the agricultural land. When adjusting for inflation, we examined the real cropland price-to-rent ratios over the past five years, mirroring the findings of Zulauf, et al. (2022), which revealed a consistent upward trend in the U.S. However, as shown in Figure 1, in California, these ratios trended down between 2018 and 2020. From 2021 onward, there was a rapid and substantial increase, surpassing the national trend. This divergence can be attributed to pre-pandemic conditions, when cash rents for cropland in California experienced a notably faster growth compared to the appreciation of farmland values. In 2021, when cash rents decreased, farmland value in the state continued to rise.

To further understand the trends and elements that influence the farmland values in California, in the rest of the paper, we will analyze secondary data from 2018-2022 to track recent trends in farmland values for three tree nuts (walnuts, almonds, pistachios) and a group of fruits (wine, raisin, and table grapes, peaches, cherries, citrus, avocados, strawberries, and dates) in California. Given the prevalence of specialty crops in the state, we consider a diverse group of factors that might influence farmland values in California. Additionally, we use correlation analysis to discern associations between farmland values and these factors, depending on the specific type of commodity. Our study aims to shed light on the varied trends in California's farmland values and their connections to commodity and farmland market conditions, as well as the broader macroeconomic environment.

CALIFORNIA FARMLAND VALUES IN RECENT YEARS

Tree nuts—walnuts, almonds, pistachios—collectively contribute 6% to California's farm value (CDFA 2023). As displayed in Table 2, from 2018 to 2022, average per-acre values for pistachio land were highest at $46,100, followed by almonds at $38,142, and walnuts at $32,680. In 2020, values for all three increased, with pistachios leading at 14.29%. Post-2020, almonds and pistachios continued rapid growth, while walnut values slightly dropped in 2021 but rebounded in 2022. Over five years, almond values increased 25%, pistachios rose 55%, and walnuts remained stable.

For grapes, significant increases occurred in wine grape farmland values (28% from 2018 to 2022), raisin grapes (26%), and moderate changes in table grapes. In 2020, grape values remained stable, except for table grapes, which surged by 28.16%. Post-pandemic, wine and raisin grapes resumed upward trends, while table grape values dropped in 2022.

Farmland values for various fruits showed diverse trends. Avocado and date values surged over 20%, citrus and strawberries rose around 16%, and peaches and cherries increased slightly over 10%. In 2020, values remained stable or slightly increased, with significant variations post-2020.

Factors that Influence Farmland Values

Agricultural Returns to Farmland

California contributes 73% of total farm cash receipts for key commodities in the U.S. (Skorbiansky et al., 2022). Figure 2 illustrates nominal cash receipts for fruits and nuts, revealing a 4.5% drop in 2020 due to COVID-19 challenges (Johnson, 2020). However, 2021 and 2022 saw a rebound, reaching $30.84 million, driven by increased consumer demand and adaptive food supply chains.

Commodity Prices

Approximately 75% of U.S. fruits and nuts are from California, contributing 44% to total farm sales (Goodhue, Martin, and Simon, 2021). Table 3 indicates significant price fluctuations for walnuts, pistachios, almonds, and grapes. Notably, walnut prices rose by 20.83%, but in 2022, walnut growers faced a 56.55% decrease. Grapes are an important specialty crop cultivated in California, contributing a total of $5.23 billion in 2022 (CDFA, 2023). Grape growers also witnessed notable fluctuations, with table grapes leading to a 19.13% price increase in 2022.

In the post-2020 years, most commodities saw rapid price increases such as peaches, cherries, and avocados. Avocado prices, in particular, surged at a remarkable rate partially due to the growing global demand for this commodity (Huang, Blare, and Hammami, 2023).

Commodity Production

Table 4 depicts fluctuations in tree nut and grape production. Noteworthy is the 2020 surge in tree nut production and a subsequent decline in almond and pistachio production in 2022. Grape production showed declines, and as of 2022, production levels for several commodities remained below pre-pandemic levels.

Macroeconomic Environment

Numerous macroeconomic variables can influence farmland values, such as interest rates, inflation rates, housing prices, and prevailing trends in the stock market (Lawley, 2020; Schnitkey, 2016). Table 5 highlights the 58.41% drop in the 10-year treasury bond interest rate in 2020. Although lower interest costs might cause additional investments with lower capital costs, Cheng, Wessel, and Younger (2020) found that the drastic decline triggered investment uncertainty, resulting in altered investment strategies. By 2022, the interest rate had rebounded to its 2018 level, which marked a possible sign in the economic recovery.

Regarding inflation, we examine the Consumer Price Index (CPI) and Producer Price Index (PPI) for fruits and vegetables, key indicators of price trends in these essential specialty crop commodities (BLS, 2023a; BLS, 2023b). Inflation, measured by CPI and PPI for fruits and vegetables, surged in 2022, with CPI rising by 8.53% and PPI by 14.78%.

We also consider housing prices, which have been shown to be associated with farmland values, depending on proximity (Huang, et al., 2006). Over the course of the last five years, the most striking development occurred in 2022, when the median prices of single-family homes in California surged by 44% when compared to the baseline year of 2018.

Before the pandemic, the stock market was thriving. However, when COVID-19 struck, and many businesses across various industries were forced to close, the growth rate of the Dow Jones Index plummeted significantly. The pattern of the S&P 500 Index over the last five years closely mirrors that of the Dow Jones Index, which underscores the synchronized movement of these two influential market indicators. However, the growth rate of the S&P 500 Index did not plummet as steeply as that of the Dow Jones Index. This could be attributed to the broader diversity of companies represented in the S&P 500 Index, which includes a wider range of industries.

RESULTS FROM CORRELATION ANALYSIS

In examining the factors influencing fluctuations in farmland values across various commodities in California, three distinct groups of factors were analyzed. The first group focused on commodity-specific factors, including cultivated acres, crop yield, total production, and grower prices. The second group extended the analysis to macroeconomic indicators such as CPI, PPI, Dow Jones Index, 10-year treasury bond interest rates, and housing prices. The third group explored factors linked to agricultural land and farm returns, including cash rent for irrigated crop land, assessed value of irrigated crop land, and cash receipts for fruit and tree nut farmers.

Tree Nuts

Figure 3 illustrates correlations between farmland values of different tree nuts and the three groups of factors. Notably, associations vary among almonds, pistachios, and walnuts. Almond and pistachio farmland values show a positive correlation with acres but a negative correlation with yield, while walnut values exhibit different patterns. Macro-economic factors show interesting relationships, with pistachios and almonds aligning closely with CPI, PPI, Dow Jones Index, and housing prices, while walnuts display distinct correlations. Agricultural land and farm returns indicate shared patterns for almonds and pistachios, with a potential tradeoff between crop land rental costs and land values.

Grapes

Figure 4 reveals consistent correlations for farmland values of wine, raisin, and table grapes. Negative correlations exist with factors like acres, yield, and total production, while positive associations are observed with grower prices. Macro-economic factors exhibit shared patterns, with all grape varieties showing a negative correlation with 10-year treasury bond interest rates. Wine and raisin grapes display positive relationships with the value of irrigated cropland and cash receipts, while table grapes show a negative association.

Other Fruits

In Figure 5, farmland values for different fruits demonstrate positive correlations with various indicators and negative correlations with cash rent for irrigated cropland. Varied relationships exist with factors like acres, yield, total production, grower prices, and interest rates.

Except for peach land, farmland values of all commodities demonstrate a positive relationship with acres bearing. Similarly, these values show a negative relationship with yield except for dates land. Furthermore, farmland values of peaches, cherries, citrus, and avocados are negatively correlated with total production, while the land values for strawberries and dates display a strong positive relationship with total output. Moreover, farmland values of peaches, cherries, avocadoes, and strawberries exhibit a robust positive correlation with grower prices, whereas the land values for citrus and dates show a negative relationship with prices.

Based on the correlation coefficients, we present a list of commodities with significant associations with variables in the three groups. Table 6 shows that farmland values for pistachios, almonds, cherries, citrus, strawberries, and dates display robust positive correlation with acres bearing. Meanwhile, land values for strawberries and dates also display strong positive correlations with total production. Conversely, farmland values of three types of grapes and peaches show significant negative correlations with yield and total production. The land values of peaches, cherries, avocadoes, and strawberries trend in line with grower prices, while those of the three tree nuts and citrus move inversely to prices.

In addition, farmland values for pistachios, almonds, wind grapes, raisin grapes, peaches, cherries, citrus, avocados, strawberries, and dates share a significantly positive relationship with CPI, PPI, Dow Jones Index, and housing prices. They also demonstrate strong positive correlations with values of irrigated cropland and cash receipts but a marked negative relationship with cash rents for irrigated cropland. Furthermore, farmland values for walnuts, peaches, and cherries show a strong positive relationship with 10-year treasury bond interest rates, whereas those of table grapes and dates exhibit a strong negative association with the same variable.

CONCLUSIONS

Farmland values in California experienced varying degrees of fluctuations between 2018 and 2022. Among the 12 tree nuts and fruits assessed, all showed stability or increases in land value in 2020 compared to 2019. The majority of these commodities continued an upward trajectory in farmland value in the post-pandemic years.

Additionally, we examined the changes in three groups of factors that might influence farmland values and their correlations with land value changes. Farmland values of 10 selected commodities exhibited a strong positive correlation with CPI, PPI, and housing prices. Stock market conditions showed a positive relationship with land values for pistachio, almond, wine grape, raisin grape, citrus, strawberry, and dates. Moreover, walnut, peach, and cherry land values were positively related to 10-year treasury bond interest rates. However, higher land values for table grapes and dates were associated with lower interest rates.

We find that farmland values for all selected commodities have a significant positive association with cash receipts, except for walnut, table grape, and dates. Land values for pistachio, almond, wine grape, raisin grape, cherry, citrus, avocado, strawberry, and dates share a significant negative association with cash rent paid for irrigated cropland. Furthermore, the land values of tree nuts are positively associated with either acres bearing or yield. Strawberry land values are positively related to acres bearing, total production, and grower prices. Interestingly, farmland values for all three grape varieties are negatively correlated with acres bearing, yield, and total production, while those for tree nuts and citrus are negatively correlated with grower prices.

Our study is exploratory, and our findings do not establish direct causal relationships between farmland values in California and variables in the three groups covering commodity and land markets, as well as the macroeconomic environment. Nevertheless, they offer valuable insights into the intricate dynamics of the agricultural land market. Our findings also suggest several avenues for future research, all of which have the potential to yield insights for industrial and policymaking audiences. By shedding light on the significant relationships and identifying potential influential factors, our study contributes to a deeper understanding of the various factors in shaping farmland values for specialty crops in the state.

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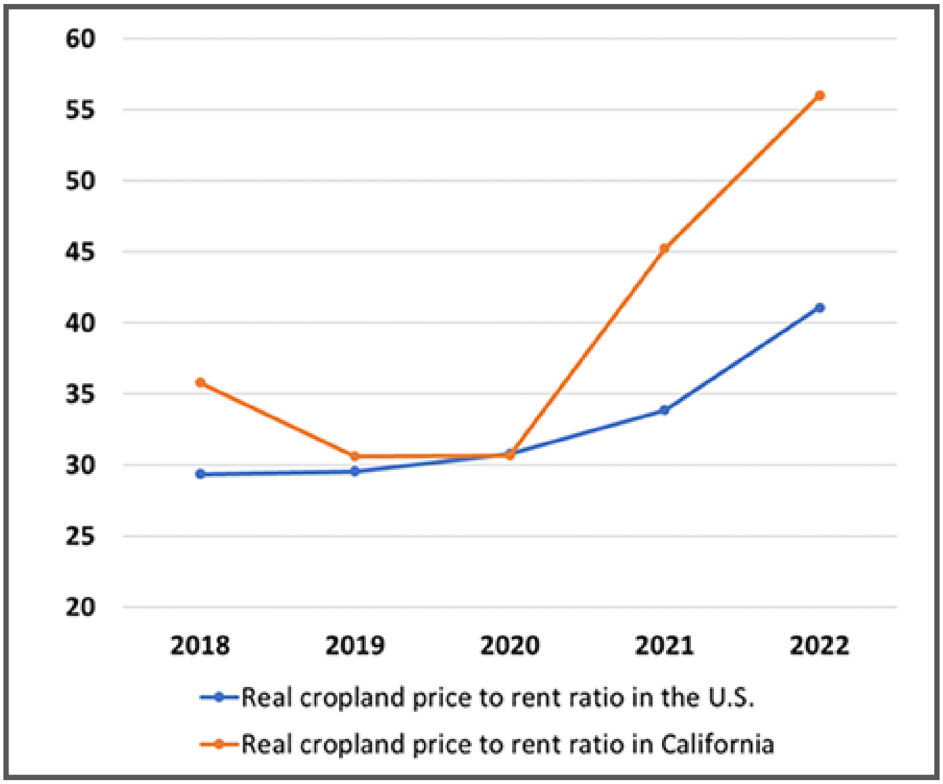


Figure 1. Real cropland price to cash rent ratios in California and in the United States during 2018–2022 (Source: Ratios calculated based on the data from USDA NASS and BLS)

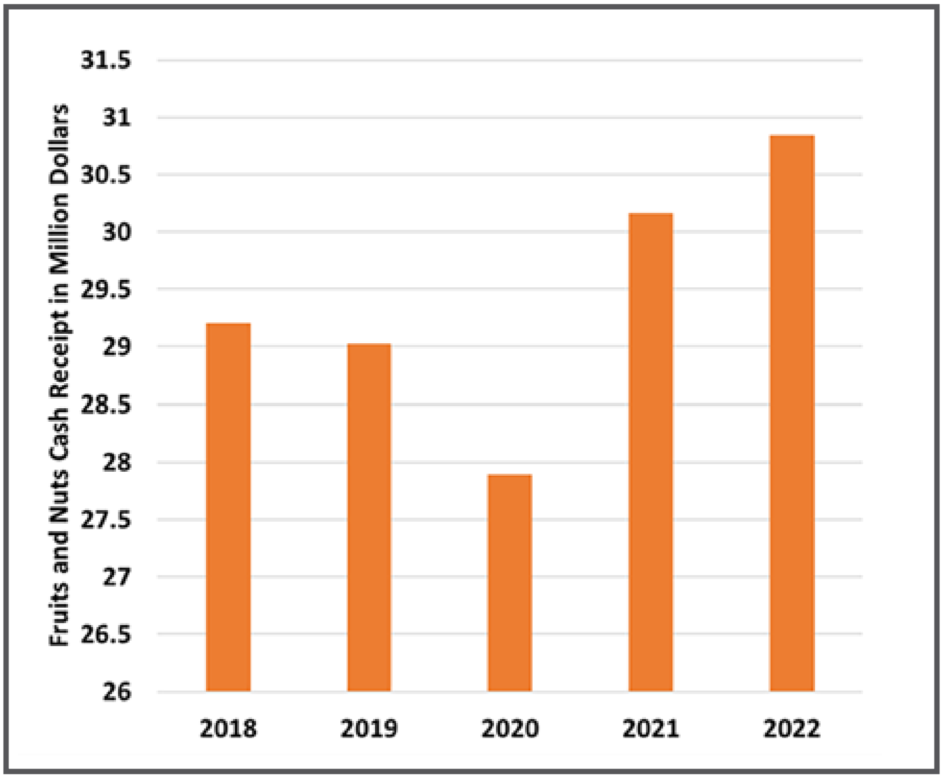


Figure 2. Nominal cash receipts for fruits and nuts in the United States during 2018–2022 (Source: USDA ERS 2022)

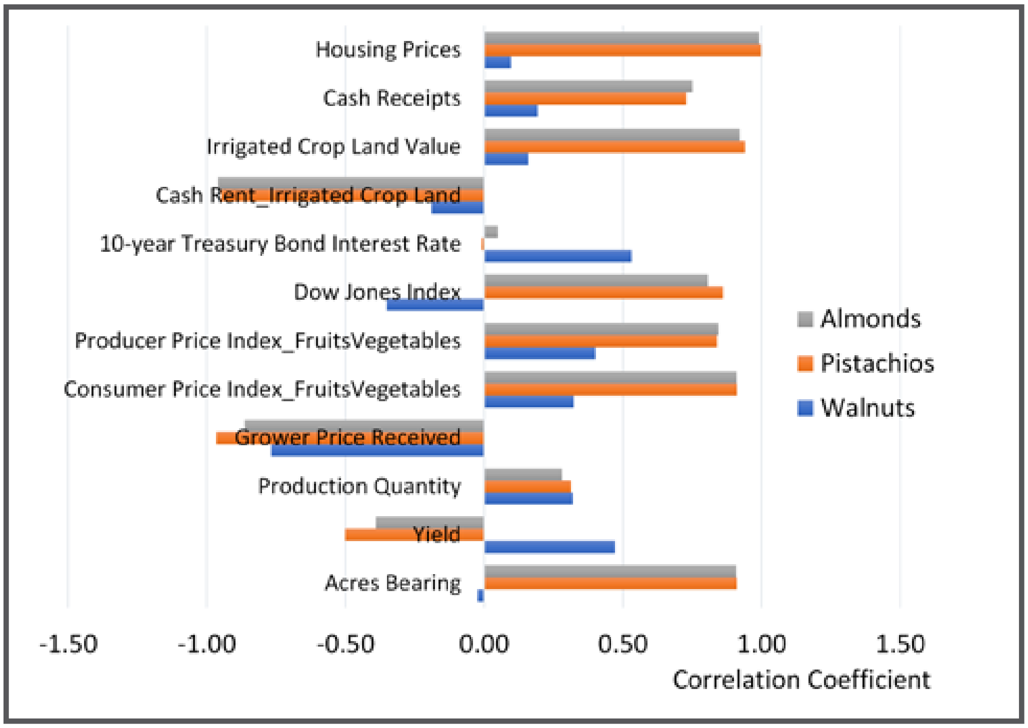


Figure 3. Correlations between California tree nut farmland values and selected factors

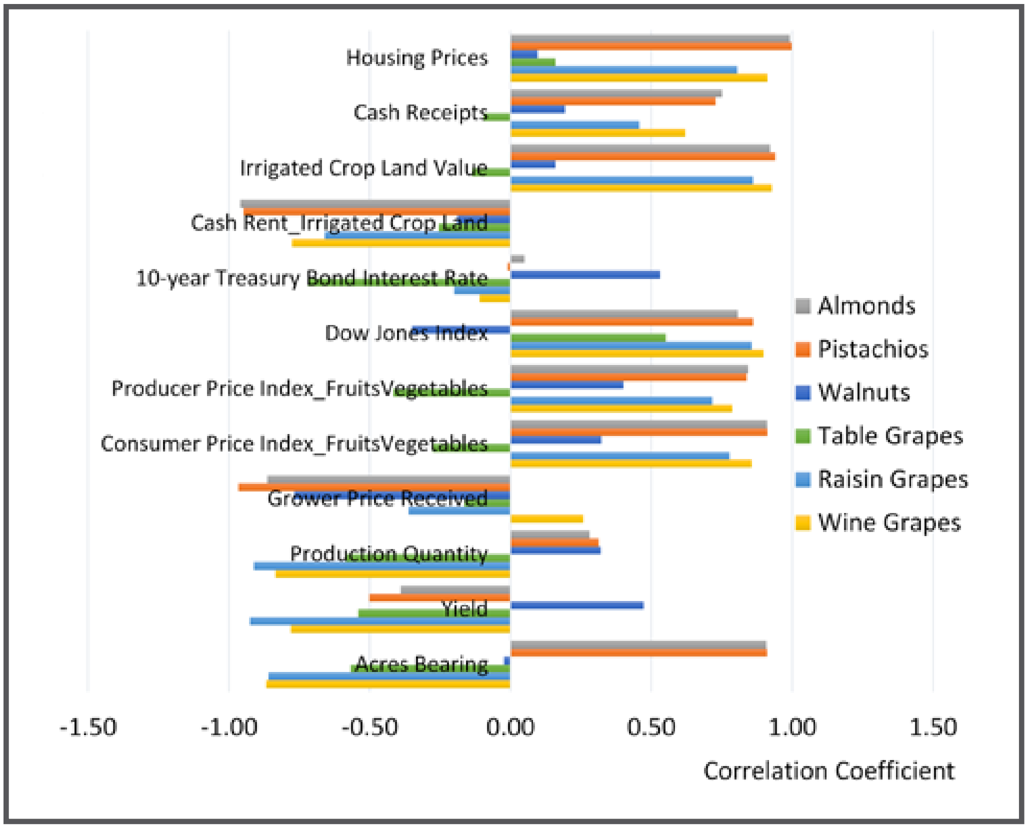


Figure 4. Correlations between California grape farmland values and selected factors

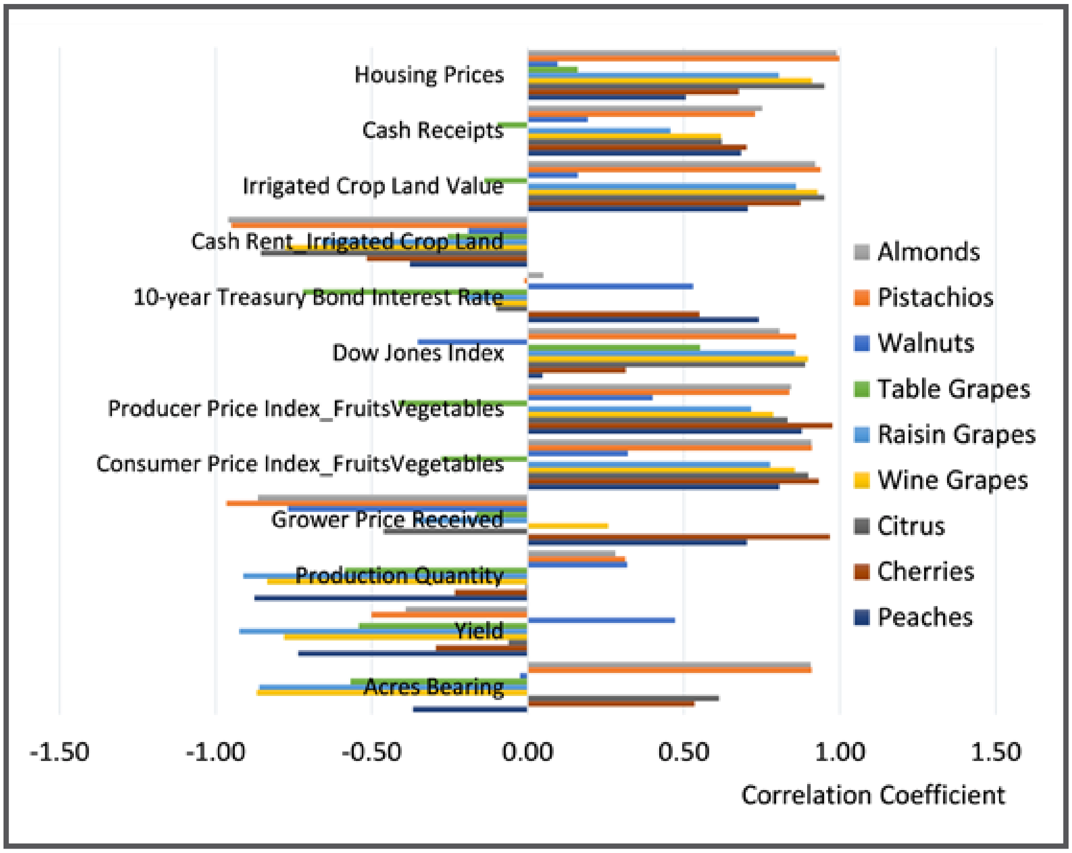


Figure 5. Correlations between California fruit farmland values and selected factors

Table 1. Nominal Agricultural Land Values in California and in the United States, 2018–2022, $/Acre

Year	California				United States			
	Cropland	Annual % change	Ag Land including buildings	Annual % change	Cropland	Annual % change	Ag Land including buildings	Annual % change
2018	$12,170		$9,350		$ 4,050		$3,100	
2019	$12,830	5.4%	$10,000	7.0%	$ 4,100	1.2%	$3,160	1.9%
2020	$12,900	0.5%	$10,000	0.0%	$ 4,100	0.0%	$3,160	0.0%
2021	$13,860	7.4%	$10,900	9.0%	$ 4,420	7.8%	$3,380	7.0%
2022	$15,410	11.2%	$12,000	10.1%	$ 5,050	14.3%	$3,800	12.4%

Source: USDA NASS Quick Stats 2023.

Table 2. Nominal Agricultural Land Values and Annual Returns for Selected Specialty Crops in California

Tree Nuts Year	Walnuts		Almonds		Pistachios	
	$/Acre	% change	$/Acre	% change	$/Acre	% change
2018	$33,650	$34,750		$37,000		
2019	$31,500	-6.39%	$34,000	-2.16%	$38,500	4.05%
2020	$32,750	3.97%	$37,000	8.82%	$44,000	14.29%
2021	$32,000	-2.29%	$41,500	12.16%	$53,500	21.59%
2022	$33,500	4.69%	$43,458	4.72%	$57,500	7.48%
Grapes **Year**	**Wine Grapes**		**Raisin Grapes**		**Table Grapes**	
	$/Acre	% change	$/Acre	% change	$/Acre	% change
2018	$127,700	$30,000	$37,667			
2019	$145,400	13.86%	$35,000	16.67%	$38,667	2.65%
2020	$145,400	0.00%	$35,000	0.00%	$38,667	0.00%
2021	$156,400	7.57%	$36,000	2.86%	$40,500	4.74%
2022	$164,000	4.86%	$38,000	5.56%	$37,167	-8.23%
Other Fruits **Year**	**Peaches**		**Cherries**		**Citrus**	
	$/Acre	% change	$/Acre	% change	$/Acre	% change
2018	$30,000	$36,000	$42,667			
2019	$28,000	-6.67%	$36,000	0.00%	$45,000	5.47%
2020	$28,000	0.00%	$36,000	0.00%	$46,083	2.41%
2021	$28,000	0.00%	$36,000	0.00%	$47,833	3.80%
2022	$34,000	21.43%	$40,000	11.11%	$49,583	3.66%
Year	**Avocadoes**		**Strawberries**		**Dates**	
	$/Acre	% change	$/Acre	% change	$/Acre	% change
2018	$44,000	$60,167	$50,000			
2019	$45,000	2.27%	$64,333	6.93%	$57,000	14.00%
2020	$45,000	0.00%	$66,167	2.85%	$60,000	5.26%
2021	$45,000	0.00%	$68,917	4.16%	$60,000	0.00%
2022	$54,000	20.00%	$70,250	1.93%	$60,000	0.00%

Source: Trends 2023.

Table 3. Prices Received by Growers in California for Selected Specialty Crops

Tree Nuts Year	Walnuts		Almonds		Pistachios	
	$/lb	% change	$/lb	% change	$/lb	% change
2018	$0.68		$2.50		$2.65	
2019	$0.95	40.00%	$2.45	-2.00%	$2.81	6.04%
2020	$0.60	-36.51%	$1.71	-30.20%	$2.51	-10.68%
2021	$0.73	20.83%	$1.86	8.77%	$2.16	-13.94%
2022	$0.32	-56.55%	$1.40	-24.73%	$2.11	-2.31%
***Grapes* Year**	**Wine Grapes**		**Raisin Grapes**		**Table Grapes**	
	$/lb	% change	$/lb	% change	$/lb	% change
2018	$0.51		$0.21		$0.49	
2019	$0.49	-3.76%	$0.13	-37.85%	$0.52	5.32%
2020	$0.40	-18.11%	$0.13	-3.76%	$0.66	28.16%
2021	$0.50	25.25%	$0.18	38.28%	$0.58	-12.88%
2022	$0.54	7.32%	$0.19	6.78%	$0.69	19.13%
***Other Fruits* Year**	**Peaches**		**Cherries**		**Citrus**	
	$/lb	% change	$/lb	% change	$/lb	% change
2018	$0.32		$1.59		$23.94	
2019	$0.30	-6.42%	$1.76	10.69%	$16.64	-30.51%
2020	$0.37	22.24%	$1.66	-5.97%	$15.45	-7.15%
2021	$0.38	2.87%	$1.72	3.93%	$19.15	23.99%
2022	$0.44	17.42%	$2.24	29.94%	$18.40	-3.94%
Year	**Avocadoes**		**Strawberries**		**Dates**	
	$/lb	% change	$/lb	% change	$/lb	% change
2018	$1.14		$0.90		$1.48	
2019	$1.72	51.54%	$1.10	22.91%	$1.43	-3.38%
2020	$1.10	-36.34%	$0.93	-15.36%	$1.16	-18.88%
2021	$1.22	10.96%	$1.25	34.26%	$1.54	32.33%
2022	$1.77	45.27%	$1.08	-13.60%	$1.42	-7.49%

Source: USDA NASS Quick Stats 2023.

Table 4. Total Production Quantity in California for Selected Specialty Crops

Tree Nuts Year	Walnuts		Almonds		Pistachios	
	1,000 tons	% change	1,000 tons	% change	1,000 tons	% change
2018	679		1,140		494	
2019	655	-3.53%	1,280	12.28%	371	-24.92%
2020	790	20.61%	1,558	21.68%	523	41.03%
2021	725	-8.23%	1,458	-6.42%	578	10.53%
2022	752	3.72%	1,283	-12.01%	441	-23.64%
***Grapes* Year**	**Wine Grapes**		**Raisin Grapes**		**Table Grapes**	
	1,000 tons	% change	1,000 tons	% change	1,000 tons	% change
2018	4,285		1,545		1,300	
2019	3,920	-8.52%	1,380	-10.68%	1,190	-8.46%
2020	3,415	-12.88%	1,190	-13.77%	1,110	-6.72%
2021	3,635	6.44%	1,070	-10.08%	1,050	-5.41%
2022	3,380	-7.02%	1,010	-5.61%	1,120	6.67%
***Other Fruits* Year**	**Peaches**		**Cherries**		**Citrus**	
	1,000 tons	% change	1,000 tons	% change	1,000 tons	% change
2018	479		44		3,536	
2019	498	3.97%	53	19.38%	4,072	15.16%
2020	503	1.00%	64	20.54%	4,260	4.62%
2021	505	0.40%	99	55.79%	4,136	-2.91%
2022	475	-5.94%	54	-45.80%	3,472	-16.05%
Year	**Avocadoes**		**Strawberries**		**Dates**	
	1,000 tons	% change	1,000 tons	% change	1,000 tons	% change
2018	169		1,165		29	
2019	108	-35.88%	1,039	-10.85%	48	65.50%
2020	188	73.33%	1,188	14.35%	49	1.74%
2021	135	-28.25%	1,208	1.68%	53	7.16%
2022	138	2.52%	1,239	2.61%	49	-6.57%

Source: USDA NASS Quick Stats 2023.

Table 5. Macroeconomic Indicators and Annual Changes During 2018–2022

Year	10-Year Treasury Bond Interest Rate		Consumer Price Index		Producer Price Index	
	Average Yield	% change	F&V	% change	F&V	% change
2018	2.91%		297.79		186.83	
2019	2.14%	-26.46%	300.85	1.03%	188.30	0.79%
2020	0.89%	-58.41%	304.93	1.35%	190.46	1.15%
2021	1.45%	62.92%	314.81	3.24%	195.83	2.82%
2022	2.95%	103.45%	341.67	8.53%	224.78	14.78%

Year	Prices of Single-Family Home		Dow Jones Index		S&P 500 Index	
	Median price in CA	% change	Year Close Price	% change	Average Closing Price	% change
2018	$571,058		$23,327		$2,507	
2019	$591,866	3.64%	$28,538	22.34%	$3,231	28.88%
2020	$650,157	9.85%	$30,606	7.25%	$3,756	16.26%
2021	$786,275	20.94%	$36,338	18.73%	$4,766	26.89%
2022	$822,527	4.61%	$33,147	-8.78%	$3,840	-19.44%

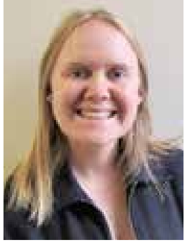
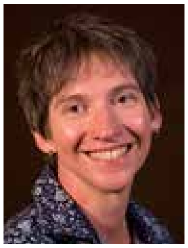
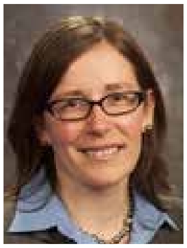
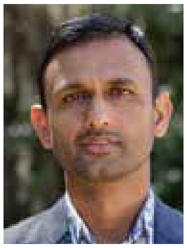
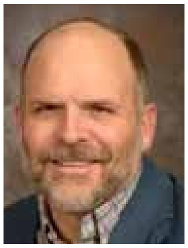
Sources: Consumer Price Index and Producer Price Index data are collected from BLS 2023a and BLS 2023b. Housing Prices are collected from https://www.car.org/marketdata/data/housingdata. Data of the Dow Jones Index, S&P 500 Index, and 10-year treasury bond interest rates are collected from https://www.macrotrends.net/.

Table 6. Relationship Between California Farmland Values and Selected Factors

	Variables	Highly Positive Correlations	Highly Negative Correlations
Commodity Specific Factors	**Acres Bearing**	Pistachio, Almond, Cherry Citrus, Strawberry, Dates	Wine Grape, Raisin Grape, Table Grape
	Yield	Walnut, Dates	Pistachio, Wine Grape, Raisin Grape, Table Grape, Peach, Strawberry
	Production Quantity	Strawberry, Dates	Wine Grape, Raisin Grape, Table Grape, Peach
	Grower Price Received	Peach, Cherry, Avocado, Strawberry	Walnut, Pistachio, Almond, Citrus
	Consumer Price Index_ Fruits&Vegetables	Pistachio, Almond, Wine Grape, Raisin Grape, Peach, Cherry, Citrus, Avocado, Strawberry, Dates	
Macroeconomic Factors	**Producer Price Index_ Fruits&Vegetables**	Pistachio, Almond, Wine Grape, Raisin Grape, Peach, Cherry, Citrus, Avocado, Strawberry, Dates	
	Dow Jones Index	Pistachio, Almond, Wine Grape, Raisin Grape, Citrus, Strawberry, Dates	
	10-year Treasury Bond Interest Rate	Walnut, Peach, Cherry	Table Grape, Dates
	Housing Prices	Pistachio, Almond, Wine Grape, Raisin Grape, Peach, Cherry, Citrus, Avocado, Strawberry, Dates	
Agricultural Land and Return Factors	**Cash Rent for Irrigated Crop Land**		Pistachio, Almond, Wine Grape, Raisin Grape, Chery, Citrus, Avocado, Strawberry, Dates
	Irrigated Crop Land Value	Pistachio, Almond, Wine Grape, Raisin Grape, Peach, Cherry, Citrus, Avocado, Strawberry, Dates	
	Cash Receipts	Pistachio, Almond, Wine Grape, Raisin Grape, Peach, Cherry, Citrus, Avocado, Strawberry	

Note: Highly positive correlation when the correlation coefficient $\rho > 0.5$; highly negative correlation when $\rho < -0.5$.

Potential Benefits of Water-Use Efficiency Technologies in Southeastern Wyoming


By Alicia Mattke, Kristiana Hansen, Dannele Peck, Vivek Sharma, Scott Miller, and Christopher Bastian

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Abstract

The southeastern portion of Wyoming is an agriculture-dependent area that relies heavily on groundwater from the High Plains Aquifer to grow crops. Like other states across the High Plains region, withdrawal rates in this area are higher than recharge rates, causing groundwater levels to decline. This study uses annual and intra-seasonal farm-level dynamic optimization models to determine whether water-use efficiency (WUE) technologies—specifically soil moisture sensors—can be beneficial to producers if water availability became more limited in the future. Results indicate that WUE technologies can help producers minimize financial losses that might otherwise occur from reduced water availability.

INTRODUCTION

Aquifer depletion has been a growing challenge across the United States due to changes in climate and irrigation pumping rates that exceed annual recharge. This can have negative impacts on agricultural producers in areas dependent on groundwater irrigation (Lansford et al., 1983). The Ogallala Aquifer, also known as the High Plains Aquifer, is the most intensively used aquifer in the United States (Maupin and Barber, 2005). In 2000, 23% of total groundwater withdrawals in the United States and 30% of total irrigation withdrawals were from the High Plains Aquifer (Maupin and Barber, 2005). The High Plains Aquifer provides groundwater for drinking water, livestock production, agricultural production, and mining in the region, which includes Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming (Figure 1). Agricultural production, specifically irrigation use, is responsible for 94% of the total withdrawal from the High Plains Aquifer (Dennehy, 2000). About 19.9 billion gallons of water are pumped from the aquifer per day (Dennehy, 2000). Pumping at these high rates exceeds the annual recharge rate in many parts of the aquifer, which is not sustainable and could lead to a decrease in groundwater availability and thus agricultural production in this region in the future.

Our study area is eastern Laramie County, Wyoming, which includes the towns of Albin, Pine Bluffs, and Carpenter. Though considerable research on aquifer depletion exists, few studies have been done in southeastern Wyoming (Willis, 2019), an agriculture-dependent area that relies on groundwater from the High Plains Aquifer for crop production. Laramie County uses groundwater to irrigate 81% of its total irrigated acres. (Dahlgreen, 2018). In 2015, total groundwater withdrawals for irrigation across the entire state of Wyoming were 602,000 acre-feet, 120,000 acre-feet of which (20%) were withdrawn in Laramie County (Dieter, 2018). Use of irrigation has made Laramie County a top agricultural producer in Wyoming, where it ranks first out of 23 counties in the state for production of wheat for grain, third in corn for grain, and fourth in dry edible beans (USDA, 2012). The economies of Albin, Pine Bluffs, and Carpenter rely almost exclusively on agricultural production, which depends in part on groundwater resources. Area producers have expressed concern about groundwater table declines in the area, which have increased energy costs and reduced available groundwater supplies for some producers.

Producers are interested in understanding the potential economic benefits of adopting water-use efficiency (WUE) technologies compared to using current "rule of thumb" irrigation practices in the area. WUE technologies are instruments that could improve irrigation scheduling throughout the growing season (e.g., soil moisture sensors and variable frequency drives). We analyze the potential for WUE technologies—specifically soil moisture sensors—to decrease energy costs, whether electric, propane, or diesel, and groundwater use while maintaining or improving producers' net returns. Soil moisture sensors can help producers with irrigation management by measuring how much moisture is in the soil, thus potentially reducing irrigation and improving field-level WUE. Reducing irrigation can decrease electricity costs of production associated with pumping, and can reduce fertilizer loss to runoff and leaching, potentially without reducing physical or economic production (Sharma, 2018). Past research regarding water conservation and adoption of irrigation technologies suggests that the benefits, costs, and economic feasibility of adopting measures such as WUE are likely to be highly variable across regions and crops (Guerrero et al., 2016; Young et al., 2004; Lansford et al., 1984).

Given past literature, this research seeks to answer whether implementing WUE technologies can potentially improve returns, compared to traditional irrigation practices in the area, particularly in the presence of limited water availability. We accomplish this objective by comparing a farm-level model using Discrete Stochastic Sequential Programming (DSSP) that allows for decisions to be made within the growing season in response to changing precipitation conditions versus an annual DSSP model. The annual model version does not allow for changes in irrigation in response to precipitation throughout the growing season, i.e., the model continues to irrigate the same amount throughout the season once a mix of crops has been chosen. The model does not incorporate soil moisture sensors directly—instead, results indicate a range of expected net revenue from adjusting irrigation use in response to changing precipitation, which represents the potential benefits from the adoption of soil moisture sensors or other WUE technologies for the representative farm modeled here.

Groundwater regulators, stakeholders, and producers in the study area recently held discussions to consider policy options to reduce pressure on the aquifer (Willis, 2019). One such policy option is allocation, which would limit the quantity of irrigation water applied on a per-acre basis. Producers in the study area are familiar with the concept of allocation because groundwater withdrawals in adjacent western Nebraska counties are limited by allocation (Willis, 2019), and although discussions in the study area ultimately did not result in adoption of allocation, it could still be adopted in the future. We consequently estimate these models under the full irrigation currently practiced in the region as well as under irrigation constrained by allocation to compare the relative economic benefits of WUE technologies under the two irrigation regimes.

DATA AND METHODS

This study models a representative farm (650 acres under 5 pivots) in eastern Laramie County at both the annual and intra-seasonal time scales. Crops included in the model are irrigated and dryland corn for grain, irrigated and dryland alfalfa, irrigated and dryland winter wheat, irrigated dry edible beans, and a dryland crop rotation. The model has three components: economic, agronomic, and hydrologic.

Economic Component of Model

Our study allows the representative farm to adjust irrigation at several points during the growing season in response to precipitation. It is flexible enough to reveal how intra-seasonal decision-making affects a hypothetical producer's expected profit, yield, groundwater use, and energy costs. DSSP was used for this intra-seasonal model, which allowed our intra-seasonal model to choose deficit irrigation strategies that optimize producers' expected profit, similar to the approach taken by Peck and Adams (2010).

Expected profit (*Eπ*) was determined by using the probability of precipitation occurring at above, near normal, or below levels in each stage (*S1*, *S2*, and *S3*) of the growing season:

$$E\pi = \sum_R (PS1_R) * (NREVS1_R) + \sum_R (PS2_R) * (NREVS2_R) + \sum_R (PS3_R) * (NREVS3_R) \quad (1)$$

where $PS1_R$ is a vector of precipitation probabilities for the first stage (*S1*) representing above, near normal, and below precipitation levels. The parameters $PS2_R$ and $PS3_R$ were similarly constructed for the second and third stages (*S2* and *S3*). We assumed precipitation in a given stage is independent of precipitation in the other stages, therefore, the joint probability of a sequence of precipitation events across the season is simply the product of their independent probabilities. The use of sequential decision variables within the growing season was informed by Houk, Taylor, and Frasier (2000). Our decision variables were as follows: 1) *X1*, the producer's cropping decisions at the beginning of the season; 2) *W2*, the first decision on how much to irrigate after stage 1 (*S1*) precipitation is revealed; 3) *W3*, the second decision on how much to irrigate after stage 2 (*S2*) precipitation is revealed; and 4) *W4*, the third decision on how much to irrigate after stage 3 (*S3*) precipitation is revealed (Figure 2).

*E*π is a function of net revenue under the three possible precipitation realizations in each stage, where net revenue is the revenue (price multiplied by yield) minus the variable costs (net revenue is also known as Returns Over Variable Costs (ROVC)). In this model, the producer's variable costs were broken into five components: 1) total electricity costs, 2) seed costs, 3) water costs, 4) all other variable costs (including wage labor), and 5) irrigation technology costs. Land and management costs were not included in the model. Profit is expected to vary with net revenue, assuming constant fixed costs. Net revenue varies by precipitation realization (*R*) in each season due to costs (e.g., total electricity costs) that vary with irrigation decisions, so the model includes four equations that ensure irrigation decisions are consistent with decisions that have been made at previous stages, such that the model cannot switch mid-season from one crop to another on a pivot-section. Six additional equations served as water balance equations to ensure that more water was not used than allowed on each pivot and for the whole farm. There were also four rotational constraints in the model to ensure that a single crop (i.e., monoculture) was not grown on every pivot section and instead reflect crop rotations common for the study area.

It should be noted that while crop insurance could be used to mitigate short-term risk associated with yield loss from drought for these crops, we did not include crop insurance payments in this model. To include crop insurance, we would have to decide on and use appropriate coverage levels for the area and related insurance costs, then calculate trigger levels and payouts across all scenarios. It was also expected that if long-term depletion and related allocation from the aquifer occurred, crop insurance rates and payoffs for the region would be adjusted as well, but we have no way of knowing what that insurance response might be. Overall, for these reasons, it was felt that addressing crop insurance in the model would detract from the primary objective of this research, which is to understand how potential changes in WUE could affect irrigation decisions and ultimately returns from crop production.

Crop and Price Data

We used data from Willis (2019), who constructed individual enterprise budgets for each crop, in each community, to estimate the costs associated with production. Willis used budgets developed by Klein et al. (2018) as a starting point. Albin, Carpenter, and Pine Bluffs producers confirmed that the modified budgets used by Willis (2019) were comparable enough to use as a foundation for the analysis. In our current study, we used the crop data collected by Willis (2019) for the Pine Bluffs community. Output prices in our model were assumed to be the 15-year (2002-2016) average price for each crop in Wyoming deflated to the same year as the crop budgets used by Willis (2019), as reported by USDA NASS (2017).

Agronomic Component of Model

In the intra-seasonal version of the model, crop yields are a function of precipitation and water applied at different points during the growing season. Precipitation occurring in each stage informs how much a producer chooses to irrigate at *W2*, *W3,* and *W4,* respectively. *S1* includes precipitation from May 7 through June 30, *S2* includes precipitation from July 1 through August 23, and *S3* includes precipitation from August 24 through October 1. Alfalfa has a different planting date (04/01) to account for the precipitation that occurs between 04/01 and 05/07. These dates were chosen based on corn and dry beans planting and harvesting dates and when their growth stages start and end. The USDA has a field crops handbook (USDA, 2010) that outlines the planting and harvesting dates for crops grown in all 50 states, which we used to decide the planting and harvesting dates for corn and dry beans.

Precipitation data are from area weather stations and span the years 1902-2015. However, we used the most recent 30 years of this historical precipitation data (1986-2015), which is standard for this type of research. From this data, we developed a set of precipitation probabilities for each stage, where an individual set reports the probability of each state of nature occurring within each stage. Each stage had three probabilities: the probability that precipitation was above normal (PA), near normal (PN), or below normal (PB). For *S1*, PA = 0.36, PN = 0.27, and PB = 0.37. For *S2*, PA = 0.34, PN = 0.39, and PB = 0.28. For *S3*, PA = 0.40, PN = 0.32, and PB = 0.28. These probabilities inform the calculation of $E\pi$ in Equation 1.

We used AquaCrop to determine the yield responses for our irrigated row crops (corn and dry beans) because of its ability to simulate yield responses in situations of deficit irrigation (Steduto et al., 2009; Steduto et al., 2012). The required inputs for AquaCrop include weather data, crop characteristics, soil profile characteristics, characteristics of the groundwater table, and irrigation and field management practices (Steduto et al., 2012). AquaCrop has default files provided for some crops, soil profiles, groundwater table levels, and irrigation and field management practices. Thus, the minimum observed data needed to parameterize AquaCrop for southeastern Wyoming is climate data.

Climate data came from area weather stations and spanned the years 1957-2015. We used 30 years of this climate data to match the 30 years of precipitation data described earlier. The climate data included maximum temperature, minimum temperature, precipitation, relative humidity (RH), wind speed, and solar radiation. These data were used to calculate reference evapotranspiration (ETo), using the Penman-Monteith conversion equation. The weather data helped to calibrate the AquaCrop model to reflect the climate of Laramie County, Wyoming.

We initially assumed the default crop characteristics provided in AquaCrop for corn and dry beans. The output from running these default parameters showed, however, that some of the crop parameters for both crops needed to be adjusted to reflect typical southeastern Wyoming yields and water application amounts.

Several corn parameters were changed to reflect the High Plains region, including the response to water stress parameters and days between growth stages. These parameters were changed based on parameter values provided in Araya et al. (2017) and Abedinpour et al. (2012). Several dry bean parameters were also changed to reflect the High Plains region. Crop-stage length and growing-season length were provided based on field trials conducted at the University of Wyoming agricultural research station in Powell, WY. Other parameters (e.g., crop response factors) were informed by Espadafor et al. (2017). These region-specific parameters improved AquaCrop's ability to replicate yield and water application levels known to exist in Wyoming, which provided greater assurance that the generated functions give reasonable estimates of the yield-water application relationship for water application levels not generally observed in Wyoming.

The soil profile characteristics for eastern Laramie County were retrieved from the NRCS SSURGO database. The majority of southeastern Laramie County has sandy loam soil, which helped develop specific soil-type characteristics such as soil hydraulic properties, total thickness of soil compartments, total number of soil layers, readily evaporable water, percent sand, percent clay, organic matter, penetrability, saturation, field capacity, wilting point, and saturated hydraulic conductivity (*Ksat*). The default soil file for sandy loam in AquaCrop was used for the simulations.

AquaCrop was not used to estimate the yield-water relationship for alfalfa because, at the time of this research, AquaCrop did not yet have default files available for alfalfa. AquaCrop was also not used to estimate the yield-water relationship for winter wheat due to time constraints. Instead, we used an equation from FAO 33 (Doorenbos and Kassam, 1979) and Bernardo et al. (1987) to simulate the yield response to intra-seasonal irrigation decision-making for alfalfa and winter wheat. This equation indicated that yield

(Ya is actual yield, and Ym is maximum yield expressed in units per area of land such as kg/ha) is a function of crop coefficients, K_{yi}, actual evapotranspiration, Et_{ai}, and potential evapotranspiration, Et_{pi}. The i subscript indicates different stages within the growing season. The equation is as follows:

$$\frac{Ya}{Ym} = \Pi_i^3\left[1 - K_{yi}\left(1 - \frac{Et_{ai}}{Et_{pi}}\right)\right] \quad (2)$$

Initial K_{yi} values came from FAO 56 and were adjusted to reflect local crop stress conditions in Wyoming. The Et_{pi} values came from the observed weather data collected in Cheyenne, WY. Et_{ai} was calculated by summing precipitation, irrigation, and soil moisture contributions. In this study, we assumed that soil moisture contribution is the same throughout the growing season. For the equation to be intra-seasonal, K_{yi}, Et_a, and Et_p varied throughout the growing season.

Hydrologic Component of Model

The hydrologic component of our intra-seasonal model consisted of equations governing lift and pumping costs. $Lift$ is the depth to water, in feet, and helps determine how much pumping water from the aquifer will cost a producer. It was calculated by:

$$Lift_t = Lift_{t-1} + CalRatio * WatUseDepth_{t-1} - Recharge \quad (3)$$

where $WatUseDepth$ represents the irrigation water applied converted to feet, and $CalRatio$ and $Recharge$ are used to calibrate the aquifer to status quo. Status quo represents the aquifer if no changes are made to reduce groundwater use.

Pumping costs were calculated by using the four-step approach from Black and Rogers (1993), who used lift, well pressure, pumping capacity, and pumping hours to determine total electricity costs per pivot section. (Please see Willis (2019) and Grahmann (2020) for details.) Irrigation in the study area is primarily powered by electricity, which we therefore assumed in our model. If other, more costly, energy options had to be employed, the benefits of implementing WUE technologies would be even greater than our estimates indicate.

Annual versus Intra-Seasonal Versions of the Model

The annual version of the model was identical to the intra-seasonal version described above except that the producer no longer had the option of making mid-season changes to irrigation management in response to precipitation. Thus, the only decision variable was the decision of what crops to plant on each pivot section at the start of each season. Crops planted were either fully irrigated throughout the season (D1) or dryland (D3). The producer has no ability to switch to deficit irrigation (D2) at later stages of the season in response to precipitation. This annual version of the model is similar to most studies that have been done on water use in groundwater-dependent agricultural areas (Golden and Johnson, 2013; Brozovic and Islam, 2010; Golden and Guerrero, 2017). The only exceptions of which we are aware are Foster, Brozovic, and Butler (2015) and Hrozencik et al. (2017).

These changes simplify equation (1) by removing the expectation operator and the indices representing mid-season precipitation realizations and decisions:

$$\text{NETREV} = \Sigma_{PS,C}^{1}[(O_C * Yld_{X,PS,C}) - (ElectT + WaterRt_C * OtherWaterCost + SeedRt_C * SeedCost_C + OtherCost_C)] \quad (4)$$

Everything else about the economic component of the model remained the same as it was in the intra-seasonal version. The only impact of the annual version of the model on the agronomic component was that any permutations of precipitation and yield that involved deficit irrigation (D2) were not considered. This reduced the number of permutations from 216 to 81.

The hydrology component of the model was unchanged from the intra-seasonal version described above. Regardless of model version, the hydrology component was annual in the sense that depth to water did not increase over the course of the season in response to pumping. If depth to water were to increase over the course of the season in response to pumping, the additional pumping cost associated with increased depth to water could influence producers to pump less water, depending on aquifer conditions and pumping costs.

Baseline versus Allocation Scenarios

In the Baseline scenario, the farm had 12,000 ac-in of water available (2,400 ac-in per pivot, or approximately 18 ac-in per acre on average), which is more than enough to grow any fully irrigated crop. For example, fully irrigated alfalfa is the thirstiest crop, and 18 ac-in per acre is more than sufficient to grow fully irrigated alfalfa on all pivot sections. In the Allocation scenario, the farm had 7,800 ac-in of water available (1,560 ac-in per pivot, or approximately 12 ac-in per acre on average).

RESULTS

Figure 3 indicates crop mix and irrigation levels by model version and scenario. The annual version of the model, Baseline, replicated the typical crop mix observed in the study area: four half-pivots of alfalfa, two each of corn, dry edible beans, and winter wheat, all fully irrigated (Figure 3, column a). In the annual version, Allocation, two half-pivots of alfalfa were converted to the dryland crop rotation; the other half-pivots remained fully irrigated (Figure 3, column b). We assumed that a producer would never choose to deficit irrigate throughout the whole season, based on conversations with area producers and yield results for the area from AquaCrop. Thus deficit irrigation was not included as an option in the annual version of the model. Expected profit in the annual model decreased by 20.98% ($50,798) between the Baseline and Allocation scenarios, and water use decreased by 26.82% (3.46 ac-in/ac) (Table 1).

In the intra-seasonal model version, deficit irrigation can be used in any season, and the model allows for irrigation adjustments in response to within-season precipitation. In the intra-seasonal model, Baseline, the crop mix is the same as it was in the annual model (Figure 3, column c). However, deficit irrigation was used for irrigated alfalfa, corn, dry edible beans, and winter wheat. (A crop appears as deficit-irrigated in Figure 3 if deficit irrigation was used on the crop in at least one stage, under at least one type of precipitation.) In the Allocation scenario, the crop mix is the same as it was in the annual model except that now, one half-pivot is planted to the dryland crop rotation instead of two (Figure 3, column d). Deficit irrigation is once again used for irrigated alfalfa, corn, dry edible beans, and winter wheat in at least one stage, under at least one type of precipitation.

When intra-seasonal Allocation is compared to intra-seasonal Baseline, there is a 9.79% ($23,995) decrease in expected profits and a 19.44% (1,551.72 ac-in) decrease in water use. Table 1 shows the differences between the two scenarios. There is a larger drop in water use than there is in expected profits on a percentage basis, which is useful information for policy makers. Producers would need to receive approximately $15.69 per ac-in. to consider participating in water use reduction programs.

In the Baseline scenario, expected profits increased by 1.27% ($3,069) in the intra-seasonal model relative to the annual model. Water use declined by 4.81% (0.62 ac-in/ac) in the intra-seasonal model relative to the annual model. This was because the producer found it optimal to deficit irrigate even when water was plentiful (i.e., in the Baseline scenario) to avoid pumping costs. Although there was an increase in expected profits and a decrease in water use in the intra-seasonal version relative to the annual version, this was not a large difference, suggesting that the choice of adopting water saving technology is less impactful when water is plentiful.

The difference in results between the annual and intra-seasonal versions of the model were more substantial for the Allocation scenario. Under the constraint of allocation, expected profits in the intra-seasonal model were 15.62% ($29,872) higher relative to the annual model. Water use in the intra-seasonal allocation scenario was 4.77% (0.45 ac-in/acre) higher relative to the annual allocation scenario. To clarify, allocation reduced expected profit in both models, by $50,798 in the annual model, and by $23,995 in the intra-seasonal model. But the reduction in expected profit was smaller in the intra-seasonal model, thanks to the added flexibility of intra-seasonal deficit irrigation decisions informed by precipitation in each stage.

The difference in profitability between the annual and intra-seasonal models under allocation can help inform producers trying to decide whether it would be feasible to include WUE technologies to help manage irrigation scheduling. Given the crops grown and climate conditions prevalent in eastern Laramie County, expected profits were almost $30,000 (16%) higher for a five-pivot farm when irrigation decisions were updated throughout the season based on precipitation amounts rather than just one decision at the beginning of the year when groundwater was limited. These results suggest that a producer whose operation's characteristics are similar to those modeled here would find it beneficial to spend up to $30,000 on soil moisture sensors or other WUE technologies that could help them adjust irrigation decisions in response to within-season precipitation.

CONCLUSION

This study compared the expected profit and water use between annual and intra-seasonal versions of a farm-level dynamic optimization model. We used the two model versions to simulate whether WUE technologies could be economically beneficial to producers. To do this, we ran two scenarios: a Baseline scenario (i.e., assuming plentiful irrigation water) and an Allocation scenario in which irrigation water is limited. The results of those two scenarios (Baseline versus Allocation) were then compared between the two model versions (annual versus intra-seasonal).

The intra-seasonal Baseline scenario increased expected profits by $3,069 (1.27%) and decreased water use by 0.62 ac-in (4.81%) relative to the annual Baseline scenario. Incorporating intra-seasonal decision-making into the model had minimal impact on expected profits and water use when water was sufficiently available (i.e., in the Baseline scenario). However, incorporating intra-seasonal decision-making had a greater impact on expected profits and water use when water availability was restricted (i.e., in the Allocation scenario). The intra-seasonal Allocation scenario increased expected profits by $29,872 (15.62%) but also increased water use by 0.45 ac-in (4.77%), relative to the annual Allocation scenario.

If we focus on the more realistic intra-seasonal model alone, we see that allocation decreased expected profits by $23,995 (9.79%) and water use by 2.39 ac-in (19.46%) relative to the baseline. These changes in expected profits and water use were impactful for a producer, yet smaller than what was observed when allocation was implemented in the annual model. In the annual model, allocation decreased expected profits by $50,798 (20.98%) and water use by 3.46 ac-in (26.82%). This suggests that implementing WUE technologies (i.e., adjusting irrigation within the growing season in response to precipitation events) can help producers mitigate the negative economic impacts associated with a reduction in available water supplies. If water availability becomes limited or restricted in the future, our results suggest that producers might consider turning to WUE technologies. Soil moisture sensors and other WUE technologies do not explicitly enter the model, but incorporating mid-season irrigation adjustments could generate increases in expected profits, some of which could be used to implement the soil moisture sensors or other WUE technology that could facilitate these profit increases in the first place. If the net benefits of WUE technologies are positive, as our estimates indicate for the representative farm modeled here, WUE technologies could help producers determine whether a crop needs to be irrigated during different parts of the growing season and reduce (but not eliminate) the economic pain of reduced water availability.

We recognize that producers likely already make some adjustments to their irrigation plans following precipitation events, for example, they likely reduce irrigation after a heavy rainstorm, but we have no data to quantify whether this is a general practice in the area. The question is how close to the hypothetical outcomes of the intra-seasonal model might real-world producers be able to get using WUE technologies? Their actual changes in decisions and outcomes would reveal the true value of WUE technologies, as opposed to the full difference between the results of the hypothetical annual and intra-seasonal models presented in this study.

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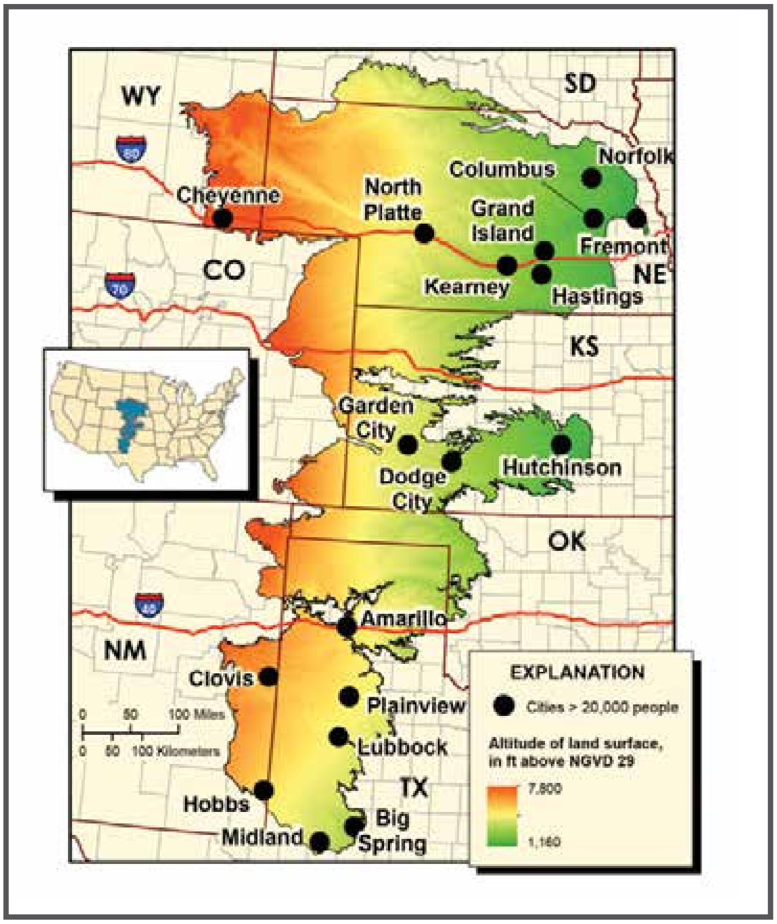
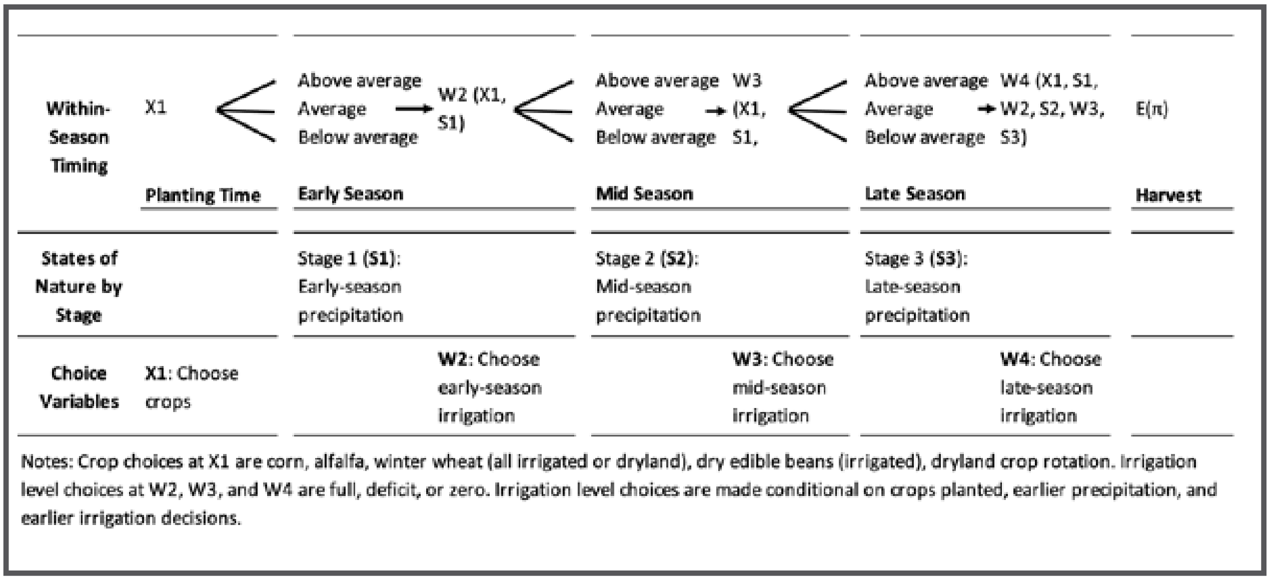


Figure 1. High Plains Aquifer region (Source: USGS, 2013)



Within-Season Timing	X1	Above average Average → W2 (X1, S1) Below average	Above average W3 Average → (X1, Below average S1,	Above average W4 (X1, S1, Average → W2, S2, W3, Below average S3)	E(π)
	Planting Time	**Early Season**	**Mid Season**	**Late Season**	**Harvest**
States of Nature by Stage		Stage 1 (**S1**): Early-season precipitation	Stage 2 (**S2**): Mid-season precipitation	Stage 3 (**S3**): Late-season precipitation	
Choice Variables	**X1**: Choose crops	**W2**: Choose early-season irrigation	**W3**: Choose mid-season irrigation	**W4**: Choose late-season irrigation	

Notes: Crop choices at X1 are corn, alfalfa, winter wheat (all irrigated or dryland), dry edible beans (irrigated), dryland crop rotation. Irrigation level choices at W2, W3, and W4 are full, deficit, or zero. Irrigation level choices are made conditional on crops planted, earlier precipitation, and earlier irrigation decisions.

Figure 2. Visual representation of decision points throughout the irrigation season

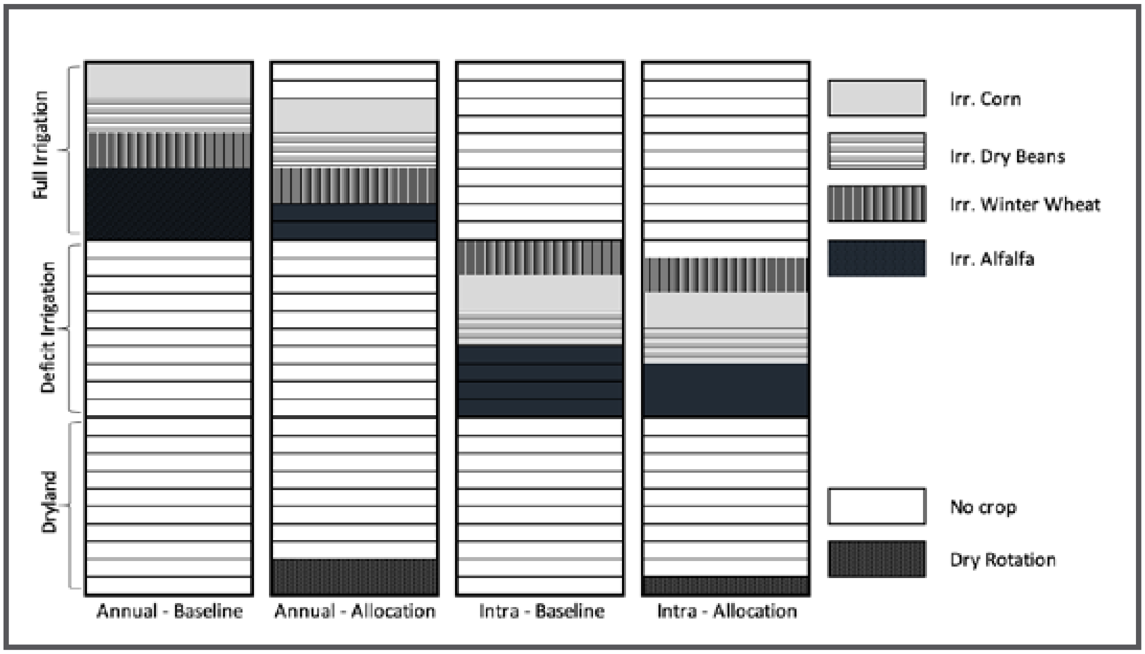
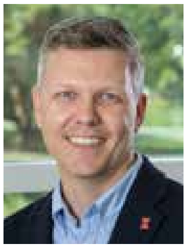


Figure 3. Crop mix and irrigation levels by model version and scenario (each bar represents one half-pivot)

Table 1. Comparison of Average Returns Over Variable Costs and Water Use by Model Version and Scenario

Scenario	Average ROVC	Water Use	
	$	Average ac-in/ac	Total ac-in
Annual Model - Baseline	$242,090	12.90	8,384
Annual Model - Allocation	$191,292	9.44	6,135
Intra-Season Model - Baseline	$245,160	12.28	7,981
Intra-Season Model - Allocation	$221,165	9.89	6,430

Realized Farm-Level Returns to Post-Harvest Grain Storage and Marketing



By Joseph P. Janzen

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Abstract

Commodity price variability is a major component of fluctuations in net farm income. Farm managers assume some of this price risk by choice when they store grain after harvest. This study estimates the realized returns from these post-harvest grain storage and marketing activities and shows that they are small on a risk-adjusted basis, particularly relative to the downside risk of negative returns. One explanation is that farm managers' use of post-harvest forward contracting is limited so they are subject to considerable flat price risk.

INTRODUCTION

Farm managers express consistent concern about grain market price risk. Surveys of farmer risk perceptions routinely rate commodity marketing as one of the most important risks faced in farm business management (Thompson, Bir, and Widmar, 2019; Atta and Micheels, 2020). In the aggregate, grain price variability is a major determinant of changes in farm profitability: elevated grain prices in 2007-2012 and 2020-2022 coincided with periods of record net farm income (USDA Economic Research Service, 2023). While these commodity price gyrations are certainly beyond the control of the farm manager, he or she does have some choice about how much price risk the farm is exposed to with various market-based and government-backed risk management tools, including forward contracting, futures hedging, crop insurance, and commodity programs. This is especially true after harvest: post-harvest price risk is assumed voluntarily since the farm manager can transfer this risk to others by selling the crop at harvest or contracting for sale later in the marketing year. Farm managers may want to store to take advantage of seasonal price patterns—higher prices later in the marketing period compared to the harvest-time price—but doing so may be risky.

How much post-harvest price risk do farmers bear? This study assesses the post-harvest marketing performance of individual farms and quantifies the risk borne by farm managers who hold grain in storage after harvest. The analysis suggests post-harvest marketing and storage is a major component of the overall marketing strategy for corn and soybean farms in Illinois and throughout the US corn belt. I quantify the range of marketing outcomes experienced by individual farms that hold grain after harvest and compare it to realized prices received for grain sales made near to harvest. This assumes these farm-level distributions are informative about the range of returns to post-harvest marketing that farm managers may realize in the future.

Quantifying the realized range of potential post-harvest grain marketing outcomes is the major contribution of this study relative to prior research. Most previous analyses of farm marketing performance, including analyses of post-harvest marketing, use market-level data. In these studies, the returns to an assumed set of post-harvest marketing strategies are measured against a benchmark that is typically the cash price level observed during the harvest period. For instance, Edwards, et al. (2020) compare the net returns to unhedged and hedged post-harvest sales at varying storage horizons, with gains from these strategies assessed against the harvest-time cash price. Dietz, et al. (2009) conduct a similar analysis and show that different price baselines against which to compare the post-harvest price achieved by storage lead to significant differences in results. Because these studies rely on a limited set of market-level outcomes, they tend to be more prescriptive; it is unclear how they compare to actual behavior, which is the result of a more complex set of marketing strategies. In reality, farm managers can choose to sell on any day (including all those days before harvest) for delivery on any day post-harvest. Other analyses of grain marketing performance do study farm-level marketing decisions (e.g., Anderson and Brorsen, 2005; Jacobs, Li, and Hayes, 2018) using grain purchaser records, but these data only record the interactions between farms and a single buyer.

This study differs by using farm-level data that covers the entirety of the farm manager's marketing decisions within a marketing year. Previous studies showed there are positive profits to post-harvest marketing that vary significantly across years. I show that realized marketing outcomes' returns vary more: there is substantial variation across farms even within the same year. This suggests both that farms employ more complex marketing strategies than accounted for in previous studies and that farmers may be assuming more price risk than previously thought.

This study proceeds as follows. First, I describe the typical seasonal pattern in local cash prices for corn and soybeans. I show prices typically rise about 20% between the harvest-time low and the post-harvest high. However, markets may deviate dramatically from this pattern in any given year, so holding commodity inventories after harvest does not guarantee the farm will receive higher prices. Next, using farm-level data, I show that farms generally hold significant proportions of their own production in inventory at calendar year end, which closely follows the harvest period. Only limited corn and soybean sales are realized in the near-to-harvest period between September 1 and December 31.

My main analysis calculates realized gross returns to grain storage for corn and soybeans on farms in Illinois as the difference between the price received by farm managers for deferred sales realized after January 1 and prices received for near-to-harvest sales. I show these returns are on average small and positive, which is roughly consistent with the average difference in cash prices between deferred and near-to-harvest periods of the marketing year. However, gross returns vary widely across farms in nearly all years. Observed variation across farms within each marketing year quantifies the risk to grain marketing. Using these volatility measures, I calculate risk-adjusted returns to post-harvest marketing, finding that the realized risk-adjusted returns are small and the downside risk is significant. As a group, farm managers are not choosing to capture seasonal price appreciation through risk-minimizing marketing strategies such as forward contracting or storage hedges considered in earlier studies.

BACKGROUND

Seasonal Price Patterns

Seasonal price patterns provide incentives for farm managers and other decision-makers in the grain supply chain to store grain and make sales for delivery after harvest. Broadly, this pattern involves relatively low prices at harvest and relatively high prices later in the marketing period prior to the next harvest. Figure 1 illustrates the seasonal pattern for corn and soybeans using USDA Agricultural Marketing Service cash market price data for Central Illinois from the 2004-05 to 2019-20 marketing years. Note the marketing year for corn and soybeans runs from September 1 to August 31 of the following calendar year. The values shown in Figure 1 are deviations in a given week from the simple marketing year average price, which is the unweighted mean of daily price observations from that marketing year. These deviations remove differences in price levels across marketing years to focus on seasonal price changes within each year. The mean price series represents the typical difference between the price in a given week and the marketing year average price.

Figure 1 shows both corn and soybean prices hit seasonal lows at the beginning of October. The mean weekly deviation from the season average price (the thick line in Figure 1) is lowest at this point, coinciding with the typical harvest period in Central Illinois. Seasonal highs occur in the months of June and July, with prices tending to rise steadily between October and June. Based on the mean price pattern in Figure 1, both corn and soybean prices appreciate approximately 20% between the seasonal low and high. It is this seasonal price pattern that farm managers may seek to exploit by holding grain inventory after harvest. Note the seasonal high prices observed in June apply only to old-crop supplies and not to new-crop production that is typically planted before June and harvested in the fall; this seasonal pattern does not apply to pre-harvest marketing.

In any given year, there may be substantial differences between observed prices and the typical seasonal pattern. Figure 1 shows variation across years in prices at each week of the marketing year using the minimum and maximum deviations from the season average price observed between 2004/05 and 2019/20 and the standard deviation of these values across years for each week. The minimum values show that actual price levels may be below the season average price at any point in the marketing year, so positive returns to storage are never guaranteed.

To evaluate marketing performance, note seasonal price patterns typically break even or equal the season average price near January 1 at the end of one calendar year and beginning of the next. (For soybeans, the mean seasonal price pattern reaches a point just below zero around January 1 and remains slightly below zero for several weeks.) Thus, farm managers would typically need to wait to sell grain until the new calendar year to receive prices above the marketing year average (assuming only cash sales are made). This calendar year end cut-off point is important for my farm-level analysis below.

Measuring Returns to Storage

Assessing profitability of farm commodity storage relies on some comparison of nearby and deferred prices. The nearby price represents in part the opportunity cost of storage, i.e., the value the farm would have received had it not stored. A common benchmark for the nearby price in many storage analyses is the cash price at harvest time. The deferred price represents the value the farm receives or expects to receive when the commodity is removed from inventory. The deferred price is typically the cash price later in the marketing year or the forward contract price offered at harvest for delivery later in the marketing year. In percentage terms, the gross return to storage is therefore

$$Gross\ Return = \frac{P_D - P_N}{P_N} \tag{1}$$

where P_D is the deferred price and P_N is the nearby price. This price comparison is grounded in the economic theory of commodity storage (Williams and Wright, 1991), which explains how a theoretical commodity-storing firm evaluates current and expected future prices. It is a gross return because it does not account for physical storage costs such as the handling, maintenance, and deterioration of grain inventories. It also ignores the time value of money associated with the foregone revenue from selling at the nearby price.

Accounting for storage costs at the farm level is more complex than in market-level analyses such as Edwards, et al. (2020). Market-level analysis typically assumes a physical storage cost that is a single fixed rate per month. Physical storage costs are likely to vary across farms and to vary with length of the storage period in ways not encapsulated by a single per-month rate. In the same way, firms may have different opportunity costs of storage that depart from the time value of money given by benchmark interest rates. For example, recent research suggests grain storage decisions may be a function of working capital and the farm's financial position, not just market-level interest rates (Janzen, Swearingen, and Yu, 2023). Given these complications, I consider gross returns only.

DATA

To measure post-harvest marketing performance at the farm level, I use data on corn and soybean production, sales, and inventories from Illinois Farm Business Farm Management (FBFM). Illinois FBFM is a cooperative association of more than 5,000 farmer cooperators who work with association field staff to collect financial and agronomic data for tax filing, financial statement preparation, and business benchmarking. FBFM partners with the Department of Agricultural and Consumer Economics at the University of Illinois, Urbana-Champaign, and its *farmdoc* extension project team to make data available for use in extension and research activities.

Illinois FBFM cooperators cover all regions of the state and represent approximately 25% of Illinois farmland acreage. FBFM data are used to develop University of Illinois crop budgets, which are based on audit-quality financial records from more than 1,000 farms each year. Note that an FBFM farm may include multiple farmer cooperators whose farm operations are joint. Since FBFM is a voluntary association, its records by design do not constitute a statistically representative sample of Illinois farms. However, recent comparisons of summary statistics and demographic measures for FBFM and those from the USDA's Agricultural Resource Management Survey (ARMS) indicate good representation of commercial-scale Illinois crop farms in the FBFM data (Kuethe et al., 2014).

Observing farms for multiple years (and thus across varied market and agronomic conditions) is one major advantage of the FBFM data. For this analysis, the data include records for all member farms in the period 2004 to 2020. I compile a sample of farm financial records certified as useable for research and benchmarking purposes by FBFM field staff, including only grain farms that grew corn or soybeans each year and excluding farms with zero operated acres and zero tillable acres. Most farms record production of both corn and soybeans each year. However, since farms participate in FBFM voluntarily, I do not observe all farms or commodities every year. For this analysis, the data are an unbalanced panel of 31,111 farm-commodity-year observations from 17 calendar years. Each observation is specific to a farm, commodity (corn or soybeans), and calendar year. While farms almost always report both corn and soybean production and sales in a given year, farms generally are not observed in the data for all 17 years; the mean length of time a farm remains in the data is just less than six years.

I quantify the importance of post-harvest storage and marketing to these Illinois grain farms by extracting relevant quantities from farm financial statements. The balance sheet shows the level of key state variables, principally the quantity of inventories, at the end of each calendar year, and the income statement includes measures of important commodity flows during the calendar year. The basic accounting identity that describes inventory quantity dynamics is

$$Inventory_{t-1} + Production_t - Sales_t = Inventory_t \qquad (2)$$

That is, inventory for the current year (t) must equal inventory for the previous year ($t - 1$) plus current year production less current year sales. I observe both the quantity in bushels and value in nominal dollars for both inventory and sales, then infer an implicit average price by dividing value by quantity. For example, I can calculate the farm-specific price received for all sales made within a calendar year by dividing the value of sales recorded on the farm income statement by the quantity of sales for a given commodity.

Observing calendar year sales quantity and value alone would be insufficient to evaluate post-harvest marketing performance because the inferred average sales price includes sales of both old-crop inventory carried into the calendar year ($Inventory_{t-1}$)and new-crop production ($Production_t$). However, Illinois FBFM records the quantity and value of what it calls old-crop and new-crop sales. New-crop sales are sales of current calendar year production realized prior to the end of the calendar year; I call these near-to-harvest sales and denote them as . Near-to-harvest sales are realized in the sense that delivery is made and revenues are received before January 1. Commodities held in on-farm storage and unsold, those delivered into commercial storage where ownership is retained, and those held in any location but forward contracted for delivery and transfer of ownership on or after January 1 are old-crop sales for the next calendar year. I refer to these old-crop sales as deferred sales and denote them as $Sales_{t+1}^D$ to make clear these sales are realized in calendar year and accounting period ($t + 1$).

The quantities $Sales_t^N$ and $Production_t$ allow us to assess the importance of near-to-harvest sales to each farm. Figure 2 describes the distribution across farms of near-to-harvest sales realized prior to January 1 as a proportion of calendar year crop production by crop for FBFM farms in the period 2004 to 2019, i.e., $Sales_t^N/Production_t$. Farms with a zero share of near-to-harvest sales have realized no sales of new-crop production before January 1. These farms may have made forward sales of current production, but such sales are not yet realized prior to the new calendar year; new-crop production remains in inventory. Farms with 100% near-to-harvest sales have sold their entire calendar year production by January 1 and hold no commodity inventories as of year-end.

Figure 2 shows that although I observe farms at all points in the distribution, small shares of new-crop production sold before January 1 are much more common. Most notable is the share of farms that have realized zero or near-zero sales of crops produced in a given calendar year. For both corn and soybeans, more than 40% of farms have no sales of near-to-harvest sales. This holds across all years, and it is also true in specific years. While the specific share of farms with zero near-to-harvest sales fluctuates from year to year, it typically ranges between 30% and 50%.

The large proportion of farms that have little or no grain sold by January 1 of a given marketing year suggests these farms may face substantial price risk on the inventories they hold into the new calendar year. As noted above, these farms do have access to a wide array of price risk management tools. If these farms are proactively using these tools, then farms face less price risk, and marketing outcomes may not vary across farms or vary with post-January 1 market-level price changes. I use data on realized marketing performance on Illinois FBFM farms to assess these conditions.

RESULTS

To describe the post-harvest marketing performance of farms in my data, I estimate annual gross returns to storage for both corn and soybean farms in the Illinois FBFM. I use the panel structure of the data to calculate the prices received by farms for both near-to-harvest and deferred sales in each year. The average price received for each type of sales i in dollars per bushel, P_t^i, is the value of sales in dollars divided by the sales quantity in bushels. Near-to-harvest sales realized prior to January 1 represent the opportunity cost incurred by holding the commodity in storage and realizing sales later in the marketing year. Gross returns from deferred sales relative to this near-to-harvest benchmark assume sales made after January 1 could have been sold at the price realized for the farm's earlier near-to-harvest sales. The near-to-harvest price benchmark is the amalgam of all pre-harvest marketing actions, which include the harvest cash sales used as a benchmark in previous studies as well as forward contracts delivered at harvest and other pre-harvest marketing strategies.

The gross return to storage is a summary measure of the profitability of post-harvest marketing that requires data from separate calendar years, i.e., the near-to-harvest price at year t and the deferred price from year $t + 1$. I calculate the gross percentage return for the marketing year that spans calendar years t and $t + 1$ as

$$Gross\ Return = \frac{P_{t+1}^{D} - P_{t}^{N}}{P_{t}^{N}} \tag{3}$$

This calculation limits the number of observations available for two reasons. First, many farms in my sample have no near-to-harvest sales $(Sales_t^N = 0)$, so I cannot calculate P_t^N for these farms. As shown in Figure 2, this is more than 40% of the sample. Second, I can only calculate gross returns for farms for which I have data in consecutive calendar years. I therefore lose at least one observation per farm and commodity, including all those near-to-harvest sales observed in calendar year 2020. These limitations reduce sample size to 11,874 farm-commodity-year observations.

The gross return measure is particularly informative because it represents an individual-adjusted measure of marketing performance. It is specific to the farm's location and the set of local markets to which it can deliver, which do not change substantially between the pre-January 1 and post-January 1 periods. It is also specific to the quality of grain produced by the farm in that calendar period. In general, this comparison adjusts for many farm-specific factors that affect marketing performance and do not vary over time. These include farm manager ability, education, and risk preferences as well as other relevant aspects of the farm's business operations and financial capacity.

Variation Across Farms in Returns to Storage

I plot the distribution of gross returns from commodity storage and marketing for each commodity and marketing year in my sample period in Figure 3. Note these distributions weight each farm-level observation equally; outcomes for large farms (which market more bushels) are treated as equally likely as outcomes for small farms. These distributions also do not account for the proportion of near-to-harvest and deferred sales on each farm. Gross returns only represent the raw price difference between realized near-to-harvest and deferred sales. Extreme values are also replaced (winsorized) at the top and bottom 0.5% of the entire distribution to reduce the impact of outliers.

Figure 3 shows that gross returns to commodity storage vary widely across farms producing corn and soybeans in Illinois. The range across all years runs from roughly -40% to +50%. For individual marketing years, the range of returns for the bulk of the distribution is at least 10 percentage points, but it is often much greater, and in some extreme cases, significant numbers of farms are receiving returns to storage that are 20 to 30 percentage points below the top performing farms. Both crops experience similar levels of cross-farm variation in returns.

Negative gross returns to storage are surprisingly common. A gross return of zero indicates the price received for near-to-harvest and deferred sales is equal, so there was no realized benefit to holding grain in storage. The marker below each distribution in Figure 3 indicates the median value in that year. Median returns are below zero in 6 of 16 marketing years for both corn and soybeans. Substantial portions of the mass of the distribution of returns are below zero every year, even in years like 2006/07 and 2007/08 when deferred marketing was exceptionally profitable. The common presence of negative returns suggests that farm managers realize more downside risk from storage than one might think, given the typical seasonal price pattern observed in Figure 1.

Marketing years with strongly positive returns tend to be those where cash prices rose a lot after harvest, such as 2006/07, 2007/08, and 2010/11. Farm managers realize that much of this upside price movement is suggestive (but not definitive) evidence that significant portions of the stored corn and soybean crops are uncontracted and/or unpriced until late in the marketing year. The converse, that farm managers realize negative returns when prices fall after harvest, is less clear. Years with negative returns such as 2008/09, 2014/15, and 2019/20 featured periods of modest price declines below the marketing year average during the deferred January 1 to August 31 marketing period. A full assessment of the relationship between market-level price outcomes and farm-level marketing outcomes is beyond the scope of this analysis and left for future study.

Estimating Aggregate Risk-Adjusted Returns

To summarize findings on the realized returns to commodity storage for Illinois farms, summary statistics for the gross returns data visualized in Figure 3 are presented in Table 1. First, I calculate the mean and median returns across all farms and years for each crop. I find the average gross return is 6.5% for corn and 5.0% for soybeans, with the median gross return 3.4% for corn and 2.6% for soybeans. Mean values above the median indicate a slight right skew in the distribution of returns across all years driven in part by those high return years where price appreciation led nearly all farms to experience positive gross returns.

Mean gross returns are remarkably similar to the seasonal market-level price changes found in Figure 1. Recall the low-to-high average seasonal price increase is roughly 20%, but it is unreasonable to expect farms to time their sales on these exact dates. The difference between the average weekly price between January 1 and August 31 (the deferred period of the marketing year) and the average weekly price between September 1 and December 31 (the near-to-harvest sales period) is 7.2% for corn and 7.0% for soybeans. This level of price appreciation between the two periods of the marketing year is similar in magnitude to the mean gross returns to post-harvest storage and marketing of 6.5% and 5.0%, respectively, suggesting that cash price variability and the timing of cash market sales may drive much of the variation in farm marketing performance.

To assess the variability of storage returns, I calculate two standard deviations in Table 1. The first unconditional standard deviation includes variation across all farms and years for each crop. The second standard deviation assesses variability across farms within years by subtracting the year-specific mean return from each gross return observation prior to calculating the standard deviation. The within-year standard deviation is slightly smaller since it does not include variability in returns across years.; the second measure is the preferred estimate of the realized risk borne by farm managers in post-harvest grain marketing. Supposing a given farm manager is not predisposed to overperform or underperform his or her peers, he or she can expect the distribution of gross return outcomes in any given year to reflect the expected probability of his or her own returns. Then the within-year standard deviation accurately describes the risk he or she should expect to face.

I find the volatility or standard deviation of within-year gross returns is 14.9% for corn and 12.9% for soybeans. To place this risk measure in context, I employ a standard measure of risk-adjusted return, i.e., the Sharpe Ratio, a unitless measure of reward relative to variability. The Sharpe Ratio is calculated as the expected excess return relative to a risk-free asset divided by the standard deviation of the excess return (Sharpe, 1994). In this case, gross returns to storage are a form of excess return since the price of near-to-harvest sales represents foregone revenue from potential sales that would not be subject to post-harvest price variability (and thus could be considered “risk free” relative to the option to retain ownership and market grain after harvest).

In Table 1, I calculate the Sharpe Ratio as the mean gross return divided by the within-year standard deviation. I find Sharpe Ratios of approximately 0.43 for corn and 0.38 for soybeans, suggesting both crops exhibit similar returns to storage on a risk-adjusted basis. These levels would be considered low in the context of most investment/portfolio analysis. They are similar to Sharpe Ratios calculated for farm-level returns from all farm operations, not just storage (Langemeier and Yeager, 2021). More generally, my results suggest the risk-adjusted returns for post-harvest grain marketing are not large. Grain storage returns are unlikely to feature returns much larger than other aspects of the farm operation. These risk-adjusted returns are also likely smaller than the returns from readily available off-farm investments in public equity and bond markets. However, this does not necessarily imply grain storage is a “bad” investment as there may be other returns to holding commodity inventories. I discuss this possibility in the conclusion.

One limitation of the Sharpe Ratio is that it views upside and downside risk equally. In the context of post-harvest grain marketing, upside risk may be viewed as a benefit of holding unpriced inventory rather than selling. Farms may instead assess risk-adjusted returns relative only to downside risk or the probability that returns fall below some minimum acceptable level. While this level is unobservable, I consider gross returns below zero as exhibiting considerable downside for the farm. There are a significant number of instances of negative gross returns to storage, i.e., 39.6% of farm-year observations for corn and 38.4% of farm-year observations for soybeans.

To calculate a measure of returns adjusted for downside risk only, I calculate the Sortino Ratio, which replaces the standard deviation term in the Sharpe Ratio with the target semi-deviation, i.e., the standard deviation of excess returns below a target (Sortino and Price, 1994). In this case, the target is positive gross returns. Table 1 shows that the Sortino Ratio in my sample period is 0.73 for corn and 0.64 for soybeans. While there is no objective threshold below which the Sortino Ratio is too low, these levels are concerning as they are well below the levels observed in Langemeier and Yeager (2021) for farm-level returns from all operations. The Sortino Ratio suggests the downside risk from post-harvest grain marketing is economically significant.

CONCLUSIONS

This study uses farm-level data to estimate the price risk assumed by farm managers who store grain after harvest. Post-harvest grain marketing is a strategy designed to profit from seasonal price appreciation typical in many agricultural commodity markets. I show that many farms employ this strategy, but near-to-harvest sales are typically a small share of production, and many farms realize no sales of new-crop corn or soybeans before January 1 following a fall harvest. I show the returns to post-harvest marketing are on average small and positive, approximately equivalent to the average difference in cash prices between deferred and near-to-harvest periods of the marketing year. However, farm-specific gross returns differ dramatically. I use observed variation across farms within each marketing year to quantify the risk to grain marketing and calculate risk-adjusted measures of the returns to post-harvest marketing. I find realized risk-adjusted returns are small and the downside risk is significant.

There are at least two caveats to the analysis of gross returns to post-harvest storage and marketing presented above. First, my gross return measure does not account for all benefits and costs of commodity storage incurred by deferred sales. Waiting to realize sales until after calendar year end entails additional physical and opportunity costs of storage. If these are the only excluded benefits or costs to post-harvest marketing, then realized farm-level returns from storage are even poorer than indicated here. However, there may be additional unobserved benefits to storage beyond the price improvement realized on deferred sales. First, storage may be used to facilitate other aspects of farm operations that may provide significant benefits to farm managers. For example, on-farm storage may be used to speed harvest progress when local grain elevators or processing plants experience harvest-time congestion. Second, deferring grain sales until a new calendar year may provide income tax benefits to farm businesses that are difficult to quantify. By smoothing revenue across tax periods, deferred grain sales can reduce income tax liabilities for farms (Davenport, Boehlje, and Martin, 1982; McNew and Gardner, 1999). A second caveat is that this analysis ignores quantities when calculating the gross returns to storage. Farm managers who defer a large portion of sales to a subsequent calendar year assume more risk than those who realize large sales near to harvest. If farms that have a small share of near-to-harvest sales (those to the left of the distributions in Figure 2) are systematically able to realize better prices on deferred sales, then my results understate the risk-adjusted returns to post-harvest marketing. However, I have no evidence to indicate this is the case.

This study suggests that farm managers should carefully weigh the risks of deferring grain sales until later in the marketing year, especially unhedged sales. Although farmers do realize profits in the aggregate from selling later, the wide variety of outcomes from deferred sales shows that the downside risk of losing money on stored grain is substantial. Farmers can manage this risk and secure gains from deferred sales through forward contracting. Seasonal price appreciation is real but cannot be realized with certainty unless farmers use forward sales to capture those gains.

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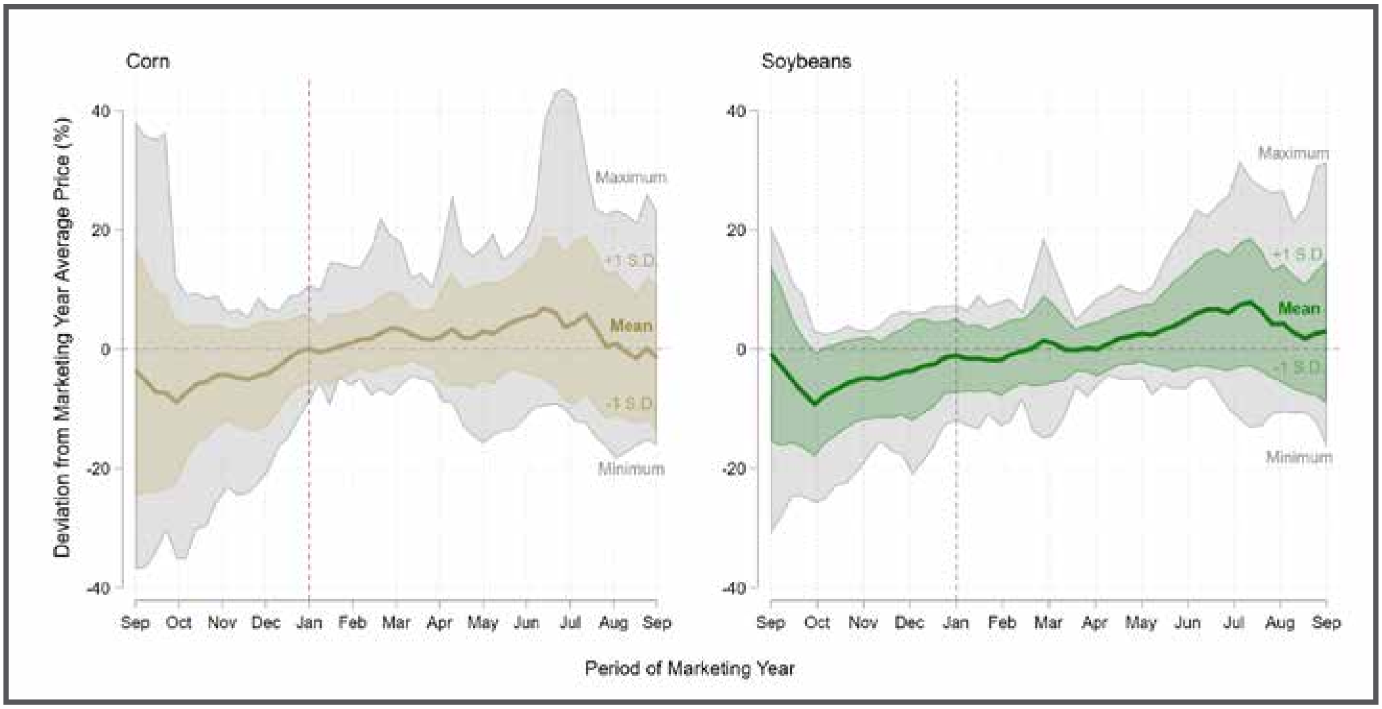


Figure 1. Typical and extreme seasonal variation in corn and soybean prices in Central Illinois, 2004–2020 (Mean (thick) lines indicate the average across all years of the weekly deviation from the marketing year average price, shaded areas indicate the range given by one standard deviation above and below the mean value (colored) and the maximum and minimum deviations observed (gray))

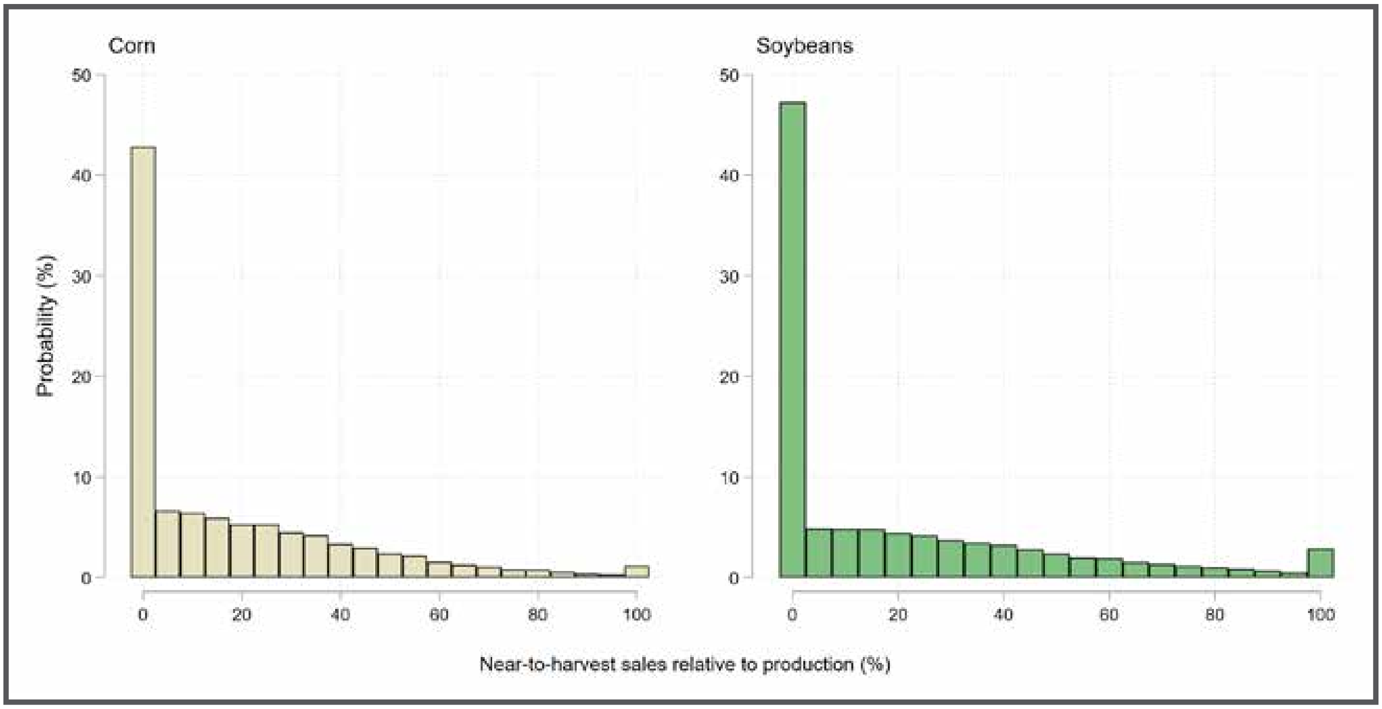


Figure 2. Distribution across farms and years of the proportion of corn and soybean sales made near to harvest

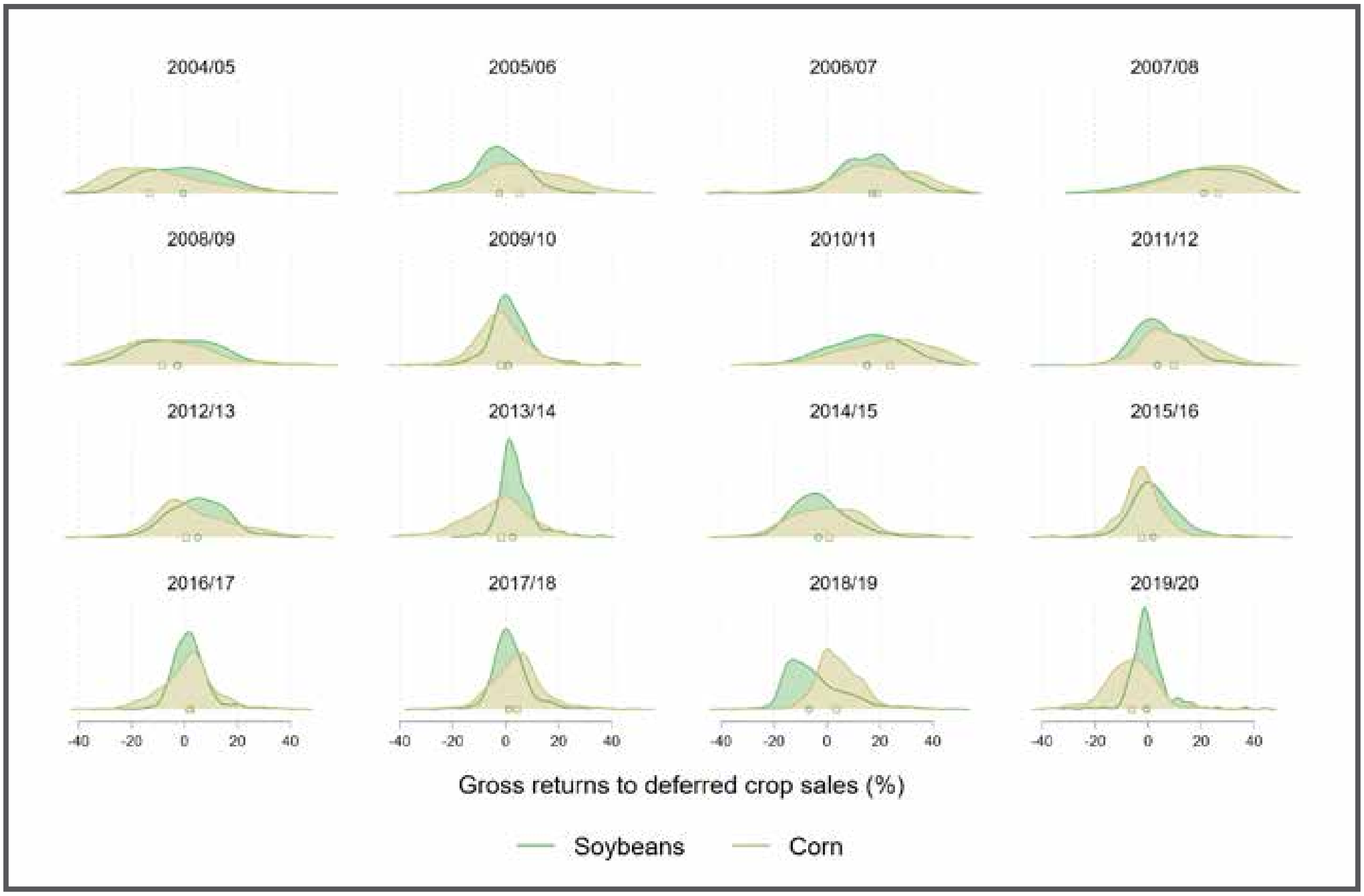
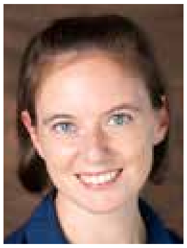


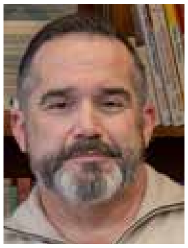
Figure 3. Distribution of gross returns from deferred (post-January 1) crop sales by commodity and marketing year, 2004/05 to 2019/20 (Markers below each distribution function indicate the median gross return in that marketing year)

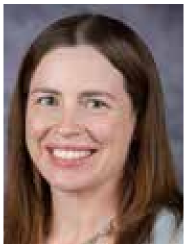
Table 1. Summary Statistics for Gross Returns to Post-harvest Storage and Marketing by Crop*		
Gross Return	**Corn**	**Soybeans**
Mean	6.5%	5.0%
Median	3.4%	2.6%
Standard Deviation (Unconditional)	19.2%	15.1%
Standard Deviation (Within-Year)	14.9%	12.9%
Prob()	39.6%	38.4%
Target Semi-Deviation	8.8%	7.8%
Sharpe Ratio	0.43	0.38
Sortino Ratio	0.73	0.64

*Summary statistics are calculated from 11,874 farm-commodity-year observations for 17 marketing years from 2004–05 to 2019–20

An Analysis of Sweat Equity Arrangements in Farm Succession Planning







By Jenn D. Krultz, Gregg Hadley, Robin Reid, Dan O'Brien, and Rich Llewelyn

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Abstract

How can a retiring farmer and returning heir set up an agreement to ensure that the heir's unpaid efforts will be compensated when the family farm transitions? In this study, three simulation farms were created using the Top Third Profit Category of Kansas Farm Management Association data. Then, three sweat equity arrangements were established and analyzed: a percentage agreement, a salary agreement, and an hourly agreement. Results found all three scenarios to be successful for each farm, with the percentage agreement being the most successful, the annual salary agreement being the next successful, and the hourly agreement being the least successful while still being a profitable option.

INTRODUCTION

Many farmers dream of passing their operation to their children someday. However, the farming landscape has changed significantly over the past several decades, and taking over the family operation is not as simple as it used to be. Many farmers rely on their farm equity for their retirement and may not be able to gift it to their heirs who may be interested in taking over the farm. These heirs can struggle in securing and later paying off loans if they must purchase the farm at a market value from the retiring generation at the time of transition. The on-farm heirs also may not be able to afford to purchase the assets from the off-farm heirs, should the off-farm heirs decide to sell their portion of an inheritance. With volatile commodity markets, farm income may not always support competitive wages on the farm in any given year. One way to address this is for the heir to work his or her way into ownership of the farm, a concept known as sweat equity.

As defined, "sweat equity arises in part when an on-farm heir is paid less than their true opportunity cost to work for the business," (Langemeier, 2017). This could result in the farm heirs receiving more assets in the form of land, equipment, animals, and/or buildings to compensate (Kirkpatrick, Schlesser, et al., 2021). A strategy such as this can ensure the success of the farm as it transitions to the next generation but also needs to be done in a way to ensure success for the family and the farm.

Farms will transfer with or without a plan. If the farm family does not have a plan documented, the farm may not transition in the desired manner. While there is plenty of research (and resources) available on farm estate and succession planning, there is not a lot of emphasis on sweat equity arrangements. How can a retiring farmer and heir set up an agreement to ensure that the heir's unpaid efforts will be compensated fairly when the family farm transitions?

The objective of this research is to determine the value of sweat equity based on arrangements made when the heir returns to the farm. It will be focused on providing resources for those at the beginning of their farming career to determine feasible strategies and determine a sweat equity value available at the time of anticipated farm transfer.

The research will consist of the following:

1. Develop three simulation farms based on typical Kansas agricultural operations.
2. Identify three different sweat equity strategies to apply to each simulation farm.
3. Use these results to compare which strategies work best with each farm type.

DATA AND METHODS

Data

This research used Kansas Farm Management Association (KFMA) data to run economic simulations analyzing sweat equity investments and returns. At the time of the research, data were readily available for years 2008 to 2020. Based on the average age of the American farmer in 2008 of 58 years old, this work was set up as a 12-year simulation to represent the beginning of a transition to the end, with the farmer scaling back to retirement at 70 years of age in 2020.

Summary of Simulation Farms

Data provided by the KFMA Top Third Profit Category of the Whole-Farm Analysis were used to develop simulation farms upon which to create the 12-year analysis. Three farms were developed for this simulation: a dairy farm, a crop farm, and a cow-calf operation with a cash-crop enterprise. All three farms were set up as sole proprietorships, with each scenario having a parent generation (owner) and a returning child (heir).

Assets and liabilities were considered using typical Kansas farm property and appreciation values. Using the 2008 net worth value for each respective farm, an annual asset appreciation of 7.6% was calculated based on National Agricultural Statistics Service (NASS) Quick Stats data analyzing Kansas farm property values from 2008-2012. Total liabilities in 2008 were used to determine a one-time loan created for each simulation, and an annual percentage rate of 7.5% for 12 years was factored into a monthly rate of 0.625% for 180 months. Current liabilities for each year were determined by the sum of principal payments for the given year, and non-current liabilities were determined by the remaining balance on December 31st of the prior year.

Regarding income and expenses, the Top Third report of each respective simulation farm type was used to focus on farms that are currently successful and most likely to survive into transition. These values were then used to calculate gross income, expenses, interest, and depreciation. The data were also used to prepare a loan schedule for the farm during the transition. Once the farm financials were analyzed, family living expenses and tax values for each of the heir and owner generations were determined by the simulation farm's family size and age using KFMA Family Living Expense reports. Off-farm employment for the heir was also considered as all heirs start the simulation with an off-farm job. All heirs in the salary arrangement scenario left their off-farm employment at the beginning of the simulation. For the percentage and hourly arrangements, a sliding scale was assessed to determine if the heir was working off the farm full-time (<1,399 hours), three-quarters time (1,400-1,799 hours), or half-time (1,800-1,999 hours). Once the heir reaches 2,000 labor hours in a year on the farm, the assumption was that the heir will leave their job to work on the farm full time.

Once the net farm income was determined and family living expenses and taxes were deducted, the remaining income needed to be delegated: 20% went into savings once all farm and family living expenses were paid, with an interest rate of 5% used for anything saved during this 12-year simulation, including savings, money market, and stock market accounts. If expenses exceeded income, this negative amount was represented in the annual savings and deducted from the total savings for this simulation. The remainder was invested back into the farm.

Sweat Equity Arrangements

Three sweat equity arrangements were studied in this research: a percentage agreement, a salary agreement, and an hourly agreement. The three sweat equity farm scenarios were built and compared against the KFMA Whole-Farm Analysis historical data from 2008 to 2020 to see how proposed sweat equity arrangements would have resulted. When assessing pay rates, competency levels described by Roehl and Herbel with KFMA were used (2009).

Percentage Agreement

The percentage agreement begins in 2008, with the owner being responsible for 75% of the income and expenses while the heir is responsible for the remaining 25%. This initial 25% will be put toward living expenses and savings as well as the opportunity to invest back into the farm with the purchase of assets, such as replacement calves, equipment, or land. This percentage will grow over time for the returning generation as skills and contributions increase and result in the retiring farmer being responsible for 25% of the income and expenses in 2020 while the heir has moved up to 75%.

Salary Agreement

The salary agreement will be an arrangement between the owner and the heir to provide a compensation package competitive to the heir's current corporate salary for the heir to join the farm full time. As it can be difficult for a farm to pay a returning heir a full salary in cash only each year, assets can sometimes be provided to compensate. In this simulation, the remaining portion of the compensation will come from housing expenses based on the KFMA Whole-Farm Summary of Family Living Expenses.

Hourly Agreement

The hourly agreement will be an arrangement between the owner and the heir to provide training and management experience on an hourly basis. This hourly wage will be based on KFMA data for part-time and full-time employees. Like the percentage agreement, this portion will start with the heir at 25% responsibility for the operation and grow during the transition period to show the increase in management decisions and farm operation responsibility. Instead of basing compensation on the overall net income, pay will be based on the hours dedicated to the operation.

Simulation Farms

Once each farm was built, a representative family was created to use for the narrative of each simulation. These narratives introduce the families, discuss the background of the farm, and the decisions being made when bringing the next generation back to the farm, exemplifying what many farms may face when discussing family farm transitions and the role sweat equity plays.

Dairy Farm

A typical Kansas dairy farm in 2008 consists of a 58-year-old farmer with a 56-year-old spouse. There is a 31-year-old heir and spouse who have an interest in taking over the farm when the parents retire. There is also a 29-year-old off-farm heir who is not involved in the farm. The farm consists of 120 cows and 790 acres for a net worth of $819,903. There is a current loan of $310,253. Both parents work on the farm, and one spouse also has off-farm employment. The heir and spouse have regularly helped on the farm during these busy times while each maintaining full-time off-farm employment, with a total nonfarm income of $72,339 after taxes.

With record-high milk prices in 2007, this appears to be a great time for the heir to take a larger role on the farm while scaling back on off-farm employment. They begin contributing to daily chores and take over all calf management decisions. Over time, the responsibilities and contributions grow. At the end of 2020, the farm's net worth is $2,629,442.

Crop Farm

A typical Kansas crop farm in 2008 consists of a 58-year-old farmer with a 56-year-old spouse. They have an heir and spouse who are interested in taking over the farm when the parents retire. There is also an off-farm heir who is not involved on the farm. The farm consists of 1,600 acres total, half of which are owned. The farm rotates between corn, soybeans, and wheat and is worth $843,782, with a total outstanding loan balance of $367,285. One owner is fully employed by the farm, while the other has a full-time job off the farm. They have a nonfarm income of $53,610. The returning heir and spouse each have off-farm jobs with a total nonfarm income is $72,339 after taxes. The recent ethanol boom appears to be a great time for the heir to take a larger role on the farm in 2008 and begin scaling back off-farm employment. At the end of 2020, the farm's net worth has grown to $2,807,306.

Beef Operation

A typical Kansas beef operation in 2008 consists of a 58-year-old farmer with a 56-year-old spouse. They have an heir and spouse who are interested in taking over the farm when the parents retire. Two other adult children are not involved on the farm. The farm consists of 144 beef cows and 1,041 acres total, half of which are owned. The farm rotates between corn, soybeans, and wheat, with a loan of $86,783. The farm is worth $437,887. One owner is fully employed by the farm, while the other works off-farm with a nonfarm income of $53,610. Both the returning heir and spouse are employed off the farm with a total nonfarm income of $72,339 after taxes. By 2020, the farm's net worth has grown to $1,238,917.

Assessment of Sweat Equity Agreements

The final analysis of the success of each arrangement on each farm was determined by a sum of the total savings, total reinvestment, and total sweat equity for the heir. The arrangement with the highest value will be deemed the best arrangement for each farm while the arrangement with the lowest value will be deemed the least successful. The arrangement that is determined to be the best for most farms will be considered the best overall arrangement in this simulation.

Results

Dairy Farm Percentage Agreement

At the end of 2008, the returning heir puts $5,091 in savings and reinvests $20,363 into the farm. The off-farm job has allowed the heir to make great investments in the farm, but it's time to focus all their time on the operation. As the heir leaves the off-farm job and switches to full-time employment on the farm at the end of 2013, they save $13,872 and reinvest an impressive $55,489 throughout 2014.

By the end of 2020, the returning heir has saved a total of $94,374 and reinvested a total of $324,862 during the transition period. The total farm net worth started at $819,903 and is now $2,629,442. During this 12-year simulation, the farm's net worth increases by $1,809,540, of which $908,389 is attributed to the heir's contributions. Given the investment of $324,862, the sweat equity is worth $583,527. Adding in the total reinvestment and total savings, the total value of the percentage arrangement for the dairy farm is $1,002,763.

Crop Farm Percentage Agreement

At the end of 2008, the returning heir has put $13,602 in savings and reinvested $54,406. Despite changes in the market over the next 10 years, it's time for the returning heir to leave the off-farm job and commit to the farm as it's taking more time and attention in 2017. By the end of 2020, the returning heir has saved a total of $159,725 and reinvested a total of $481,045 during the transition period. The total farm net worth started at $843,782 and is now $2,807,306. During this 12-year simulation, the farm's net worth increases by $1,963.524, of which $985,689 is attributed to the returning heir's contributions. Given the investment of $481,405, the sweat equity ends up being $504,644. Adding in the total reinvestment and total savings, the total value of the percentage arrangement for the crop farm is $1,145,414.

Beef Operation Percentage Agreement

At the end of 2008, the returning heir sets aside $7,757 in savings and reinvests $31,030. As the returning heir leaves their off-farm job and switches to full-time employment on the farm at the end of 2018, they are only able to reinvest $5,267 as expenses continue to increase.

By the end of 2020, the returning heir has saved a total of $120,968 and reinvested a total of $367,678 during this transition period. The total farm net worth started at $437,887 and is now $1,238,917. During this 12-year simulation, the farm's net worth increases by $801,030, of which $400,515 is attributed to the returning heir's contributions. Given their investment of $367,678, their sweat equity is $32,837. Adding in the total reinvestment and total savings, the total value of the percentage arrangement for the beef operation is $521,483.

Dairy Farm Salary Agreement

At the end of 2008, the returning heir has set aside $3,965 for savings and reinvested $15,860. By the end of 2020, the returning heir has saved a total of $100,795 and reinvested a total of $300,778 during this transition period. The total farm net worth started at $819,903 and is now $2,629,442. During this 12-year simulation, the farm's net worth increased by $1,809,540, half of which, $904,770, is attributed to the returning heir's contributions. Given the investment of $300,778, their sweat equity is worth $603,992. Adding in the total reinvestment and total savings, the total value of the salary arrangement for the dairy farm is $1,005,565.

Crop Farm Salary Agreement

At the end of 2008, the returning heir sets aside $7,135 for savings and reinvests $29,260. By the end of 2020, the returning heir has saved $123,385 and reinvested $368,820 during this transition period. The total farm net worth started at $843,782 and is now $2,807,306. During this 12-year simulation, the farm's net worth increased by $1,963,524, half of which, $985,689, is attributed to the returning heir's contributions. Given the investment of $368,820, the sweat equity is worth $612,942. Adding in the total reinvestment and total savings, the total value of the salary arrangement for the crop farm is $1,105,147.

Beef Operation Salary Agreement

At the end of 2008, the returning heir has set aside $3,965 in savings and reinvested $15,860. The salary arrangement provides value already in the second year as the ag economy goes into a downturn. By the end of 2020, the returning heir has saved $111,041 and reinvested $342,521 during this transition period. The total farm net worth started at $437,887 and is now $1,238,917. During this 12-year simulation, the farm's net worth increased by $801,030, half of which, $400,515, is attributed to the returning heir's contributions. Given their investment of $342,521, their sweat equity is worth $57,995. Adding in the total reinvestment and total savings, the total value of the salary arrangement for the beef operation is $511,557.

Dairy Farm Hourly Agreement

At the end of 2008, the returning heir puts $8,299 in savings and reinvests $33,195 into the farm. The next year proves to be tough for the dairy economy, but this wage agreement helps support the heir as they are just beginning their dairy career. By the end of 2020, the returning heir has saved a total of $69,246 and reinvested a total of $195,449 during this transition period. The total farm net worth started at $819,903 and is now $2,629,442. During this 12-year simulation, the farm's net worth increases by $1,809,540, of which $908,389 is attributed to the returning heir's contributions. Given the investment of $195,449, the sweat equity is worth $709,321. Adding in the total reinvestment and total savings, the total value of the hourly wage arrangement for the dairy farm is $974,016.

Crop Farm Hourly Wage Agreement

At the end of 2008, the returning heir puts $7,386 in savings and reinvests $29,546 into the farm. The next year proves to be tough for the ag economy, but this wage agreement helps support the heir as they are just beginning their career on the farm. By the end of 2020, the returning heir has saved a total of $84,182 and reinvested a total of $250,874 during this transition period. During this 12-year simulation, the farm's net worth increases by $1,809,540, of which $908,389 is attributed to the returning heir's contributions. Given their investment of $250,874, the sweat equity is worth $730,888. Adding in the total reinvestment and total savings, the total value of the hourly wage arrangement for the crop farm is $1,065,944.

Beef Operation Hourly Wage Agreement

At the end of 2008, the returning heir puts $3,361 in savings and reinvests $13,442 into the farm. The next year proves to be tough for the ag economy, but this wage agreement helps support them as they are just beginning their career on the farm. By the end of 2020, the returning heir has saved a total of $77,709 and reinvested a total of $230,524 during this transition period. The total farm net worth started at $437,887 and is now $1,238,917. During this 12-year simulation, the farm's net worth increased by $801,030, of which $400,515 is attributed to the returning heir's contributions. Given the investment of $230,524, the sweat equity is worth $169,991. Adding in the total reinvestment and total savings, the total value of the hourly wage arrangement for the beef operation is $478,224.

Comparisons

Figure 1 shows a condensed summary of the findings. Each farm was analyzed using each arrangement type, with the total savings, total reinvestment, and sweat equity were added to determine the total result. Sweat equity was calculated using the farm's change in net worth during the 12-year simulation and subtracting the heir's reinvestment from the portion of the net worth change attributed to the heir, which was approximately 50% for each simulation.

Dairy Farm

For the dairy farm, the salary arrangement was the best but by a slim margin. When comparing the full value received, the salary agreement proved to be the best option, with a total value of $1,005,565. The total value of the percentage agreement was $1,002,762, a difference of $2,803 when compared to the total value of the salary agreement. The hourly agreement was $974,016, which lagged the percentage agreement by $28,746.

Crop Farm

The crop farm benefited the most when using the percentage agreement, which resulted in $1,145,414. When comparing the percentage agreement to the salary agreement in the overall sweat equity calculation, the salary agreement's total value was $1,105,147, showing the percentage agreement was better by $40,267. The hourly agreement's total value was $1,065,944, behind the salary agreement by $39,203.

Beef Operation

The beef operation also saw the most success when using the percentage agreement, which saw a total value of $521,483. The salary arrangement was similarly effective, with a total value of $511,556, a difference of $9,927. The hourly agreement saw success but had the lowest total value of $478,224, which was $33,332 less than the salary agreement.

CONCLUSIONS

The percentage agreement was overall the most successful for all three farms in this simulation. Not only did it provide the most successful combined financial results, but it allowed the returning heir generation to slowly learn and take on more responsibilities each year while seeing the impact of their decision-making on the bottom line of the farm. When the farm was successful, both the heir and owner generations saw success. Conversely, challenges in farm profitability were felt by both generations, helping the returning generation understand the impacts of their own decisions as well as market factors beyond their control. This arrangement could be viable in a family that is looking to begin transferring the labor and management decisions right away to allow the retiring generation to guide the returning generation through various, and sometimes unexpected, market conditions.

The salary agreement was the second most successful arrangement in this simulation, allowing the owner generation to employ the returning heir full time to learn best practices for the farm while also earning a guaranteed living salary and receiving housing to compensate for cash that the farm may not be able to provide in any given year. Between this salary and the spouse's income, there was no need for additional off-farm employment to compete for the time and attention the farm requires. The owner generation, however, must cover these wages and housing expenses regardless of the success of the farm, with no cap on their financial risk. The heir generation will eventually see risk should the farm become unprofitable as the salary would need to be reduced. This is an arrangement that could be feasible for a family that has noncash assets available to offer a returning heir while also looking to provide a guaranteed salary during the first years of transition if the farm is profitable enough and/or the owner generation has enough savings to sustain this arrangement.

The hourly agreement was the least successful in this simulation. The returning heir didn't necessarily see their impacts directly on the farm's financials, their time on the farm competed for wages that could be earned off-farm, and as with the salary agreement, the owner generation needed to pay the heir whether there was farm income or not. Moreover, not only did it have the lowest return of the methods studied, but off-farm employment could prove to be more profitable than farming for the heir. On the other hand, this arrangement can provide flexibility should there be concerns over a farm's financial viability to support another generation as the returning heir can potentially put more hours in off-farm employment while continuing involvement on the farm during times of market volatility.

This research relied on second-hand data, which can have limitations. While KFMA data are compiled consistently by analysts to prevent bias, the purposes behind the data collection would not necessarily be the same as the objectives in this research. There is always the opportunity for some assumptions and biases to be made from reading second-hand data.

These simulations were built in the interest of using the fewest number of variables possible to reduce fluctuations and bias. Because of this, they might not represent certain farm situations as no two farms are alike, and the factors studied may not apply to some reading this research to make decisions for their own operations. Using figures from a diverse dataset can result in averages that aren't representative of any of the individuals studied.

When setting up a simulation, decisions need to be made, which can lead to assumptions being necessary. In this simulation, all farms were successful to the end of the 12-year model. All family members on each farm remained on the farm, eliminating the risk of death, divorce, or departure of any members of either generation. Also, there were no external factors impacting the financial success of the farm, such as medical bills, legal action, or external debts. Since the research was focused on the impacts of the transition arrangements, respective farm sizes did not change throughout the simulation. To ensure financial stability for each household, at least one family member of each generation maintained off-farm employment.

As with any research, many questions arose that didn't fit the simulation but are excellent opportunities for further research. The proposals for sweat equity agreements are up to the discretion of the researcher, with countless strategies to study. Since this research was looking at a broad view of various arrangements, only one proposal of each type was used. However, there are plenty of opportunities to compare different proposals within one arrangement type. With this research focusing on the impact of different arrangements, the families were set up to be rather similar. Additional research and sensitivity analyses could be done on other factors, such as age and number of heirs, proportions assigned to owner and heir generations, and investment decisions, both on and off the farm.

One of the few constants in life is change. Proper sweat equity valuations in succession planning can ensure the interests of the farm, as well as all stakeholders, are protected. Since no two farms are alike, no two transition plans can be the same. Despite the multitude of factors involved, Grahame, et al. (2018) provide two goals for successful transitioning that will apply to every farm: "Secure the farm's financial viability and transition the farm in such a way to make everyone happy." While all arrangements were viable in this simulation, any given farm is going to have its own financial obligations and management needs. There's not one single way that will work for all farms, but there are multiple strategies to successfully transition many farms to accommodate the needs of each generation of a given family.

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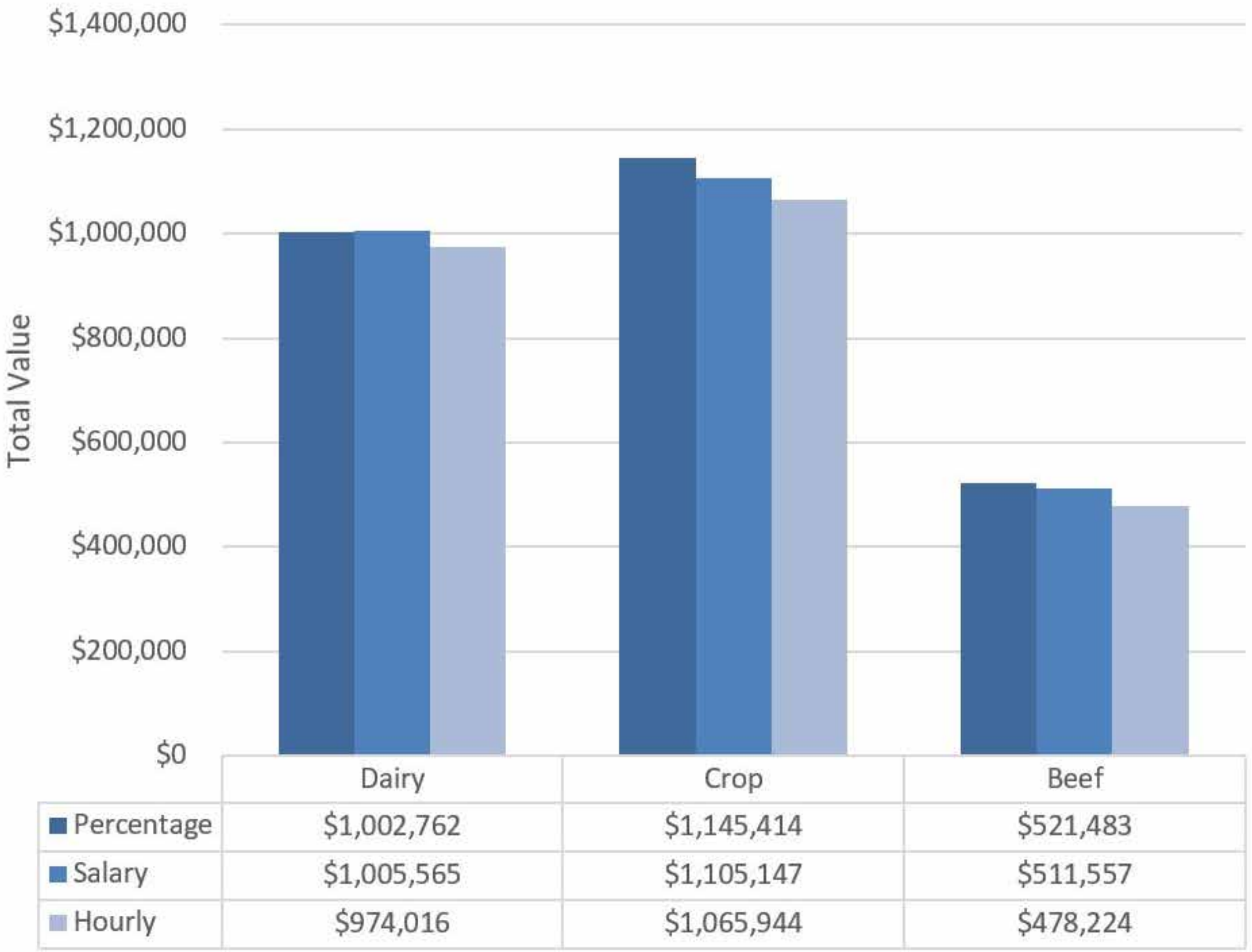
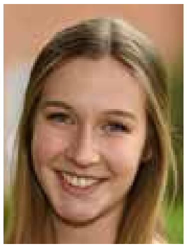


	Dairy	Crop	Beef
■ Percentage	$1,002,762	$1,145,414	$521,483
■ Salary	$1,005,565	$1,105,147	$511,557
■ Hourly	$974,016	$1,065,944	$478,224

Figure 1. Sweat equity agreement total value by simulation farm type

Factors Influencing Producer Sentiment

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Abstract

Producer sentiment is typically analyzed on an aggregate basis and believed to be largely driven by market conditions. Our research introduces alternative determinants of producer sentiment. Drawing from survey data gathered in April 2023, we analyze the interplay between producer sentiment, current market dynamics, future anticipations, and underlying farm-specific attributes. Specifically, correlation coefficients and t-tests are used to pinpoint characteristics that inherently differ across three sentiment-defined groups. Our findings indicate that producer sentiment intertwines with expected financial performance, farm resilience, growth prospects, and educational achievements, rather than being solely reliant on current market conditions.

INTRODUCTION

Farmers are feeling the crunch—adverse conditions, including high interest rates, high input prices, and unpredictable weather, present significant risk to farmers and negatively influence producer sentiment. Farmers have plenty of reason to be concerned about the future of their operations, yet despite turbulent market conditions, our survey results indicate many farmers remain relatively optimistic. At the same time, some farmers are relatively pessimistic. If producer sentiment was solely tied to current market conditions for the agricultural industry, variability in sentiment across producers would be minimal. This leads us to believe there are other factors driving producer sentiment, such as intrinsic characteristics unique to each farming operation.

On a monthly basis, the Purdue University-CME Group Ag Economy Barometer samples approximately 400 agricultural producers across the United States to generate a cumulative score indicating the health of the agricultural economy. While the index score is representative of overarching trends in farmer sentiment, variability in individual survey responses is lost in computations of the cumulative index. Prior reports on the Ag Economy Barometer Index focus on connections between aggregate farmer sentiment, land values, input costs, interest rates, farm policy, farm growth as well as many other dimensions impacting commercial farms (Mintert and Langemeier, 2023b).

This study explores how individual farm characteristics, such as management practices and farm resilience influence producer sentiment measured by the Purdue University-CME Group Ag Economy Barometer, a standalone measurement of farmer sentiment in the United States. Instead of just aggregating producer sentiment scores, we use individual survey responses to pinpoint how farm characteristics and other factors sway producer sentiment.

SURVEY METHODS

A phone survey of U.S. crop producers was conducted in early April 2023 using a similar methodology as that used for the monthly Ag Economy Barometer Index (Purdue University Center for Commercial Agriculture, 2023). The survey targeted commercial producers, which are defined as agricultural producers having annual market value of production equal to or exceeding $500,000, and was developed specifically to contrast producer sentiment, farm characteristics, management practices, and resilience among a sample of farms. Question categories included producer sentiment, farm growth, risk preferences, farm demographics, management practices, and strategic risk.

The first five questions replicated those used for the monthly Ag Economy Barometer Index. Use of these questions allows us to compute the Index of Current Conditions, the Index of Future Expectations, and the Ag Economy Barometer Index for each respondent and for groups of respondents.

Farm growth questions asked respondents about opportunities to expand their farm and their planned annual growth rate over the next five years. These two questions have been asked in previous Ag Economy Barometer surveys. For example, Langemeier and Mintert (2023) indicated that approximately 50% of survey respondents in February 2023 had either no plans to grow or plan to exit or retire. Based on Langemeier and Mintert (2023), we expect sentiment to be positively related to farm growth.

Survey respondents were also asked to rate their risk preferences. Risk aversion measures a producer's willingness to take on risk in their operation. High levels of risk aversion are often associated with hesitation to adopt new farming practices or technologies, lack of self-efficacy, reluctance to engage in social networks, maintenance of large financial reserves, and low levels of farm growth (Sulewski and Kłoczko-Gajewska, 2014; Finger, Wüpper, and McCallum, 2023).

Popular strategies to elicit risk preferences include lottery questionnaires and domain-specific risk assessments (Charness, Gneezy, and Imas, 2013). Data for this study were collected via a call center, which makes it difficult for respondents to answer complex questions effectively, such as those involving lotteries or gambles. Studies on farmer risk preference indicate most farmers are risk averse across all domains, which signals the presence of a common underlying risk trait (Dohmen et al., 2011; Hansson and Lagerkvist, 2012). Thus, little additional value would be derived from using domain-specific risk assessments, further motivating our use of generic questions to measure risk preferences. Specifically, two questions were posed. The first question addressed each survey respondent's attitude toward risk, and the second asked each survey respondent to describe how a neighbor would describe their risk-taking behavior.

Demographic questions involved total acres operated, educational level, and operator age. We had a priori hypotheses regarding the relationship between producer sentiment and the answer to each demographic question. Each of the demographic variables was expected to have a positive relationship with producer sentiment. Increases in age, education, and farm size give farm operators a greater resource base and superior ability to deal with adversity, providing them a more optimistic outlook for their operation.

Management practice questions addressed the implementation of written succession plans, written crop lease agreements, advice from agronomic consultants, use of financial ratios, documentation and evaluation of crop pricing performance, use of standard operating procedures, no-till adoption, and adoption of specific precision agriculture technologies such as variable rate fertilizer application, grid or zone soil sampling, GPS guidance systems, yield monitors, and drones. These questions make it possible to examine the relationship between producer sentiment and each management practice.

Strategic risks are related to shocks in a farm's strategic position and stem from a multitude of factors, including a shift in the political or social environment, changes in government policy, and a growing or contracting macroeconomy (Miller et al., 2004). Survey respondents were asked six questions pertaining to absorption capacity and agility that were adapted from Sull (2009). Absorption capacity is related to a farm's ability to withstand shocks from strategic risk, while agility measures a farm's ability to identify and capture business opportunities more quickly than rivals. We hypothesized that producer sentiment would be positively related to a farm's resilience score, computed using responses to the six strategic risk questions. In two related questions, survey respondents were asked to evaluate potential threats to their operation and to identify which source of risk was most important to their farm.

STATISTICAL METHODS

In addition to summarizing the aggregated responses to each survey question, we analyze correlation between producer sentiment and various farm characteristics. Segmenting survey responses into three groups by producer sentiment level allows us to test differences in means for each survey question, across groups. Producers with sentiment levels within one standard deviation of the mean were categorized as having "medium" sentiment, those above one standard deviation of the mean were categorized as having "high" sentiment, and those below one standard deviation of the mean were categorized as having "low" sentiment.

Correlation coefficients were used to examine the relationship between the aggregated sentiment indices (i.e., Ag Economy Barometer, Index of Current Conditions, and Index of Future Expectations) and the relationship between producer sentiment and farm characteristics. Correlation coefficients reveal which component questions of the Ag Economy Barometer Index have the greatest influence on overall producer sentiment. Correlation coefficients between producer sentiment and each farm characteristic identify the sign and strength of relationships between producer sentiment and factors such as farm growth, risk aversion, farm demographic variables, management practices, and strategic risk.

Due to the nature of the dataset, which primarily consists of ordinal variables, we had two options for calculating correlation coefficients, Spearman's Rho and Kendall's Tau, both of which are designed to accommodate non-linear relationships among data. Research on the two methods indicate similar results in correlation coefficients, with slightly lower coefficient values reported using Kendall's Tau. However, when examining statistical significance of the correlation coefficients for varying sample sizes, Kendall's Tau consistently produces smaller confidence intervals and smaller mean squared errors across tested confidence levels (Croux and Dehon, 2010; Puth, Neuhäuser and Ruxton, 2015). Kendall's Tau correlations are also considered more robust and have higher efficiency than Spearman correlations (Croux and Dehon, 2010).

Additionally, when deciding on a method to test correlations, tied data need to be taken into consideration. Tied data occur when two or more observations have the same values, preventing rank from being assigned. For example, two farms that were independently sampled may have the same responses to a variety, but not necessarily all, of the survey questions. Similarities in responses create issues assigning rank to observations in a dataset. Because the survey sampled more than 400 producers using questions with small ranges of ordinal responses, we would expect significant presence of ties within the data. Spearman correlations are calculated using rank for each observation. Therefore, if Spearman correlations were used for this data, risk of reporting inaccurate correlation coefficients is high. Kendall's Tau measures correlations using concordances and discordances in paired observations rather than based on rank measurements, as used for Spearman correlations, resulting in more accurate correlation coefficients for tied data (Puth, Neuhäuser, and Ruxton, 2015).

T-tests were also used to evaluate whether the survey responses among the three producer groups (i.e., low producer sentiment, medium producer sentiment, and high producer sentiment) were statistically different. Discussion will focus on the variables that were statistically different between the groups with "low" and "high" producer sentiment.

PRODUCER SENTIMENT AMONG SURVEY RESPONDENTS

Survey results for the Ag Economy Barometer Index ranged from 0 to 324 with a mean of 122 (Table 1). The Index of Current Conditions had slightly more optimistic readings, with scores ranging from 0 to 397 and a mean of 130. Future expectations as measured with the Index of Future Expectations were on average more pessimistic with scores ranging from 0 to 288 with an average of 119. These results are consistent with the Ag Economy Barometer Index report for April 2023, which collected data from April 10-14th. For April 2023, the Ag Economy Barometer Index was 123, with the Index of Current Conditions at 129 and the Index of Future Expectations at 120 (Mintert and Langemeier, 2023a).

In addition to reporting the average producer sentiment values for the entire sample, Table 1 reports the average values for each producer sentiment group. Given that we sorted the survey responses on producer sentiment, it was not surprising to find a significant difference between the "low" and "high" producer sentiment groups for each of the questions used to compute the Ag Economy Barometer Index. What was surprising was how different these averages were from the mean for the entire sample. For example, the average Ag Economy Barometer Index for the group categorized as having "low" producer sentiment was only 20, while the average index for the group categorized as having “high” producer sentiment was 259.

While values range by question in Table 1, on average, those categorized as having “low” sentiment have extremely negative outlooks on the agricultural economy compared to those with “medium” or “high” sentiment levels. For example, 95% of respondents with “low” sentiment believe the general agricultural economy will have poor times financially in the coming year. In contrast, 73% of farmers with “high” sentiment believe there will be good times financially in the coming year. T-tests indicate that for all questions used to calculate the producer sentiment index, we are 99% confident the average values for farms in the “low” versus “high” sentiment categories are statistically different from one another.

Table 2 reports the correlation coefficients between each producer sentiment index and the five questions used to assess producer sentiment. As expected, the correlations between the three sentiment indices are significant, with correlation coefficients ranging from 0.228 to 0.785. Also, as expected, the Index of Current Conditions is more correlated with its components (i.e., current financial positioning and large farm investments) than it is with the components for the Index of Future Expectations (future financial positioning and ag economy outlook). Similarly, the Index of Future Expectations is highly correlated with its components. Determining the influence of each question helps identify concerns that are top of mind for farmers and whether producer sentiment is more dependent on current market conditions or future expectations.

Initially, one might expect that each of the five questions used for the Ag Economy Barometer Index influences sentiment equally. However, correlation coefficients and their relative significance levels displayed in Table 2 show higher correlations between sentiment, questions relating to financial performance, and prospects for the agricultural economy in the coming year. This demonstrates that uncertainties (particularly financial uncertainties) within the next 12 months have greater influence over farmers’ sentiment than current conditions.

The results in Tables 3-6 discuss differences in survey responses with respect to farm growth, risk aversion, demographic variables, management practices, and strategic risk between survey respondents with “low” and “high” sentiment, and present correlation coefficients between producer sentiment and these factors. This will help us identify which factors are influencing producer sentiment.

PRODUCER SENTIMENT AND FARM CHARACTERISTICS

In prior research, positive relationships are observed among farm growth, operator age, farm size, and education (Villatoro and Langemeier, 2006; Akimowicz, et al., 2013). We hypothesize that farmer sentiment reacts concurrently with these characteristics. This section analyzes the relationship between each of these farm characteristics and producer sentiment.

On an aggregate basis, 55% of farmers expect their operation to grow in the next five years (Table 3). This is only slightly higher than the proportions reported in Langemeier and Mintert (2023). Farms categorized as having “low” sentiment had lower growth expectations on average, with 50% expecting growth at any level over the next five years and only 18% believing they will have greater opportunities to expand over the next five years. In comparison, 60% of farmers with “high” sentiment expect positive growth within the next five years and 33% believe there will be more opportunities to expand their operation. Using Kendall’s Tau correlation coefficients, both questions used to assess farm growth display positive, statistically significant correlations with producer sentiment (Table 6). Results demonstrate that among respondents in our sample, positive outlooks on the agricultural economy tend to be associated with higher annual growth expectations and the belief that opportunities to expand will be greater over the next five years.

Survey questions on risk aversion asked farmers to rate their risk preferences and estimate how their neighbors would rate their risk-taking behaviors (Table 3). Of the 403 survey respondents, 11% self-selected as strongly risk averse and 7% selected this category based on their neighbor’s perceptions. Moderate risk aversion was the most popular choice among respondents, with 61% for the self-assessment and 66% based on their neighbor’s perceptions.

Once farms are split into groups by sentiment level, those with both “low” and “high” sentiment are relatively more risk seeking than the farms with “medium” sentiment. In fact, responses to both questions on risk-taking behavior were not statistically different between producer groups with “low” and “high” producer sentiment. Correlation coefficients between the two questions on risk aversion also display differing signs, furthering suspicions of a non-linear relationship between producer sentiment and risk aversion.

Farm demographics, including farm size, educational attainment, and operator age all display positive correlations with producer sentiment (Table 6), but only the correlations between producer sentiment and educational attainment are statistically significant. Differences in operator age and farm size are not significant across producer sentiment levels for the most part, the only exception being for farms operating less than 1,000 acres. Approximately 36% of farmers with "low" sentiment operate less than 1,000 acres, while only 20% of farms with "high" sentiment operate farms this small. Correlations also show that, on average, more positive sentiment is associated with having obtained more schooling. In particular, 49% of farms with "low" sentiment have only a high school diploma and less than 12% obtained graduate level education. In contrast, 33% of farmers with "high" sentiment only have a high school education and nearly the same proportion (31%) have completed graduate school.

PRODUCER SENTIMENT AND MANAGEMENT PRACTICES

Much of current research in farm management focuses on the impacts of specific practices such as fertilizer application rates, irrigation, planting density, and education on farm performance (Rains, Olson and Lewis, 2011; Agnolucci et al., 2020; Akhavizadegan et al., 2022). Our assessment of management practices strays from this trend. We assess specific management practices and overall managerial ability by assessing an array of six questions, including questions on succession planning, written lease agreements, advice from agronomic consultants, financial ratios, documentation and evaluation of crop pricing alternatives, and standard operating procedures. For each of the management practices assessed in our survey, at least one-half the farms had already adopted the practice. The highest adoption rates (60%) were associated with written crop lease agreements, as well as documentation and evaluation of crop pricing alternatives.

The adoption rates of management practices were not statistically different for producers with "low" versus "high" sentiment, nor were correlation coefficients between management practices and producer sentiment statistically different from zero. In a question pertaining to the adoption of a no-till cropping system, 46% of the survey respondents indicated that they used no-till practices on more than one-half of their crop acreage. Differences in the adoption of no-till between producer sentiment groups were minimal.

The adoption of precision agriculture technologies showed greater variation by sentiment group compared to those seen for management practices and no-till adoption. Questions on adoption of precision agriculture technologies mimic those studied in Thompson, et al. (2018) and DeLay, Thompson, and Mintert (2021). Thompson, et al. (2018) reported over 90% of farms used GPS guidance and yield monitors, 66% used grid soil sampling, and 25% used drones or other unmanned aerial vehicles. In our survey, 62% of farms used VRT fertilizer application, 73% used grid or zone soil sampling, 67% used GPS guidance, 69% used yield monitors, and 27% used drones. Approximately 8% of the survey respondents indicated that they did not use any of the listed precision agriculture technologies.

Use of grid or zone soil sampling, yield monitors, and drones tended to be highest for farms with "high" sentiment, followed by those with "medium," then "low" sentiment (Table 4). More than 9% of farms with "low" sentiment reported not using any of the listed precision agriculture technologies, whereas only 7% of producers with "high" sentiment did not use precision technologies. Precision agriculture technology adoption rates were not statistically different for producers with "low" versus "high" sentiment. Moreover, correlation coefficients between adoption rates and producer sentiment were not statistically different from zero.

It is important to note that while prior studies focused on crops farms with 1,000+ crop acres, our study focused on commercial farms, regardless of the number of crop acres. According to the 2021 census, the average farm size in the U.S. was 445 acres (USDA, 2022). Considering 31% of our survey respondents operate farms with less than 1,000 acres, adoption rates reported here are likely a more accurate representation of average U.S. farmers.

PRODUCER SENTIMENT AND STRATEGIC RISK

Resilience to strategic risk is measured by assessing absorption capacity and agility, which act as a proxy for a farm's ability to adapt to change and weather unfavorable market conditions. Six survey questions, adapted from Sull (2009), were used to measure absorption capacity and agility. The first three questions (i.e., questions related to per-unit fixed cost, diversification, and balance sheet) measure absorption capacity. Of the 403 survey respondents, 72% believe they have lower fixed costs than competitors, 55% have more diversified operations now relative to five years ago, and 90% believe they have a strong balance sheet (Table 5). The second three questions (i.e., questions related to goals and objectives; opportunities; and advantages and disadvantages) measure agility. Of the 403 respondents, 90% have established goals, objectives, and core values; 83% seek out opportunities new enterprises may provide; and 71% actively compare their farm's advantages and disadvantages with competitors.

Using the six questions assessing resilience to strategic risk, we created a strategic risk score. Based on this cumulative score, 15% of respondents have low resilience to strategic risk while 85% have high resilience. Results presented in Table 6 also show that resilience to strategic risk is positively correlated with producer sentiment, so on average, we would expect producers with "low" sentiment to have lower resilience to strategic risk. In fact, of the respondents with "low" sentiment, 20% have low resilience in comparison to the "high" sentiment group which only has 7% of respondents with low resilience to strategic risk. Additionally, t-test results show that resilience for producers with "low" versus "high" sentiment is statistically different at a 95% confidence level.

Differences in responses are also apparent across producer sentiment groups for each of the six questions assessing resilience. Farms with "high" sentiment had low fixed costs and strong balance sheets. Correlation coefficients corroborate these results with positive statistically significant relationships among producer sentiment, balance sheet strength, and low per-unit fixed costs. Slight positive relationships between sentiment and farms looking for new business opportunities are also observed, but these coefficients are not statistically significant, thus we are unable to draw any conclusions from the data based on these results. The other three metrics for resilience to strategic risk display negative correlations with producer sentiment, but again, none of the correlation coefficients were statistically different from zero.

While many farmers possess relatively high resilience to strategic risk, when asked to identify threats to their operation, few farmers identified strategic risk as a major threat. In fact, from the aggregate sample, only 5% of respondents chose this option. The group most sensitive to strategic risk was the "high" sentiment group, with 6% identifying strategic risk as a major threat.

The identification of other threats was largely comparable across different sentiment levels. Producers with "low" sentiment exhibited slightly fewer concerns regarding extreme weather and the ability to find skilled farm workers, but showed greater concern pertaining to high input costs and geopolitical conflicts. The reduced concerns in the "low" sentiment group regarding the ability to find skilled workers may be attributed to the smaller average size of these farms, resulting in lower demand for hired labor. However, it's important to note that these relationships did not attain statistical significance.

Farmers with "low" sentiment also expressed the highest level of concern about financial risks, followed by marketing risks. Among farms categorized as having "medium" sentiment, marketing risk was the primary concern, followed by financial risks. Interestingly, farms with "high" sentiment did not rank financial risk among their top two concerns. Instead, human risk and marketing risk took the lead as the primary worries for farms with "high" sentiment. This is likely attributed to their larger average farm size and dependence on more farm workers.

CONCLUSIONS

In this paper, we examined connections between producer sentiment and farm growth, risk aversion, demographic variables, management practices, and strategic risk. Measurements of farmer sentiment using the Purdue University-CME Group Ag Economy Barometer are available monthly and provide a comprehensive view of sentiment towards the current agricultural economy. Results from this research add to reports provided on the Ag Economy Barometer by identifying factors that influence variation in sentiment scores among producers.

Producer sentiment varied widely among the farmers surveyed. Pessimistic producers believe the agricultural sector is experiencing bad times and will continue to do so for the next five years. On the other hand, optimistic producers believe we are experiencing good times and will continue to do so. However, most respondents lie somewhere in the middle, with a mix of positive and negative perceptions of current and future performance for the agricultural economy.

By segmenting farms into three groups based on sentiment, distinct differences in farm characteristics become apparent. On average, farms with higher sentiment have operators that are older (40% at or above age 65), are more educated (with 31% having graduate education compared to 12% of those with "low" sentiment), have greater growth expectations (60% expect positive farm growth over the next 5 years), and are more resilient to strategic risk. Farmers with lower sentiment were less likely to indicate that they have low per-unit costs or a strong balance sheet and correspondingly were more concerned about financial risk.

Correlations in the data corroborate patterns observed when survey respondents were split by sentiment level, with statistically significant relationships between producer sentiment, farm growth, the operator's educational attainment, and farm resilience. Correlation coefficients also reveal that sentiment on the agricultural economy has a distinct reliance on future expectations, particularly financial performance over the next 12 months.

While we do not attempt to assign causality, our findings provide insight into factors that influence the range of producer sentiment scores collected by the Ag Economy Barometer Index. Farm managers are encouraged to assess their own operations using survey questions presented in this study to evaluate which sentiment category and related characteristics they best align with. Self-evaluation may aid farm managers in identifying strengths and weaknesses of their own operation and how these compare to other commercial farms across the United States.

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Table 1. Measurements of Producer Sentiment

	Aggregate	Low	Medium	High	Significance
	n=403	n = 76	n = 272	n = 55	(Low vs High)
Ag Economy Barometer Index	122.4	19.6	123.6	258.8	0.0000
Indices of Current Conditions	130.2	26.1	125.1	299.3	0.0000
Indices of Future Expectations	118.6	16.4	122.8	239.1	0.0000
Barometer Questions	**Aggregate** n = 403	**Low** n = 76	**Medium** n = 272	**High** n = 55	**Significance** (Low vs High)
Would you say that your farm operation today is financially better off, worse off, or about the same compared to a year ago?					
Better Off	19.6%	0.0%	16.5%	61.8%	0.0000
Worse Off	32.0%	73.7%	26.5%	1.8%	0.0000
Do you think that a year from now your farm operation will be better off financially, worse off, or just about the same as now?					
Better Off	19.1%	0.0%	15.4%	63.6%	0.0000
Worse Off	34.7%	82.9%	27.6%	3.6%	0.0000
Turning to the general agricultural economy, do you think that during the next twelve months there will be good times financially, or bad times?					
Good Times	24.8%	0.0%	22.1%	72.7%	0.0000
Bad Times	52.4%	94.7%	50.4%	3.6%	0.0000
Do you think it is more likely that US agriculture during the next five years will have widespread good times or widespread bad times?					
Good Times	31.0%	0.0%	30.9%	74.5%	0.0000
Bad Times	40.2%	85.5%	34.6%	5.5%	0.0000
Thinking about large farm investments – like buildings and machinery – generally speaking, do you think now is a good time or bad time to buy such items?					
Good Times	17.4%	0.0%	12.5%	65.5%	0.0000
Bad Times	73.7%	100.0%	76.5%	23.6%	0.0000

Note: Results of U.S. survey conducted in April 2023.

Table 2 : Correlation Coefficients bewteen Producer Sentiment Indices **April, 2023**

	Ag Economy Barometer	Index of Current Conditions	Index of Future Expectations
Ag Economy Barometer	1	0.567***	0.785***
Index of Current Conditions	0.567***	1	0.228***
Index of Future Expectations	0.785***	0.228***	1
Sentiment (Current Financial Positioning)	0.478***	0.764***	0.22***
Sentiment (Future Financial Positioning)	0.543***	0.203***	0.612***
Sentiment (Ag Economy 12-Month Outlook)	0.611***	0.274***	0.666***
Sentiment (Ag Economy 5-Year Outlook)	0.501***	0.089**	0.637***
Sentiment (Large Farm Investments)	0.445***	0.685***	0.182***
Significance Levels: p < .01 '***' p < .05 '**' p < .1 '*'			

Note: Results of U.S. survey conducted in April 2023.

Table 3. Farm Growth, Risk Aversion, and Farm Demographics

Farm Growth	Aggregate n = 403	Low n = 76	Medium n = 272	High n = 55	Significance (Low vs High)
Do you think opportunities to expand your farm will be greater than, fewer, or about the same in the next 5 years?					
Greater	26.3%	18.4%	27.2%	32.7%	0.0695
Fewer	29.8%	42.1%	29.4%	14.5%	0.0003
What is the planned annual growth rate you have for your farm over the next 5 years?					
Growth	54.6%	50.0%	54.8%	60.0%	0.2591
No Growth	45.4%	50.0%	45.2%	40.0%	
Risk Aversion	**Aggregate** n = 403	**Low** n = 76	**Medium** n = 272	**High** n = 55	**Significance** (Low vs High)
How would you rate your attitude towards risk?					
Strongly Risk Averse	10.9%	14.5%	10.7%	7.3%	0.1835
Moderately Risk Averse	60.8%	51.3%	64.0%	58.2%	0.4395
Slightly Risk Averse	28.3%	34.2%	25.4%	34.5%	0.9686
How would your neighbors describe your risk-taking behavior?					
Risk Avoider	7.2%	5.3%	8.1%	5.5%	0.9622
Cautious	65.5%	61.8%	68.4%	56.4%	0.5337
Real Gambler	27.3%	32.9%	23.5%	38.2%	0.5377
Farm Demographics	**Aggregate** n = 403	**Low** n = 76	**Medium** n = 272	**High** n = 55	**Significance** (Low vs High)
How many total acres do you operate?					
< 1000 acres	31.3%	35.5%	32.4%	20.0%	0.0475
1000 to 2000 acres	25.1%	26.3%	24.3%	27.3%	0.9039
2000 to 5000 acres	29.0%	19.7%	30.5%	34.5%	0.0649
5000 to 10,000 acres	7.7%	7.9%	7.4%	9.1%	0.8114
> 10,000 acres	6.9%	10.5%	5.5%	9.1%	0.7861
What is your highest completed level of education?					
High School	41.2%	48.7%	40.8%	32.7%	0.0662
Undergraduate	32.8%	38.2%	30.9%	34.5%	0.6739
Graduate	24.6%	11.8%	26.8%	30.9%	0.0106
What is the average age of the primary farm owner/operator?					
< 35 Years Old	4.7%	5.3%	4.4%	5.5%	0.9622
35 - 65 Years Old	59.1%	65.8%	58.1%	54.5%	0.1995
65+ Years Old	36.2%	28.9%	37.5%	40.0%	0.1950

Note: Results of U.S. survey conducted in April 2023.

Table 4. Management Practices and Adoption of Precision Ag Technologies

Management Practices	Aggregate n = 403	Low n = 76	Medium n = 272	High n = 55	Significance (Low vs High)
Does your farm have written succession plans in place?					
Yes	55.1%	51.3%	57.0%	50.9%	0.9637
No	44.9%	48.7%	43.0%	49.1%	
Are most of your farm's crop lease agreements written?					
Yes	60.5%	64.5%	59.9%	58.2%	0.4708
No	39.5%	35.5%	40.1%	41.8%	
Does your farm use advice from agronomic consultants when making decisions?					
Yes	57.3%	56.6%	57.0%	60.0%	0.6977
No	42.7%	43.4%	43.0%	40.0%	
Does your farm use financial ratios to make decisions?					
Yes	50.6%	52.6%	48.9%	56.4%	0.6749
No	49.4%	47.4%	51.1%	43.6%	
Does your farm document and evaluate crop pricing alternatives?					
Yes	60.3%	67.1%	57.7%	63.6%	0.6840
No	39.7%	32.9%	42.3%	36.4%	
Are standard operating procedures documented for reptitive and routine tasks?					
Yes	49.6%	52.6%	49.6%	45.5%	0.4215
No	50.4%	47.4%	50.4%	54.5%	
Adoption of No-Till and Precision Ag Technologies	**Aggregate** n = 403	**Low** n = 76	**Medium** n = 272	**High** n = 55	**Significance** (Low vs High)
On average, what percent of your crop acreage uses no-till practices?					
> 50%	45.9%	46.1%	46.0%	45.5%	0.9465
< 50%	54.1%	53.9%	54.0%	54.5%	
Does your farm use any of the following precision agriculture technologies?					
VRT fertilizer application	61.8%	60.5%	62.5%	60.0%	0.9521
Grid or zone soil sampling	73.0%	72.4%	72.1%	78.2%	0.4477
GPS guidance	67.2%	68.4%	66.9%	67.3%	0.8907
Yield monitor	68.7%	64.5%	69.1%	72.7%	0.3163
Drones	27.3%	27.6%	26.5%	30.9%	0.6879
None	8.4%	9.2%	8.5%	7.3%	0.6909

Note: Results of U.S. survey conducted in April 2023.

Table 5. Resilience to Strategic Risk & Threats to Operation

Resilience to Strategic Risk	**Aggregate** n = 403	**Low** n = 76	**Medium** n = 272	**High** n = 55	**Significance** (Low vs High)
We have low per unit fixed costs relative to our most efficient competitors.					
Agree	72.0%	55.3%	74.6%	81.8%	0.0009
Disagree	28.0%	44.7%	25.4%	18.2%	
Our farm enterprise is more diversified today than it was 5 years ago.					
Agree	55.1%	60.5%	54.4%	50.9%	0.2789
Disagree	44.9%	39.5%	45.6%	49.1%	
We have a strong balance sheet.					
Agree	90.1%	77.6%	92.3%	96.4%	0.0008
Disagree	9.9%	22.4%	7.7%	3.6%	
Our farm has established goals, objectives, and core values.					
Agree	89.6%	96.1%	88.2%	87.3%	0.0867
Disagree	10.4%	3.9%	11.8%	12.7%	
Our farm looks for opportunities that new enterprises may provide.					
Agree	82.9%	82.9%	82.0%	87.3%	0.4872
Disagree	17.1%	17.1%	18.0%	12.7%	
We regularly assess our advantages and disadvantages compared to other farms.					
Agree	70.7%	73.7%	72.1%	60.0%	0.1056
Disagree	29.3%	26.3%	27.9%	40.0%	
Cumulative Resilience to Strategic Risk					
Low (6-15)	14.9%	19.7%	15.1%	7.3%	0.0334
High (16-24)	85.1%	80.3%	84.9%	92.7%	
Threats to Operation	**Aggregate** n = 743	**Low** n = 144	**Medium** n = 499	**High** n = 100	**Significance** (Low vs High)
Looking ahead to next year, my farming operation has evaluated potential threats caused by ...					
Low market prices	24.6%	20.8%	26.5%	21.0%	0.8821
High input costs	35.8%	39.6%	35.1%	34.0%	0.1147
Extreme weather events	14.0%	9.0%	15.4%	14.0%	0.2586
Limited ability to find skilled farm workers	11.7%	12.5%	10.6%	16.0%	0.4948
Geopolitical conflict	13.9%	18.1%	12.4%	15.0%	0.3974
Which of the following risks would you say is most threatening to your organization?					
	n = 640	n = 126	n = 435	n = 79	
Financial	24.7%	31.7%	24.6%	13.9%	0.0001
Legal	7.3%	7.9%	7.4%	6.3%	0.4631
Marketing	25.8%	23.8%	26.4%	25.3%	0.7196
Production	20.0%	19.0%	20.5%	19.0%	0.5958
Strategic	4.8%	5.6%	4.4%	6.3%	0.9815
Human	17.3%	11.9%	16.8%	29.1%	0.0078

Note: Results of U.S. survey conducted in April 2023.

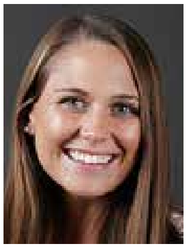
Table 6. Correlation Coefficients (Producer Sentiment & Farm Characteristics)

	Ag Economy Barometer	Index of Current Conditions	Index of Future Expectations
Opportunities to Expand	0.129***	0.129***	0.093**
Farm Growth	0.089**	0.092**	0.07*
Risk Aversion (Self-Percieved)	-0.037	-0.017	-0.022
Risk Aversion (Neighbors' Perception)	0.031	0.07	0.003
Farm Size	0.038	0.058	0.025
Education	0.118***	0.057	0.119***
Operator Age	0.012	0.007	0.01
Succession Planning	0.004	0.002	0.013
Use of Written Lease Agreements	-0.017	0.008	-0.037
Use of Agronomic Consultants	0.063	0.097**	0.017
Use of Financial Ratios	-0.007	-0.023	0.012
Use of Crop Pricing Alternatives	-0.015	0.051	-0.053
Use of Standard Operating Procedures	-0.015	-0.017	-0.014
Use of No-Till Practices	-0.013	0.064	-0.05
Precision Ag Technology (VRT Fertilizer Application)	0.003	0.096**	-0.058
Precision Ag Technology (Grid/Zone Soil Sampling)	0.022	0.076*	-0.012
Precision Ag Technology (GPS Guidance)	0.019	0.108**	-0.047
Precision Ag Technology (Yield Monitor)	0.038	0.109**	-0.014
Precision Ag Technology (Drones)	0.03	0.073	-0.013
Precision Ag Technology (None)	-0.016	-0.067	0.019
Cumulative Resilience to Strategic Risk	0.071*	0.066*	0.051
Low Per Unit Fixed Costs	0.199***	0.11***	0.196***
Farm Diversification	-0.045	-0.028	-0.046
Balance Sheet Strength	0.184***	0.191***	0.136***
Established Goals, Objectives, & Core Values	-0.012	0.068	-0.055
Exploration of New Enterprises	0.023	-0.009	0.03
Assess Advantages/Disadvantages	-0.047	-0.031	-0.057
Threats Identified: Low Market Price	-0.006	0.075*	-0.064
Threats Identified: High Input Costs	-0.084**	-0.024	-0.102**
Threats Identified: Extreme Weather	0.081*	-0.023	0.122***
Threats Identified: Issues Finding Skilled Workers	-0.006	-0.041	0.019
Threats Identified: Geopolitical Conflict	-0.03	-0.012	-0.022
Threats Identified: Financial Risk	-0.159***	-0.207***	-0.088**
Threats Identified: Legal Risk	-0.06	0.045	-0.094**
Threats Identified: Marketing Risk	0.022	0.029	0.006
Threats Identified: Production Risk	-0.016	-0.008	-0.015
Threats Identified: Strategic Risk	0.003	-0.046	0.023
Threats Identified: Human Risk	0.116***	0.113**	0.094**

Significance Levels: p < .01 '***' p < .05 '**' p < .1 '*'

Note: Results of U.S. survey conducted in April 2023.

Optimal Grain Marketing Strategies for a Southeast Indiana Case Farm



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Abstract

This paper examined optimal grain marketing strategies for a southeast Indiana case farm. Specifically, a downside risk model was used to examine the tradeoffs between net return and downside risk, and to determine whether the optimal marketing strategy changed as downside risk was reduced. The hedge and roll marketing strategy had the highest net return for both corn and soybeans. Even when downside risk was reduced, the hedge and roll strategy was an important component of optimal marketing strategies. Results stress the importance of using a portfolio of marketing strategies for corn and soybeans.

INTRODUCTION

While many studies have evaluated corn and soybean marketing strategies, few have evaluated marketing strategies in a portfolio context. Moreover, many studies utilize data prior to the start of the ethanol boom in 2007. To help fill the gap in research, this study examined the risk/return tradeoff between marketing strategies in a portfolio context for a farm in southeast Indiana using data from 1992 to 2021.

To provide motivation for our study, we summarize a few previous studies that have addressed a similar topic. Ke and Wang (2002) found a combination of revenue-based crop insurance with futures and government payments to be an optimal risk management portfolio for wheat farmers in the Pacific Northwest. The authors also found substitution effects between revenue-based crop insurance and the use of futures markets. Specifically, the optimal hedging ratio was reduced with the addition of revenue-based crop insurance.

Pritchett et al. (2004) simulated returns for corn and soybean farmers to assess the effectiveness of marketing and crop insurance risk management tools, where value-at-risk (VaR) was used to measure downside risk. Results indicated that of the 73 different risk management strategies examined, 9 out of the 10 top strategies included some form of price insurance in addition to yield insurance.

Using a portfolio approach, Schaffer (2010) examined various combinations of crop insurance and marketing strategies for four regions in Illinois. Results indicated that pre-harvest pricing and revenue-based crop insurance, when used together, significantly reduced risk and, in some cases, increased returns.

Edwards et al. (2020) addressed whether corn and soybeans should be hedged or unhedged, and for how long corn and soybeans should be stored. Results suggested that storing corn and soybeans in Indiana could be a profitable strategy. Though the study did not use a risk/return model to capture inter-relationships between marketing strategies, the authors suggested that a combination of marketing strategies should be used since it is not possible to predict which strategy will be optimal in a specific year. Marketing strategies examined included unhedged storage, simple storage hedges, and rolling hedges. This article extends the results in Edwards et al. (2020) by computing the optimal mix of cash price and hedging strategies using a portfolio risk/return model. Also, our study, captures the interaction between crop insurance programs and marketing strategies.

Walters and Preston (2023) indicated that hedging should be viewed as a portfolio of prices. Although pre-harvest hedging can give poor returns if prices go up in the fall, when viewing a hedge as a portfolio, farm price increases as unsold bushels are worth more. Walters and Preston's study evaluated two strategies. The first strategy was to sell 100% of expected production at harvest, and the second examined the results of a portfolio that utilized the Terry Timer Approach, which stores grain until March 1 and then completes 10 equal bushel sales every 10 days after March 1, for 40% of expected production and selling the remainder of the crop at harvest. Results indicated that the 40/60 portfolio approach reduced the probability of receiving low prices in the fall and provided an example of how hedging reduces risk.

MARKETING STRATEGIES AND DOWNSIDE RISK

Marketing strategies were combined with an 80% revenue protection (RP) product, which is commonly used in southeast Indiana, to examine risk/return tradeoffs for corn and soybeans. Specifically, the 80% RP product was combined with three cash price strategies, a basic storage hedge strategy, and a hedge and roll strategy. Cash strategies included a marketing year average cash price strategy (October through August), a harvest cash price strategy (October through December), and a 6-month cash price strategy (October through March). The harvest cash price and 6-month cash price strategies used equal marketing weights for the individual months. The marketing year cash price strategy utilized historical monthly marketing weights reported by USDA-NASS. The basic storage hedge strategy allows a producer to sell July futures in October, then offset the July futures in May when the cash crop is sold.

The hedge and roll strategy is similar to the basic storage hedge strategy, the difference being that the producer initiates the hedge earlier in the year. With this strategy, a producer sells November futures for soybeans and December futures for corn in June. In October, the producer would then offset the futures position and simultaneously sell July futures. In May, the producer would offset the July futures position and simultaneously sell cash corn and soybeans.

The marketing strategies are designated by abbreviations in the results discussed below: "mktg year" represents the marketing year cash price strategy, "harvest" represents the harvest cash price strategy, "6-month" represents the 6-month cash price strategy, "basic hedge" represents the basic storage hedge strategy, and "hedge and roll" represents the hedge and roll strategy.

Numerous models can be used to examine the tradeoffs between risk and return (Barry, 1984; Hardaker et al., 2004). Given our interest in the potential safety net provided by crop insurance products and marketing strategies, expected net return and risk for combinations of marketing strategies were examined with a downside risk model. The Target MOTAD model maximizes expected income subject to a constraint or limit on the total negative deviation measured from a fixed target or target income (Tauer, 1983; Watts et al., 1984). This model focuses on the downside risk that occurs when net return falls below a target level. As with other portfolio models, tradeoffs between risk, as measured by the total negative deviations below a target income, and expected income or net returns are examined. The solution of the model that identifies the maximum expected income also has the highest level of total negative deviations below the target income. In other words, this is the profit maximizing solution. To generate the frontier, the constraint that computes the total negative deviations below the target income is relaxed. As we move along the frontier or risk/return tradeoff curve, solutions with lower deviation levels (i.e., lower downside risk) also have lower net returns. In general, solutions (i.e., suboptimal combinations of marketing strategies) that are below the frontier either have a lower net return and the same level of risk or the same net return and a higher level of risk. A target income or net return of $95 per acre was used for the analysis in this paper. This target income represents the average net return for all of the corn and soybean strategies during the 30-year study period.

FARM SETTING

Per acre costs for crop storage and interest varied among the marketing strategies so net returns, rather than gross returns, were computed and compared for each marketing strategy for a 30-year period (1992 to 2021). Gross returns were computed using crop yields obtained from an experimental field at the Southeast Purdue Agricultural center located in Jennings County, Indiana, cash crop prices (USDA-NASS), futures prices, crop insurance indemnity payments, and government payments. The experimental field was located on Clermont silt loam soil, with tile drainage. Prior to the installation of the tile drainage system in 1983, the soil was poorly drained (Kladivko, 2020). Crop insurance indemnity payments were computed using historical crop yields and historical projected and harvest crop insurance prices. Government payments were the same across marketing strategies and were obtained from several sources including Carson (2017), Purdue crop budgets, and estimated ARC-CO/PLC payments for Jennings County in Indiana from 2014 to 2021.

Historical costs were generated using actual costs, base year costs, and input price indices. Base year costs and input price indices were used for all costs except for crop storage costs, interest costs, cash rent, and crop insurance costs, which were computed using actual cost estimates. Crop budget information for 2021 for rotation corn and soybeans grown on high productivity soil was obtained from Dobbins et al. (2021). Thus, the base year for the crop budget was 2021. Keeping in mind the exceptions noted above, historical costs were computed using base year costs and USDA-NASS input price indices from 1992 to 2021. Turning to the actual cost estimates, crop storage costs were computed using a fixed rate per bushel ($0.01 per bushel per month), crop yields, and agricultural interest rates from the Federal Reserve Bank of Chicago. Interest costs for each crop were computed using agricultural interest rates, crop budget information, and bushels in storage. Crop insurance costs for the base year were estimated for Jennings County, Indiana, using the University of Illinois *farmdoc* crop insurance tools. Historical crop insurance costs were estimated using cost indices created with historical costs per acre in the FINBIN database (Center for Farm Financial Management). Cash rents were obtained from the annual Purdue cash rent and land value survey (Kuethe, 2023) and represent high-quality land in southeast Indiana.

RESULTS

The tradeoff between net return and downside risk is examined below for corn, soybeans, and both corn and soybeans together. This allows us to contrast the differences in corn and soybean marketing strategies when analyzed separately and together. More emphasis will be given to the results for corn and soybeans evaluated together. The negative deviations in the result tables represent total negative deviations below the $95 target income over the 30-year period. Annual deviations can be computed by dividing total negative deviations by 30.

Corn Marketing Strategies

Table 1 presents the expected net return for corn and negative deviations below the target income for individual marketing strategies (scenarios a, b, c, d, and e) as well as the expected net return and downside risk for the risk/return frontier (scenarios 1-7). The net return and downside risk for the individual marketing strategies will be discussed first. Of the individual strategies, the hedge and roll marketing strategy had the highest net return per acre ($113.60) and the lowest level of downside risk (1413). The net return for the basic storage hedge was $66.69. Net returns for the marketing year cash price, harvest cash price, and 6-month cash price strategies were $91.46, $59.27, and $77.98 per acre, respectively. Downside risk for the basic storage hedge and three cash price marketing strategies was from 18% (marketing year cash price strategy and 6-month cash price strategy) to 135% (basic storage hedge) higher than downside risk for the hedge and roll marketing strategy.

Turning to the risk/return tradeoff results in the upper part of Table 1, downside risk declines from scenario 1, the profit maximizing solution, to scenario 7. Notice that the levels of downside risk for scenarios 2 through 7 are lower than the downside risk levels for the individual marketing strategies. This result emphasizes the importance of diversification. Simply put, diversifying marketing strategies enables the farm to reduce downside risk. To further emphasize the reduction in downside risk, compare scenario 1 to scenario 4 and 7. Scenario 4, which is a mixed strategy composed of 12.8% of the crop marketed with the marketing year cash price strategy and 87.2% of the crop marketed with the hedge and roll strategy, has a net return that is 2.5% lower than the net return for scenario 1 and a downside risk level that is 8.0% lower. Going from scenario 1 to scenario 7, net return is reduced by 6.4%, but downside risk is reduced by

18.6%. Scenario 7 employs a mixed strategy composed of 32.7% of the crop marketed with the marketing year cash price strategy and 67.3% of the crop marketed with the hedge and roll strategy. In summary, as you move down the risk/return frontier, downside risk declines at a faster rate than net returns.

Soybean Marketing Strategies

The expected net return for soybeans and negative deviations below target income for individual marketing strategies (scenarios a, b, c, d, and e) and the risk/return frontier (scenarios are illustrated in Table 2. Similar to the standalone corn results, the hedge and roll marketing strategy had the highest net return per acre ($108.97). However, for soybeans, downside risk for the hedge and roll marketing strategy was from 6 to 11% higher than downside risk for the three cash price marketing strategies. Also, the marketing year cash price strategy had a net return that is less than $1 per acre lower than the net return for the hedge and roll strategy.

Looking at the risk/return tradeoff results, there is very little reduction in expected net return as downside risk is reduced. For example, the expected net return for scenario 4 is only $0.10 per acre less than that for scenario 1. In contrast, downside risk is reduced by 5.5% as you move from scenario 1 to scenario 4. Similar to the corn results, the soybean results point to the power associated with diversifying marketing strategies. As we move from scenario 1 to scenario 6 in Table 2, the amount of crop marketed with the hedge and roll strategy is smaller, and the amount of crop marketed with the marketing year cash price strategy increases.

Corn and Soybean Marketing Strategies

The results in the two subsections above represented optimal marketing strategies for corn and soybeans analyzed separately. This section analyzes corn and soybean marketing strategies simultaneously. Before discussing the results, we will provide some insight into why combining the marketing year cash price strategy with the hedge and roll strategy makes sense from a risk/return standpoint. First, note that the correlation between the two corn strategies is only 0.09 and that the correlation between the two soybean strategies is 0.37. These correlations are quite a bit lower than the correlations between the hedge and roll strategy and the other marketing strategies. Given this fact, it would be interesting to contrast the annual net returns between these two strategies. Figure 1 illustrates the difference in net returns between the hedge and roll strategy and the marketing year cash price strategy when we average the corn and soybean net returns (i.e., utilize a corn/soybean rotation). The difference in Figure 1 was computed by subtracting the average net return for corn and soybeans using the marketing year cash price strategy from the average net return for the hedge and roll strategy. Thus, low deviations indicate a preference toward the marketing year cash price strategy, and high deviations reveal a preference for the hedge and roll strategy. Obviously, there are some large differences in net returns in certain years. For example, the hedge and roll strategy performed very well in 2008 but had relatively low net returns in 2010 and 2020.

Table 3 illustrates the net return and downside risk for each individual marketing strategy. The hedge and roll strategy had the highest average net return per acre ($111.29). The average net return per acre for the other marketing strategies ranged from $78 for the harvest cash price strategy to $100 for the marketing year cash price strategy. The hedge and roll strategy also had the lowest downside risk level of any of the individual marketing strategies. Downside risk for the other marketing strategies ranged from 22% (6-month cash price strategy) to 38% (harvest price cash strategy), higher than that for the hedge and roll strategy.

Consistent with the standalone corn and soybean results, combining marketing strategies reduced downside risk (Table 4). When corn and soybeans are analyzed together, the model allocated the entirety of the corn crop (or 50% of the total portfolio) to the corn hedge and roll strategy in all four scenarios. When examined from a whole-farm perspective, declines in downside risk were achieved through different combinations of soybean marketing strategies. For example, for scenario 1 the model chose to market both corn and soybeans using the hedge and roll strategy. Net return per acre and downside risk for this scenario was $111.29 and 979, respectively. For scenario 4, the model chose to market corn with the hedge and roll strategy, and to use a combination of the marketing year cash price and 6-month cash price strategies to market soybeans. Consistent with the standalone corn and soybean results, as we reduced downside risk, the reduction in net return was much smaller than the reduction in downside risk.

SUMMARY AND CONCLUSIONS

The purpose of this study was to identify which marketing strategies contributed to an optimal portfolio of strategies for a case farm in Jennings

County, Indiana, with Clermont silt loan soil. Risk/return tradeoffs were evaluated using a downside risk model. Marketing strategies examined included three cash price strategies (marketing year price, 6-month price, and harvest price), a basic storage hedge strategy, and a hedge and roll strategy. The hedge and roll strategy had the highest net return per acre over the study period when evaluating corn and soybeans separately, and when evaluating corn and soybean strategies together. To reduce downside risk, it was necessary to combine the hedge and roll strategy with a cash price strategy. When corn and soybeans were evaluated separately, the hedge and roll strategy was combined with a marketing year cash price strategy. When corn and soybeans were evaluated together, the corn hedge and roll strategy was combined with various combinations of the soybean hedge and roll, marketing year cash price, and six-month cash price strategies. The low correlation between the hedge and roll strategies and the other marketing strategies encouraged the use of mixed strategies. In general, the results strongly suggest that a portfolio approach is a beneficial strategy to mitigate downside risk. Specifically, combining various marketing strategies reduced risk, with, in many instances, only slightly lower net returns compared to the profit maximizing solution.

The results also suggest that there are advantages of storing corn and soybeans well into the next calendar year. This strategy does not always work, but in general it results in higher net returns compared to selling at harvest or marketing the crop during the first 6 months of the marketing year.

It is important to note that there are numerous assumptions that need to be considered when examining the results of this study. These assumptions relate to the years used in the analysis; the case farm's crop yields, which were higher than the county average; the cost structure of the case farm; the marketing strategies used in this study; and the location of the case farm, which would impact the relationships between crop prices and futures prices. It is important to note, however, that Edwards et al. (2020) studied a similar set of marketing strategies and did not assume a specific location in Indiana. Our results are consistent with their study. In summary, though changing the assumptions used in this study may create slightly different combinations of marketing strategies; the importance of combining marketing strategies, or the benefits of diversification, would likely hold for case farms located in other U.S. Corn Belt states and crop reporting districts.

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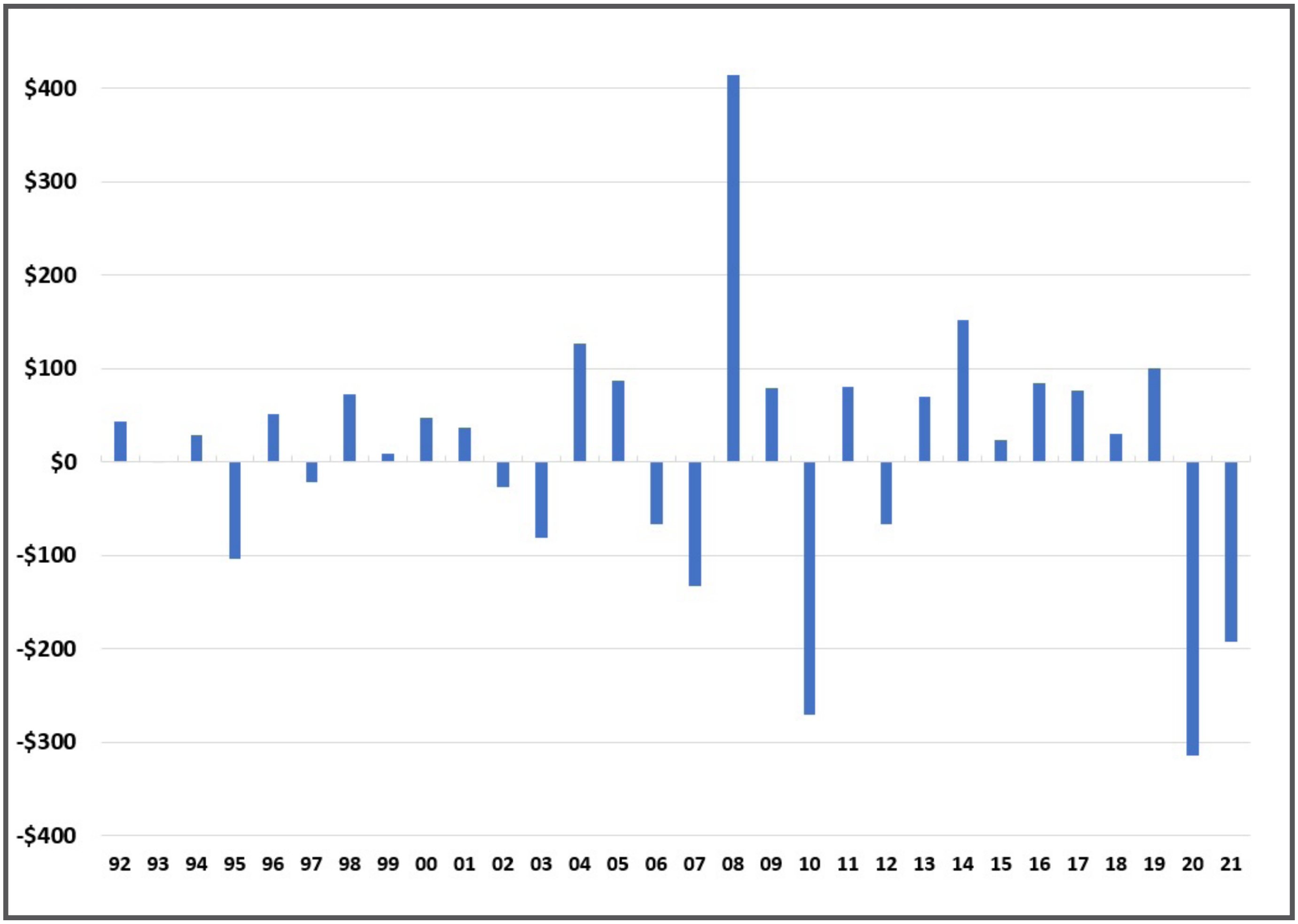


Figure 1. Difference in net return per acre between hedge and roll and marketing year cash price strategies

Table 1. Expected Net Return and Downside Risk for Corn on a Southeast Indiana Case Farm

Scenario	Expected Net Return ($/acre)	Δ in Net Return (%)	Negative Deviations ($/acre)	Δ in Neg Dev (%)	Mktg Year (%)	Harvest (%)	6-Month (%)	Basic Hedge (%)	Hedge and Roll (%)
1	113.60	N/A	1413	N/A	0.000	-	-	-	1.000
2	113.33	-0.002	1400	-0.009	0.012	-	-	-	0.988
3	112.11	-0.013	1350	-0.045	0.067	-	-	-	0.933
4	110.77	-0.025	1300	-0.080	0.128	-	-	-	0.872
5	109.36	-0.037	1250	-0.115	0.192	-	-	-	0.808
6	107.91	-0.050	1200	-0.151	0.257	-	-	-	0.743
7	106.35	-0.064	1150	-0.186	0.327	-	-	-	0.673
a	91.46	N/A	1674	N/A	1.000	0.000	0.000	0.000	0.000
b	59.27	N/A	1904	N/A	0.000	1.000	0.000	0.000	0.000
c	77.98	N/A	1673	N/A	0.000	0.000	1.000	0.000	0.000
d	66.69	N/A	3327	N/A	0.000	0.000	0.000	1.000	0.000
e	113.60	N/A	1413	N/A	0.000	0.000	0.000	0.000	1.000

Definitions:

a: 100% allocated to marketing year cash price strategy

b: 100% allocated to harvest cash price strategy

c: 100% allocated to 6-month cash price strategy

d: 100% allocated to basic hedge strategy

e: 100% allocated to hedge and roll strategy

Table 2. Expected Net Return and Downside Risk for Soybeans on a Southeast Indiana Case Farm

Scenario	Expected Net Return ($/acre)	Δ in Net Return (%)	Negative Deviations ($/acre)	Δ in Neg Dev (%)	Mktg Year (%)	Harvest (%)	6-Month (%)	Basic Hedge (%)	Hedge and Roll (%)
1	108.97	N/A	1005	N/A	0.000	-	-	-	1.000
2	108.96	0.000	1000	-0.005	0.015	-	-	-	0.985
3	108.91	-0.001	975	-0.030	0.078	-	-	-	0.922
4	108.87	-0.001	950	-0.055	0.142	-	-	-	0.858
5	108.78	-0.002	925	-0.080	0.262	-	-	-	0.738
6	108.64	-0.003	900	-0.104	0.462	-	-	-	0.538
a	108.25	N/A	948	N/A	1.000	0.000	0.000	0.000	0.000
b	96.75	N/A	939	N/A	0.000	1.000	0.000	0.000	0.000
c	105.80	N/A	908	N/A	0.000	0.000	1.000	0.000	0.000
d	91.28	N/A	1115	N/A	0.000	0.000	0.000	1.000	0.000
e	108.97	N/A	1006	N/A	0.000	0.000	0.000	0.000	1.000

Definitions:

a: 100% allocated to marketing year cash price strategy

b: 100% allocated to harvest cash price strategy

c: 100% allocated to 6-month cash price strategy

d: 100% allocated to basic hedge strategy

e: 100% allocated to hedge and roll strategy

Table 3. Expected Net Return and Downside Risk for Individual Marketing Strategies, Southeast Indiana, Case Farm

	Scenario				
	a	b	c	d	e
Expected Net Return ($/acre)	99.86	77.85	91.96	78.99	111.29
Negative Deviations ($/acre)	1300	1350	1194	1240	979
Corn: Mktg Year (%)	0.500	0.000	0.000	0.000	0.000
Corn: Harvest (%)	0.000	0.500	0.000	0.000	0.000
Corn: 6-Month (%)	0.000	0.000	0.500	0.000	0.000
Corn: Basic Hedge (%)	0.000	0.000	0.000	0.500	0.000
Corn: Hedge and Roll (%)	0.000	0.000	0.000	0.000	0.500
Soybeans: Mktg Year (%)	0.500	0.000	0.000	0.000	0.000
Soybeans: Harvest (%)	0.000	0.500	0.000	0.000	0.000
Soybeans: 6-Month (%)	0.000	0.000	0.500	0.000	0.000
Soybeans: Basic Hedge (%)	0.000	0.000	0.000	0.500	0.000
Soybeans: Hedge and Roll (%)	0.000	0.000	0.000	0.000	0.500

Definitions:

a: Marketing year cash price strategy

b: Harvest cash price strategy

c: 6-month cash price strategy

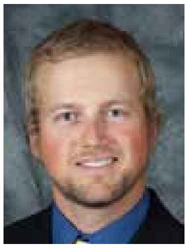
d: Basic hedge strategy

e: Hedge and roll strategy

Table 4. Expected Net Return and Downside Risk for Corn and Soybeans on a Southeast Indiana, Case Farm

	Scenario			
	#1	#2	#3	#4
Expected Net Return ($/acre)	111.29	111.18	111.00	110.24
Change in Net Return (%)	N/A	-0.001	-0.003	-0.009
Negative Deviations ($/acre)	979	950	925	900
Change in Negative Deviations (%)	N/A	-0.030	-0.055	-0.081
Corn: Mktg Year (%)	0.000	0.000	0.000	0.000
Corn: Harvest (%)	0.000	0.000	0.000	0.000
Corn: 6-Month (%)	0.000	0.000	0.000	0.000
Corn: Basic Hedge (%)	0.000	0.000	0.000	0.000
Corn: Hedge and Roll (%)	0.500	0.500	0.500	0.500
Soybeans: Mktg Year (%)	0.000	0.147	0.395	0.222
Soybeans: Harvest (%)	0.000	0.000	0.000	0.000
Soybeans: 6-Month (%)	0.000	0.000	0.000	0.278
Soybeans: Basic Hedge (%)	0.000	0.000	0.000	0.000
Soybeans: Hedge and Roll (%)	0.500	0.353	0.105	0.000

Feasibility of Integrating Cover Crops into Irrigated Barley



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Abstract

Cover crops are becoming more widely accepted as a viable management practice because of their ability to provide important environmental and soil health benefits. However, adoption of cover crops remains low in certain areas, and the high cost of cover crop integration into irrigated crop rotations appears prohibitive. This paper evaluates cover crop options and management practices to determine if different cover crop scenarios can provide additional income to producers.

INTRODUCTION

Poor irrigated cropland management can lead to stressed or strained soil, requiring changes in practices to retain or improve productivity. In order to maintain or improve soil health, agricultural producers must understand and utilize a variety of sustainable management practices to add resiliency to their farming operations. Hurisso et al., (2015) conducted an on-farm study in Wyoming's Bighorn Basin, where they found very low soil organic matter with sugarbeet-barley rotations. However, when compared to soils under more diverse cropping rotations (sugarbeet-barley-alfalfa-alfalfa), the resulting soils showed improved soil quality, which led to higher sucrose yields in the sugarbeet crop. While longer and more diverse crop rotations is one management tool producers may be able to use to help improve soil health, incorporating cover crops into the existing rotation is another to consider. The use of cover crops is increasing in popularity as an option to address poor soil health and improve soil quality. Cover crops, such as grasses, legumes, and forbs, are planted for seasonal cover and other conservation purposes (USDA-NRCS, 2010) and may offer agronomic benefits to systems with poor soil health (Hartwig and Ammon, 2002).

Cover crops are becoming increasingly popular in modern agriculture due to their potential to provide benefits to a cropping system (USDA-NRCS, n.d.) including, but not limited to, reduced erosion, increased soil organic matter, improved soil water holding capacity, forage production, and increased soil microbial biomass (Drewnoski et al., 2018). However, the biological benefit of cover crops isn't often immediately observed, making some producers question their economic benefit. Further, due to a short growing season, incorporating cover crops into modern cropping systems requires a greater need for timeliness of management (Drewnoski et al., 2018).

Producers may be hesitant to utilize cover crops for an entire growing season because of lost revenue that would have been realized from growing a cash crop in that field. In addition, if producing winter cover crops, which are planted at the end of a cash crop growing season, concerns over soil moisture depletion and water scarcity may hinder adoption of cover crop use. Another issue with a late season cover crop planting is that the limited growing season in semiarid, cold desert environments limits biomass growth and production potential.

DATA AND METHODS

This research examines the economic performance of different cover crops and management options as compared to the baseline of the absence of cover crops in a sugarbeet-barley rotation. Specifically, we compare the economic outcomes of three different cover crop types combined with three different cover crop management practices to a baseline scenario without any cover crops in the Big Horn Basin of Wyoming.

Study Area

The Bighorn Basin in the northern part of Wyoming is classified as a semiarid climate with 30-year (1981-2010) annual average precipitation of 6.80 inches and monthly average temperatures ranging from 7.7˚F to 85.5˚F (Western Regional Climate Center, 2016). The data included in our analysis come from research trials at the University of Wyoming Powell Research and Extension Center (PREC) and on six different farms in the Bighorn Basin, WY, and the lower Yellowstone River Basin, MT. The on-farm sites were selected after consultation with local extension educators, NRCS employees, local agronomists, and local producers. Previous research examining soil organic matter and nutrient content in the Bighorn Basin of Wyoming and surrounding areas found that the two-year rotation between sugarbeet and barley, combined with intensive tillage and irrigation, led to deteriorated soils. Further, Hurriso et al., (2014) found that the cessation of tillage alone did not prove to be sufficient for the recovery of soil organic matter within the study's 10-year time frame.

Treatments

The three cover crop types, along with planting and weed control protocols and the composition of the mix, were selected by a group of stakeholders that included cooperating farmers, MT and WY extension specialists, consulting agronomists, and a cover crop producer at a project inception meeting in June 2018.

Volunteer barley is an easy method that many producers utilize by not tilling in the fall, but rather letting the volunteer regrowth produce biomass until the first freeze in late fall. However, this strategy does not always result in a good stand due to little barley seed being left after harvest. This is a low-cost option for producers because it doesn't require any additional seed purchase, and the only additional inputs for this scenario are discing the field to stimulate barley growth and subsequent irrigation of the regrowth. A major disadvantage to this scenario is no new forage species are introduced to the system, so biodiversity does not increase.

Replanted barley, which consists of volunteer barley and additional barley replanted after harvest at a rate of 75 lb ac^{-1}, is also a low-cost possibility for producers. In this scenario, the producer plants some harvested barley directly back into the field. When comparing to the volunteer barley option, there is potentially more biomass growth in the replanted scenario so that the agronomic effects could be increased. However, while additional biomass can help with the stand establishment and production, it can also potentially negatively affect the barley growth due to stunting from overcrowding. As with volunteer barley, a disadvantage to this scenario is no new forage species are introduced, so biodiversity is not improved.

An alternative cover crop mix consisting of volunteer barley, nematode-control radish (*Raphanus sativus L.*), flax (*Linum usitatissimum L.*), forage collards (*Brassica oleracea L.*), and common vetch (*Vicia sativa Roth*) was offered as an additional option. The diverse cover crop mix is important as it has the potential to improve biodiversity within the system. Also, including legumes in the mix introduces the opportunity to increase soil nitrogen levels due to nitrogen fixation. The cover crop mix is planted into the barley stubble as soon as possible after harvest. A potential issue with the cover crop mix is the volunteer barley establishing more quickly and vigorously than the cover crop species, negatively affecting growth of the selected species. If volunteer barley outcompetes the cover crop mix, the producers do not benefit from the species that were selected while still incurring the extra cost of the mix.

In addition to the three cover crop types, three management options were identified by the stakeholder group for this study: green manure, haying, and grazing. Green manure is a common management option where the above ground biomass is incorporated back into the soil, usually through plowing, as a means to increase soil organic matter (Pratt and Wingenbach, 2016). Plowing under the biomass is usually accomplished through heavy tillage, a management option that is believed to enhance soil health by returning more organic matter to the soil compared to other management options. In this scenario, producers improve soil microbe diversity, maintain or improve soil structure, and provide readily available nutrients to the subsequent crop. Here, the cover crop is grown exclusively for soil benefits and not for harvest or grazing. Rather than harvest or graze the cover crop, it is plowed into the soil. The largest disadvantage to the green manure scenario is lack of immediate financial return—producers pay the input costs on these cover crops and incur the cost of management (e.g., establishment costs and plowing the cover crop into the soil) and have no financial return that year. They assume that the benefits will come through improved soil fertility and improved yields in subsequent crops.

Haying is a popular option for producers because they receive immediate benefits from the cover crop as harvestable feed for livestock. In both the on-station and on-farm trials, the cover crop was grown until it was terminated by frost (late September/early October), at which point it was swathed and baled. The remaining residue is either incorporated or used as cover for the sugarbeet crop the following spring. In the study, minimal tillage was used to incorporate cover crop residues in the spring.

The management option of haying potentially provides the least benefit to the soil because you are removing most of the above ground biomass as hay and only incorporating the roots and residue into the soil. However, the roots and cover crop stubble still provide benefits to the soil by reducing erosion, trapping snow and rainfall to improve soil hydraulics, and maintaining or improving soil structure. Since the forage produced is an immediate benefit, this could aid in adoption of these practices in the short term, improving the long-term health and resilience of this system. The three cover crops averaged a dry matter crude protein of 15.92%, dry matter total digestible nutrient of nearly 70%, and a dry matter acid detergent fiber analysis of 28.56%. This allowed the cover crop hay to be sold at alfalfa hay prices, since nutrient composition from the cover crop hay is similar to alfalfa.

The last management option that was considered for this research was grazing the cover crops. Livestock grazing returns via Animal Unit Days, like haying, can provide immediate revenue (or cost savings for livestock producers) and in turn increase the likelihood of adoption of cover crops. Many producers find it hard to overcome the time and money investment in cover crops alone (Hayden et al., 2018), and integration of livestock can overcome these challenges in a manner that can lead to increased soil quality and overall agroecosystem resilience (Carvalho et al., 2018). Rakkar & Blanco-Canqui (2018) have shown that moderate grazing may increase soil organic matter (SOM) content compared to no grazing, however overgrazing can decrease SOM content in the long term. Bardgett et al., (2001) reported that high stocking rates and grazing intensity can have negative impacts on soil properties, which is an important aspect to consider from a management standpoint. Also, with the removal of aboveground cover crop biomass for forage, the benefits to soil quality can still be realized and can provide extra income to producers (Franzluebbers & Stuedemann, 2014). The extra income associated with grazing leases can help to encourage farmers to adopt cover crops even with the extra costs (Sulc & Tracy, 2007). In this study, cattle begin to graze the cover crop after growth stops in late October/early November.

Unlike haying, where biomass is strictly removed, livestock remove biomass in grazing but also add organic matter back through manure. The recycled nutrients in the form of manure can have a positive effect on soil fertility (Liebig et al., 2012), returning about 75-85% of the forage nutrients back to the soil (Whitehead, 2000). The biggest disadvantage to incorporating livestock into a cover crop system is time and management. Producers are often short on labor and time, and an additional enterprise such as cattle or sheep may not be feasible. Renting out the cover cropped areas to other producers who already own livestock may be an acceptable option. In this scenario, a grazing fee is charged by the landowner to the livestock owner for the cover crop grazed.

Our study includes nine total combinations of treatments, three different cover crop strategies paired with three different uses of each cover crop option. Using data gathered from both on-station and on-farm trials as well as custom rate and economic and market data, nine separate partial budgets were created to evaluate all management combinations (Table 1).

Establishment

The on-station experiment was initiated during the barley phase of a long-term bean-barley-sugarbeet rotation experiment established at PREC in 2014 with conservation and conventional tillage treatments. Three replications of each of the 12 crop-tillage-irrigation treatments were grown each year, resulting in 36 plots, each 13.5-m wide by 37-m long. After barley harvest, three cover crop treatments (volunteer barley (VB), replanted barley (RB), cover crop mix (CC)) were established as split plots (hayed, not hayed) in the conservation tillage replications and allowed to grow until late fall when they were terminated by frost. A no-cover-crop control plot was established in the adjacent conventional tillage plots. Sugarbeet was planted the following spring on the cover crop plots.

For on-farm scenarios, all farms that were selected for the study implemented both conservation tillage and cover crop use for several years prior to the study. The on-farm plots consisted of one acre of the cover crop mix planted by each farmer within a larger field of barley stubble. Treatments included the three cover crop types in split plots, where biomass was removed by haying or grazing from one split and not removed from the other. The volunteer barley plots were established by leaving a strip adjacent to the cover crop without replanting barley into the barley regrowth. The replanted barley plots were established by the producers that already replanted barley in their fields. The cover crop mix was the same as the on-station mix with the same establishment methods (Bush, 2020).

The plots were grazed or hayed depending on the producer's current management practices. If the treatments were grazed, a 4- by 7-m grazing exclosure was built with steel fence panels to prevent biomass removal from small plots across the three cover crop types. If hayed, the same area that was enclosed at the grazed site was left uncut in the producer's field. This amounted to six treatments on each farm for a total of 48 on-farm plots. Each farm was considered a replicate and one forage sample was collected from each treatment for each sampling time (Bush, 2020).

Partial Budgets

A partial budgeting approach was used to quantify how the nine combinations of cover crops and management options compare to the baseline scenario of sugarbeet-barley rotation without cover crops. There are four major components of a partial budget: additional costs, reduced income, additional income, and reduced costs. By subtracting the additional costs and reduced income from the additional income and reduced costs, we can estimate the difference in net income from the proposed change. It is important to note that partial budgets show relative gains and losses to income resulting from a certain change in production, not absolute profitability.

All field operations and production data used in the partial budgets were averaged across the research and on-farm trials that participated in each cover crop/management combination. Reported market prices for malt barley, corn, alfalfa, sugarbeet, feed barley, and pasture rent per Animal Unit Month were collected from USDA-NASS (USDA-NASS, 2017a-e). Other costs, such as fencing, were estimated by average local prices. Fencing is assumed to be a single strand electric fence and is based on a square 50-acre field, with estimated fencing costs at $19.34 per acre. All historical prices were deflated to 2019 dollars using the producer price index (PPI) (U.S Department of Labor, 2019). For a full list of costs and filed operations, see Asay (2021).

Monte Carlo Simulation

To include the impact of historical price variation on financial outcomes, Monte Carlo simulations (@RISK, Palisade Corporation, 2010) were used to estimate expected changes in returns of each cover crop and management combination as compared to the control. This tool also allowed the use of historical data to fit data to a probability distribution. The batch fit tool fit probability distributions to multiple data series (Palisade Corporation, 2010). Table 2 shows the average of observed adjusted prices, along with distributional parameters for all variables that were found using the batch fit process (Palisade Corporation, 2010). The batch fit tool also returned a matrix of correlations calculated between multiple data series to evaluate which series were related and to what degree (Table 3). The matrix of correlation was also used by the model when randomly drawing variables, so that all variables were still correctly correlated to one another.

The relative gain/losses associated with each of the cover crop and management options were compared to the control over 100,000 simulations, using random draws for prices based on the parameter values in Tables 2 and 3. Tukey's LSD test was used to compare differences of means of the 100,000 iterations across scenarios.

RESULTS INCLUDING SUGARBEET YIELD IMPACTS

The mean, 5th percentile value (5th %), and 95th percentile value (95th %) of the 100,000 observations of the Monte Carlo simulation for each partial budget are listed in Table 4. These values represented the gain or loss to net income (average) as compared to relative profitability to standard farming practices with no cover crops. All scenarios differed from one another at the 5% level (Tukey's LSD).

It is important to note that much of the negative impact seen in the partial budget results was due to decreases in the subsequent sugarbeet crop yield. Table 5 shows all the sugarbeet yield impacts from the field trials included in the partial budgets. The average sugarbeet yield after the cover crop was 27.11 tons per acre, an average decrease of 2.92 tons per acre in sugarbeet yield the year after cover crops were grown.

RESULTS EXCLUDING SUGARBEET YIELD IMPACTS

When using replanted barley as the cover crop and then incorporating the biomass as green manure, removing the effects of the decreased sugarbeet yield changed the loss to net income of RB GM from $360.80 to a net loss of only $31.83. In this situation, assuming the 20-year average sugarbeet price of $53.49, a producer would need to see a yield increase of 0.60 tons per acre to breakeven in one year.

The expected loss or gain to net income for all nine scenarios assuming no impact to sugarbeet yield are listed in Table 6. Green manure still had a loss to net income across all three cover crop options, due to the lack of any immediate financial returns. Haying the cover crop presented a gain to net income across all three cover crops as the cover crop hay can be sold, increasing net revenue. Grazing had a negative result for net income when using the cover crop mix and replant barley options, as grazing revenues were not high enough to cover the cover crops' establishment and fencing costs. However, grazing the volunteer barley had a positive net income because volunteer barley had such low establishment costs that the grazing revenues were able to surpass the costs and create a gain to net income.

We also calculated the breakeven yields for low, average, and high prices using the first quartile (25%) $47.88, average (50%) $53.49, and third quartile (75%) $59.55 prices for historical sugarbeet prices, which can be seen in Table 7. Across all price scenarios CCHAY, VBHAY, VBGRZ, and RBHAY do not require a yield boost to breakeven. In these scenarios, revenues from either haying or grazing were large enough that they could compensate for drops in sugarbeet yields and still have a positive impact to the net income as compared to the baseline. The other five scenarios, however, required an increase in yield, ranging from 0.29 tons per acre to 1.35 tons per acre, to cover the costs associated with cover crops. This represented an increase in subsequent sugarbeet yield of 0.97% to 4.5% based on the control yields from this study. This implies that total tons harvested per acre would need to increase from the control group of 30.03 tons per acre to a range of 30.32 tons per acre to 31.38 tons per acre, depending on which cover crop and management option was used.

While there are few published studies that report potential yield increases in sugarbeet from cover cropping practices, this increase may be feasible given the study by Miguez and Bollero (2005), which reported that a biculture (combination of legume and grass species) winter cover crop increased corn yields by 27%. However, there is also a study that concludes there may be a 10% reduction in wheat yield following a cover crop (Nielson et al., 2015). There is also a study that determined cover crops had no compromising or beneficial impacts on soybean and wheat yields (Hunter et al., 2019). It is apparent that there is no clear consensus on how much of a yield boost should occur following cover crops, or if a yield boost should be expected at all.

Sugarbeet yield is not measured in quantity only, but also quality through sugar content of the sugarbeet crop. Sugar content of the control plots averaged to be 15.14%, with the average sugar content of all test plots at 15.16%. There was no statistically significant difference between the control plots and the test plots, nor was there a statistically significant difference in sugar content between all cover crop management scenarios. The lack of a statistically significant difference in sugar content leads us to conclude that a boost in yield quality is not to be expected, yet a boost in yield quantity may be possible.

SUMMARY AND CONCLUSIONS

Debate remains whether cover crops improve subsequent crop yield. Our assumptions can provide some insight on the potential impacts cover crops have on sugarbeet yields and farm profitability, for example, we can show which scenario is most profitable, accounting for the sugarbeet yield effects realized by our study. We can also show the sugarbeet yield required for each of the potential cover crop and management options. However, a producer must have a clear goal for incorporating cover crops before comparing the expected outcomes of various strategies to help guide adoption of cover crop type and management option.

Based on the impacts to subsequent yields of sugarbeet observed in this study, from a maximum profit perspective, producers should choose to hay replanted barley (RBHAY) as that combination of cover crop type and management is expected to provide the highest gain to net revenue. RBHAY increased expected net revenue by over $485 per acre on average. This is not $485 per acre in profit, but rather a $485 per acre increase in profit compared to a no cover crop control. RBHAY has an expected average net revenue nearly $200 per acre higher than the second-best option of haying the cover crop mix (CCHAY), which has an average gain to net revenue of nearly $300 per acre. RBHAY's net revenue is almost $850 per acre higher than that of the green manuring the replanted barley (RBGM), which had the greatest average loss to net revenue of over $360 per acre.

The preferred cover crop/management option may change, however, if the producer's goal is simply improving soil health. This goal would focus less on the immediate economic impacts of cover crops and more on the agronomic benefits of management. Scenarios including green manure or grazing would likely be more suitable for these conditions, given that both management options offer returns to the soil as opposed to haying, which simply removes biomass. Green manure returns all the grown biomass back into the soil and increases soil organic matter levels (Pratt and Wingenbach, 2016). Grazing does remove biomass, however, and unlike haying, livestock also add organic matter back through manure. The recycled nutrients in the form of manure can have a positive effect on soil fertility (Liebig et al., 2012). Recycled nutrients could also help to return about 75-85% of the nutrients back to the soil (Whitehead, 2000).

The cover crop mix yielded the most forage at 1.75 tons per acre, while volunteer barley and replanted barley yielded 1.68 tons per acre and 1.39 tons per acre, respectively. This data would then suggest that the cover crop mix would be most beneficial to soil if the entirety of forage biomass was used for green manure or grazed with the nutrient cycling effects of livestock. Under this assumption, either cover crop green manure (CCGM) or cover crop graze (CCGRZ) would be the most likely scenarios to improve soil health.

With the data available, we can conclude which cover crop option is best for each management option, as well as which management option is best for each cover crop option. If the management option of green manure is incorporated into production cycles, then the cover crop mix would offer the best results regarding net revenue. If haying is the management option of choice, then replanted barley should be the cover crop option used. When grazing the cover crop, the cover crop mix again offers the best result in net revenue. When choosing the best management option for each cover crop option, haying has the best net revenue for all cover crop options compared to the other management options.

Since there is no clear consensus on cover crops' effects on subsequent yields, the sugarbeet yield data were removed from the partial budgets to estimate the required sugarbeet yield impacts required to cover the costs of cover crop inclusion in a standard barley/sugarbeet rotation. This analysis allowed the cover crop management options to be ranked by their cost effectiveness regarding impacts to sugarbeet yield. The sugarbeet yield in subsequent years required for breakeven can be seen in Table 8. Changes in prices would not affect the rankings of these scenarios, but it would affect the breakeven yield amounts. Haying volunteer barley (VBHAY) proves to be the most cost-effective scenario as it requires the lowest sugarbeet yield to breakeven. However, producers should use their own discretion to choose which scenario best fits their production system and management goals. For example, producers who need additional livestock feed may prefer any of the haying or grazing as opposed to those that implement green manure.

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Table 1. Different Budget Scenarios

	Management Option		
	Green Manure (GM)	Hay (HAY)	Graze (GRZ)
Cover Crop Option	Pure Cover Crop Mix (CC)	1 - CC/GM	2 - CC/HAY
	Volunteer Barley (VB)	4 - VB/GM	5 - VB/HAY
	Replant Barley (RB)	7 - RB/GM	8 - RB/HAY

Table 2. Price Distribution Parameters Used in Monte Carlo

Data Series	Barley	Corn	Alfalfa	Sugarbeet	Feed Barley	Pasture Rent
Average	4.63	4.04	148.58	53.49	3.55	20.08
Best Fit	Uniform	Triangle	Pareto	Normal	Triangle	Uniform
SD	0.9893	1.0993	32.5276	9.8157	0.8428	2.7193

Table 3. Correlations of Price Data Used in @RISK Analysis

Correlation	Barley	Corn	Alfalfa	Sugarbeet	Feed Barley	Pasture rent/ac
Barley	1.000					
Corn	0.851	1.000				
Alfalfa	0.632	0.626	1.000			
Sugarbeet	-0.234	0.065	-0.304	1.000		
Feed Barley	0.463	0.679	0.567	0.232	1.000	
Pasture rent/ac	-0.534	-0.762	-0.299	-0.238	-0.608	1.000

Table 4. Distributions of Profitability by Scenario in @RISK

Scenario	Average	SD	CV	5th %	95th %
CC GM	-$196.87^{a}	$24.24	-0.12	-$236.75	-$157.00
CC HAY	$299.84^{b}	$56.08	0.19	$240.47	$396.50
CC GRZ	-$292.85^{c}	$53.57	-0.18	-$381.27	-$204.85
VB GM	-$253.13^{d}	$43.29	-0.17	-$324.33	-$181.93
VB HAY	$89.83^{e}	$63.08	0.70	$23.02	$202.55
VB GRZ	-$424.26^{f}	$85.60	-0.20	-$565.28	-$283.61
RB GM	-$360.80^{g}	$60.68	-0.17	-$460.76	-$260.92
RB HAY	$485.21^{h}	$66.59	0.14	$392.24	$593.32
RB GRZ	-$352.48^{i}	$67.60	-0.19	-$463.99	-$241.53

Note: Superscript letters denote significance at the 0.05 level

Table 5. Subsequent Sugarbeet Crop Yield Changes when Including Cover Crops as Compared to the Control

	GM	HAY	GRZ
CC	-2.47	2.5	-5.07
VB	-4.41	-2.12	-8.37
RB	-6.15	6.35	-6.26

Table 6. Average Net Income or Loss for Each Scenario Assuming no Impact to Subsequent Sugarbeet Yields

	GM	HAY	GRZ
CC	-64.75	166.11	-21.65
VB	-17.23	228.23	23.47
RB	-31.83	145.54	-1.58

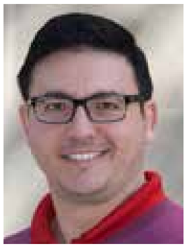
Table 7. Sugarbeet Yield Change Required to Breakeven across Low, Average, and High Sugarbeet Prices

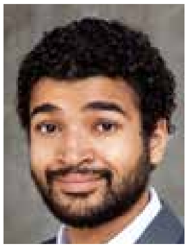
Scenario	Low	Average	High
CC GM	1.35	1.21	1.09
CC HAY	-3.47	-3.11	-2.79
CC GRZ	0.45	0.40	0.36
VB GM	0.36	0.32	0.29
VB HAY	-4.77	-4.27	-3.83
VB GRZ	-0.49	-0.44	-0.39
RB GM	0.66	0.60	0.53
RB HAY	-3.04	-2.72	-2.44
RB GRZ	0.03	0.03	0.03

Table 8. Breakeven Subsequent Sugarbeet Yield Required to Cover Costs Associated with Cover Crop Management Scenarios Assuming Average Crop Prices

Rank	Scenario	Sugarbeet Breakeven Yield (tons/ac), Average Prices
1	VB HAY	25.76
2	CC HAY	26.92
3	RB HAY	27.31
4	VB GRZ	29.59
5	RB GRZ	30.06
6	VB GM	30.35
7	CC GRZ	30.43
8	RB GM	30.63
9	CC GM	31.24

By How Much Can Appraised Farm Values Differ Across Appraisers?





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Abstract

We compared 54 appraisal reports, completed by nine Certified General Appraisers (CGAs) for three Iowa farms at two points in time (2019 and 2020), to evaluate the variability of appraised values and its causes. Our findings confirm that, despite the norms and regulations that CGAs abide by, the appraisal process is subjective in nature, and appraised values can differ by as much as 20% of their average appraised values. Furthermore, observed discrepancies in basic facts considered by CGAs to form their expert opinions on the value of a farm, such as tillable acres and productivity indexes, are non-trivial.

INTRODUCTION

Rural property appraisals are used to inform the value of rural property to interested parties in multiple situations, including loan determinations, litigations, partition cases, financial and estate planning, condemnation, and right-of-way disputes. An appraisal is a systematic process of classifying and evaluating the characteristics of an asset in order to make a well-reasoned judgment of its value (Murray et al., 1983). The appraisal process typically involves collecting relevant data, inspecting the asset in person, and organizing and analyzing data to arrive at a value opinion (ASFMRA 2021). Appraisers must follow certain established procedures to complete an appraisal.

In 1989, U.S. Congress established a real estate appraiser regulatory system involving the federal government, the states, and the Appraisal Foundation and authorized federal bank regulators to require appraisals for real estate loans made by federally regulated financial institutions. Currently, federal law requires that any real estate loan for $250,000 or more must be supported by an appraisal by a Certified Appraiser. The Foundation's Appraiser Qualifications Board sets the minimum Real Property Appraiser Qualification Criteria, and the Appraisal Standards Board develops the Uniform Standards of Professional Appraisal Practice (USPAP). The USPAP is the generally recognized set of ethical and performance standards for the appraisal profession in the United States. Furthermore, each U.S. state has a real estate appraiser regulatory agency that is responsible for licensing and certifying real estate appraisers and supervising their appraisal-related activities (The Appraisal Foundation, 2023).

Despite the regulated nature of the appraisal profession, and because appraising rural property is giving a well-informed opinion of the value of the property, the appraiser's well-reasoned judgments are critical in the appraising process. For example, for the sales comparison approach to valuation, appraisers are tasked to identify the "area" with similar influences or delineate the "neighborhood" of homogeneous uses in which the property would compete. Farmland sales are generally less frequent and more heterogenous than urban real estate property, so the rural appraiser's judgement plays a key role in choosing which set of recent sales from a geographically wide rural real estate market to include in the analysis (ASFMRA, 2023). Another instance when appraisers' judgments can strongly influence the resulting appraised value is when selecting the expected cash rent and the comparable sales that inform the calculation of the capitalization rate used in the income approach to valuation, as the property value is calculated as net income divided by the capitalization rate. A third example consists of the expert judgements called for on the value adjustments in the market or sales comparison approach due to differences in the characteristics of the properties compared, such as the "farmability" of a parcel or "ease of access" adjustments (Drozd and Johnson, 2004).

While previous research has concluded that average farmland values from expert opinion surveys (Shultz, 2006; Stinn and Duffy, 2012; Zhang et al. 2021), as well as from agricultural producers' self-reported farmland value estimates (Bigelow, Ifft, and Kuethe, 2020), are poor predictors of transacted farmland values, the peer-reviewed literature on comparisons of appraised values across Certified Appraisers is scant. Ma and Swinton (2012) documented that the variability in the tax-assessment appraised values for 203 land parcels determined by local assessors in the tax equalization offices of 33 townships in Michigan was lower than the variability in land sale values for the same 203 parcels. However, we are not aware of any previous study analyzing the magnitude and sources of variability in appraised values by Certified General Appraisers (CGAs) for the same set of farms.

The present article quantifies the variability in appraised values of three Iowa farms across nine CGAs in two consecutive years and identifies the major sources of discrepancies in the appraisal process. To the best of our knowledge, this is the first study to document the impact of subjective appraisers' judgments on appraised farmland values.

MATERIALS AND METHODS

With the approval of Iowa State University's Institutional Review Board (Study 18-366-00), our team hired nine CGAs to appraise three farms in Washington County, Iowa, in 2019 and 2020.

The participating CGAs were randomly selected from the list of members of the Iowa Chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA) in late 2018. To mitigate the potential effect of information-sharing among participating appraisers, participants were recruited from competing real estate companies and signed confidentiality agreements. Appraisers were explicitly instructed to freely choose the methods that they would use to generate the appraisal reports, as well as the effort and time devoted to each appraisal, to avoid influencing their evaluations. The appraisal authorization contract or transmittal letter stated the subject property address, the deed holder contact information, the assessed acres to be appraised as a whole, the appraisal effective date (April 1 of each year), the contact information of the local Farm Service Agency (FSA) office staff member who had received the information release requests signed by the deed holders, the contact information for the person who would evaluate property inspection requests, the monetary compensation for each appraisal report, the preferred method of delivery (U.S. Postal Service and email), and the intended user of the appraisal (only our team members). Importantly, the transmittal letter also stated that the intended use of the appraisal report was "research purposes, treat as developing a selling price." Appraisers received monetary compensation from our team after submitting each set of three appraisal reports, one in mid-2019 and the other one in mid-2020.

The three farms were identified with the support of Practical Farmers of Iowa following the premise that they had to be in long-term corn and soybean rotations and actively farmed, lack major structures or improvements that would complicate the appraisal process, and consist mostly of tillable acres with non-extreme productivity indexes. The owner-operators of the participating farms (called A, B, and C to maintain anonymity) received monetary compensation as well as a report on their own farm's appraised values (but not for the farms they did not own), and they, in turn, authorized the local FSA office to release the following information to each of the nine appraisers for the completion of their appraisal process: 156-EZ reports, field maps, and copies of any Conservation Reserve Program (CRP) contracts. According to their owners, Farm A was 113.4 acres in size, of which 104.7 were tillable with an average corn suitability rating (CSR2)[1] of 87.2; Farm B was 78.6 acres in size, of which 72.9 were tillable with an average CSR2 of 57.8; and Farm C was 69.6 acres in size, of which 65.7 were tillable with an average CSR2 of 57.3.

The analysis of the appraisal reports by our team members consisted of identifying a list of variables of interest within each report, and the evaluating similarities and differences across appraisers (identified as appraiser IDs 1 through 9 to maintain anonymity) and across years.

RESULTS

Table 1 shows the appraised values for Farm A across the nine appraisers, three appraisal methods, and both years. The mean appraised value as of April 1, 2019, amounted to $1,136,003, with a standard deviation of $66,617, or 5.9% of the mean value (i.e., the coefficient of variation = 5.9%). The range, or difference between the highest and lowest appraised value, amounted to $194,075, or 17.1% of the mean value. Since Farm A did not have major improvements or structures, three appraisers chose not to include a cost valuation. Across the three valuation methods, the coefficients of variation (i.e., the standard deviations divided by mean values) were close to 6%, and the range percentages (i.e., the ranges of values divided by mean values) were between 15% and 17%. These differences in appraised values by CGAs is a strong indication that farmland valuation is highly subjective, with strong implications for lending, estates, and strategic planning of agricultural stakeholders.

The mean appraised value for Farm A as of April 1, 2020, amounted to $1,189,300, or 4.7% higher than a year earlier. Interestingly, while the coefficients of variation for the income and the cost approach were higher in 2020 than in 2019 (6.9% vs. 6.0% and 7.6% vs. 6.5%, respectively), reflecting the increased uncertainty from the COVID-19 pandemic, the coefficient of variation for the comparative sales approach was slightly lower: 5.5% vs. 5.9%. More importantly, while the range percentages increased across valuation methods from 2019 to 2020, the same indicator declined for the appraised values. A lower coefficient of variation and a smaller range of prices in 2020 than in 2019 indicate that appraised values were more similar in 2020 than in 2019, despite higher market uncertainty from COVID-19, underscoring the subjective nature of the appraisal process.

The mean appraised value for Farm B as of April 1, 2019, amounted to $520,463 (Table 2), and the coefficient of variation (5.5%) and the range percentage (17.6%) were similar to those for Farm A in the same year. Three major differences between the appraised values for Farm B and Farm A were that the income approach to valuation produced the highest dispersion of values in the former (and the lowest dispersion in the latter); that the mean appraised value was only 0.6% higher in 2020 than in 2019 in the former (and 4.7% higher in the latter); and that the overall dispersion around the mean value was similar across years in the former (and slightly lower in the latter).

The mean appraised value for Farm C as of April 1, 2019, was $469,744 (Table 3), and the coefficient of variation (5.2%) and the range percentage (15.0%) were similar to the two other farms in 2019. The range percentages were higher in 2020 than in 2019 for Farm C across the four valuations, and all but one coefficients of variation were higher in 2020 than in 2019 (the exception was the comparative sales approach: 4.6% vs. 5.3%). The appraised values for Farm C increased, on average, by 1.6% across years, but the dispersion around the mean also increased slightly.

Table 4 shows the linear correlation coefficients between each valuation approach and the final appraised value in each year, across years. The comparative sales approach series was the most correlated with the final appraised value series (except for Farm C in 2020). In 2020, a year of high market uncertainty due to COVID-19, the correlation between the values obtained with each valuation approach and the final appraised value were lower than in 2019 (except for the cost approach in Farm C). All in all, it seems that appraisers put more weight on the sales comparison approach than in the other two valuation methods and when faced with higher uncertainty, relied more heavily on subjective perceptions.

To illustrate the similarities and differences in the appraisal reports completed by the CGAs, Table 5 compares the variables of interest from the nine appraisal reports completed in 2019 for Farm A (Appendix Section 1 expands the analysis to Farms B and C). As expected, all appraisers used April 1, 2019, as the effective date of appraisal. However, the property was inspected, on average, 43 days later, and the appraisal reports were signed 75 days later. All appraisers followed the USPAP, personally inspected the property, valued the farmland as "fee simple," used aerial maps and soil maps, considered the CRP encumbrance on the property, and used the sales and income approach to value to form their final opinions. Two appraisers explicitly mentioned valuating the property “as is,” and one appraiser mentioned valuating the property under the criterion of “undivided ownership interest.” Six appraisers declared to having conducted the sales research and preparing the report themselves, while two reported having used help to complete those activities, and one indicated not having been personally involved in those activities. One appraiser did not disclose the date of the property inspection. Seven appraisal reports included pictures of the farm taken by the appraisers from outside or inside the property, and one included a LiDAR map. While three appraisers mentioned “date adjustment only” under hypothetical assumptions, three others listed “property in same condition on date inspected as on effective date,” one appraiser referred to acre measurements being approximate, and two others listed “none.” In 2019, none of the appraisals listed hypothetical assumptions. The assumed exposure and marketing times varied from 1-3 months to 6-9 months. The average reported net/taxable area for Farm A was 112.48 acres (with a standard deviation of 1.61 acres); and the average reported tillable acres amounted to 105.33 (with a standard deviation of 4.90 acres), characterized by an average CSR2 index of 86.85 (with a standard deviation of 1.35 CSR2 points). One appraiser reported a land quality index value using the first version of the CSR index (excluded from the previous calculations). Importantly, the number of comparative sales or “comps” chosen by the appraisers varied between three and six and included farms in the same county as the subject farm and in neighboring counties. Furthermore, while one appraiser (ID 8) used the same comps for Farms A, B, and C, most appraisers selected a fully different set of comps for Farm A than for Farms B and C (IDs 1, 2, 3, 5, 7, and 9), and others selected a mix of repeated and different comps (IDs 4 and 6). Another difference in the valuation process stems from the value adjustments applied to the comps: while most appraisers considered land quality parameters, others focused on time of sale, ease of access and farming, CRP adjustments, and buyers’ motivation (adjoining property). The use of different comps and value adjustments resulted in different valuations according to the sales comparison approach. For the income method, differences stemmed from the estimated gross income per acre, the estimated expenses included in the calculation and their magnitudes, and the capitalization rates. All appraisers included real estate taxes in the list of expenses, and most included insurance, maintenance, and management expenses. The latter ranged from 4% to 8% of the gross income. The capitalization rates for Farm A in 2019 averaged 2.19%, with a range from 1.79% to 2.65%, and a coefficient of variation of 12.7%. Finally, five of the appraisers reported contacting the farm owner to request information about the property.

Table 6 highlights the differences in the appraisal procedures followed by appraisers in 2020 with respect to 2019 for Farm A (Appendix Section 2 extends the analysis to Farms B and C). Besides obvious differences in dates, comps, and estimated gross income, other differences included the reported total net/taxable acres (appraiser IDs 4 and 6), number of tillable acres (appraiser IDs 2 and 5), CSR2 rating (appraiser ID 8), exposure and marketing time assumptions (appraiser IDs 4 and 9), and that appraiser ID 1 conducted the sales research and prepared the appraisal report by self in 2020. Capitalization rates used in 2020 were similar to the rates used in 2019, with the average difference across farms and appraisers amounting to -0.01 percentage points. However, while appraiser IDs 2, 4, and 8 used the same or lower capitalization rates in 2020 than in 2019, appraiser IDs 3, 5, 6, 7 used the same or higher capitalization rates in 2020 than in 2019; and appraiser ID 1 used the same rates across years.

CONCLUSIONS

This exploratory study of actual appraisal processes for three farms by nine CGAs across two years provides insights on the variability of appraised values for each farm and identifies similarities and differences in the appraisal processes implemented by each appraiser. To the best of our knowledge, this is the first study to compare real appraisals of farms across multiple CGAs.

Our findings confirm that despite the norms and regulations that CGAs abide by, the appraisal process is subjective in nature, and the appraised value of a farm in Iowa at a particular point in time can be very different (by as much as 20% of their mean value) across CGAs. Furthermore, the observed discrepancies in basic facts considered by CGAs throughout the appraisal process, such as tillable acres and productivity indexes, were non-trivial.

In practice, institutions have developed multiple mechanisms to mitigate the effects of subjectivity as described in this article. For example, entities considering high-value transactions (including government agencies, venture funds, and businesses) typically obtain multiple appraisals. Furthermore, some entities that regularly deal with appraisal reports in their daily operations (including lenders and developers) usually employ an internal or external review appraiser (who has completed more training than CGAs) to evaluate whether USPAP rules were followed and clarify any concerns in cooperation with the authors of the appraisal reports. Finally, when competing appraisal reports are presented in court and their valuations differ substantially, the judge might submit the appraisals to a Review Appraisal Committee for expert guidance on the valuation to use.

This article is not intended to discredit the work of highly qualified CGAs but to raise awareness about the complexity of their profession and the convenience of applying caution and discounting appraised values in loan determinations and other instances when the asset might need to be sold at a market price determined by a different appraiser than the author of the original report. It is also more applicable to the land markets in the Midwest than other regions of the country due to the subject farm's location.

FOOTNOTES

1 The Corn Suitability Rating 2 (CSR2) is the potential farmland productivity index used in Iowa. It ranges from 0 to 100, where higher values indicate higher agricultural productivity potential (Burras et al., 2015). The average CSR2 indexes for participating farms ranged between 57 and 88, while the row-crop CSR2 indexes for Washington County and the state of Iowa are, respectively, 82 and 80 (Plastina et al., 2023). The CSR2 index was originally created to equalize tax assessments on agricultural land based on soil types and their inherent properties, it does not incorporate any information on actual soil health or fertility level.

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Table 1. Appraised Values for Farm A in 2019 and 2020

Appraiser ID	Sales Comparison Approach	Income Approach	Cost Approach	Final Opinion of Value
Year 2019 ($ per farm)				
ID 1	1,179,255	1,152,389	n/a	1,165,000
ID 2	1,091,000	1,110,000	1,060,000	1,091,000
ID 3	1,062,000	1,094,000	n/a	1,070,000
ID 4	1,112,000	1,095,000	1,102,000	1,110,000
ID 5	1,164,500	1,208,100	1,158,800	1,178,600
ID 6	1,250,000	1,245,000	1,250,000	1,250,000
ID 7	1,205,659	1,263,200	n/a	1,206,000
ID 8	1,097,500	1,086,500	1,098,000	1,097,500
ID 9	1,055,925	1,108,792	1,056,122	1,055,925
Mean ($ per farm)	1,135,315	1,151,442	1,120,820	1,136,003
StDev ($ per farm)	67,545	69,546	73,335	66,617
Range ($ per farm)	194,075	176,700	193,878	194,075
CoeffVar (%)	5.9%	6.0%	6.5%	5.9%
Range Percent (%)	17.1%	15.3%	17.3%	17.1%
Year 2020 ($ per farm)				
ID 1	1,212,948	1,142,129	n/a	1,180,000
ID 2	1,067,000	1,050,000	1,067,000	1,067,000
ID 3	1,240,000	1,236,000	n/a	1,240,000
ID 4	1,319,000	1,152,000	1,303,000	1,260,000
ID 5	1,179,300	1,181,500	1,180,900	1,180,400
ID 6	1,193,000	1,208,000	1,211,000	1,200,000
ID 7	1,205,994	1,236,286	n/a	1,206,900
ID 8	1,176,000	1,174,500	1,177,500	1,176,000
ID 9	1,193,400	1,007,500	1,073,980	1,193,400
Mean ($ per farm)	1,198,516	1,154,213	1,168,897	1,189,300
StDev ($ per farm)	65,889	79,065	88,732	53,979
Range ($ per farm)	252,000	228,786	236,000	193,000
CoeffVar (%)	5.5%	6.9%	7.6%	4.5%
Range Percent (%)	21.0%	19.8%	20.2%	16.2%

Notes: StDev=standard deviation; Range=maximum value-minimum value; CoeffVar=StDev / Mean; Range Percent=Range / Mean; n/a: not available.

Farm A had about 100 acres in a corn-soybean rotation and an average CSR2 index of 87.

Table 2. Appraised Values for Farm B in 2019 and 2020

Appraiser ID	Sales Comparison Approach	Income Approach	Cost Approach	Final Opinion of Value
Year 2019 ($ per farm)				
ID 1	569,473	579,767	n/a	575,000
ID 2	528,000	520,000	541,000	528,000
ID 3	510,000	529,000	n/a	515,000
ID 4	538,000	532,000	543,000	538,269
ID 5	541,900	521,300	545,500	535,400
ID 6	515,000	540,000	510,000	525,000
ID 7	491,909	483,522	n/a	492,000
ID 8	483,500	463,000	489,000	483,500
ID 9	492,000	486,110	476,743	492,000
Mean ($ per farm)	518,865	517,189	517,541	520,463
StDev ($ per farm)	28,138	35,100	30,054	28,741
Range ($ per farm)	85,973	116,767	68,757	91,500
CoeffVar (%)	5.4%	6.8%	5.8%	5.5%
Range Percent (%)	16.6%	22.6%	13.3%	17.6%
Year 2020 ($ per farm)				
ID 1	546,070	575,488	n/a	560,000
ID 2	520,000	497,000	497,000	520,000
ID 3	550,000	550,000	n/a	550,000
ID 4	562,000	550,000	551,000	553,871
ID 5	539,100	532,200	533,000	535,500
ID 6	515,000	527,000	531,000	522,000
ID 7	468,220	469,120	n/a	468,000
ID 8	515,000	493,500	515,500	515,000
ID 9	488,000	506,255	502,310	488,000
Mean ($ per farm)	522,599	522,285	521,635	523,597
StDev ($ per farm)	30,420	33,613	20,480	30,676
Range ($ per farm)	93,780	106,368	54,000	92,000
CoeffVar (%)	5.8%	6.4%	3.9%	5.9%
Range Percent (%)	17.9%	20.4%	10.4%	17.6%

Note: StDev=standard deviation; Range=maximum value-minimum value; CoeffVar=StDev / Mean; Range Percent=Range / Mean; n/a: not available

Farm B had about 70 acres in a corn-soybean rotation and an average CSR2 index of 58.

Table 3. Appraised values for Farm C in 2019 and 2020

Appraiser ID	Sales Comparison Approach	Income Approach	Cost Approach	Final Opinion of Value
	Year 2019 ($ per farm)			
ID 1	504,673	521,070	n/a	515,000
ID 2	476,000	476,000	493,000	476,000
ID 3	445,000	459,000	n/a	450,000
ID 4	501,000	504,000	484,000	501,192
ID 5	475,700	475,100	475,600	475,500
ID 6	435,000	465,000	435,000	450,000
ID 7	460,327	445,217	n/a	460,000
ID 8	455,500	445,500	458,000	455,500
ID 9	444,500	450,000	441,620	444,500
Mean ($ per farm)	466,411	471,210	464,537	469,744
StDev ($ per farm)	24,799	26,395	23,459	24,556
Range ($ per farm)	69,673	75,853	58,000	70,500
CoeffVar (%)	5.3%	5.6%	5.1%	5.2%
Range Percent (%)	14.9%	16.1%	12.5%	15.0%
	Year 2020 ($ per farm)			
ID 1	487,270	516,884	n/a	500,000
ID 2	476,000	454,000	453,000	476,000
ID 3	496,000	483,500	n/a	495,000
ID 4	519,000	528,000	522,000	522,075
ID 5	477,500	478,600	464,700	475,500
ID 6	440,000	456,000	452,000	448,000
ID 7	460,327	445,217	n/a	427,000
ID 8	479,500	474,500	483,000	479,500
ID 9	472,500	478,500	456,040	472,500
Mean ($ per farm)	478,677	479,467	471,790	477,286
StDev ($ per farm)	22,022	27,772	27,165	27,962
Range ($ per farm)	79,000	82,783	70,000	95,075
CoeffVar (%)	4.6%	5.8%	5.8%	5.9%
Range Percent (%)	16.5%	17.3%	14.8%	19.9%

Note: StDev=standard deviation; Range=maximum value-minimum value; CoeffVar=StDev / Mean; Range Percent=Range / Mean; n/a: not available.

Farm C had about 65 acres in a corn-soybean rotation and an average CSR2 index of 57.

Table 4. Linear Correlation between Valuation Approach and Final Value Opinion

	Sales Comparison Approach	Income Approach	Cost Approach
Year 2019			
Farm A	99%	92%	98%
Farm B	99%	95%	92%
Farm C	97%	94%	85%
Year 2020			
Farm A	95%	52%	78%
Farm B	98%	91%	82%
Farm C	89%	89%	91%
Years 2019–2020			
Farm A	98%	66%	88%
Farm B	98%	93%	87%
Farm C	92%	91%	88%

Table 5. Comparison of Salient Features of 2019 Appraisal Reports for Farm A

Items in Report	Appraiser			
	ID 1	ID 2	ID 3	ID 4
Effective Date of Appraisal	4/1/2019	4/1/2019	4/1/2019	4/1/2019
Property Inspected	6/13/2019	n/a	6/3/2019	5/1/2019
Report Signed	6/24/2019	6/22/2019	6/13/2019	7/3/2019
Valuation Approaches	S, I	S, I, C	S, I	S, I, C
Comments to Value	FS, AI	FS, AI	FS	FS
Followed USPAP	Yes	Yes	Yes	Yes
Personal Inspection	Yes	Yes	Yes	Yes
Sales Research & Report Preparation by Self?	No	As team (2)	Yes	Yes
Info Used by Appraiser	AM, SM, P	AM, SM, P, LM	AM, SM	AM, SM, P
Extraordinary Assumptions	None	None	Date adjustment only	Acreage measurements used in the Addendum are approximate
Hypothetical Assumptions	None	None	None	None
Exposure Time (pre-valuation), in Months	3-6	1-3	1-4	6-9
Marketing Time (post-valuation), in Months	3-6	1-3	n/a	6-9
Total Net/Taxable Acres	112.31	111.78	111.78	112.31
Tillable Acres	92.61	111.60	106.73	107.00
CSR2 Rating on Tillable Acres	88.5	87.2	86.1	85.9
Reported Flood Zone	X - low risk	X-minimal flood hazard	n/a	X
Topography Description	Rolling	Rolling, undulating	Gently sloping topography	Surface water drains to the open ditch in the middle from both sides
Number of Comparable Subjects and County	3 Washington, 1 Johnson (All different from comps for B and C)	2 Washington, 1 Keokuk (All different from comps for B and C)	6 Washington (All different from comps for B and C)	2 Washington, 3 Johnson (1 comp same as for B and C)
Value Adjustments to at Least One of the Comparable Properties	CSR2, land mix adj.	CSR2, land mix adj.	Farming ease-internal barriers	Improvements, land quality
Estimated Gross Income per Acre	$30,188	$30,953	$27,000	$32,170
Estimated Expenses as % of Gross Income	Real estate tax (11.9%) and insurance (0.3%) only.	Real estate tax (11.6%), insurance (0.5%), maintenance (0.5%), and management (5%)	Real estate tax only (13.5%)	Real estate tax (11.2%), insurance (0.6%), and maintenance (3.1%); no management expense
Capitalization Rate	2.30%	2.30%	2.10%	2.50%
Mentioned CRP Encumbrance	Yes	Yes	Yes	Yes
Reported Requesting Information from Owner	No	Yes	Yes	No

Notes: S: Sales valuation approach; I: Income valuation approach; C: Cost valuation approach; FS: fee simple; AI: as is; AM: Aerial maps; SM: Soil maps; P: Pictures taken by appraiser; LM: LiDAR maps; n/a: not available.

Table 5. Comparison of Salient Features of 2019 Appraisal Reports for Farm A (Continued)

Items in Report	Appraiser				
	ID 5	ID 6	ID 7	ID 8	ID 9
Effective Date of Appraisal	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019
Property Inspected	4/20/2019	4/16/2019	5/28/2019	5/14/2019	5/12/2019
Report Signed	7/10/2019	6/5/2019	6/5/2019	5/28/2019	5/30/2019
Valuation Approaches	S, I, C	S, I, C	S, I	S, I, C	S, I, C
Comments to Value	FS, UOI	FS	FS	FS	FS
Followed USPAP	Yes	Yes	Yes	Yes	Yes
Personal Inspection	Yes	Yes	Yes	Yes	Yes
Sales Research & Report Preparation by Self?	Yes	Yes	Yes	Yes	Yes (with help of others to collect data)
Info used by Appraiser	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM
Extraordinary Assumptions	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date	Property in same condition on date inspected as on effective date	Date adjustment only
Hypothetical Assumptions	None	None	None	None	None
Exposure Time (pre-valuation), in Months	3-6	2-4	3	6	n/a
Marketing Time (post-valuation), in Months	n/a	2-4	3	6	2
Total Net/Taxable Acres	111.78	111.80	111.78	111.78	117.00
Tillable Acres	106.73	106.30	106.73	103.53	106.73
CSR2 Rating on Tillable Acres	86.7	86.9	89	84.5	85.9 CSR (previous version)
Reported Flood Zone	X-minimal flood hazard	X-minimal flood hazard	n/a	Minimum flood potential	No flood zone
Topography Description	From nearly level to gently sloping to moderately sloping	Mostly level with a slight slope to the creek. The slopes range from 0% to 9%	Ranges from nearly level to rolling	From nearly level to gently rolling	Level to gently rolling with waterways
Number of Comparable Subjects and County	3 Washington, 2 Keokuk (all different from comps for B and C)	1 Washington, 3 Keokuk (1 comp same as for B and C)	2 Washington, 3 Keokuk (all different from comps for B and C)	5 Washington (Same comps for 3 farms)	4 Washington (all different from comps for B and C)
Value Adjustments to at Least One of the Comparable Properties	Flood zone, CSR2, other (time of sale), farming ease-internal barriers, location, tillable adj., CRP adj.	Time of sale, land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Time of sale, improvements, land quality	Time of sale, location & access, land quality, tillable adj., term adj.
Estimated Gross Income per Acre	$30,381	$29,523	$32,077	$31,981	$34,389
Estimated Expenses as % of Gross Income	Real estate tax (11.8%), insurance (0.7%), maintenance (6%), and management (8%)	Real estate tax (12.1%), insurance (0.5%), maintenance (3.8%), and management (8%)	Real estate tax (11.2%), insurance (0.3%), maintenance (1.7%), and management (8%)	Real estate tax (11.2%), insurance (0.9%), maintenance (1.7%), and management (8%)	Real estate tax (10.4%), insurance (0.2%), and management (4%); no maintenance expense
Capitalization Rate	1.80%	1.79%	2.00%	2.30%	2.65%
Mentioned CRP Encumbrance	Yes	Yes	Yes	Yes	Yes
Reported Requesting Information from owner	Yes	Yes	No	Yes	No

Notes: S: Sales valuation approach; I: Income valuation approach; C: Cost valuation approach; FS: fee simple; AI: as is; AM: Aerial maps; SM: Soil maps; P: Pictures taken by appraiser; LM: LiDAR maps; n/a: not available.

Table 6. Differences in Appraisal Reports between 2020 and 2019 for Farm A

Items in Report	Appraiser			
	ID 1	ID 2	ID 3	ID 4
Effective Date of Appraisal	4/1/2020	4/1/2020	4/1/2020	4/1/2020
Property Inspected	6/26/2020	n/a	6/3/2019	5/29/2020
Report Signed	9/1/2020	6/12/2020	6/10/2020	6/4/2020
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes
Extraordinary Assumptions	None	None	Date adjustment only	Acreage measurements used in the Addendum are approximate
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes
Exposure Time (pre-valuation), in Months	3-6	1-3	1-4	6-12
Marketing Time (post-valuation), in Months	3-6	1-3	n/a	6-12
Total Net/Taxable Acres	112.31	111.78	111.78	111.78
Tillable Acres	92.61	101.42	106.73	106.47
Number of Comparable Subjects and County	1 Washington, 2 Johnson (all different from comps B and C)	2 Washington, 3 Johnson (all different from comps for B and C)	5 Washington (same as comps for C, 1 different from comps for B)	5 Washington (all different from comps for B and C)
Value adjustments:	CSR2, land mix adj.	Time of sale, land mix adj., changing market conditions	Access to field, farming ease-internal barriers, drainage	Tract size, improvements, land quality
Estimated Gross Income per Acre	$30,188	$28,398	$32,154	$29,845
Estimated Expenses as % of Gross Income	Real estate tax (12.6%), insurance (0.3%), no maintenance or management charge	Real estate tax (12.6%), insurance (0.5%), maintenance (0.5%), management (5%)	Real estate tax only (11.6%)	Real estate tax (12.4%), insurance (0.7%), and maintenance (2%); no management expense
Capitalization Rate	2.30%	2.20%	2.30%	2.20%

Notes: n/a: not available.

^ The Washington Co. Courthouse was shut down for a few months before the date of the appraisal and no direct search could be made of their records and data.

* Very few sales in the area, impossibility to access records due to COVID-19. Instead of using a comparison grid, the appraiser proved occurrence of sale and discussed adjustments in a narrative form.

Table 6. Differences in Appraisal Reports between 2020 and 2019 for Farm A (Continued)

Items in report	Appraiser				
	ID 5	ID 6	ID 7	ID 8	ID 9
Effective Date of Appraisal	4/1/2020	4/3/2020	4/1/2020	4/1/2020	4/1/2020
Property Inspected	4/30/2020	4/3/2020	5/12/2020	5/22/2020	4/17/2020
Report Signed	6/26/2020	5/8/2020	5/22/2020	6/3/2020	6/8/2020
Sales Research & Report Preparation by Self?	Yes	Yes	Yes	Yes	Yes (with help of others to collect data)
Extraordinary Assumptions	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date. Market not impacted significantly by COVID.	Property in same condition on date inspected as on effective date. No direct record searches.^	Departure provision: did not include a comparison grid for comparable sales approach.*
Sales Research & Report Preparation by Self?	Yes	Yes	Yes	Yes	Yes (with help of others to collect data)
Exposure Time (pre-valuation), in Months	6-12	2-4	3	6	n/a
Marketing Time (post-valuation), in Months	n/a	2-4	3	6	3
Total Net/Taxable Acres	111.78	111.78	111.78	111.78	117
Tillable Acres	106.11	106.28	106.73	103.53	106.73
Number of Comparable Subjects and County	3 Washington, 2 Keokuk (all different from comps for B and C)	3 Washington, 1 Keokuk (all different from comps for B and C)	2 Washington, 3 Keokuk (all different comps from B and C)	5 Washington (same comps for 3 farms)	4 Washington, no comparison grid (same comps for 3 farms)
Value Adjustments:	Flood Zone, CSR2, farming ease-internal barriers, tillable adj., soil quality adj., CRP Adj	Land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Land quality	Not applicable
Estimated Gross Income per Acre	$30,207	$29,333	$33,004	$32,691	$32,806
Estimated Expenses as % of Gross Income	Real estate tax (12.4%), insurance (0.7%), maintenance (6.6%), and management (8%)	Real estate tax (12.7%), insurance (0.5%), maintenance (3.8%), and management (8%)	Real estate tax (11.3%), insurance (0.3%), maintenance (1.7%), and management (8%)	Real estate tax (11.4%), insurance (0.9%), maintenance (1.7%), and management (8%)	Real estate tax (11.4%), insurance (0.2%), management (4%); no maintenance expense
Capitalization Rate	1.80%	1.82%	2.10%	2.17%	2.75%

Notes: n/a: not available.

^ The Washington Co. Courthouse was shut down for a few months before the date of the appraisal and no direct search could be made of their records and data.

* Very few sales in the area, impossibility to access records due to COVID-19. Instead of using a comparison grid, the appraiser proved occurrence of sale and discussed adjustments in a narrative form.

APPENDIX

Section 1. Comparison of 2019 appraisal reports for Farms B and C.

Tables A1 and A2 in this appendix compare the variables of interest from the nine appraisal reports completed in 2019 for Farms B and C, respectively. Both tables illustrate in detail a number of similarities and differences in the information considered by appraisers during the appraisal process to produce the final opinion value. While some procedural characteristics of the appraisal process followed by each appraiser tend to be the same for the three farms (such as the sources of information and assumptions), farm-specific characteristics and comps, estimated gross incomes, and capitalization rates are key to tailoring the appraised value to a specific farm. Given the similarities between Farms B and C (size, location, CSR2, etc.), eight appraisers used the same comps, and seven used the same capitalization rate for both farms. The variability in the capitalization rates used by each appraiser across farms was substantially smaller than the variability in the capitalization rate used for each farm across appraisers (coefficient of variations between 13.3% and 14.1%). The only exception was appraiser ID 6, whose capitalization rate coefficient of variation amounted to 20.1%. Appraiser ID 5, on the other extreme, used the same capitalization rates for the three farms.

Section 2. Comparison of appraisal reports across years for Farms B and C.

Tables A3 and A4 highlight the differences in the appraisal procedures followed by appraisers in 2020 with respect to 2019 for Farms B and C. Besides obvious differences in dates, comps, and estimated gross income, other differences included the reported total net/taxable acres (appraiser ID 6 for Farm C), number of tillable acres (appraiser ID 6 for Farm C), CSR2 rating (appraiser ID 9 for Farm B, and appraiser ID 3 for Farm C), exposure and marketing time assumptions (appraiser IDs 4 and 9), and that appraiser ID 1 conducted the sales research and prepared the appraisal report by self in 2020. Capitalization rates used in 2020 were similar to the rates used in 2019, with the average difference across farms and appraisers amounting to -0.01 percentage points. However, while appraiser IDs 2, 4, and 8 used the same or lower capitalization rates in 2020 than in 2019, appraiser IDs 3, 5, 6, 7 used the same or higher capitalization rates in 2020 than in 2019; appraiser ID 1 used exactly the same rates across years, and appraiser ID 9 used a lower rate for Farm A, the same rate for Farm B, and a lower rate for Farm C.

Table A1. Comparison of Salient Features of 2019 Appraisal Reports for Farm B

Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Effective Date of Appraisal	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019
Property Inspected	6/13/2019	n/a	6/3/2019	5/1/2019	4/20/2019	4/16/2019	5/28/2019	5/14/2019	5/8/2019
Report Signed	6/24/2019	6/29/2019	6/13/2019	7/7/2019	7/10/2019	6/5/2019	6/5/2019	5/28/2019	5/30/2019
Valuation Approaches	S, I	S, I, C	S, I	S, I, C	S, I, C	S, I, C	S, I	S, I, C	S, I, C
Comments to Value	FS, AI	FS, AI	FS	FS	FS, UOI	FS	FS	FS	FS
Followed USPAP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Personal Inspection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sales Research & Report Preparation by Self?	No	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Info Used by Appraiser	AM, SM, P	AM, SM, P, LM	AM, SM	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P
Extraordinary Assumptions	Date adjustment only	None	Date adjustment only	Property in same condition on date inspected as on effective date	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date	Property in same condition on date inspected as on effective date	Date adjustment only
Hypothetical Assumptions	None	None	None	None	None	None	None	None	None
Exposure Time (pre-valuation)	3-6 months	1-3months	1-4 months	6-9 months	6-12 months	2-4 months	3 months	6 months	n/a
Marketing Time (post-valuation)	3-6 months	1-3 months	n/a	6-9 months	n/a	2-4 months	3 months	6 months	3 months
Total Net/ Taxable Acres	78.01	78.18	78.18	78.01	78.18	78.20	78.18	78.18	80.00
Tillable Acres	71.28	71.47	72.00	74.00	74.40	74.40	72.16	72.16	74.40
CSR2 Rating on Tillable Acres	58.3	57.6	57.9	56.9	56.7	57.6	58	49.7	56.6 CSR (previous version)
Reported Flood Zone	X - low risk	X-minimal flood hazard	n/a	X	Not in flood hazard area according to Agridata. Also discussed with operator	X-minimal flood hazard	n/a	X	No flood zone

Table A1. Comparison of Salient Features of 2019 Appraisal Reports for Farm B (Continued)

Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Number of Comparable Subjects and County	1 Washington Co., 2 Keokuk Co. (Same comps as for farm C)	1 Washington Co., 4 Keokuk Co. (Same comps as for C)	5 Washington Co. (Same comps as for C)	4 Washington Co., 1 Johnson Co. (Same comps as for B)	4 Washington Co., 1 Keokuk Co. (Same comps as for C)	4 Washington Co. (Same comps as for C)	2 Washington Co., 1 Keokuk Co., 1 Johnson Co., 1 Iowa Co. (Same comps as for C)	5 Washington Co. (Same comps for 3 farms)	4 Washington Co. (All comps different from A and C)
Value Adjustments:	CSR2, time of sale, land mix adj.	CSR2, land mix adj.	Farming ease-internal barriers	Land quality	CSR2, time of sale, farming ease-internal barriers, location, tillable adj.	Time of sale, land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Time of sale, improvements, land quality	Time of sale, location & access, land quality
Estimated Gross Income per Acre	$14,256	$14,294	$13,320	$17,760	$13,710	$18,100	$14,432	$13,226	$16,000
Estimated Expenses as % of Gross Income	Real estate tax (11.8%) and insurance (0.7%) only.	Real estate tax (11.8%), insurance (0.7%), maintenance (0.7%), and management (5%)	Real estate tax only (12.7%)	Real estate tax (9.6%), insurance (1.1%), and maintenance (8.4%); no management expense	Real estate tax (12.3%), insurance (1.5%), maintenance (6%), and management (8%)	Real estate tax (9.3%), insurance (0.6%), maintenance (4.3%), and management (8%)	Real estate tax (11.7%), insurance (0.6%), maintenance (2.7%), and management (8%)	Real estate tax (11.3%), insurance (2.3%), maintenance (2.6%), and management (8%)	Real estate tax (10.5%), insurance (0.2%), and management (4%); no maintenance expense
Capitalization Rate	2.15%	2.25%	2.10%	2.70%	1.80%	2.60%	2.30%	2.25%	2.75%
Reported Requesting Information from Owner	No	Yes	Yes	No	Yes	Yes	No	Yes	No

Notes: S: Sales valuation approach; I: Income valuation approach; C: Cost valuation approach; FS: fee simple; AI: as is; AM: Aerial maps; SM: Soil maps; P: Pictures taken by appraiser; LM: LiDAR maps; n/a: not available.

Table A2. Comparison of Salient Features of 2019 Appraisal Reports for Farm C

Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Effective Date of Appraisal	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019	4/1/2019
Property Inspected	6/13/2019	n/a	6/3/2019	5/1/2019	4/20/2019	4/16/2019	5/28/2019	5/14/2019	5/8/2019
Report Signed	6/24/2019	6/28/2019	6/13/2019	7/3/2019	7/10/2019	6/5/2019	6/5/2019	5/28/2019	5/30/2019
Valuation Approaches	S, I	S, I, C	S, I	S, I, C	S, I, C	S, I, C	S, I	S, I, C	S, I, C
Comments to Value	FS, AI	FS, AI	FS	FS	FS, UOI	FS	FS	FS	FS
Followed USPAP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Personal Inspection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sales Research & Report Preparation by Self?	No	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Info used by Appraiser	AM, SM, P	AM, SM, P, LM	AM, SM	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P	AM, SM, P
Extraordinary Assumptions	None	None	Date adjustment only	Acreage measurements used in the Addendum are approximate	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date (p.3)	Property in same condition on date inspected as on effective date	Date adjustment only
Hypothetical Assumptions	None	None	None	None	None	None	None	None	None
Exposure Time (pre-valuation)	3-6 months	1-3 months	1-4 months	6-9 months	6-12 months	2-4 months	3 months	6 months	n/a
Marketing Time (post-valuation)	3-6 months	1-3 months	n/a	6-9 months	n/a	2-4 months	3 months	6 months	3 months
Total Net/ Taxable Acres	69.61	70.00	69.41	69.61	69.41	69.40	69.41	69.41	70.00
Tillable Acres	64.04	65.17	65.00	68.00	66.40	65.70	66.05	64.74	66.00
CSR2 Rating on Tillable Acres	57.4	57.2	56.1	56.4	57.8	57.9	58	51.6	55.7 CSR (previous version)
Reported Flood Zone	X - low risk	X-minimal flood hazard	n/a	X	X-minimal flood hazard	X-minimal flood hazard	n/a	Minimum flood potential	No flood zone
Topography Description	Rolling	Rolling	Nearly level to moderately sloping	The 2 south fields are classified as HEL due to slope	From gently sloping to moderately steep	Mostly level on the southeast and northwest sloping to the creek that runs across the farm. The slopes range from 0% to 14%.	Ranges from rolling to strongly rolling	Nearly level to rolling	Gentle to strongly rolling side slopes off of ridge tops

Table A2. Comparison of Salient Features of 2019 Appraisal Reports for Farm C (Continued)

Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Number of Comparable Subjects and County	1 Washington Co., 2 Keokuk Co. (same comps as for farm B)	1 Washington Co., 4 Keokuk Co. (same comps as for B)	5 Washington Co. (same comps as for B)	4 Washington Co., 1 Johnson Co. (same comps as for B)	4 Washington Co., 1 Keokuk Co. (all same as for farm B)	4 Washington Co. (all same comps as for C)	2 Washington Co., 1 Keokuk Co., 1 Johnson Co., 1 Iowa Co. (same comps as for B)	5 Washington Co. (same comps for 3 farms)	4 Washington Co. (all comps different from A and B)
Value Adjustments:	CSR2, time of sale, land mix adj.	CSR2, land mix adj.	Farming ease-internal barriers	Land quality	CSR2, time of sale, farming ease-internal barriers, tillable adj.	Time of sale, land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Time of sale, improvements, land quality	Tract size, time of sale, land quality, tillable adj.
Estimated Gross Income per Acre	$12,808	$13,047	$11,700	$16,320	$12,473	$15,673	$13,210	$13,865	$15,180
Estimated Expenses as % of Gross Income	Real estate tax (11.7%) and insurance (0.8%) only.	Real estate tax (11.5%), insurance (0.7%), maintenance (0.7%), and management (5%)	Real estate tax only (13.7%)	Real estate tax (9.2%), insurance (1.2%), and maintenance (6.1%); no management expense	Real estate tax (12%), insurance (1.6%), maintenance (6%), and management (8%)	Real estate tax (9.6%), insurance (0.5%), maintenance (4.4%), and management (8%)	Real estate tax (11.4%), insurance (0.5%), maintenance (2.6%), and management (8%)	Real estate tax (12.2%), insurance (1.8%), maintenance (2.9%), and management (8%)	Real estate tax (9.9%), insurance (0.2%), and management (4%); no maintenance expense
Capitalization Rate	2.15%	2.25%	2.20%	2.70%	1.80%	2.60%	2.30%	2.25%	2.90%
Reported Requesting Information from Owner	No	Yes	Yes	No	Yes	Yes	No	Yes	No

Notes: S: Sales valuation approach; I: Income valuation approach; C: Cost valuation approach; FS: fee simple; AI: as is; AM: Aerial maps; SM: Soil maps; P: Pictures taken by appraiser; LM: LiDAR maps; n/a: not available.

Table A3. Differences in Appraisal Reports between 2020 and 2019 for Farm B

Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Effective Date of Appraisal	4/1/2020	4/1/2020	4/1/2020	4/1/2020	4/1/2020	4/3/2020	4/1/2020	4/1/2020	4/1/2020
Property Inspected	6/26/2020	n/a	6/3/2019	5/29/2020	4/30/2020	4/3/2020	5/12/2020	5/22/2020	4/17/2020
Report Signed	9/1/2020	6/17/2020	6/6/2020	6/9/2020	6/26/2020	5/8/2020	5/22/2020	6/3/2020	6/10/2020
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Extraordinary Assumptions	None	None	Date adjustment only	Property in same condition on date inspected as on effective date	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date. Market not impacted significantly by COVID.	Property in same condition on date inspected as on effective date. No direct record searches.^	Departure provision: did not include a comparison grid for comparable sales approach.*
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exposure Time (pre-valuation)	3-6 months	1-3months	1-4 months	6-12 months	6-12 months	2-4 months	3 months	6 months	n/a
Marketing Time (post-valuation)	3-6 months	1-3 months	n/a	6-12 months	n/a	2-4 months	3 months	6 months	2-3 months
Total Net/ Taxable Acres	78.01	78.18	78.18	78.01	78.18	78.20	78.18	78.18	80.00
Tillable Acres	71.28	71.47	72.00	74.00	74.40	74.40	72.16	72.16	74.40
Number of Comparable Subjects and County	2 Washington Co., 1 Keokuk Co. (same comps as for C)	2 Keokuk Co., 3 Iowa Co. (same comps as for C)	5 Washington Co. (4 comps same as for A and C)	3 Washington Co., 1 Keokuk Co., 1 Johnson Co. (4 same as comps for C)	2 Washington Co., 3 Keokuk Co. (same comps as for C)	2 Washington Co., 1 Keokuk Co., 1 Iowa Co. (2 same comps as for C)	2 Washington Co., 1 Keokuk Co., 1 Johnson Co., 1 Iowa Co. (same comps as for C)	5 Washington Co. (same comps for 3 farms)	4 Washington Co., no comparison grid (same comps for 3 farms)
Value Adjustments to at Least One of the Comparable Properties:	CSR2, land mix adj.	Land mix adj.	Access to field, farming ease-internal barriers, drainage	Land quality	Flood Zone, CSR2^, Other (farming ease-internal barriers), other (improvements), tillable adjustment	Land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Land quality	Not applicable
Gross Income per Acre	$14,256	$13,222	$14,400	$17,750	$13,710	$17,695	$15,154	$13,865	$15,360
Estimated Expenses for Income Approach as % of Gross Income	Real estate tax (12.5%), and insurance (0.7%) only	Real estate tax (13.2%), insurance (1.4%), maintenance (1.4%), and management (5%)	Real estate tax only (12.1%)	Real estate tax (9.9%), insurance (1.1%), and maintenance (8.5%); no management expense	Real estate tax (12.7%), insurance (1.5%), maintenance (6%), and management (8%)	Real estate tax (9.5%), insurance (0.6%), maintenance (4.4%), and management (8%)	Real estate tax (11.5%), insurance (0.5%), maintenance (2.6%), and management (8%)	Real estate tax (12.6%), insurance (1.8%), maintenance (2.9%), and management (8%)	Real estate tax (10.1%), insurance (0.2%), and management (4%); no maintenance expense
Capitalization Rate in Income Approach to Value	2.15%	2.10%	2.30%	2.60%	1.85%	2.60%	2.50%	2.10%	2.75%

Notes: n/a: not available.

^ The Washington Co. Courthouse was shut down for a few months before the date of the appraisal and no direct search could be made of their records and data.

* Very few sales in the area, impossibility to access records due to COVID-19. Instead of using a comparison grid, the appraiser proved occurrence of sale and discussed adjustments in a narrative form.

Table A4. Differences in Appraisal Reports between 2020 and 2019 for Farm C

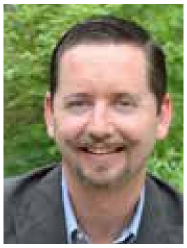
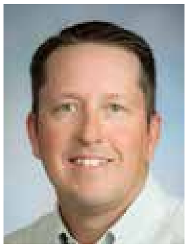
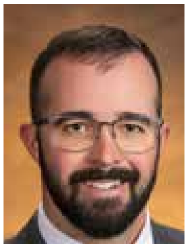
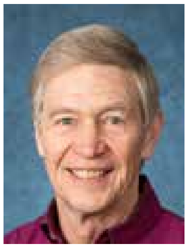
Items in Report	Appraiser								
	ID 1	ID 2	ID 3	ID 4	ID 5	ID 6	ID 7	ID 8	ID 9
Property Inspected	6/26/2020	n/a	6/3/2019	5/28/2020	4/30/2020	4/3/2020	5/12/2020	5/22/2020	4/17/2020
Report Signed	9/1/2020	6/13/2020	6/5/2020	6/5/2020	6/24/2020	5/8/2020	5/22/2020	6/3/2020	6/10/2020
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Extraordinary Assumptions	None	None	Date adjustment only	Acreage measurements used in the Addendum are approximate	Property in same condition on date inspected as on effective date	Date adjustment only	Property in same condition on date inspected as on effective date. Market not impacted significantly by COVID.	Property in same condition on date inspected as on effective date. No direct record searches.^	Departure provision: did not include a comparison grid for comparable sales approach.*
Sales Research & Report Preparation by Self?	Yes	As team (2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exposure Time (pre-valuation)	3-6 months	1-3 months	1-4 months	6-12 months	6-12 months	2-4 months	3 months	6 months	n/a
Marketing Time (post-valuation)	3-6 months	1-3 months	n/a	6-12 months	n/a	2-4 months	3 months	6 months	2-3 months
Total Net/ Taxable Acres	69.61	70.00	69.41	69.61	69.41	69.41	69.41	69.41	70.00
Tillable Acres	64.04	65.17	65.00	68.00	66.40	65.71	66.05	64.74	66.00
Number of Comparable Subjects and County	2 Washington Co., 1 Keokuk Co. (same comps as for B)	2 Keokuk Co., 3 Iowa Co. (same comps as for B)	5 Washington Co. (all same as comps for A, 1 different from comps for B)	3 Washington Co., 2 Johnson Co. (4 same as comps for B)	2 Washington Co., 3 Keokuk Co. (same comps as for B)	2 Washington Co., 1 Keokuk Co., 1 Iowa Co. (2 same comps as for B)	2 Washington Co., 1 Keokuk Co., 1 Johnson Co., 1 Iowa Co. (same comps as for B)	5 Washington Co. (same comps for 3 farms)	4 Washington Co., no comparison grid (same comps for 3 farms)
Value Adjustments to at Least One of the Comparable Properties:	CSR2, land mix adj.	Land mix adj.	Access to field, farming ease-internal barriers	Land quality	Flood Zone, time of sale, farming ease-internal barriers, tillable adj., soil quality adj.	Land quality, motivation (adjoining)	Time of sale, land mix adj., efficiency	Land quality	Not applicable
Gross Income per Acre	$12,808	$12,056	$12,675	$17,000	$12,473	$15,370	$13,871	$13,226	$16,368
Estimated Expenses for Income Approach as % of Gross Income	Real estate tax (12.4%) and insurance (0.8%) only	Real estate tax (12.9%), insurance (1.5%), maintenance (1.5%), and management (5%)	Real estate tax only (12.3%)	Real estate tax (9.1%), insurance (1.2%), and maintenance (5.9%); no management expense	Real estate tax (12.5%), insurance (1.6%), maintenance (6%), and management (8%)	Real estate tax (9.8%), insurance (0.7%), maintenance (4.5%), and management (8%)	Real estate tax (11.2%), insurance (0.5%), maintenance (2.5%), and management (8%)	Real estate tax (11.7%), insurance (2.3%), maintenance (2.6%), and management (8%)	Real estate tax (10.7%), insurance (0.2%), and management (4%); no maintenance expense
Capitalization Rate in Income Approach to Value	2.15%	2.10%	2.30%	2.70%	1.80%	2.60%	2.50%	2.10%	2.75%

Notes: n/a: not available.

^ The Washington Co. Courthouse was shut down for a few months before the date of the appraisal and no direct search could be made of their records and data.

* Very few sales in the area, impossibility to access records due to COVID-19. Instead of using a comparison grid, the appraiser proved occurrence of sale and discussed adjustments in a narrative form.

Total Ranch Analysis Colorado (T.R.A.C.): A Ranch Benchmarking Program


By Ryan D. Rhoades, Daniel F. Mooney, Matthew McQuagge, Franklyn Garry, and Jason Ahola

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Abstract

Benchmarking is a valuable tool for tracking and comparing the performance of ranch operations over time and relative to peers. However, no benchmark averages have historically been available to cow-calf operators dependent on extensive grazing lands in Colorado. Total Ranch Analysis Colorado (T.R.A.C.) was developed as a collaborative partnership involving Colorado State University faculty and Extension personnel, cattlemen associations, and beef producers. Personnel make onsite visits to collect production and financial records, and participants receive an in-depth analysis that includes a suite of production, financial, and integrated metrics. This article reports benchmark averages from the first cohort of 30 ranch visits.

INTRODUCTION

Total Ranch Analysis Colorado (T.R.A.C.) was developed as a statewide collaborative partnership in Colorado State University (CSU) Extension programming involving campus faculty, Extension personnel, cattlemen associations, and beef producers. Participant ranches are provided an in-depth financial, production, and management analysis of the ranch using a standardized approach. University personnel make onsite ranch visits to meet with producers, listen to their unique successes and challenges, and collect an array of production and financial data. The data collected are then analyzed to determine critical production, financial, and integrated metrics. A customized report with benchmarks is given to the ranch, providing a unique opportunity to identify areas to reduce the cost of production and improve production and marketing efficiency. This article reports benchmark averages from the first cohort of ranch visits.

The T.R.A.C. program aims to provide ranchers with the most accurate cow-calf enterprise analysis possible by using accrual adjustments, accounting for non-cash expenses (depreciation), and allocating overheads based on Animal Unit Month (AUM) equivalents. When applicable, enterprise analyses of stockers, hay production, and raised replacement heifers are conducted. Participants also complete a survey to help clarify current management strategies. Livestock production and financial performance data from participant ranches are assessed and used to establish key performance indicators (KPIs) and benchmarks. Livestock production and financial performance are only two components of ranch sustainability. Therefore, we are actively developing new KPIs related to ranch sustainability's human and ecological dimensions to create a systems approach to ranch analysis.

The overall T.R.A.C. program's goals are to 1) create a comprehensive ranch scorecard to be used by individual operations to set targets and track performance over time, 2) build a robust database of regional benchmarks to help producers (both participating and non-participating) make informed ranch management decisions, and 3) improve ranch family livelihoods through a long-term partnership centered on continual analysis and integration of financial, animal, human, and natural resource data. The T.R.A.C. program was developed in response to a 2018 Colorado beef producer needs assessment suggesting that ranch business management was a priority for further education and training (Rhoades and Mooney, 2018).

BENCHMARKING FOR THE COW-CALF BUSINESS

Benchmark data can help evaluate past performance, measure progress toward current goals, and plan for the future (Kahan, 2010). Benchmarking is the process of conducting a comparative analysis of the same cow-calf enterprise over time (internal benchmarking) or relative to reference herds on similar ranches (external benchmarking) (Langemeier, 2018). Although most ranchers in Colorado collect and record appropriate data, few know how to interpret and analyze this information, for instance, to calculate an accurate breakeven cost for the operation (Rhoades and Mooney, 2022). Extension can play a vital role in assisting ranchers with addressing this and similar gaps.

While cow-calf benchmarking programs exist in other states, there are no existing cow-calf benchmark data for Colorado. Because ranching in Colorado operates under a distinct set of social, financial, and environmental conditions, it requires its own set of benchmark numbers. The benchmarking process can help transform collected information into wisdom to make management decisions (Ramsay, Hanna, and Ringwall, 2016), with KPIs to measure a business's production and financial health (Bevers, 2016). The KPIs within T.R.A.C. are used as a report card to evaluate components of the ranch that are critical to success.

There are several important considerations to keep in mind when interpreting benchmarking averages. The ranch manager should always be the final decision-maker on interpreting what is a strength and weakness. Unique circumstances can make one ranch's performance logically differ from the benchmark ranches—if so, the benchmark averages should not be interpreted as "target" values to be attained. Additionally, ranches should use a systems approach to utilizing benchmark information to make changes. Focusing on improving a single metric alone will often not improve overall ranch performance.

T.R.A.C. BENCHMARKS AND KEY PERFORMANCE INDICATORS

T.R.A.C. benchmarks more than 20 production, financial, and integrated metrics (Table 1). From that extensive list, we identify and describe six KPIs that are particularly critical for cow-calf operations in Colorado dependent on extensive grazing systems (Bevers, 2016). It is important to note that most participating ranches are involved in multiple enterprises (e.g., hay production, raised replacement heifers, and backgrounding). However, the KPIs below only apply to a ranch's cow-calf enterprise. Analyses of the additional enterprises are provided when applicable.

Production KPIs

KPI #1: Pounds Weaned per Exposed Female: A product of weaning weight and weaning percentage. It reflects the number of saleable pounds a ranch has produced and can be influenced by environment, management, and genetics.

Financial KPIs

KPI #2: Return on Assets: Calculated by dividing ranch net income (including interest expenses) by total ranch assets. Because cow-calf producers are first and foremost asset managers, this metric demonstrates how efficiently assets on the ranch are returning the owner a profit.

KPI #3: Fixed to Variable Expense Ratio: Fixed expenses do not change (to a point) based on the number of animal units on the ranch. Variable expenses increase with each additional unit on the ranch. By knowing the fixed cost structure, managers can project how stocking density and expansion opportunities will affect operation efficiency.

Integrated KPIs

KPI #4: Cost/Female: Cumulative cow-calf enterprise expenses are divided by the number of breeding females at the beginning of the fiscal year. Data include depreciation of vehicles, machinery, equipment, buildings, and improvements; raised and purchased livestock; and a conservative management salary (if not already assumed). Opportunity costs are not currently included. No interest is charged if assets (land, cattle, etc.) are owned.

KPI #5: Cost/ CWT of Weaned Calf: Calculated by dividing the total cow-calf enterprise expenses by the total amount of weaned pounds produced by the ranch. This metric can be directly compared to the price received ($/CWT) for calves to determine whether the cow-calf enterprise was profitable each year.

KPI #6: Grazed vs. Fed Days: Calculated as a percentage of days cattle graze pastures annually. The percentage of grazed days is determined by recording the AUMs of each livestock class spent grazing pastures with no fed feed. Maximizing the percentage of grazed days can help reduce feed costs, one of the most significant and variable costs.

Data Requirements

Data are collected, and benchmarks calculated, following Standard Performance Analysis (SPA) guidelines (McGrann, 2010) developed by the National Cattlemen's Beef Association Integrated Resource Management (NCBA IRM) program. Thus, T.R.A.C. is an analysis tool, not a record-keeping system, but that said, many T.R.A.C. participants report improved record-keeping habits and skills as an additional benefit of program participation. Data are collected on ranches where the cow-calf enterprise is the primary source of revenue. Essential records for data calculation of T.R.A.C. benchmark KPIs are listed below (Table 2).

First Cohort Benchmarks

In 2022, the first T.R.A.C. program benchmarks were presented to producer groups at ranch gatherings, Extension meetings, trainings, and industry events (Rhoades and Mooney, 2022). This article makes these benchmark averages available to a broader audience (Table 3). The first cohort of ranches participating in T.R.A.C. were recruited statewide to represent all Colorado geographical regions: 27% from the Northwest, 14% from the Southwest, 13% from the Front Range, 23% from the Northeast, and 23% from the Southeast. They represented small (30% of herds, < 250 head), medium (40%, 250-500 head), and large (30%, >500 head) cow-calf operations. They brought a range of ranch management experience, with 12% considered to be beginning ranchers (>10 years), 19% considered to be intermediate (11-20 years), and 69% considered experienced (>20 years). Just under half of the participating ranches (48%) indicated they work full time on the ranch, with the remainder working most of the time (42%) or part time (10%). More than half (56%) owned less than 25% of the land used for cattle production (56%), whereas fewer (6%) owned 25-50% of the land or (38%) owned more than 50%. One-quarter (25%) of ranchers managed a fourth-generation family ranch, while the remaining (75%) managed a third-generation one.

IMPACT AND FUTURE ANALYSIS

Ranch management is complex, and ranchers need access to systems-level data and metrics to make effective decisions. T.R.A.C. aims to provide producers with the information needed to make more informed management decisions. Ranchers are busy people with limited time for strategic planning and data analysis. Moreover, some ranchers may not consider financial management to be "real" ranch work and leave this activity to evenings, weekends, or other less-than-ideal times of the day (Chase and Dietmann, 2012). Monitoring benchmark data through programs like T.R.A.C. can help focus limited management time on critical areas of the cow-calf business, quickly identify potential areas for improvement, and continuously measure progress toward meeting business goals.

Planning, gathering, and determining the benchmark averages for the first cohort of ranches produced several critical takeaways for Colorado cow-calf enterprises in these areas:

- First, production benchmarks (pregnancy, weaning, pounds weaned/exposed female, etc.) remain challenging for some producers but not most. Management decisions can impact productivity, but rainfall has the most significant influence. Therefore, this resource limitation likely prevents producers operating at or above the median production benchmarks from further cost-effectively increasing their productivity. As costs rise, managers must also evaluate the marginal returns of increasing productivity.

- Second, financial management represents the number one barrier to success. Ranch net income and return on assets vary considerably between the upper and lower producer groupings. Most operations that struggle financially have higher fixed costs. Cow-calf businesses are asset-based, and fixed costs (equipment, labor, and cows) on benchmark operations accounted for 50-70% of every dollar spent. Fixed costs on ranches are difficult to change once assets have been acquired. An effective way to lower them is to spread it out over more units by increasing cow numbers, but maintaining or even increasing stocking rates (rainfall dependent) can be challenging.
- Third, the total costs of owning a cow will continue to rise due to inflation. Substantial variation in cow costs exists between the upper and lower 30% of producers in the first T.R.A.C. benchmark cohort. A breakdown of cow costs can identify which specific expenses might need improvement. The top four expenses are typically depreciation, labor, feed, and pasture. Costs per CWT of weaned calf (i.e., breakeven relative to price received) could be the most important number to focus on and compare. Although every ranch has different resources available, this metric incorporates expenses and productivity.
- Last, most cow-calf operations aim to wean the most profitable calf possible. To do so takes excellent management, which requires a clear view of the financial position of the ranch and drivers of net income and return on assets; making a multitude of small decisions to collectively keep costs low relative to the value of weaned calves; and finding leverage in the production system that can have long-lasting systematic benefit to the operation. Good records and accounting systems are critical to accurate financial information. Benchmarking and completing an in-depth enterprise analysis to evaluate potential changes (partial budgeting, capital budgeting, etc.) can assist with decision-making and continuous improvement.

For Extension, developing programs like T.R.A.C. can support strong stakeholder relationships, facilitate valuable comparative analysis for clientele, and create unique long-term datasets for research, Extension, and educational programming. Analysis and comparison of early T.R.A.C. records highlighted depreciation, labor, feed, and pasture expenses as the top four contributors to overall cow costs (McQuagge et al., 2021). Subsequent publications and Extension materials will be developed by T.R.A.C. team members, Extension personnel, and graduate students to demonstrate the value of using benchmarking information for improved decision-making to producers and beef industry stakeholders. As mentioned, livestock production and financial performance are only two components of ranch sustainability. T.RA.C. benchmarks should, therefore, be used in conjunction with other indicators (e.g., animal health, rangeland health) and long-term strategic planning when deciding to make significant changes to ranching operations to maintain a holistic approach to ranch management and analysis.

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Table 1. T.R.A.C. Benchmarks and KPIs[1] for Ranch Analysis

Production Benchmarks	Financial Benchmarks	Integrated Benchmarks
Breeding Females	Return on Assets[1]	Cost/Female[1]
Acres/Female	Investment/Female	Weaned Calf Price
Feed Fed/Exposed Female	Equity to Assets Ratio	Labor & Management Expense Ratio
Normal Rainfall	Asset Turnover Ratio	Nutrition Expense Ratio
Pregnancy Rate	Net Worth Change	Cost/CWT Weaned Calf[1]
Calving Distribution	Operating Ratio	Cost/Weaned Calf
Weaning Rate	Depreciation	Grazed vs Fed Days[1]
Replacement Rate	Interest Rate	
Weaning Weight	Net Income from Operation	
Pounds Weaned/Exposed Female[1]	Fixed to Variable Expense Ratio[1]	
Pounds Weaned/Acre		

[1] KPI = Key Performance Indicator.

Table 2. T.R.A.C. Data and Records Utilized for Ranch Analysis

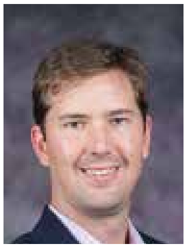
Production Benchmarks	Financial Benchmarks	Grazing Benchmarks
Cattle Inventory • Cows Exposed • Cows on January 1 • Weaned Calves	Profit & Loss Statement	Acreage Utilization
Feed Inventory • Raised • Purchased	Balance Sheet	AUMs
Pregnancy Check Records	Depreciation Schedules	
Calving Distribution Records	Loan Schedules	
Weaning Weights		

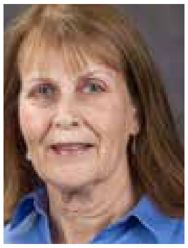
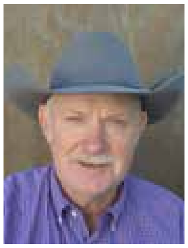
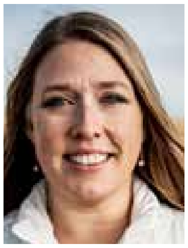
Table 3. T.R.A.C. Benchmark Averages from First Cohort (N = 30)

	Lower 30% (N=9)	Median (N=30)	Upper 30% (N=9)
Production Benchmarks			
Pregnancy (%)	89.5	93.0	96.0
Calving (%)	85.0	89.1	93.0
Weaning (%)	81.0	85.0	90.0
Weaning weight (lbs)	480	558	608
Lbs weaned/exposed female[1] (lbs/head)	417	487	528
Grazing acres/female (acres/head)	81.0	43.5	18.4
Lbs. weaned/acre (lbs/acre)	6.0	11.6	29.0
Calving distribution (% of cow herd)			
1-21 days	---	46.5	---
22-42 days	---	38.8	---
43-63 days	---	11.1	---
63+ days	---	3.6	---
Financial Benchmarks			
Return on assets (%)[1]	-6.1	-0.6	5.0
Ranch net income ($1,000s)	-70.0	3.6	121.8
Fixed vs variable expenses[1]			
Variable expenses (%)	31%	36%	49%
Fixed expenses (%)	69%	64%	51%
Integrated Benchmarks			
Cow cost ($/cow)[1]	1,326	1,013	799
Grazed vs fed days[1]	53.0%	70.0%	92.5%
Cost per calf vs price received			
Cost / CWT weaned calf ($/cwt)[1]	280	211	159
Price received ($/cwt)	146	157	169

[1] KPI = Key Performance Indicator.

Water Management and Information Gaps in the High Plains Aquifer



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Abstract

Water is a critical input to agricultural production in arid regions. Understanding irrigator perspectives and determining their information and technical needs are critical to increasing water conservation while maintaining profitable yields. This paper summarizes survey data for 140 irrigators operating in the High Plains Aquifer portion of southcentral Kansas. We document adoption of different farm management practices, key challenges facing irrigators, information gaps, and qualitative information obtained from open-ended questions. Survey response patterns are discussed in the context of local water use conflicts and water governance.

INTRODUCTION

Groundwater is fundamental to crop production in arid geographies such as the Great Plains region of the United States. Approximately 60% of all irrigated agricultural land in the United States is irrigated from groundwater (Siebert et al., 2010). The High Plains Aquifer (HPA) in Kansas provides water for approximately 2.6 million acres of irrigated land annually (Kansas Department of Agriculture, 2017). Using the relative difference between irrigated and non-irrigated land values, Sampson, et al. (2023) estimate that agricultural land values in Kansas are $3.8 billion greater today due to access to irrigation water from the HPA. However, decades of pumping that exceed the rate of aquifer recharge has led to predictions that future irrigated crop production over some areas of the HPA will not be possible without changes to groundwater management (Haacker et al., 2016).

This paper summarizes information on irrigation and water management practices obtained from survey responses of 140 irrigators located in southcentral

Kansas (Figure 1). We document different elements of irrigation technology adoption and outcomes, conservation practice adoption and outcomes, key challenges facing irrigators, and current information gaps perceived as impeding irrigation management and agricultural production. Additionally, we document qualitative data collected through open-ended survey questions aimed at improving current and future irrigation programs.

BACKGROUND

Irrigation in Kansas is governed by prior appropriation rights first established by the Water Appropriation Act of 1945. Under this act, any producer seeking to use groundwater for irrigated production must first file a water use application with the Division of Water Resources (DWR). If the application is approved, the water-using entity is granted a water right that places limitations on the well location, where the water may be applied (i.e., the place of use), the annual volume of water that may be pumped, the number of acres that may be irrigated, and the priority date (i.e., seniority ranking).

The Kansas legislature authorized the Groundwater Management District Act in 1972, which led to the formation of five Groundwater Management Districts (GMDs). These districts have the power to set local water governance across the district's irrigators subject to approval of the DWR. GMD 5 is in southcentral Kansas, spans eight counties, and is the context of our mail survey (Figure 1). Total annual water use and irrigated acreage for GMD 5 averages around 500,000 acre-ft and 450,000 acres, respectively. GMD 5 is the second largest GMD in Kansas in terms of total annual water use and irrigated acreage.

Kansas requires annual water use reporting for all irrigators. The irrigation and cropping data are made publicly available through the Water Information Management and Analysis System (WIMAS) of the DWR. We summarize this data for GMD 5 below. One challenge to interpreting the WIMAS data is that two or more water rights may spatially overlap in the location of the well or the place of use (Earnhart and Hendricks, 2023). Due to this potential overlap, we choose to aggregate water use data up to the level of a "water right group," which is defined by the smallest legal combination of well location and place of use such that no two water right groups overlap. Each water right group thus provides information to a common farming operation.

Panel A of Table 1 summarizes water use and cropping data for all 3,358 active water right groups located in GMD 5 for the years 2000-2019. On average, a single water right group uses about 143 acre-ft of water per year and irrigates 137 total acres with an average water application depth of 12.5 inches. Corn and soybean are the two most commonly irrigated cash crops. The average number of irrigated corn and soybean acres is 67 and 26, respectively. Cropping practices in southcentral Kansas commonly involve a rotation, which explains why the average crop-specific acreage is lower than the average total irrigated acreage.[1]

There are 1,148 registered holders of agricultural water rights in GMD 5. We refer to these entities as water use correspondents because they are responsible for filing annual water use reports with the DWR. Taken together, the total number of water right groups in GMD 5 with the total number of water use correspondents in GMD 5 suggests that approximately three water right groups are registered to each water use correspondent, on average (i.e., 3,358/1,148). Using this information together with panel A of Table 1 implies that each correspondent in GMD 5 operates approximately 402 irrigated acres per year and uses approximately 432 acre-ft of water per year. By comparison, the average number of acres irrigated from groundwater and the total amount of groundwater used per farm in the U.S. in 2018 was approximately 323 acres and 371 acre-ft, respectively (United States Department of Agriculture, 2019).

Our study region, GMD 5, has two notable water conflicts that are likely to influence irrigator perceptions of water use challenges. In 2013, the U.S. Fish and Wildlife Service (USFWS) filed a water use impairment against nearby irrigators holding junior water rights. The USFWS holds a senior surface water right to Rattlesnake Creek, which is used to flood wetland habitat in Quivira National Wildlife Refuge. USFWS argues that junior irrigators in GMD 5 are reducing streamflow in Rattlesnake Creek via hydrologic connections to the aquifer and thus affecting USFWS's ability to pump their water allocation into the wetland. The Chief Engineer of the DWR concluded that an impairment existed. Several years of negotiation between irrigators and USFWS ensued. Dissatisfied with proposed water management plans that emerged from negotiations, the USFWS in 2023 requested secure water in the amount of 14,632 acre-ft per year. The issue is still in dispute, and there is warranted concern about a resolution requiring water curtailments for nearby junior water rights holders, as has occurred elsewhere in Kansas.

The Walnut Creek Intensive Groundwater Use Control Area (IGUCA) was established in the northwestern region of GMD 5 in 1992 because of conflict between senior surface water rights to Walnut Creek streamflow and junior groundwater irrigators. Walnut Creek supplies water to Cheyenne Bottoms Wildlife Area. Under the IGUCA, groundwater irrigators were forced to curtail their annual water use to support long-term sustainable use of the aquifer. Water rights are divided by priority dates before and after October 1, 1965. Water rights with a priority date prior to October 1, 1965, had water allocations curtailed to 12-14 inches/acre, or about the net irrigation requirements for corn in the region. Water rights with a priority date after October 1, 1965, were required to curtail their usage an additional 60% (about 5-6 inches/acre). Irrigators with post October 1, 1965 priority dates responded to IGUCA water curtailments by reducing the number of acres they irrigate by an average of 26% (Earnhart and Hendricks, 2023).

METHODS

Names and mailing addresses were obtained from DWR water use reports for all 1,148 water rights holders in GMD 5 who were the recipients of our mail survey. A pre-survey postcard notifying recipients of the survey and its purpose was mailed on January 24, 2023, followed by the full survey on January 31, 2023, which included business reply envelopes. The survey contained 18 questions on irrigation practices, outcomes, information gaps, concerns over future irrigation viability, and space to provide qualitative feedback for the implementation of future irrigation programs. All aspects of the survey were reviewed and approved by the Kansas State University Institutional Review Board prior to data collection. Survey responses were anonymized and hand-entered into Qualtrics survey software for aggregation and then downloaded into a spreadsheet for analysis

RESULTS

Four surveys were returned as blank, and a total of 140 surveys were returned at least partially completed, for a response rate of 12%.[1] The remainder of this paper details the information provided in the mail survey. We organize the survey results into sections, starting with factors influencing irrigator decisions to adopt a new technology or conservation practice.

Demographics

A wide range of ages were represented in the survey responses (Figure 2). The youngest and oldest age ranges represented were 30-39 years and above 80 years, respectively. Approximately half of the sample indicated an age range of either 50-69 or 60-69 years. Approximately 10% of the sample indicated an age younger than 50 years, and approximately 40% of the sample indicated an age range of 70 years or older. By comparison, the 2017 USDA Agricultural Census indicated that 34% of US farm producers were 65 years or older while 36% of all Kansas producers were 65 years or older (United States Department of Agriculture, 2019).

Adoption of New Technologies/ Practices

We summarize in Panel B of Table 1 the frequency of different irrigation technologies currently being used by the survey respondents. Nearly 90% of respondents use crop consultants and nearly two-thirds use remote pivot monitoring. Approximately one-third of respondents use soil moisture probes, and less than one-third use aerial imagery or other forms of remote sensing technology, variable frequency drives, variable rate irrigation speed control, or rain sensors.

We included in the survey a series of questions related to the various motivations leading an irrigator to adopt new technologies/practices or barriers to the adoption of technologies/practices. We asked irrigators to identify the three most important considerations when choosing to make changes to their irrigation or cropping system (Panel A, Table 2). The three most frequently chosen considerations were the potential for increased income generation (78%), need for greater irrigation efficiency (69%), and availability of farm labor (34%). Sampson and Perry (2019) documented the importance of peer networks in the diffusion of irrigation technologies in Kansas. Consistent with this research, we observed that positive or negative experiences of peers was chosen by 29% of respondents.

When asked to identify the three most important barriers to implementing a new irrigation technology or practice, the most frequently chosen was the cost associated with the new technology or necessary equipment upgrade (83%) (Panel B, Table 2). The second most frequently indicated barrier was the need to maintain historical water use to protect against potential future allocation reductions (39%). As previously discussed, curtailing water allocations as a proportion of historical water use (as opposed to the maximum permitted amount) is one method the DWR uses to manage water conflict. Curtailing based on historic use is viewed by some respondents as unjustly punitive toward irrigators who have been voluntarily conserving by using amounts below the permitted maximum. The third most frequently indicated barrier was lack of available financial information on return-on-investment (32%). Approximately one-quarter of respondents indicated a lack of user-friendly cost-share programs or, on leased land, where landowners are unwilling to invest in the new technology/practice. Nearly half the farmland in Kansas is leased (Bigelow et al., 2016), and landlords typically own the irrigation equipment (Tsoodle and Li, 2022).

We dedicated a few questions to conservation practices, the results of which we document in Tables 3 and 4. Over three-quarters of respondents currently practice no-till or reduced-till farming (Panel A, Table 3), and more than half of respondents currently practice cover cropping, with approximately one-third practicing conservation crop rotations or livestock integration. Numerous respondents noted in comments that they have been practicing no-till and cover cropping for well over five years, which is consistent with previous surveys of Kansas producers, indicating widespread implementation of no-till and cover crops. Using a survey of 237 producers across Kansas, Canales et al. (2024) found that 62% had some prior adoption of continuous no-till and 34% had some prior adoption of cover crops. Using a survey of 429 landowners in central and western Kansas, Gardner (2022) found that approximately 80% had some prior adoption of no-till and 30% had some prior adoption of cover crops.

For respondents who had implemented a conservation practice within the past five years, we asked them to identify the environmental outcomes that have been observed post-implementation (Panel B, Table 3). The most frequently indicated outcome was reduced soil erosion (64%), followed by improved water utilization (51%). Over one-third of respondents indicated higher crop yields, improved soil water holding capacity, and improved soil moisture during field preparation or planting.

Respondents who are currently implementing a conservation practice were also asked to indicate their top three reasons for implementing the practice (Table 4). There were four reasons that were indicated at high frequency: to improve production efficiency (56%), to improve soil health or to reduce soil erosion (54%), to increase profitability (53%), and to reduce input costs (52%)[3]. Other reasons that were frequently indicated were in response to weather patterns or risks (29%), to reduce labor costs (27%), and to increase long-run sustainability (26%). Only 2% of respondents indicated implementing a conservation practice as part of a carbon sequestration contract. While the number of carbon credit programs has grown in recent years (Wongpiyabovorn et al., 2023), our results indicate that carbon contracts are not widely utilized in Kansas, nor do they serve as important motivation for implementing new conservation practices. Moreover, producers must typically implement a new conservation practice to qualify for carbon credit programs—a requirement known as additionality (Wongpiyabovorn et al., 2023). If already implemented on the farm, no-till or cover cropping would not count as a qualifying practice in generating carbon credits. Given that no-till and cover cropping already has widespread implementation in Kansas, the scope for participating in carbon credit programs may be limited.

Concerns and Challenges for Irrigation in the Future

We included two questions in the survey to collect information on the key concerns and challenges facing irrigators. We asked irrigators to identify their top three concerns regarding the future of collective irrigation within GMD 5 (Panel A, Table 5). The concern indicated with most frequency by far was regulatory uncertainty, including concerns about reduced water allocations. Again, two prominent water conflicts have occurred in GMD 5 between senior surface water rights and junior groundwater rights. Our findings provide evidence that regulatory uncertainty is almost unanimously viewed by irrigators as one of the most salient concerns for the future of irrigation. The second most frequently indicated concern was insufficient pumping capacities or lack of water in the aquifer (54%). Pumping capacity is defined as the upper limit on the volumetric rate of water withdrawal and is correlated with saturated thickness of the aquifer (i.e., stocks of water). Declining saturated thickness generally correlates with decreases in pumping capacity (Foster et al., 2015). One respondent provided a note that his single irrigation well had declined in pumping capacity from 2,000 gallons per minute when it was first drilled in 1969 to less than 700 gallons per minute currently. Over one-quarter of respondents indicated lack of farm labor or low water quality as one of the top three concerns regarding the future of irrigation. Water quality in GMD 5 is deteriorated by intrusions of brackish water from oil well drilling or from saline surface waters such as the Arkansas River (Whittemore, 2000). Additionally, rapid groundwater withdrawals can trigger upward movement of saline water that is present in the underlying hydrogeologic formation (Ma et al., 1997). Our result is consistent with Gardner et al. (2021), which found that over 20% of sampled irrigators in southcentral and southwest Kansas reported either "moderate" or "major" impacts of low groundwater quality on their crop yields.

Irrigators were also asked to indicate the top three challenges personally facing them. Whereas the previous question was designed to gather information on factors presenting collective challenge to irrigation within GMD 5, this question was designed to gather information on challenges specific to each respondent. Over 70% of respondents indicated that increased drought was a challenge to irrigated production (Panel B, Table 5). Over half of respondents also indicated uncertainty about future water allocations, suggesting that irrigators view regulatory uncertainty as a regional problem that is likely to present future difficulties, even though it might not directly threaten the individual respondent. Over half of respondents indicated power costs associated with operating their pump plants as a challenge to irrigation[4]. Roughly one-third of respondents indicated an aging irrigation system or limited water allocations. Salinity or other water quality problems was indicated by 15% of irrigators.

Information Provision and Information Gaps

Our survey concluded with a series of questions designed to collect information on key information gaps currently impacting irrigators and the ways in which researchers, university extension, and government agencies might better provide services deemed useful to irrigators.

We included an open-ended question of what irrigators wished that researchers, university extension, GMD managers, and state and federal government agency staff would consider when planning irrigation outreach and programs. Respondents were provided one and one-half pages of writing space to provide their feedback, and we received written feedback from 66 respondents. We organize the responses into major themes to summarize the information along with some salient quotes.

Approximately one-third of the responses touched on the value of flexibility when water use curtailments are implemented in response to water use conflict. For instance, a flexible curtailment might involve a five-year ceiling on water use with carryover between years such that more water could be used in dry years and less water could be used in wet years. This type of flexibility is built into current and proposed Local Enhanced Management Areas (LEMAs) in GMDs 1 and 4. Seven responses focused on compliance burdens associated with state or local water governance. Six responses detailed how agencies need to do a better job of understanding "on the ground" consequences of water governance. Another six responses argued that controls on woody encroachment should be part of the solution to water management. Plant species such as eastern red cedar are expanding beyond their historic range in Kansas and can reduce available water and disrupt grassland ecosystem function (Zou et al., 2018). Another five responses were critical of the use of end guns, which are large sprinklers set at the end of a center pivot and are used to reach portions of the field not directly accessible by the pivot, such as field corners. However, end guns are viewed as inefficient because they do not apply water to a uniform depth and require greater pressure to operate. A bill introduced into the Kansas legislature in 2018 would have allowed the DWR to regulate the use of end guns, but the bill did not pass through committee. End gun removal and regulation is currently authorized through the formation of IGUCAs and LEMAs.

Below we include three salient quotes from the survey:

> *"The implementation of more rules and regulations increases the workload and becomes worrisome if you have government agencies slapping fines or penalties for what they consider negligence. This is not always the case, sometimes it is too many rules that confuse the farmer when he is the busiest."*

> *"Flexibility should be the first consideration in any of the plans going forward. We will have to have clear goals or benchmarks to work towards, however, how we get there can look several different ways. Making sure each operation knows the goal, and is given the flexibility to reach it, will allow the most positive outcome."*

> *"I believe it should be a very high priority for those who make these decisions to avoid putting a high economic burden on irrigators. Rather than simply reducing allocations, I would propose 'rewarding' irrigators for efficiency and other conservation practices. We farmers are very good at improvising effective solutions. Set us a target of some sort and let us try to hit it."*

We next discuss three questions focused on key information gaps impacting irrigators. We asked irrigators to indicate the three pieces of information most needed to improve irrigation management (Panel A, Table 6). Just under one-half of respondents indicated information on the benefits of conservation practices, such as reduced tillage or cover crops, information on determining whether upgrades to pumping plant and irrigation systems were needed to maximize efficiency, or information on the selection and use of remote sensors to aid in irrigation decisions. Approximately one-third of respondents indicated that interpretation of existing agency program availability/eligibility or information on the selection and use of irrigation scheduling software would be helpful.

For livestock producers, we asked respondents to indicate their top three pieces of information that would improve livestock production on irrigated ground (Panel B, Table 6). Over one-third of respondents indicated comparison of livestock to crop production returns, managing livestock impact on soil conditions such as compaction, or selecting forage varieties. Approximately one-quarter of respondents indicated "other" or managing grazing considerations, such as duration and timing. Somewhat surprisingly, less than one-fifth of respondents indicated information on finding cost-share programs or the selection of water sources.

We also asked how crop consultants might improve their water application recommendations (Table 7). Over half of respondents indicated crop consultants could improve recommendations by reducing reliance on maximum water application to achieve yield goals. Within the Walnut Creek IGUCA in GMD 5, some water allocations were curtailed to 5-6 inches/acre, which is generally not adequate to meet net irrigation requirement of corn. Thus, information on how to achieve profitable yields with limited water is of value to irrigators.

Just under half of respondents indicated considerations for times when their permitted annual water allocation is spent before the end of the irrigation season (i.e., end-of-water). Over one-third of respondents indicated improving consultant skills through ongoing agronomic or irrigation training and by including the contribution of rainfall to estimated crop water needs. However, it should be noted that there were numerous written comments accompanying this question indicating that the respondent's crop consultant was already performing adequately with respect to each factor listed.

Lastly, we asked respondents to indicate their top five sources of reliable information for irrigation decisions and crop management (Table 8). It is not surprising that agronomists and crop consultants were the sources of reliable information indicated with the most frequency (78%). There is a financial relationship between crop consultant and producer, so it makes intuitive sense that the producer would value information delivered by the consultant. The second most frequently indicated source of information was the respondent's own experience or education (57%). Over one-third of respondents indicated peer producers, local irrigation organizations, or GMD 5. Less than one-quarter of respondents indicated university extension or Natural Resource Conservation Service as reliable sources of information. Industry trade groups such as the Kansas Corn Growers Association and state agencies such as the Kansas Department of Agriculture were selected by fewer than 10% of respondents.

SUMMARY AND CONCLUSIONS

This paper summarizes survey data for 140 irrigators in a water-stressed region of southcentral Kansas. Two local water use conflicts between senior surface rights and junior groundwater rights contextualize the regulatory challenges encountered by irrigators. One region of the study area (Walnut Creek IGUCA) implemented annual water use cutbacks that were differentiated by water right seniority. Water rights granted after October 1, 1965, had their annual allocations cut to 5-6 inches/acre within the IGUCA. Elsewhere in the study area, irrigators and the USFWS are engaged in a water dispute that has yet to be resolved.

Survey respondents near unanimously viewed regulatory uncertainty, including the risk of reduced allocations, as a top concern confronting the future of irrigation in the region. Drought, energy costs associated with operating pumping plants, and reduced pumping capacities were also highly cited as irrigation challenges and concerns. Crop consultants, the producer's own past experiences, and peer producers ranked the highest in terms of reliable provision of information. Equipment dealers, trade groups, and state agencies (including the DWR) ranked the lowest in terms of reliability. Respondent data on sources of reliable information coupled with written comments provided in the survey are indicative of general skepticism of state government dissemination of groundwater information.

It is almost certain that changes to groundwater management will be necessary to prolong the useful life of the aquifer (Haacker et al., 2016). Respondent feedback highlights that irrigators most value flexibility and incentive-based approaches to achieving water conservation. Policies designed to curtail water allocations based on a proportion of historic use are generally viewed as punitive toward irrigators who have actively applied water conservation practices. This type of policy can have unintended consequences as irrigators are forced to use their entire allocation or suffer reductions in their allocated water, discouraging conservation.

Lastly, it is worth noting some caveats to the survey information. First, a portion of the survey area is experiencing an unresolved water right conflict. Information provided by irrigators involved in this conflict may not be entirely representative of irrigators in other parts of Kansas or other plains states where water use conflicts are less of an issue. Secondly, we did not collect any demographic information apart from age. Thus, we cannot speak specifically to the representativeness of the survey sample with respect to certain demographic characteristics.

FOOTNOTES

1. The WIMAS data do not indicate crops grown as a single crop versus a second crop. However, irrigated double cropping in Kansas is limited (Kansas Department of Agriculture, 2017).
2. The survey response rate is similar to other mail surveys targeted to Kansas irrigators (Gardner et al., 2021; Perez-Quesada and Hendricks, 2021).
3. Separate options for profitability and input costs were included to account for the possibility that a conservation practice might jointly affect costs and revenue.
4. Irrigation pumping stations in Kansas are powered by natural gas, diesel, or electricity (Sampson and Perry, 2019). We did not include a question specific to the respondent's energy source.

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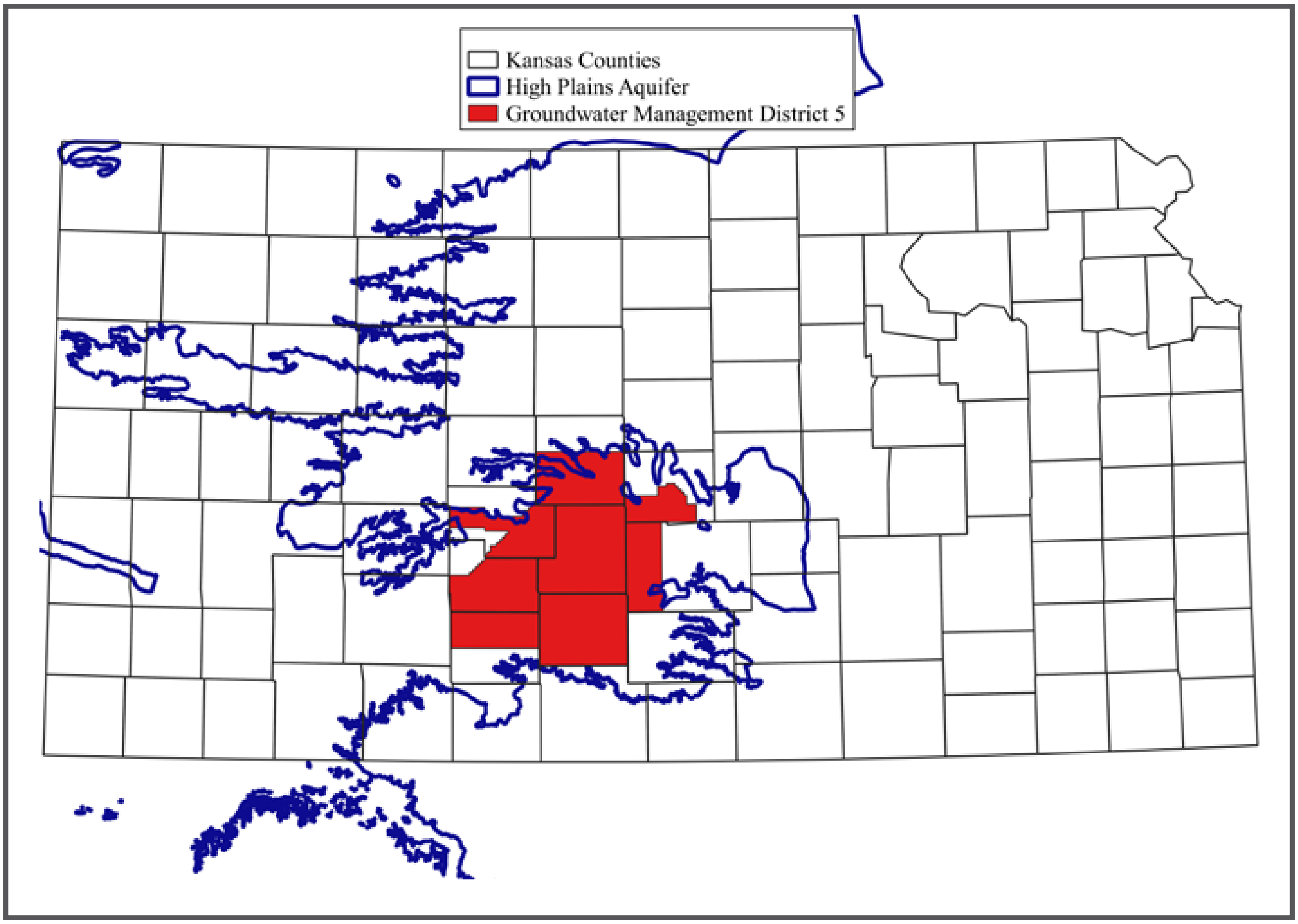


Figure 1. Location of GMD 5 in Kansas, the region covered by the mail survey

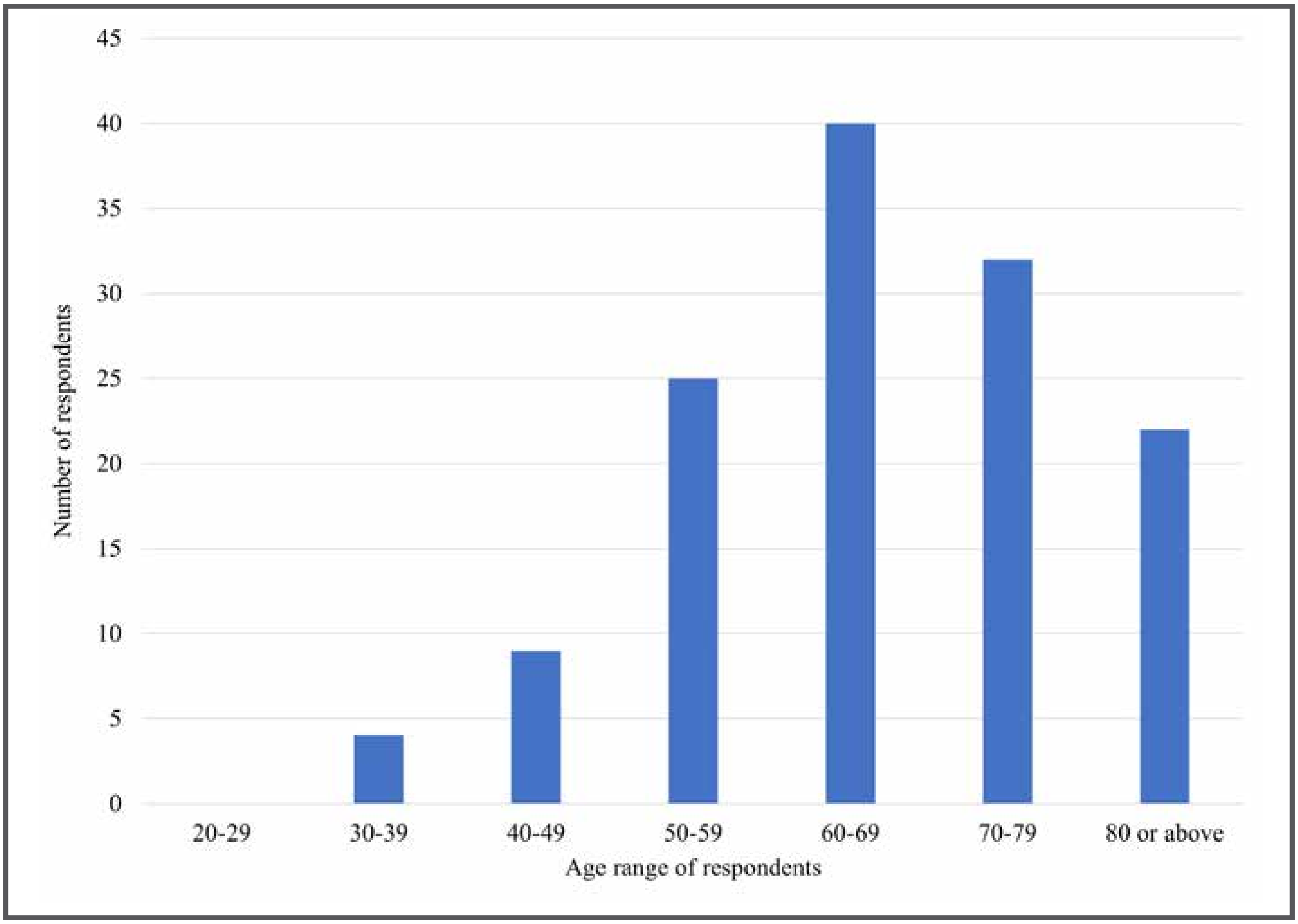


Figure 2. Distribution of age range for survey respondents (source: original data collection from survey of 140 irrigators in GMD 5)

Table 1. Water Use Characteristics for GMD 5 (Panel A) and Technology Use of Survey Respondents (Panel B)

Panel A: GMD 5 water use	n	Mean (Std. D)
Total water use (acre-ft)	65,198	147.3 (83.32)
Total irrigated acreage	65,198	137.28 (64.50)
Corn irrigated acreage	65,198	66.98 (71.63)
Soybean irrigated acreage	65,198	26.19 (51.76)
Panel B: Survey respondent technology use	**n**	**%**
Crop consultants	116	87.2%
Remote pivot monitoring	84	63.2%
Soil moisture probes	46	34.6%
Aerial imagery or other remote monitoring	37	27.8%
Variable frequency (Hz) drives	34	25.6%
Variable rate irrigation-speed control	24	18.0%
Rain sensors	18	13.5%
Other	15	11.3%
Irrigation scheduling software (e.g., KanSched, CropFlex, etc.)	14	10.5%

(Source: WIMAS (Panel A) and original data collection from survey of 140 irrigators in GMD 5 (Panel B))

Note: Panel A is averaged over all water right groups in GMD 5 for 2000-2019.

Table 2. Most Important Considerations When Adopting New Irrigation/Cropping System (Panel A) and Top Barriers to New Technology Adoption (Panel B)

Panel A: Most important considerations when adopting new irrigation/cropping system	n	%
Potential for increased income generation	102	77.9%
Need for greater irrigation efficiency	90	68.7%
Availability of farm labor	45	34.4%
Positive or negative experiences of peers	38	29.0%
Availability of new farm management information	27	20.6%
Agreements with farm management team (i.e., siblings, landlords, etc.)	24	18.3%
Availability of farm equipment	22	16.8%
Other	13	9.9%
Panel B: Top barriers to adoption	**n**	**%**
Cost of new technologies or equipment upgrades	108	83.1%
Maintaining historical water use to protect against future allocation reductions	51	39.2%
Lack of financial information on return-on-investment	42	32.3%
Lack of user-friendly cost-share programs or crop insurance requirements	36	27.7%
Landowners unwilling to invest in new technologies	31	23.8%
Lack of available training or information on new technologies/practices	24	18.5%
Previous negative experiences by yourself or peers	19	14.6%
Other	14	10.8%
Lack of engagement/information from crop consultants	12	9.2%
Generational disputes over new practices	8	6.2%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Table 3. Conservation Practice Implementation and Outcomes

Panel A: Conservation practices implemented in past 5 years	n	%
No-till or reduced-till	98	77.2%
Cover crops	68	53.5%
Conservation crop rotations	48	37.8%
Livestock integration	43	33.9%
Other	21	16.5%
Panel B: Conservation practice outcomes	**n**	**%**
Reduced soil erosion	79	64.2%
Improved water utilization	63	51.2%
Higher crop yields	53	43.1%
Improved soil water holding capacity	51	41.5%
Improved soil moisture during field prep or planting	51	41.5%
Higher water infiltration rates	46	37.4%
None	7	5.7%
Other	4	3.3%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Table 4. Top Reasons for Implementing Conservation Practices

	n	%
Improve production efficiency	69	55.6%
Improve soil health or reduce soil erosion	67	54.0%
Increase profitability	66	53.2%
Reduce input costs	65	52.4%
Response to weather patterns or weather-related production risks	36	29.0%
Reduce labor costs	33	26.6%
Increase long-run sustainability	32	25.8%
Increase nutrient efficiency	27	21.8%
Other	7	5.6%
As part of carbon sequestration contract	3	2.4%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Table 5. Top Concerns and Challenges to Irrigation

Panel A: Top concerns for future of irrigation in GMD 5	**n**	**%**
Regulatory uncertainty, including concerns about reduced allocations	125	93.3%
Insufficient pumping capacities or lack of water in the aquifer	72	53.7%
Lack of farm labor	37	27.6%
Low water quality	35	26.1%
Lack of technical support/expertise	32	23.9%
Other	20	14.9%
Panel B: Top irrigation challenges facing the respondent	**n**	**%**
Reduced rainfall, increased drought	95	70.9%
Uncertainty about future water allocations	77	57.5%
Power costs	68	50.7%
Aging irrigation system (including pump and well)	45	33.6%
Limited water allocations	42	31.3%
Salinity or other water quality problems	20	14.9%
Limited farm labor availability	18	13.4%
Data burdens and excessive data reporting requirements	15	11.2%
Succession planning	8	6.0%
Other	7	5.2%
Limited farm equipment availability	5	3.7%
Lack of cell service for monitoring and pivot operation	2	1.5%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Table 6. Most Useful Information for Improved Irrigation Management (Panel A) and Livestock Production on Irrigated Ground (Panel B)

Panel A: Information most helpful to improved irrigation management	n	%
Benefits of reduced tillage, cover crops, and other soil conservation practices	61	49.2%
Evaluation of pumping plant and irrigation system to determine if upgrades are needed for maximum efficiency	58	46.8%
Selection and use of remote sensors to aid in irrigation decisions	57	46.0%
Interpretation of existing agency program availability and eligibility	46	37.1%
Selection and use of irrigation scheduling software and applying recommendations	39	31.5%
Utilization of data from pivot monitors to track performance and operation	27	21.8%
Other	15	12.1%
How/where to obtain employee training on any/all of the above topics	11	8.9%
Panel B: Information most useful to livestock production	**n**	**%**
Comparison of livestock to crop production returns	40	38.5%
Managing livestock impact on soil (compaction, manure, etc.)	39	37.5%
Selecting forage varieties	36	34.6%
Other	28	26.9%
Managing grazing (duration, timing, species, etc.)	26	25.0%
Finding or participating in water banking programs	22	21.2%
Managing forage production (water application, timing, amounts)	20	19.2%
Finding cost-share programs for establishment of perennial grasses	16	15.4%
Selecting water sources for livestock	13	12.5%
Managing livestock performance (animal care, etc.)	5	4.8%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Table 7. Factors that Would Improve Crop Consultant Recommendations

	n	%
Reduce reliance on maximum water applications to achieve yield	66	54.1%
Include consideration of end-of-water allocations for the field	56	45.9%
Update and improve consultant skills through ongoing agronomic and irrigation training	52	42.6%
Include contribution of rainfall to estimated crop water needs	42	34.4%
Increased awareness of opportunities for water carryover between seasons	36	29.5%
Update and adjust soil moisture and water recommendations on more frequent basis	31	25.4%
Other	16	13.1%

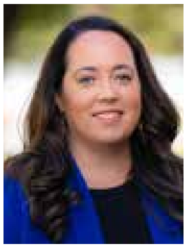
(Source: original data collection from survey of 140 irrigators in GMD 5)

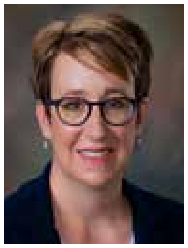
Table 8. Most Reliable Sources of Information

	n	%
Agronomists or crop consultants	101	77.7%
Your own previous experience or education	74	56.9%
Peer producers in your area	58	44.6%
Local and regional irrigation organizations (e.g., WaterPACK)	55	42.3%
GMD #5	54	41.5%
Extension	30	23.1%
Farm publications	30	23.1%
NRCS	25	19.2%
Equipment dealers and other ag businesses (including their websites)	20	15.4%
Ag industry trade groups	10	7.7%
State agencies	10	7.7%
Other	7	5.4%

(Source: original data collection from survey of 140 irrigators in GMD 5)

Farm Management Education: Insights from Industry Stakeholders



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Abstract

Professional farm managers use both work experience and higher education to develop skills necessary for the changing needs of modern agriculture. We asked professional farm managers their perspectives on the essential topics, skills, and competencies that should form the core of farm management education. Results suggest that, in addition to financial analysis and general economics, farm management education needs to focus on "soft skills" such as communication with clients and landowners, negotiations, and relationship management.

INTRODUCTION

The dynamic landscape of modern agriculture has changed significantly as the structure of farms in the U.S. has changed over time. Today's farm managers are tasked with navigating a complex interplay of technological advancements, market dynamics, environmental sustainability, and regulatory compliance. Within this rapidly evolving climate, the need for farm managers' services is on the rise. For example, non-operator landlords (owners of farmland who are not themselves engaged in farming) account for 80% of rented farmland acres in the United States (Bigelow et al., 2016). The majority of these acres were acquired through inheritance (ibid), and therefore many farmland owners lack the necessary skill and experience to manage this land themselves. As the demands on these managers continue to evolve, so must the educational foundations that prepare them.

Work experience (experiential learning) and higher education have long been recognized as the cornerstone of professional development for farm managers. The fusion of age-old agricultural knowledge with contemporary knowledge has created a demand for innovative pedagogical approaches that empower aspiring farm managers to tackle challenges with the necessary skills to be successful. Utilizing in-class games, managerial competitions, and active learning has been a staple in farm management education for decades, with computer-based farm management simulations first introduced in the 1960s (Boehlje et al., 1973; Longworth, 1970; Menz & Longworth, 1976). While the pedagogy and educational delivery methods have modernized, the question remains if the course concepts or topics have followed this modernization. This article looks to identify and categorize the topics and skills that should be incorporated into higher education farm management curricula and classrooms based on feedback from farm management professionals. While input and feedback are often solicited directly from producers, collecting information from professional farm managers has been limited. Currently, portions of an undergraduate degree can fulfill some requirements for obtaining the professional farm manager accreditation (ASFMRA, 2022). Because of this "crossover," ensuring that farm management curriculum is modern and topical is important. The results provide farm management educators with a practical view from current professionals on what skills or knowledge-building they should incorporate into their curriculum.

Over the years, farm management education has expanded significantly, mirroring the transformations within the broader agricultural sector. Historically rooted in practical know-how passed down through generations, farm management education has transitioned from the traditional "farm school" approach to more structured academic programs offered by universities and specialized institutions. The focus has broadened from the cultivation of crops alone to encompass intricate aspects of agribusiness, environmental regulations, sustainability, technological advancements, data management, resource management, and market dynamics. At the same time, the need for "soft skills" such as communication, collaboration, and interpersonal relationship-building (Gilbert and Wingrove, 2019; Sandlin et al., 2018; Vetter and Wiggenbach, 2019; Wilson et al., 2019) is garnering increased focus across the agriculture industry. This set of competencies could complement the technical skills that prospective farm managers gain on the job and in the classroom.

A transformation in pedagogical strategies has accompanied this shift in the landscape of agriculture. The emergent nature of technology, data analytics, and precision agriculture has necessitated a departure from the conventional classroom to a more holistic and experiential learning environment. The integration of case studies, simulations, and industry collaborations has bridged the gap between theory and practice, equipping students with theoretical knowledge and the critical thinking and problem-solving skills essential for success in a rapidly changing field.

SURVEYING INDUSTRY PERSPECTIVES: A HOLISTIC APPROACH TO CURRICULUM DEVELOPMENT

To gain deeper insights into the evolving educational needs of modern farm managers, this article presents the results of a survey conducted with professional farm managers, agricultural experts, and industry stakeholders at the 2022 ASFMRA Annual Meeting. The survey sought to collect perspectives on the essential topics, skills, and competencies that should form the core of farm management education. By capturing the opinions of those working directly in the profession of farm management, this study aims to outline a curriculum that aligns with the practical demands of the industry.

In the following sections, we delve into the survey's key findings, shedding light on the topics and skills identified by industry experts as integral in the education of future farm managers. By juxtaposing these insights with evolving pedagogical approaches, we aim to contribute to the ongoing discourse surrounding farm management education's pivotal role in shaping the agricultural landscape of tomorrow.

Survey: Data Collection

The objective of our survey was to ascertain what industry professionals and key stakeholders believed to be important for consideration in the development of farm management curriculum. The complete survey is included in the appendix. The survey was anonymous and followed all IRB protocols (Oklahoma State University IRB-22-450). Basic demographic information was collected but was not a central component of the study. Following the basic demographic questions, three open-ended questions were asked: 1) What would you consider the core concepts or topics that would need to be covered in farm management training or classes?, 2) What are the skills needed to be a professional farm manager?, and 3) What topics or concepts (outside of core topics mentioned in E) do you see coming in the future that need to be included in farm management training or classes?

The workshop session resulted in a collection of 32 responses, with respondents from 14 different states, predominantly the Midwest (53%, N=17). States included in the Midwest category were Iowa, Illinois, Ohio, and Indiana. Mid-South respondents were from Tennessee, Arkansas, and Kentucky. Great Plains respondents were from Oklahoma, Nebraska, Oklahoma, and Kansas. The Coastal respondents included those from North Carolina, New York, and Idaho. You can see the regional distribution in Table 1.

Fifty percent of respondents indicated they were 57-72 years of age, with 94% of all respondents being male. Respondents were also asked about their years of experience in professional farm management, and the participant average was 28 years of experience. The distribution of age and gender can be seen in Table 2.

Data Coding

Data from the workshop session was collated into NVivo. This software allows automatic coding of the survey responses across attributes such as gender, age, states, and regions and enables thematic coding of the responses based on patterns that emerge from the data. The survey responses were classified into 32 cases (each case representing a survey respondent). The three open-ended questions were coded as three parent themes: core topics, skills needed, and future topics. For each of these three parent codes, the responses of each case, i.e., each respondent, were then coded into subthemes that form the child nodes, thereby creating a parent-child code pattern that allows the software to record the frequency of subthemes under each parent node. These subthemes were identified by the authors through an iterative process of familiarization with data, generating initial codes, searching for themes, reviewing themes, and final production of the report (Braun and Clarke, 2006). After the themes were finalized, we used the Matrix-Coding Query feature in NVivo to create cross-tabulations of the subthemes under each parent node across the different attributes. All tables and figures used in the paper are based on these cross-tabulations.

RESULTS

Participants in the session were asked three questions about core concepts and professionals skills related to farm management. The first question was, “What would you consider the core concepts or topics that would need to be covered in farm management training or classes?” The answer themes for this question are shown in Figure 1, with specific responses given for each theme listed in Table A1 in Appendix 2.

The themes receiving the highest response frequency were financial analysis, communication, and marketing and general economics. For financial analysis, the primary concepts included capital and investment analysis and enterprise budgeting. This theme represented 35% of the responses to the first question, with examples of responses categorized in this theme including “Investment analysis,” “Capital improvement analysis,” “Accounting and financial modeling,” and “Enterprise budgeting/analysis.” These responses make up a category that is historically very important to professional farm managers and highlight the need for technical training in finance and accounting by students wanting to enter this profession.

The next highest response theme, with 16% of responses, was communication. Examples of what respondents said included having general communication and negotiation skills, as well as communicating across generations and helping clients with little farm knowledge to manage their farm. The importance of the communication category is highlighted by these responses, especially communication across different ages of people (farmers versus landowners) and the added challenge of communicating with absentee landowners who may not have as much first-hand knowledge of the work being done on the farm.

The third theme was marketing and general economics, with 16% of the responses. This category represented a mix of responses that reflected the need for a general understanding of agriculture, markets, and economics. Examples of answers given in this theme category include “risk management,” “basic marketing and hedging,” and understanding what causes a downturn in agriculture from a historical perspective. This last answer was followed up with a comment about applying this knowledge to current conditions and learning from the past. The average number of years of experience of professional farm managers surveyed in this study was 28 years, which suggests that most farm managers can reflect on their own personal experiences to guide decisions on the farm or ranch. Younger farm managers will have to learn about these experiences through mentoring and other forms of education.

The second question asked of the session participants was, “What are the skills needed to be a professional farm manager?” The response themes are shown in Figure 2, and specific answers are listed in Table A2 in Appendix 2. The most common theme to this question was communication, with 37% of all responses. Some of the responses included “relationship management,” “adaptability to working, communicating with various personalities,” and meeting “client goals.” Communication is a top theme for both questions 1 and 2, indicating a strong sentiment on the part of the respondents that possessing people skills is crucial to the success of a professional farm manager.

The second response theme was analytical skills, which accounted for 21% of the responses. Examples of analytical skills given by the participants included “financial skills,” “cash flow analysis,” and “budgeting.” Again, technical skills like finance and accounting ranked high by respondents and suggest that this training is an essential part of the job.

The two themes of communication and analytical skills were very common responses. Other themes such as management decisions, time management, and understanding legal issues were also mentioned, with 9% of all responses to the second question. Other technical skills such as problem-solving, with responses including “critical thinking” and “crisis management," and understanding technology (e.g., "drone and IT skills"), were also mentioned. It is worth noting that in the "other" category, responses included advice such as being a "self-starter," "life-long learner," and "well rounded in agriculture."

The final question for workshop participants was, "What topics or concepts do you see coming in the future that need to be included in farm management training or classes?" The responses to this question were slightly more diversified than the previous two and are presented in Figure 3. Specific answers to the themes are given in Table A3 in Appendix 2. The top response theme was technology applications, with 19% of the responses. Under technology, participants included drone usage and use of technology to monitor farm activities. These responses suggest that farm management is a field where technology will be affecting the day-to-day operations of the manager, and it will be important to have these technology skills to be successful in the profession.

The second most common theme was general agricultural knowledge, with 14% of responses and examples such as understanding all aspects of precision agriculture and seed genetics. It is interesting to note that the general agricultural knowledge responses also reflect updates in technological advances made in agriculture so far and those on the horizon.

The third most common response theme was policy, with 12% of responses. This category includes answers such as "environmental impacts (carbon credits)," "EPA issues," and "policies and law." Understanding the regulatory impacts on agriculture from policy changes is important and likely to become more relevant for farmers and landowners in the years to come.

Several other responses were also categorized, including regenerative agriculture, land-related issues, and generational dynamics that reflected answers such as the "how rural America is changing" and "succession strategy." Again, communication was a common theme in the responses with answers such as "soft skills," "negotiations," and "conflict resolution," which emphasizes the importance of working with people both now and in the future.

CONCLUSIONS

The responses of the session participants to questions about the core concepts needed to teach and develop professional farm managers are probably not too surprising. Financial analysis and general economics were very highly ranked, and these topics are often taught in undergraduate agricultural economics and agribusiness curriculums across the United States. However, communication was the most frequently cited career skill needed by professional farm managers. While these "people skills" are increasingly demanded across the agriculture industry, they are not commonly taught in a formal classroom setting, making the development of these competencies a challenge. The ability to communicate with clients and landowners, conduct negotiations, and manage relationships are key competencies for professional farm managers. The ability to relate to varying perspectives and personalities will enable farm managers to thrive in an increasingly diverse industry. Internships and other types of job shadowing may help with these skills, but it appears that to meet the opportunities of management jobs in the future, we may need to work more closely with students on speaking, writing, relating to, and interacting with others in a professional manner.

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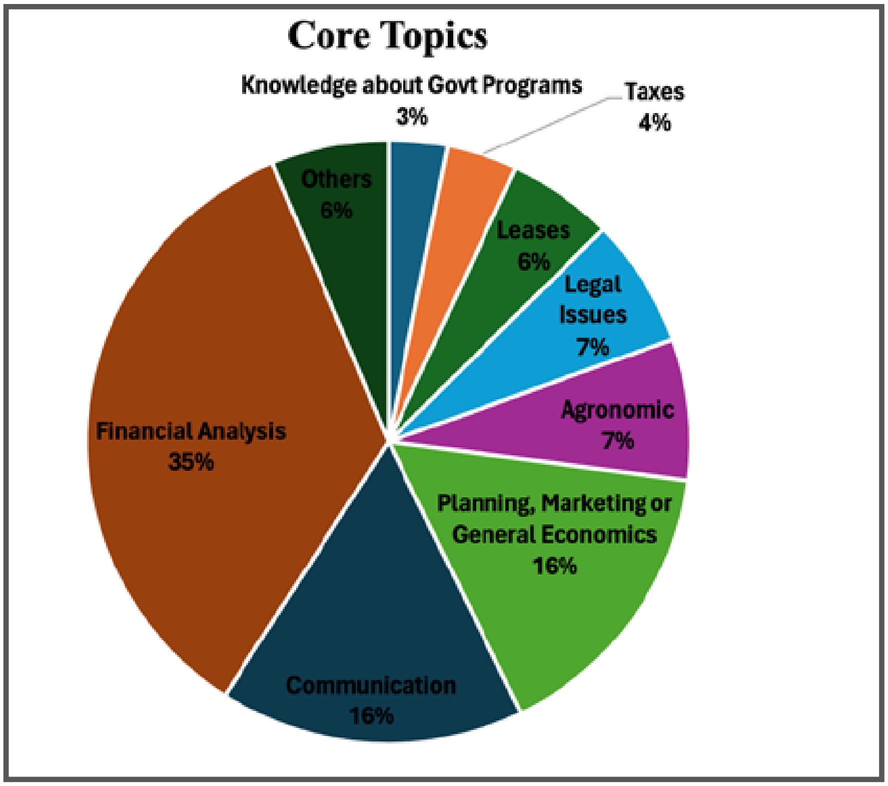


Figure 1. Themes under “What would you consider the core concepts or topics that would need to be covered in farm management training or classes?”

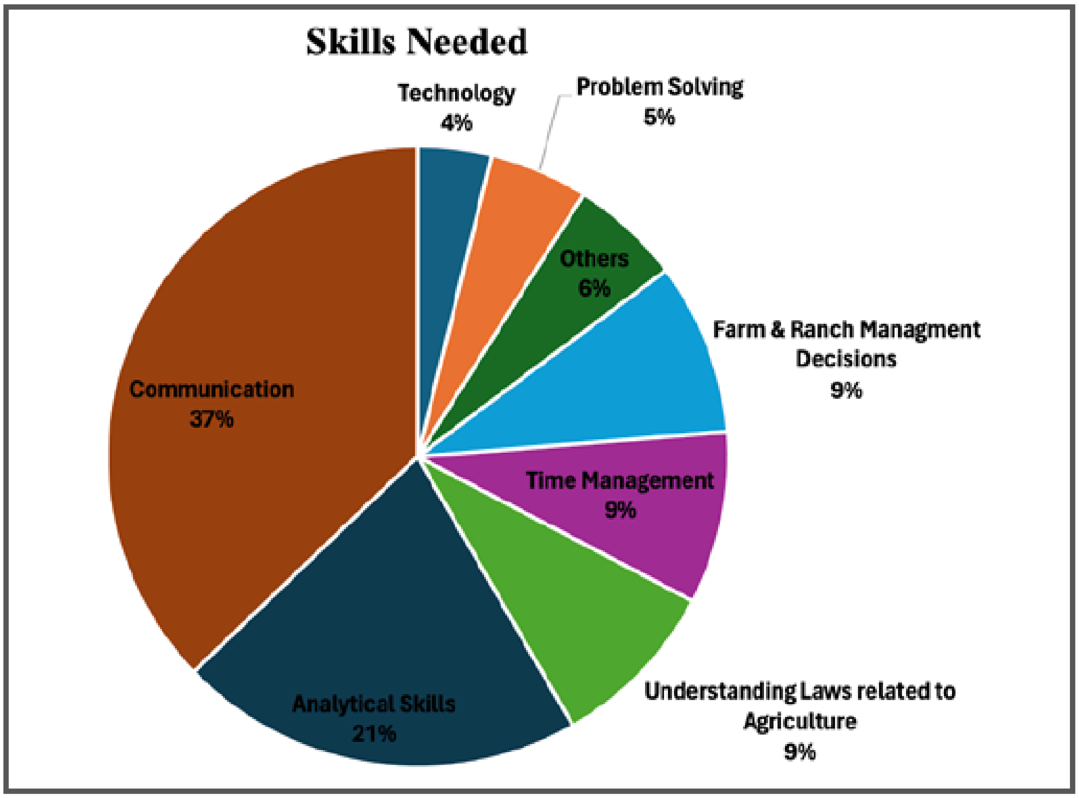


Figure 2. Themes under “What are the skills needed to be a professional farm manager?”

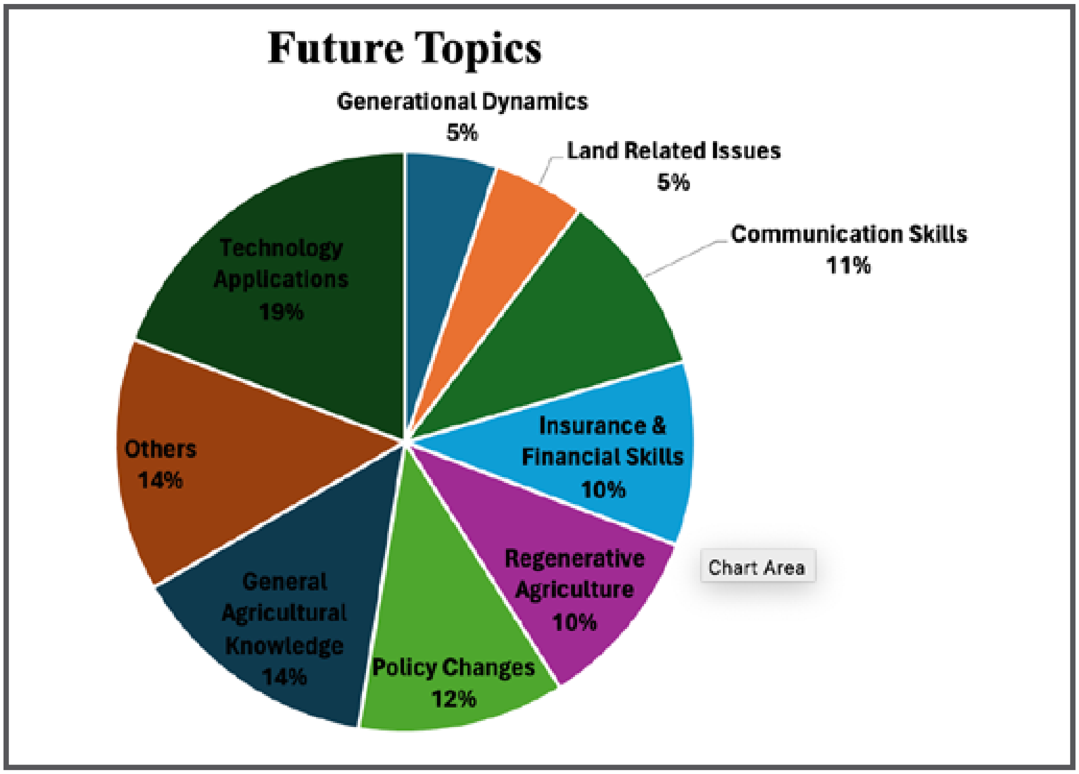


Figure 3. Themes under "What topics or concepts do you see coming in the future that need to be included in farm management training or classes?"

Table 1. Distribution of Responses Across Regions

Region	Frequency	Percent
East and West Coast	3	9
Mid-South	4	13
Great-Plains	8	25
Midwest	17	53
Total	32	

Table 2. Demographic Summary Statistics*

Attribute	Frequency	Percent	Mean
Age			
24 to 40	8	25	33
41 to 56	6	19	46
57 to 72	16	50	63
72 to 80	2	6	77
Years of Experience	21		28
Gender			
Female	2	6	
Male	30	94	
Education Level			
Bachelors	21	68	
Masters	6	19	
Doctorate	3	10	
Others	1	3	
Farm Management Training			
Continuing Education	22	71	
Others	6	19	
Extension Workshop	3	10	
Profession/Role/Occupation			
Farm Manager	25	78	
Educator	3	9	
Others	3	9	
Appraiser	1	3	

*For Education Level, Farm Management Training, and Profession/Role/Occupation, the summary statistics are calculated after removing the no-response observations.

APPENDIX

Appendix 1. Data Collection Instrument

Farm Management Content & Curriculum

ASFMRA Lunch Session

November 9, 2022

Demographic Information

Age: ______________________

Gender: __________________________

State: ______________________

Primary professional role/occupation (only pick one):

______ Appraiser

______ Farm Manager

______ Educator (higher education/extension)

Other: _______________________

How many years of experience have you had in the above role/ occupation? ______________________

Education: Please select the highest level

______ High school	______ Master Degree	______ Associate Degree
______ Doctorate Degree	______ Bachelor degree	Other: ___________

Previous Training: What type of farm management training or education have you participated in?

______ College Course

______ Extension workshops/trainings

______ Continuing education (ASFMRA classes)

Other: ___________

What would you consider the core concepts or topics that would need to be covered in farm management training or classes?

What are the skills needed to be a professional farm managers?

What topics or concepts (outside of core topics mentioned in E) do you see coming in the future that need to be included in farm management training or classes?

Appendix 2. Survey Theme Responses

Table A1. Responses to "What would you consider the core concepts or topics that would need to be covered in farm management training or classes?"

Theme	Frequency	Percent	Response Examples
financial analysis	55	35	"financial analysis/Investment analysis" "Capital improvement-analysis, design, implementation" "Capital project analysis- grain bins, tile, land levelling" "Enterprise analysis, spreadsheet utilization" "Accounting 2)financial modeling,3)investments analysis 4) enterprise budgeting 5) balance sheets 6) capital improvement 7) investment analysis"
communication	26	16	"communication for different ages" "negotiations" "report requirements, communication skills" "how to develop from new client who doesn't have info regarding their farm and how to get it"
planning or marketing or general economics	25	16	"History-when we have downturns in farming; What causes the downturn? What can we learn from the past? How can we apply it to current conditions?" "Basic marketing/hedging" "Risk Management"
agronomic	12	8	"soil type" "agronomic" "crop project analysis" "general production"
legal issues	11	7	"understanding ownership structures" "Legal Entities (LLC, Partnerships, Corps, Etc.)" "Legal Contracts- leases, construction, management agreements"
leases	9	6	"leases" "absentee landowner" "Lease negotiation/Lease types"
taxes	6	4	"Income taxes" "Tax law"
knowledge about government programs	5	3	"USDA communication" "Conservation and USDA programs (CRP, ARC, PLC, CSP etc)" "USDA-contact analysis of these programs" "Govt programs (community, insurance, conservations"
others	10	6	"Understand that Farm Manager represent the Landowner & gear some of the coursework in that direction" "Internship program to learn & get exposure to "real world" application of skills learned in school program" "insurance-crop, property, liability" "Technological Advancements" "Professionalism"

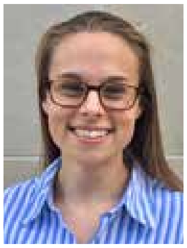
Table A2. Responses to *"What are the skills needed to be a professional farm manager?"*

Themes	Frequency	Percent	Response examples
communication	58	37	"Relationship Management" "Adaptability to working, communicating with various personalities" "Client goals"
analytical skills	33	21	"financial skills" "Cash flow analysis" "budgeting"
understanding of laws or legal issues related to agricultural or farm management	14	9	"tax law" "environmental law controversies" "farm business structure, and tax & liability implications"
time management	14	9	"Time management & setting priorities" "organizational skills- time management" "flexibility in day-to-day tasks- wear multiple hats"
farm & ranch management decisions	14	9	"building a short-term & long-term farm/business plan" "Crop Specific Exposure (relative to area)" "understanding of Ag drainage & building"
problem solving	8	5	"crisis management" "dealing with difficult clients (planning)" "critical thinking"
technology	6	4	"drone skills" "technology adaptation" "IT skills"
others	9	6	"self starter" "life long learner-keeping up with industry" "well rounded in agriculture"

Table A3. Responses to *"What topics or concepts (outside of core topics mentioned in E) do you see coming in the future that need to be included in farm management training or classes?"*

Themes	Frequency	Percent	Response examples
technology applications	15	19	"How to integrate technology into Farm management's core responsibilities" "Drone usage" "use of technology to monitor farm activities"
general agricultural knowledge	11	14	"Practical knowledge and use of all the above skills (putting all the pieces together and using it to analyze and make decisions" "seed genetics" "All aspects of precision agriculture"
policy changes	9	12	"Environmental Impacts (Carbon credits)" "EPA Issues" "policies, law"
regenerative agriculture	8	10	"use of regenerative cropping systems" "regenerative Agriculture" "Conservation/Sustainability"
Insurance and financial skills	8	10	"Understanding of Financial Markets" "Financial focus on investment strategies" "Crop Insurance"
communication skills	8	10	"soft skills/communication" "negotiations" "conflict resolutions"
land related issues	4	5	"farm lease alternatives- flex, custom, net share, cash rent" "land ownership trends"
generational dynamics	4	5	"solid grasp of generational dynamics" "demographics- how rural America is changing (i.e. Farm size, etc.)" "succession strategy"
others	11	14	"3) Career moves 4) impact of patience 5) Farm Management is long term not a "step' in a career" "Consumer Preferences" "ESG"

Exploring the Impact of Fed Cattle Grade on Transaction Type



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Abstract

In this paper, we present price and transaction information of fed cattle marketings to explore if differences exist in the quality grade of cattle marketed under different transaction types. In particular, we explore regional differences in marketings for cash, formula, forward, grid, and negotiated grid transactions from 2012 to 2022. Analysis shows that despite an industry trend toward higher-quality grade animals, most low-quality grade cattle are marketed in Texas, Oklahoma, or New Mexico using non-negotiated pricing methods.

INTRODUCTION

As part of the geographically distinct cattle supply chain that moves animals from birth on disparate cow-calf operations across the continental United States (U.S.) to slaughter facilities concentrated in the middle of the country, fed cattle are considered live animals that have reached a desired weight to be slaughtered. Often, the overwhelming majority of animals are slaughtered in Colorado, Iowa-Minnesota, Kansas, Nebraska, and Texas-Oklahoma-New Mexico. The cattle slaughter industry is also considered relatively concentrated according to numerous measures of market concentration (MacDonald et al., 2000), with 71.7% of all federally inspected cattle being processed in just 22 plants (Ma and Lusk, 2021).

Unlike other industries, fed cattle can be marketed as either negotiated (cash or grid) or non-negotiated (formula or forward), and differences exist across the U.S. as to how cattle are marketed. The main reported difference between the transaction types is how price is determined. Non-negotiated transactions (formula or forward) are often set with base prices that are then adjusted for different traits, including quality. A common method for establishing the base price of non-negotiated transactions is using the previous week's negotiated price arising from cash or grid transactions. As a result, characteristics of cattle marketed through negotiated transactions influence the value of cattle marketed through non-negotiated means in subsequent weeks and can be considered as price discovery for the market.

These different transaction types have generated interest to understand patterns and trends in marketing (Anderson, McKenzie, Mitchell, 2021), with fed cattle transaction information reported through the Livestock Mandatory Reporting Act (LMR). Growing out of increasing concern for market concentration and price discrimination in the livestock slaughter and packing sectors, the LMR Act of 1999 requires packers to provide information about transactions to the United States Department of Agriculture (USDA) for reporting purposes.

Through analysis of this data, changes to percent of total transactions arising from either transaction type over time and differences across U.S. regions has been observed but research has not addressed any issues related to the underlying differences in cattle marketed through either transaction. The detailed data reported through the LMR provides an opportunity to ask questions related to the influence of market power and concentration. Other research has looked at price spreads and marketing margins (Lusk et al., 2021) or the impact of COVID-19 on fed cattle markets (Martinez et al., 2021). Due to the complexity of the dataset, more advanced and sophisticated methods such as hedonic models have been used in addition to more basic graphical techniques (Schroeder, Coffey, and Tonsor, 2023) to answer pertinent research questions (Ward, Schroeder, and Feuz, 2004). However, the dynamic interaction of the two transaction types warrants a review of the characteristics of cattle marketed through each type that has not been clearly and succinctly addressed in previous work.

This research seeks to add to current research on fed cattle transactions through explicitly considering the quality grade of cattle marketed under each transaction type. Specifically, we seek to determine if there is a difference in the quality of cattle marketed under negotiated versus non-negotiated transactions. Anecdotally, cattleman believe that there is a difference in quality premium depending on how cattle are marketed. While there is little evidence to date suggesting differences in cattle quality marketed under each transaction type, the interdependent nature of the transactions, known differences in cattle quality regionally, and changes to transaction type over time suggests that potentially, there might be a reason to suggest that patterns have developed where lower quality cattle are marketed more frequently under a specific transaction type.

METHODOLOGY AND DATA

Weekly fed cattle transaction data were gathered from the USDA Agricultural Marketing Service Datamart from 2012-2022 and summarized to include number of head marketed at a specified weighted average price for that week. Transactions were then summarized for each of the regions within five areas: Colorado (CO), Iowa-Minnesota (IA-MN), Kansas (KS), Nebraska (NE), and Texas-Oklahoma-New Mexico (TX-OK-NM). From there, the type of transaction was indicated as cash, formula, forward, grid base, and negotiated grid (Figure 1).

Transaction data are typically recorded for cattle at the time of slaughter at federally inspected packing plants as part of the LMR reporting process (USDA, 2020). Before cleaning, the dataset used in this research included approximately 92% of the cattle purchased for slaughter in the U.S. and reported at the location of slaughter (USDA, 2020). For this reason, it is important to note that regions are defined as slaughter locations and do not necessarily reflect where the animals were born or fed before transportation to be slaughtered. The major components of reporting include weighted average price and the number of head slaughtered in a specific time period.

Weighted average prices and number of head marketed are reported here based on quality grade, class descriptions, and basis descriptions, with quality defined for the lot as over 80% choice, 65-80% choice, 35-65% choice, and 0-35% choice. Class was described as either heifer, steer, or mixed heifer/steers. This excluded other recorded classes such as dairybred steer/heifer or mixed steer/heifer/cow. As such, this analysis focused on beef cattle specifically and did not include dairy animals. Pricing was also reflective of the animal being dressed as carcass weight or live weight and priced either delivered to the plant or free on board (FOB).

A total of 188,286,226 head were marketed and their data recorded and reported through the LMR through this period, with the number of animals marketed through formula pricing increasing over time. This formula is "the advance commitment of cattle for slaughter by any means other than negotiated, negotiated grid, or forward contract" (USDA, 2020). Forward contracting involves an animal marketed in advance of slaughter, with a base price calculated off of futures prices—note, this has declined slightly over time. Generally, formula and forward contracts are considered non-negotiated.

Negotiated transactions include cash and negotiated grid pricing, with negotiated grid pricing being where a base price (negotiated base) is negotiated by buyer and seller in advance of slaughter with premiums and discounts applied after carcass grading has occurred and a net price is reported. The number of animals priced based on either negotiated grid or negotiated base is the least used transaction type, although more animals have been marketed this way since 2020, surpassing the number of animals marketed through forward contracting in recent years.

While formula pricing remains the most prevalent across all cattle marketed, there were differences observed in transaction types among regions (Table 1). Specifically in Iowa-Minnesota and Nebraska, cash transactions either made up almost the same or a greater percentage of the total head marketed as formula transactions. It can also be seen that forward contracts were used to market a greater share of cattle in Colorado, Iowa-Minnesota, and Nebraska than in Kansas or Texas-Oklahoma-New Mexico. Further, while other transaction types were present in Colorado and Texas-Oklahoma-New Mexico, 78% and 80% of animals were marketed using formula pricing, showing just how prevalent this pricing strategy is for many cattle.

RESULTS AND DISCUSSION

From 2012-2022, cattle expected to grade lower quality (0-35% choice and 35-65% choice) were priced using a formula method more frequently than other transaction types (Table 2). While cattle in the lowest grade (0-35%) only made up 2% of total head marketed, 75% were priced using formula pricing, 10% were priced with a forward contract, 10% were priced with negotiated grid, 2% cash, and 2% grid based. A similar pricing pattern was present for cattle expected to grade 35-65% choice, with 69% of animals priced with formula pricing and 8% priced through forward contracts. For these animals, 16% were priced via cash methods and 3% through negotiated grid. These transactions represented 21% of animals marketed from 2012-2022.

In contrast, cattle expected to grade higher (65-85% choice or over 85% choice categories) were also priced through formula methods (59% and 57% respectively); however, these animals were also more likely to be priced via cash pricing methods. For animals expected to grade as higher quality, 27% of the 65-85% choice animals and 26% of the over 85% choice animals were priced through cash methods. Consistent with lower quality animals, forward contracts priced 8% of animals while grid base and negotiated grid pricing represented 3-5% of animals marketed.

Contrary to anecdotal evidence or suspicions, cattle expected to grade lower or representing lower quality grade animals, have historically been priced using non-negotiated methods (formula and forward contracts) compared to cattle expected to grade higher which historically have been priced in greater proportion via negotiated methods (cash and negotiated grid).

In addition to recognizing that the majority of cattle expected to grade lower are marketed through non-negotiated pricing mechanisms, there is also an inherent time and spatial component to understanding general pricing trends. From 2012-2022, the industry saw a movement toward higher quality animals and a substantial decline in the number of animals expected to grade 0-35% choice or 35-65% choice (Figure 2). While the number of animals expected to grade 65-85% choice stayed relatively constant over this period, there was an increase in the number of animals marketed overall but also in the number of animals expected to grade over 80% choice.

Further, cattle quality grade is not consistent across regions of the U.S. From 2012-2022, 78% of the cattle expected to grade either 0-35% choice or 35-65% choice were marketed in either Kansas or Texas-Oklahoma-New Mexico, with over 54% coming from Texas-Oklahoma-New Mexico alone (Table 3). Of all the cattle expected to grade 0-65% choice from 2012-2022, 42% came from Texas-Oklahoma-New Mexico and were priced through formula transactions. In some regions, such as Iowa-Minnesota and Colorado, which combined, only marketed 9% of the lower quality cattle, only 1% of animals were priced through cash, negotiated grid, or grid base pricing mechanisms. This further supports the finding that, in general, lower quality grade animals are priced through non-negotiated transactions and does not support the hypothesis that lower quality grade cattle are marketed in a way that deviates from the dominant transaction type for the region.

IMPLICATIONS AND CONCLUSIONS

The LMR and the associated price and slaughter information that have resulted from this reporting allows for in-depth analysis of transaction characteristics through time. This research shows that despite suspicions, lower quality grade cattle were not priced differently than the broader slaughter cattle population. In fact, lower quality grade cattle originate in regions of the country such as Texas-Oklahoma-New Mexico that more frequently market cattle by formula pricing mechanisms, a non-negotiated pricing strategy. Through this research, no deviations were found in the distribution of pricing methods for low-quality cattle.

This research only considered the number of animals priced under each transaction type. Due to the amount of data available through the LMR and associated pricing reports, more detailed analysis could be completed to further analyze price differences between grade categories. Given the dynamic and interconnected nature of pricing methods, understanding price transmission across the industry and among regions remains an interesting and unexplored area of research. As shown, quality grade differences in cattle across regions remains an inherent integrated component to pricing. A further in-depth analysis of pricing methods to include class basis (dressed versus live, delivered, FOB) and dairy cattle could be considered in further analysis. In future work, other trends and dynamics to pricing strategies could be explored as well.

As lower quality grade animals have become less numerous in the national herd, the relevance of considering impacts to price and pricing methods perhaps is declining. With more homogenous herd transaction type differences, pricing strategies become more difficult to discern. Based on this analysis, there is no difference in transaction types or pricing strategies based on expected grading quality differences.

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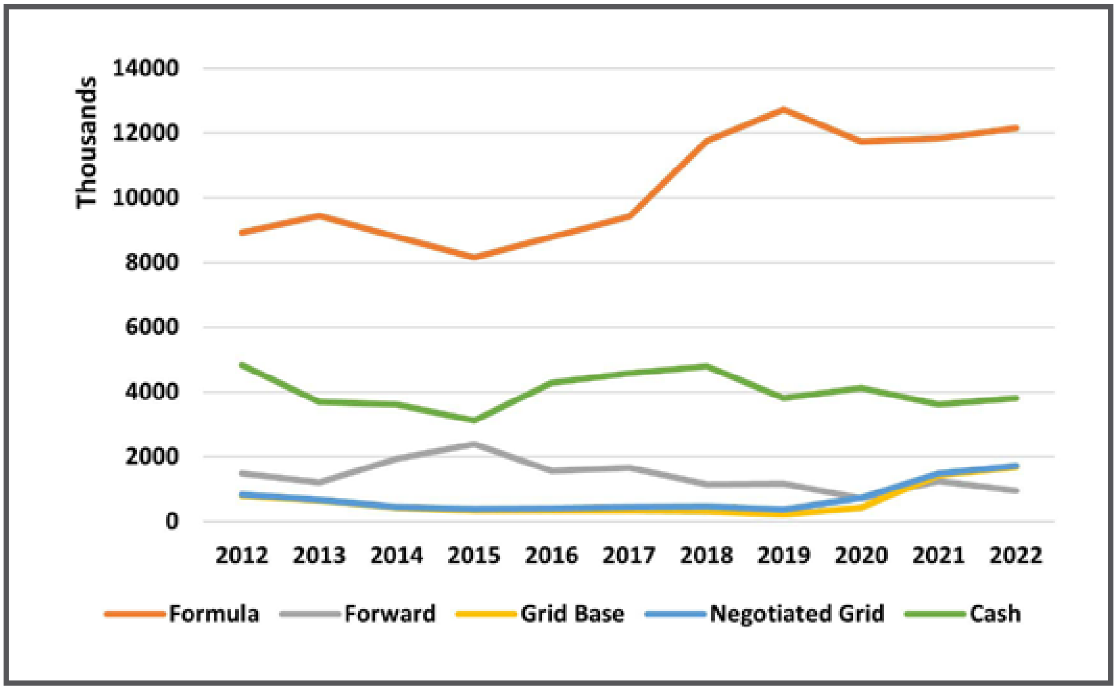


Figure 1. Annual total head marketed by transaction type

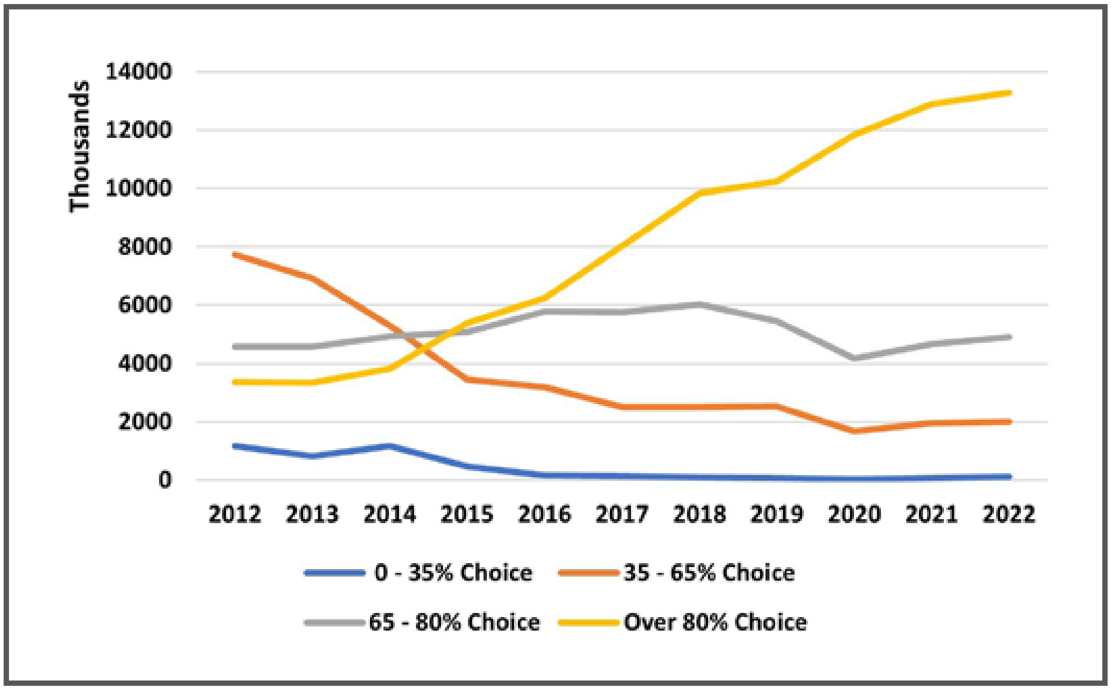


Figure 2. Number of animals by grading distribution over time

Table 1. Percent of Head Marketed by Transaction Type for Each Region (2012-2022).

	Cash	Formula	Forward	Grid Base	Negotiated Grid	Total
CO	8%	78%	12%	0%	2%	8%
IA-MN	55%	24%	12%	2%	7%	11%
KS	19%	68%	6%	4%	4%	27%
NE	37%	43%	11%	5%	4%	27%
TX-OK-NM	7%	80%	5%	4%	4%	27%
Total	24%	60%	8%	4%	4%	100%

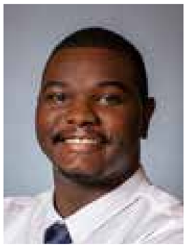
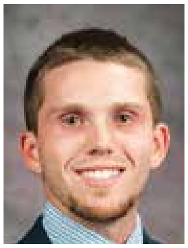
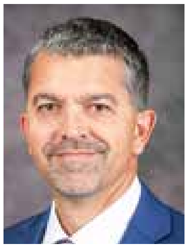
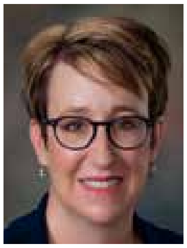
Table 2. Distribution of Transaction Type by Grade

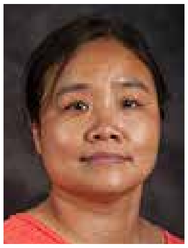
	Cash	Formula	Forward	Grid Base	Negotiated Grid	Total
0 - 35% Choice	2%	75%	10%	3%	10%	2%
35 - 65% Choice	16%	69%	8%	4%	3%	21%
65 - 80% Choice	27%	59%	8%	3%	3%	30%
Over 80% Choice	26%	57%	8%	4%	5%	47%

Table 3. Regional Breakdown of Transaction Type for Cattle Expected to Grade 0-65% Choice

	Cash	Formula	Forward	Grid Base	Negotiated Grid	Total
CO	1%	6%	1%	0%	0%	7%
IA-MN	0%	1%	0%	0%	0%	2%
KS	7%	14%	2%	0%	1%	24%
NE	3%	7%	2%	1%	1%	13%
TX-OK-NM	4%	42%	3%	3%	2%	54%
Total	15%	69%	8%	4%	4%	100%

Impact of Confined Animal Feeding Operations on Agricultural Land Values



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Abstract

Previous studies have attempted to explain variations in farmland values, but few consider the effect of confined animal feeding facilities (CAFOs) on the value of agricultural land within a certain proximity. Using parcel-level transaction data and fixed-effect models with different specifications on the distance to CAFOs, this study finds a positive relationship between agricultural land prices and CAFOs located within various distances of the parcel sale. With a distance-band specification, the positive effect of CAFOs is more prominent for the 0- to 25-kilometer distance. We also find that the price rises as the nearest CAFO is located closer.

INTRODUCTION

The value of agricultural land has a significant impact on the agricultural economy. According to the USDA's Economic Research Service (ERS), farm real estate in the U.S. comprises over 80% of assets within the farm sector (USDA ERS, 2020). The National Agriculture Statistics Service has estimated that agriculture land values have increased to roughly $3,800 per acre on average in 2022 (USDA NASS, 2022). With farm real estate comprising most farm sector assets, changes in prices of agricultural land have significant impacts on the profitability of the farm sector as well as the net worth of landowners. Understanding the drivers behind agricultural land prices helps operators, landowners, lenders, and many more participants in the farm sector to make better fiscal management decisions.

Many previous studies have estimated the impacts of specific attributes of agricultural land parcels on their sales price per acre (Taylor and Brester, 2005; Gregory et al., 2020; Sampson, Perry, and Taylor, 2020; Taylor et al., 2020), and several studies have estimated the impact of confined animal feeding operations (CAFOs) on rural-residential property values (Ready and Abdalla, 2005; Herriges, Secchi, and Babcock, 2005; Kim and Goldsmith, 2008; Isakson and Ecker, 2008). With hedonic models to measure the impact of specific attributes on the value of agricultural land or on rural-residential property, these studies found that confined animal feeding operations have a negative effect on rural and residential housing values.

One reason for this is that CAFOs hold multiple animals in a small area, and the waste produced by these animals causes odor and can become a major disposal challenge unless ample cropland is available nearby (Gurian-Sherman, 2008). Increased road traffic is another reason cited for this negative effect. These issues have been relevant in recent years such as in 2018 when Smithfield Foods was ordered to pay $473.5 million in damages to rural-residential property owners surrounding three of their farms in North Carolina because of the nuisance created by their farms from odor and noise (CBS, 2018). Due to these issues, residential neighbors of CAFOs are interested in preventing loss of property value, forced changes in their lifestyle, adverse changes in their communities, and threats to their health (Thu and Durrenberger, 1998). While the effects of CAFOs on rural-residential property values has been documented, it is unknown if a relationship between farmland values and the location of CAFOs exists. Reasons that a CAFO might positively impact nearby farmland values include giving crop producers an additional outlet to sell their crops or adding value by giving them a new source of fertilizer.

In this study, we explore the relationship between CAFOs and agricultural land values in Kansas using parcel-level transaction data of 2012-2013 and two fixed-effect models with different variables accounting for distance. Additionally, this research investigates other factors that impact land values such as physical characteristics of agricultural parcels. The analysis from the first model, which is based on a distance-band specification, reveals that there is a positive relationship between agricultural land values and CAFOs that are located within 0 to 25 kilometers of the agricultural parcel. As the distance between CAFOs and an agricultural parcel increases beyond 25 kilometers, the relationship becomes less significant. The results from the second model, which uses the inverse distance to the nearest CAFO as the key explanatory variable, follow the prior model results by also identifying a negative relationship between agriculture land values and the distance to the nearest CAFO. That is, as the distance to the nearest CAFO decreases, the land value increases.

This current research is similar to previous hedonic agricultural land value models in that specific attributes of agricultural land parcels are used to explain the variance in the sales price per acre of agricultural land. There is an extensive set of previous studies that have examined the factors affecting agricultural land values. This study contributes to the literature on land values by examining the impact of CAFOs on agricultural land rather than the impact on residential housing, which has been previously explored. The findings from this study will provide insights to operators, lenders, landowners, investors, policymakers, researchers, and anyone with a stake or interest in agricultural land.

PREVIOUS LITERATURE

Much of the literature surrounding the impact of animal agriculture on land values focuses on residential land, more specifically, housing. Residential properties are typically valued by amenities or desired features such as number of bedrooms, bathrooms, square footage, etc. One attribute often considered in the appraisal process is distance from specific community utilities or facilities such as schools, business districts, and larger cities. Previous research has consistently used these factors in addition to distance from the nearest CAFO facilities to evaluate the impact of animal agriculture on residential land (Massey and Horner, 2021; Lawley, 2021; Palmquist, Roka, and Vukina, 1997; Kuethe and Keeney, 2012; Milla et al., 2005). In most cases, findings have been consistent across studies regardless of geographic region. Residential properties have consistently faced a negative impact on housing values in the presence of a CAFO. An example is Herriges, Secchi, and Babcock (2005), who evaluated the effect of livestock facilities on housing prices and found that livestock facilities do have a significant negative effect on property values. However, this impact was only seen to be significant regarding the nearest facility, and there was a lack of evidence suggesting that the size of the facility amplified the negative relationship. Other studies have yielded comparable results while also looking to incorporate additional externalities that could potentially exacerbate the impact of CAFOs on residential properties. With the concerns arising about the potential odor exposure from animal facilities, research has considered wind direction as a factor that could amplify the negative relationship between CAFOs and property values (Kim and Goldsmith, 2009).

Overall, the literature suggests that residential property values in general are seen to be sensitive to the presence of facilities or enterprises that may detract from the convenience or comfort of homeowners. This can even be seen outside of the agriculture sector as other studies have concluded that the presence of wind facilities significantly reduced property values for homeowners (Heintzelman and Tuttle, 2012). However, given the fundamental difference between agricultural and residential land, factors that influence residential property in a particular way may not have the same impact on agriculture land values, providing an opportunity for further research. A recent study by Uter and Hadrich (2023) estimated the impact of swine feedlots on residential housing values in rural areas in Southern Minnesota and found that swine feedlots located between one-half to one mile away from rural homes had a positive impact on their value. This gives credit to the speculation that the properties and land in rural agricultural areas have a different relationship with CAFOs than those in urban or suburban areas.

Other economic studies have focused on analyzing the relevant factors that impact the value of farmland (e.g., Oltmans, Chicoine, and Scott, 1988; Just and Miranowski, 1993; Chavas and Thomas, 1999; Shi, Phipps, and Colyer, 1997). Due to the utility of farmland for production, studies have found that the price of crops can have an impact on price. An example is Taylor and Brester (2005), who found that land values for sugarbeet fields in Montana were positively impacted by factors such as the quality-adjusted price of sugarbeets and expected cash receipts.

Much like in the case of residential land, studies have suggested that the distance from urban or other highly populated areas has a positive impact on price due to the availability of markets to sell goods and the potential returns from future development opportunities (Taylor and Brester, 2005; Gregory et al., 2020). Other studies suggest that this effect may also be driven by increases in population and per capita income causing a shift in homeowners' preference toward living away from city centers (Guiling, Brorsen, and Doye, 2009). Farmland with high levels of productivity often tends to be highly valued as well, which is reflected in the literature as both soil quality and irrigation are seen to have a positive effect on cropland values (Gregory et al., 2020). As residential land and farmland are utilized in distinctly different ways, certain factors that affect residential land negatively have been shown to have either little or, in some cases, a completely different impact on farmland values.

While research surrounding the presence of wind power facilities around residential land showed a distinctly negative effect, similar relationships have been shown to be different with respect to farmland. For example, studies show that wind farms have the potential to alter local temperatures and thus impact crop yields in the surrounding area (Li et al., 2018; Kaffine, 2019). In addition, wind energy production is speculated to serve as a complementary sector to agriculture production since many are located on agriculture land. Sampson et al. (2020) examined this relationship when evaluating the on-/near-farm effects of wind turbines on agricultural land values in Kansas. The results from this study suggested that, though positive, the relationship between on-/off-farm wind turbines and land values was not statistically significant. Thus, the researchers could not conclude that wind turbines placed on or near an agriculture parcel would definitively increase the price of the land.

Other potential complementary sectors have also had their relationship to agriculture land values explored. Ethanol production, for example, has been speculated to increase corn prices and thus increase the value of neighboring farmland. Gardner and Sampson (2022) estimated that irrigated parcels within 50 km of an ethanol plant experience a price premium of about 8.8% on average, while non-irrigated acres saw a price premium of 6.3% relative to parcels that were more distant. With respect to CAFOs and their relationship or potential impact on land values, there have been no formally published studies in this area. However, results from Huang et al. (2003) suggest that the impact of swine production on farmland values in Illinois was positive, with changes in swine inventory and the scale of swine operations leading to changes in farmland prices from -\$10.56 to \$62.96 per acre and overall increasing the value of farmland. This may suggest that similar to speculations about wind energy or ethanol production, animal production and crop production serve as complementary sectors, and this relationship could potentially be observed in the prices of assets such as land.

When exploring empirical techniques for examining land values in the literature, several studies implement some variation of a hedonic modeling approach. The most frequently cited and seminal work on hedonic modeling is the study by Rosen (1974), who suggested that differences in prices are the equalizing factor between two goods with different observed characteristics. To gain insight into the effects of differing product characteristics on prices, Rosen developed the hedonic model that follows the general form where $p(z)$ is the price of the good as function of a vector of its characteristics, z, and each z_i is a different characteristic of that good. The partial derivative with respect to each characteristic, z_i, provides the marginal value for each characteristic of the good. Several studies have implemented Rosen's framework to understand key factors that influence both rural and residential land values. It allows for a clear understanding of the key attributes and environmental factors that impact prices of the land in question.

While no functional form is specified with the hedonic model, researchers commonly opt for a semi-log specification when exploring price effects on agricultural land (Sampson, Perry, and Taylor, 2020; Gardner and Sampson, 2022). Land productivity, soil quality, and environmental factors have set a precedent for having a distinctly significant impact on price (Taylor and Brester, 2005; Gregory et al., 2020). One of the of the most crucial specification considerations to address when implementing a hedonic framework is distance. This is a particular concern when trying to account for the distance from multiple locations of interest at once. A common way to incorporate distance into a hedonic framework has been through the use of distance bands (Herriges, Secchi, and Babcock, 2005; Kim and Goldsmith, 2009; Uter and Hadrich, 2023). These distance bands allow for the consideration of multiple neighboring points of interest within specified spatial rings by counting their frequency within a given range. Sampson, Perry, and Taylor (2020) noted that the way in which a neighbor is defined and the distance ranges used for the spatial bands can impact the number of observations exploitable in the treatment groups. Thus, the use of consistent spatial bands that are reasonable given the study area is a crucial point of empirical specification. Another method for considering distance is the natural log of the inverse distance from the nearest point of interest. The rationale behind this method of calculating distance is that it can potentially capture negative environmental or positive agglomeration effects (e.g., Heintzelman and Tuttle, 2012; Sampson, Perry, and Taylor, 2020).

Studies that utilized both distance variables typically saw the same sign on either coefficient. However, the magnitude and level of significance have been shown to vary slightly between approaches. Management of omitted variable bias, time-invariant heterogeneity effects, and spatial autocorrelation in land values have been noted as consistent points of concern when researching land values. These issues arise as a result land prices being affected by trends through time or by environmental factors relative to space not captured in the model. Spatial lag, spatial error, and spatial temporal models as well as fixed effects approaches are all common methods of addressing these concerns (e.g., Kim and Goldsmith, 2009; Heintzelman and Tuttle, 2012; Huang et al., 2003; Gregory et al., 2020; Sampson, Perry, and Taylor, 2020; Gardner and Sampson, 2022). This study does implement the use of fixed effects to address some of the challenges presented.

DATA AND VARIABLES

The primary source of data for this study is the Kansas Department of Revenue, Property Valuation Division (PVD) database for agricultural land sales. Data for characteristics of the parcel such as the date of sale, composition of the parcel, size of the parcel (*Size*), price per acre of the sale, and measures of productivity (*CropIndex*) were all taken from the PVD's agricultural land sales dataset. Variables calculated by using PVD data are the natural log of the real price per acre (*lnppa*), percentage of acres that are irrigated *(%Irr*), pasture (*%Past*), homestead acres (*%Home*), and total parcel acres squared (*Size*^{2}). Price data are adjusted for inflation to 2017 dollars using the Consumer Price Index (CPI) (BLS, 2019).

A list of CAFOs, including their physical addresses, was provided for the years 2012 and 2013 by the Kansas Department of Agriculture (KDA). These facilities included beef cattle, dairies, swine, and sheep. The physical address was geocoded to produce a longitude and latitude for each facility, and then the distance from each parcel sold to each CAFO was measured using the law of cosines method to get an "as the crow flies" measure of distance. Monthly data for the S&P 500 (*S&P*) were collected from Yahoo! Finance (Yahoo!, 2019). Data for the monthly 30-year fixed-rate mortgage rates were collected from the St. Louis Federal Reserve (Fed, 2019). Table 1 provides the definitions of the variables, and Table 2 presents the overall summary statistics for the variables used in this study.

Distance Variables

We first measured the distance between a parcel to the CAFOs in kilometers, considering two different specifications. First, we followed the distance band approach used by other studies in the literature (Herriges, Secchi, and Babcock, 2005; Kim and Goldsmith, 2009; Sampson, Perry, and Taylor, 2020, Uter and Hadrich, 2023). We counted the number of CAFOs within each "band," where bands were defined by the intervals 0-25, 25-50, 50-75, and 75-100 kilometers. A positive relationship was anticipated between the number of livestock facilities within 25 km of the parcel sale and the price per acre of that sale because of the option for selling grain and purchasing fertilizer created by having CAFOs near the parcel. The same relationships were also expected for the other distance bands, but the magnitude and significance of the coefficients were expected to decline the greater the distance from the parcel of land.

An alternative approach to measuring distance is to follow the method presented by Heintzelman and Tuttle (2012) and Sampson, Perry, and Taylor (2020). That method uses the natural log of the inverse distance to the nearest CAFO of the parcel sold as the key regressor. Similar to the distance-band specification previously discussed, the inverse distance to the nearest CAFO is calculated at the time of the parcel sale. The inverse distance will increase for each parcel sold in the presence of a new CAFO. As the distance between the parcel sold and the CAFO gets shorter, the inverse distance will appear larger. Taking the natural log of the inverse distance allows for the interpretation of the coefficient as an elasticity. In line with the hypothesis for the band method of distance calculation, this variable is expected to have a positive relationship with the price per acre of each agricultural land parcel sold. This is because, as the true distance between the parcels and CAFOs decreases, the inverse distance would increase, thus, a positive relationship between the price and the inverse distance would indicate a negative relationship between the true distance and price resulting in a higher price premium for parcels located closer a CAFO location.

MODEL SPECIFICATION

This study used a hedonic framework put forth by Rosen (1974). In the current study, the price per acre of a parcel of agricultural land was estimated as a function of the type of land in the parcel, parcel size, land productivity, location, timing of the parcel sale, and general economy.

The model for this analysis can be seen outlined in Equation 1:

$$lnPPA_{irmt} = \alpha + \beta X_{irmt} + \gamma_{irmt}\, CD + \mu_r + u_m + v_t + \varepsilon_{irmt} \qquad (1)$$

Here, $lnPPA_{irmt}$ is the real log price per acre for parcel in region , month , and year . Additionally, X_{irmt} is the vector of covariates, and $\gamma_{irmt}\, CD$ used to denote the distance variable in the model estimating the impact of CAFO distance on the price. We also included regional, monthly, and year-fixed effects, nothing that Pendell and Featherstone (2005) showed the seasonal effects on the price per acre of agricultural land using Kansas farmland data from the period of 1980 to 2003. Figure 1 is a histogram showing the distribution of the price per acre for 2012-2013 for all seasons of the year. As discussed above, we considered two specifications for the distance variables. The first uses the numbers of CAFOs within a “band” and can be represented as $Band^{k}_{irmt}$, which is the number of CAFOs in k_{th} band located near the land parcel in one of the four distance bands explained in the previous section. The second specification uses the log of inverse distance to the nearest CAFO, replacing the band variables given as $(\frac{1}{Distance_{irmt}})$. Figure 2 provides a visual aid for each distance variable used in the analysis. A key difference to note between the two variables is that the “band” method allows us to capture the marginal impact on the price of an additional CAFO present within a given radius, while the inverse distance method allows us to capture the immediate price effect of the closest CAFO to the parcel location. Figure 3 provides a map of the 514 CAFO locations and species types in Kansas in 2013.

Parcel Characteristics and Economic Control Variables

Size is one of the main characteristics used to determine the price of a land parcel. Here, the variables total acres in the parcel (*Size*) and total acres in the parcel squared (*Size*^{2}) were used to account for this effect. A negative relationship was expected between the per-acre sales price and total acres as larger parcels tend to have a lower sales price per acre compared to smaller parcels. Larger parcels require more financial resources, which limits the number of potential buyers (Xu, Mittelhammer, and Barkley, 1993). Conversely, a positive relationship was expected between the sales price and the squared size term since the negative effect of parcel size on the price is expected to lessen as parcel size increases.

Various physical attributes play a role in estimating the value of farmland (Swanepoel, Hadrich, and Goemans, 2015). Variables accounting for the effect of different types of land on the parcel included the percentage of total dedicated to irrigation (*%Irr*), dryland (*%Dry*), pasture (*%Past*), and to the homestead or residential portion (*%Home*). The type of land in the parcel was found by measuring the ratio of acres of a particular type and dryland acres. A positive relationship was expected between the price and percentage of irrigated and homestead acres as both are often valued more than dryland acres. Furthermore, a negative relationship was expected between price and percentage of pasture acres as it is typically less valuable than dryland acres. The variable to account for the impact of productivity on sales price was the crop index (*CropIndex*), which came from the United States Department of Agriculture Natural Resources and Conservation Service National Commodity Crop Productivity Index (NCCPI). This index measures the productivity of agricultural land for growing dryland crops. Each parcel had a score ranging from 0 to 100 measuring the least and most productive soil, respectively. A positive relationship was expected between the index score and price as it was expected that more productive soil would be more valued by potential buyers looking to farm the land.

The economic environment can also potentially impact the value of land at the time of a sale, for example, factors such as interest rates, inflation rates, and cash rents are known to have an impact on land value (Schurle et al., 2012) To address this, specific economic variables were selected as controls in this study, with the average S&P 500 value (S&P) for the month of the parcel sale used to control for alternative investments to purchasing land. It was anticipated that a positive relationship would exist between the S&P 500 and the price per acre of agricultural parcel sales. Additionally, the average 30-year fixed-rate mortgage rate for the month of the parcel sale (*Mort*) was included to account for the impact of financing options on farmland values. A negative relationship was expected between the price per acre and the 30-year fixed-rate mortgage rate as an increase in the mortgage rate would increase financing expenses. Table 1 provides a summary of the variables included in this analysis while Table 2 provides summary statistics for each variable.

RESULTS

Distance Variable Results

Table 3 displays the results from the regression models in this study. In Model 1, a positive relationship was found between the number of CAFOs within 0 to 25 kilometers of the parcel sale ($Band_{0\text{-}25}$) and the sales price per acre. The model estimated the marginal effect of one additional CAFO being located within this distance band on a parcel for sale would increase the sales price per acre by 1.5%. Positive relationships were also found between the number of CAFOs between 25 and 50 kilometers ($Band_{25\text{-}50}$), between 50 and 75 kilometers ($Band_{50\text{-}75}$), and between 75 and 100 kilometers ($Band_{75\text{-}100}$) of the parcel for sale and sales price per acre, but none of these variables were statistically significant, thus it can be surmised that CAFOs within 25 kilometers of a parcel would have the greatest influence on sale price. In Model 2, the natural log of the inverse distance to the nearest CAFO was shown to have a significant positive relationship with the price per acre of agricultural land parcels with a coefficient of 0.05. This suggests that a 1% change in the inverse distance from parcels to CAFOs yields a 5% premium. Thus, when examining similar pieces of land, the parcel that is 1% closer to a CAFO location would have a 5% higher value on average. Essentially, parcels that have a larger inverse distance (i.e., a smaller distance between the parcel and CAFO) would experience a greater price per acre on average.

Parcel Characteristics and Fixed Effect Results

The results for the remaining variables will be presented for Model 1 as there was no notable deviation in the results for most of the variables in either model. A positive relationship was found for the percent of total parcel acres that were irrigated and price per acre when compared to the percent of the total parcel acres that were dryland acres. The coefficient estimated for *%Irr* showed that a 1% increase in the percentage of total acres that were irrigated led to a 0.5% increase in the sales price per acre of an agricultural parcel relative to dryland acres. Similarly, the estimated coefficient for *%Home* showed that a 1% increase in the acres designated for the home resulted in a 3.6% increase in the sales price per acre. The *%Past* was the only land type variable to have a negative impact on the price. The results showed that a 1% increase in the percent of total parcel acres that were pasture led to a 0.5% decrease in the price per acre of a parcel sale when compared to dryland acres.

The sales price per acre and total acres in the parcel (*Size*) and total acres in the parcel squared ($Size^2$) had a negative and positive relationship, respectively. The magnitude of the coefficient (-0.003) for total acres in the parcel was small. The estimated coefficient for the squared term of total price per acre was positive but close to zero (0.00002). With the coefficient of the squared term being near zero, the coefficient for the size of the parcel was interpreted to imply that a one-acre increase in the size of the parcel would result in a 0.3% decrease in sales price per acre. These findings are consistent with previous studies. The coefficient for the crop index (*Crop Index*) was positive as expected with a one-unit increase in the crop index score for a parcel leading to an increase in the sales price per acre by 0.008%.

CONCLUSION

This is the first known published study to examine if there is a relationship, and to what extent, between the location of confined animal feeding operations (CAFOs) and agricultural land values. Because agricultural land comprises such a large majority of the assets in the farm sector, understanding the factors driving the differences in land prices between parcels is pivotal. This study employs a hedonic framework to explain the variability in the sales price per acre of agricultural parcel sales in Kansas for the years 2012 and 2013. Positive and significant relationships were found between sales price per acre of agricultural parcels and the percent of the total parcel acres that were irrigated, percent of the total parcel acres that were pasture, total acres in the parcel, and crop index score (a measure of land quality). When examining distance, it was revealed that both the number of CAFOs within the closest set radius and the distance to the nearest CAFO in proximity to the parcel have a significant positive relationship with the price per acre. The results of this study suggest that CAFOs do have an impact on the value of agricultural land via a price premium. This premium is something that landowners should be aware of when appraising the value of their assets in addition to other characteristics.

Future research can expand on this study to continue to evaluate the impact that CAFOs have on the price of agriculture land prices over a greater time period. The data used in this study included the years 2012 and 2013. By expanding the number of years included in this study we could evaluate how temporal impacts and possibly account for structural changes within the farm and livestock sector over time. Evaluating how these price impacts could complement or conflict with the price impacts from CAFOs could lead to a deeper understanding of the complementary or conflicting factors that influence the price of agricultural land parcels in Kansas. Future research could also further contribute by accounting for various types of CAFOs (i.e., swine, cattle, sheep, poultry) and exploring implications related to differences in CAFO size.

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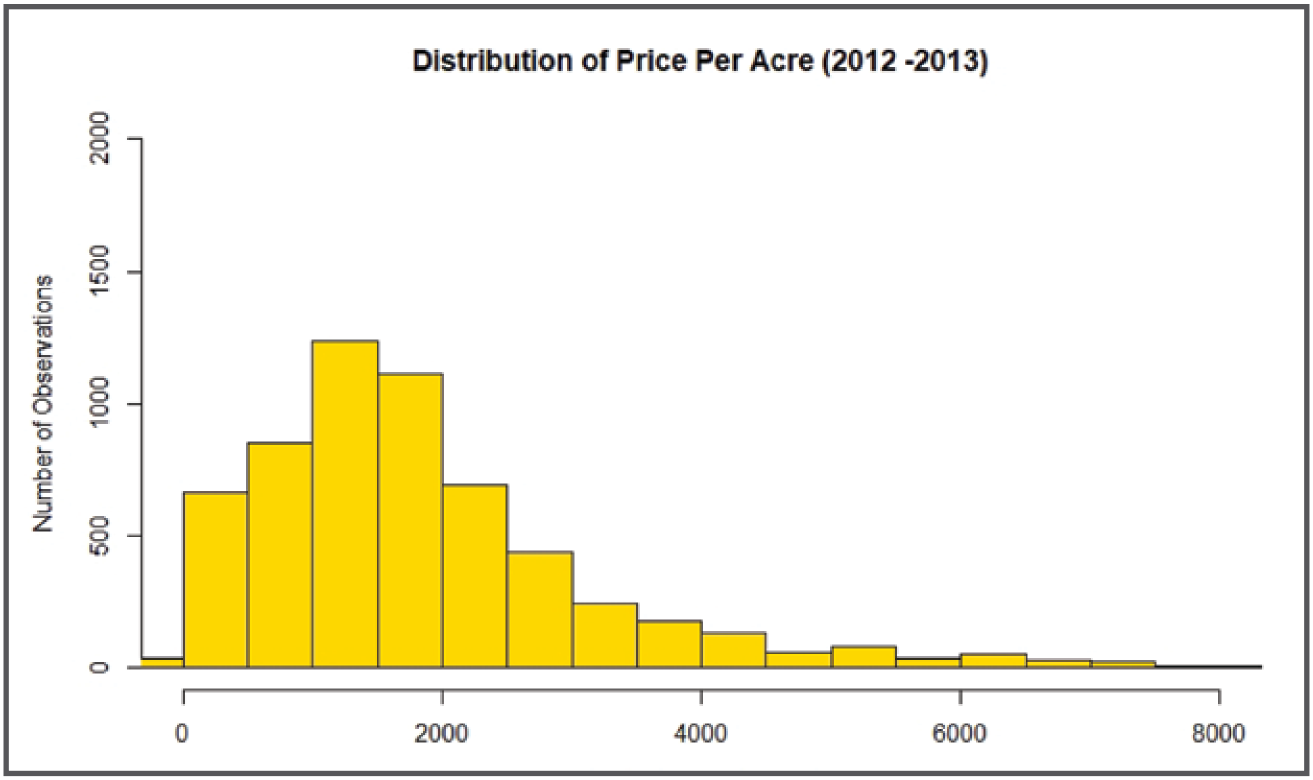

Figure 1. Histogram of sales price per acre of agricultural parcels 2012–2013

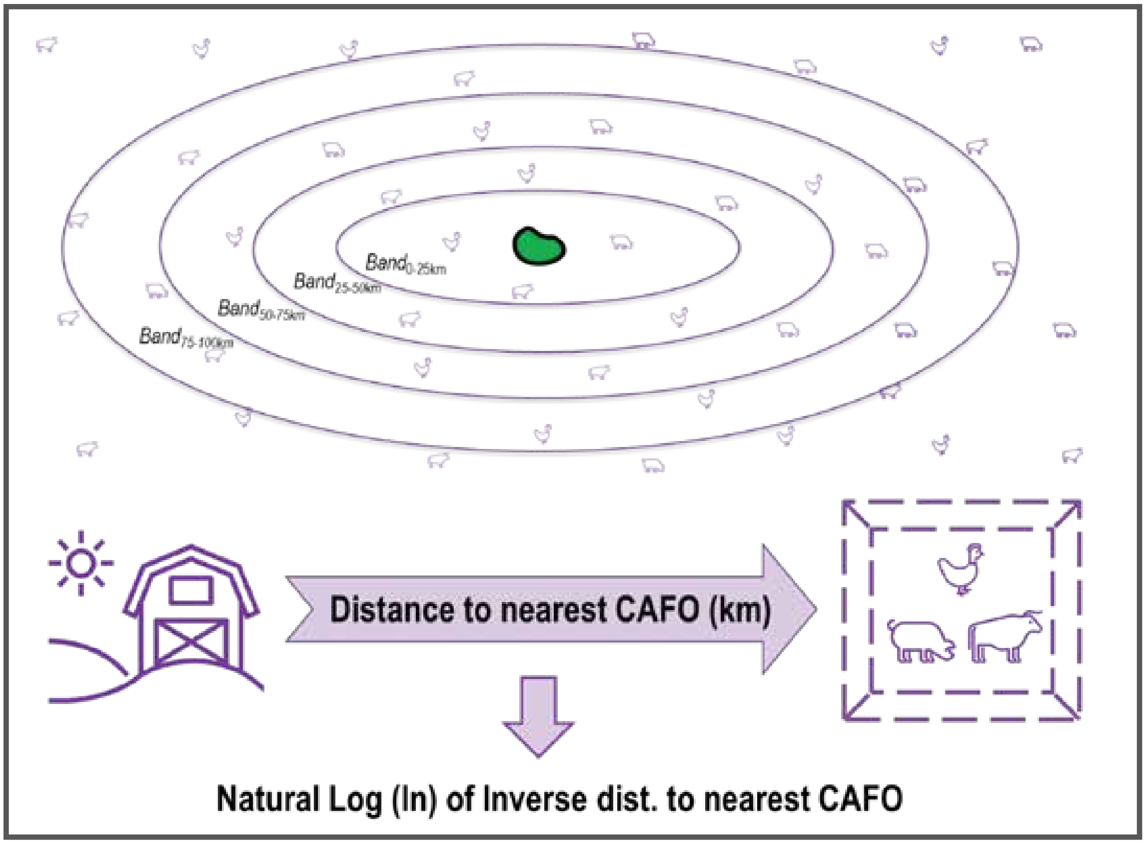

Figure 2. Visualization of distance variables

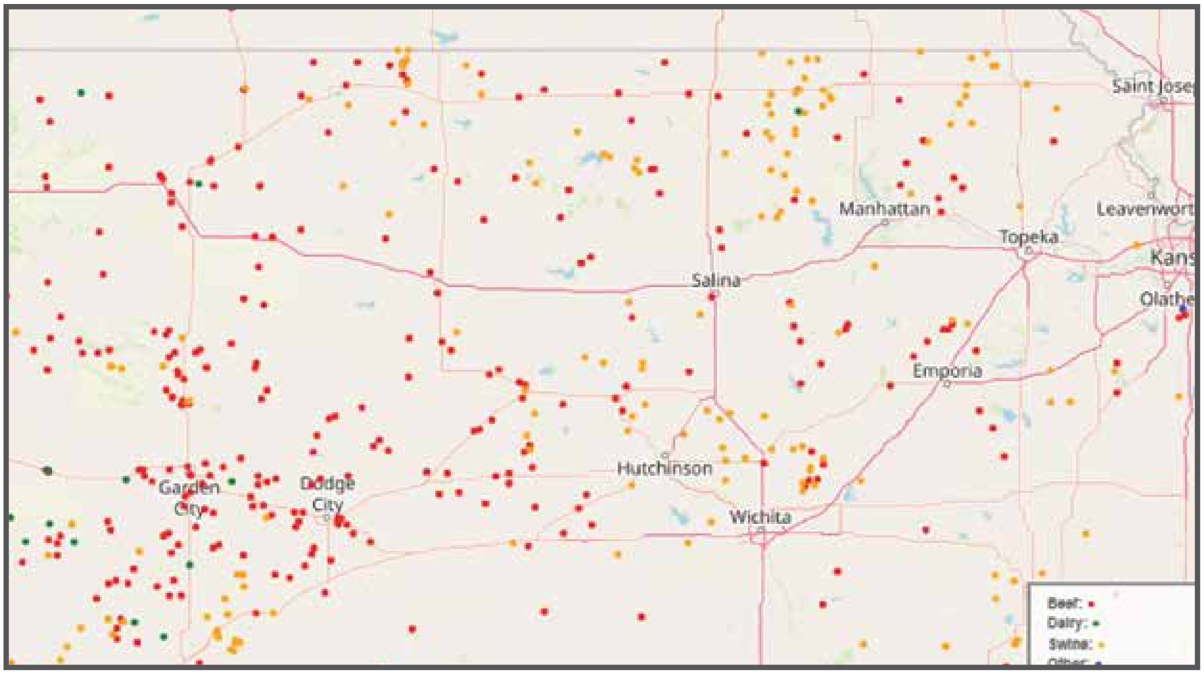

Figure 3. Map CAFO locations and types in Kansas (2013)

Table 1. Variables and Descriptions Used in the Regression Analysis

Variable	Description
Dependent	
lnppa ($/acre)	natural log of price per acre
Independent	
%Irr	percentage of the total parcel acres that are irrigated
%Past	percentage of the total parcel acres that are pasture
%Home	percentage of the total parcel acres that are homestead acres
%Crop	percentage of the total parcel acres that are cropland
Size	total acres in the parcel
Size2	total acres in the parcel squared
Crop Index	NRCS National Commodity Crop Productivity Index (NCCPI)
Band0-25	total number of CAFOs within 0 - 25 km of the parcel sale
Band25-50	total number of CAFOs between 25 km and 50 km of the parcel sale
Band50-75	total number of CAFOs between 50 km and 75 km of the parcel sale
Band75-100	total number of CAFOs between 75 km and 100 km of the parcel sale
ln(1/Distance)	The natural log of the inverse of the distance from the site of the parcel to the nearest CAFO in the area
S&P	S&P 500 index
Mort	30-year fixed-rate mortgage rate

Table 2. Summary Statistics of Variables in the Analysis

Variable	Mean	Std. Dev.	Min	Max
lnppa ($/acre)	7.25	1.05	0	12.30
Distance to nearest CAFO (km)	14.29	9.83	0.221	62.64
Band$_{0-25}$	20.96	15.41	2	119
Band$_{25-50}$	20.30	15.17	1	129
Band$_{50-75}$	25.24	16.13	1	118
Band$_{75-100}$	449.74	41.40	168	510
Size	138.58	119.64	0.1	1634.7
Size2	33,500.75	78,730.92	0	2672244
%Irr	2.53	13.60	0	100
%Past	20.21	36.10	0	100
%Home	0.07	1.35	0	54.92
% Crop	50.36	41.69	0	100
Crop Index	42.85	12.28	0	89.48
Mort	3.80	0.345	3.35	4.49
S&P 500	1,519.95	160.36	1,310.33	1,848.36

Number of Observations 5,957

Table 3. Regression Results[1]

Variable	Coefficients					
	Model 1			Model 2		
Band$_{0\text{-}25}$	0.015	***	(0.005)	-		
Band$_{25\text{-}50}$	0.004		(0.005)	-		
Band$_{50\text{-}75}$	0.003		(0.005)	-		
Band$_{75\text{-}100}$	0.008		(0.005)	-		
ln (1/Distance)	-		-	0.05	***	(0.017)
Size	-0.003	***	(0.000)	-0.002	***	(0.000)
Size^2	0.000	***	(0.000)	0.000	***	(0.000)
% Irr	0.005	***	(0.001)	0.005	***	(0.001)
% Past	-0.005	***	(0.001)	-0.004	***	(0.000)
% Home	0.036	*	(0.021)	0.032	*	(0.173)
Crop Index	0.008	***	(0.001)	0.007	***	(0.001)
Mort	-0.022		(0.067)	0.001		(0.061)
S&P 500	-0.000		(0.000)	0.001		(0.003)
Region Fixed Effects	Yes			Yes		
Month Fixed Effects	Yes			Yes		
Year Fixed Effects	Yes			Yes		
R^2	0.133			0.157		
Number of Observations	5,098			5,957		

Robust standard errors are in parentheses. *, **, and *** indicate significance at the $p< 0.1$, $p<0.05$, $p<0.01$ levels, respectively.

[1] Parcel characteristics were selected for inclusion based on the correlation table A3 found in the Appendix. Models specifications including quadratic distance variables (Distance & Distance^2) and county-level fixed effects were evaluated as a robustness check. The authors found no significant difference in the results from each and thus presented the model results seen above. [3]Tables A1 and A2 in the Appendix present the result for the alternative model specifications

APPENDIX

Table A1. Regression Results with Quadratic Distance Model

Variable	**Coefficients**								
	Model 1			Model 2			Model 3		
$Band_{0-25}$	0.015	***	(0.005)	-			-		
$Band_{25-50}$	0.004		(0.005)	-			-		
$Band_{50-75}$	0.003		(0.005)	-			-		
$Band_{75-100}$	0.008		(0.005)	-			-		
Distance	-			-0.001	***		-		
Distance2	-			0.000	***		-		
ln (1/Distance)	-			-			0.05	***	(0.017)
Size	-0.003	***	(0.000)	-0.003	***	(0.000)	-0.002	***	(0.000)
$Size^2$	0.000	***	(0.000)	0.000	***	(0.000)	0.000	***	(0.000)
% Irr	0.005	***	(0.001)	0.005	***	(0.001)	0.005	***	(0.001)
% Past	*-0.005*	***	*(0.001)*	*-0.004*	***	*(0.001)*	*-0.004*	***	*(0.000)*
% Home	*0.036*	*	*(0.021)*	*0.031*	*	*(0.021)*	*0.032*	*	*(0.173)*
Crop Index	*0.008*	***	*(0.001)*	*0.007*	***	*(0.001)*	*0.007*	***	*(0.001)*
Mort	*-0.022*		*(0.067)*	*-0.023*			*0.001*		*(0.061)*
S&P 500	*-0.000*		*(0.000)*	*-0.000*	*		*0.001*		*(0.003)*
Region FE	*Yes*			*Yes*			*Yes*		
Month FE	*Yes*			*Yes*			*Yes*		
Year FE	*Yes*			*Yes*			*Yes*		
R^2	*0.133*			*0.157*			*0.157*		
Number of Observations	*5,098*			*5,957*			*5,957*		

Robust standard errors are in parentheses. *, **, and *** indicates significance at the $p < 0.1$, $p < 0.05$, $p < 0.01$ levels, respectively.

Table A2. Regression Results with Quadratic Distance Model (County FE)

Variable	Coefficients								
	Model 1			Model 2			Model 3		
Band$_{0-25}$	0.006	*	(0.003)	-			-		
Band$_{25-50}$	0.004		(0.002)	-			-		
Band$_{50-75}$	0.001		(0.002)	-					
Band$_{75-100}$	0.002		(0.002)	-			-		
Distance	-			-0.004		(0.004)	-		
Distance^2	-			0.000		(0.004)	-		
ln (1/Distance)	-						0.015		(0.020)
Size	-0.002	***	(0.000)	-0.002	***	(0.000)	-0.002	***	(0.000)
Size^2	0.000	***	(0.000)	0.000	***	(0.000)	0.000	***	(0.000)
% Irr	0.004	***	(0.001)	0.005	***	(0.001)	0.005	***	(0.001)
% Past	-0.004	***	(0.001)	-0.003	***	(0.000)	-0.003	***	(0.000)
% Home	0.043	*	(0.041)	0.036	*	(0.017)	0.036	*	(0.169)
Crop Index	0.005	***	(0.001)	0.008	***	(0.001)	0.005	***	(0.001)
Mort	-0.031		(0.065)	-0.001		(0.059)	0.007		(0.059)
S&P 500	-0.000		(0.000)	-0.000	*	(0.000)	-0.001		(0.000)
County FE	Yes			Yes			Yes		
Month FE	Yes			Yes			Yes		
Year FE	Yes			Yes			Yes		
R^2	0.264			0.254			0.254		
Number of Observations	5,098			5,957			5,957		

Table A3. Parcel Characteristic Correlation Matrix

Variable	NCCPI	Sand Index	Silt Index	Clay Index	Organic Matter Index	Available Water Capacity Index	% Crop	% Irrigated	% Pasture	% Home
NCCPI	1									
Sand Index	-0.332	1								
Silt Index	0.246	-0.584	1							
Clay Index	0.252	-0.478	0.557	1						
Organic Matter Index	0.251	-0.39	0.461	0.757	1					
Available Water Capacity Index	0.108	-0.11	0.795	0.286	0.204	1				
% Crop	0.145	-0.136	0.09	-0.135	-0.246	0.153	1			
% Irrigated	-0.089	0.161	-0.065	-0.112	-0.128	0.044	-0.139	1		
% Pasture	-0.062	-0.022	0.013	0.154	0.228	-0.098	-0.489	-0.076	1	
% Home	0.037	0.004	0.009	0.012	0.021	0.008	-0.021	-0.003	0.041	1

Mapping and Contextualizing Foreign Ownership and Leasing of U.S. Farmland

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Abstract

Foreign ownership of U.S. farmland has recently attracted growing interest from the public as well as the federal and state policy makers. Using all reported AFIDA transactions, this article provides a comprehensive analysis on the structure of foreign land ownership in the United States. We find that (1) long-term leasing is the main driver of the increasing foreign interests of U.S. farmland in the past 20 years; (2) a considerable number of foreign transactions are related to wind and solar energy development, especially for entities holding long-term leases; and (3) "adversary" countries like China hold only 1% of all the foreign-owned agricultural land.

INTRODUCTION

Agricultural land is the most valuable asset to any country in the world. The vast agricultural land of the United States plays a vital role in producing a wide variety of food products that feeds not only the U.S. population but also contributes greatly to the global food supply through substantial amounts of exports. From a macro perspective, the U.S. economy benefits greatly from these exports as they help generate revenue, promote trade, and strengthen international relations. Taking a narrower angle, they sustain rural communities by creating employment opportunities and bolstering local economies.

Foreign ownership of U.S. farmland has been a concern among rural communities for a long time (Deaton and Lawley, 2022). While there is no outright ban on foreign land ownership at the federal level, the Agricultural Foreign Investment Disclosure Act (AFIDA) of 1978 requires foreign investors who acquire, transfer, or hold an interest in U.S. agricultural land, including leasehold interests of 10 years or more, report such holdings and transactions to the Secretary of Agriculture on Form FSA-153. Rausser and Schmitz (1980) indicate that the major concern toward foreign investment of U.S. farmland as of the time of their writing primarily came from the indirect effect on entry cost to potential farmers, increasing absentee ownership and the disruption of the traditional union between farm ownership and operation, and the economic well-being of rural communities. Lutrell (1979) argues that the opposition toward foreign investment in U.S. land is the result of emotional factors rather than economic considerations, and limiting foreign investment is not beneficial to the nation's stock of wealth and its wellbeing. There has also been an ongoing debate about whether the increasing farmland price should be attributed to the foreign purchases of U.S. farmland, but there is no common agreement toward the potential effect as little study has directly addressed this issue.

Early legislation was introduced in the 1970s and 1980s to restrict foreign ownership of U.S. land in general, and 30 states implemented some type of restrictive law by 1984 (Schian, 1984). In the context of agricultural land specifically, a more recent report states that around 24 states[1] have some kind of foreign ownership law to limit or forbid nonresident aliens, foreign business entities, or foreign governments from acquiring or owning private agricultural land (National Agricultural Law Center, 2023a), with each state taking its own approach to restrictions. With the restrictions, foreign ownership has historically been a very small portion of farmland in the United States (Nickerson et al., 2012), although there continue to be concerns regarding the issue. According to the most recent USDA annual report, foreign entities hold around 40 million acres of agricultural land in the United States as of December 31, 2021, which is 3.1% of all privately held agricultural land and 1.8% of all land within the U.S. (USDA-FSA, 2021).

Recently, public concern around this issue has been escalating due to the increasing foreign interests in U.S farmland during the past two decades and the growing attention of public media and politicians on "adversary countries." Despite rising apprehensions around this issue, the structure of foreign land ownership in the United States, especially in a more current context, has not been extensively studied in the literature and is mostly absent from the heated social discussion. This article aims to provide more quantifications of the current situation of foreign land ownership in the United States by answering three main overlooked questions in the current policy debate: (1) What is the role of long-term leases in shaping foreign interests in U.S. farmland? (2) To what extent has the recent growth in foreign interest in U.S. farmland been driven by renewable energy investments on solar or wind? (3) Which countries are the major foreign owners of U.S. farmland, U.S. allies or so-called "adversaries"? Based on the database of over 40,000 AFIDA foreign transactions from 1970–2020 obtained from a Freedom of Information Act (FOIA) request, we specifically focus on how long-term leasing and the wind/solar energy development sector play significant roles in the recent trend of foreign interests in U.S. agricultural land.

Three main results stand out from the analysis of the AFIDA data: (1) long-term leasing is the main driving force of the increasing foreign interests in U.S. farmland in the past 20 years; (2) a considerable number of foreign entities invest in renewable energy such as wind and solar energy development instead of agricultural production; and (3) "adversary" countries account for only 1% of all the foreign-owned agricultural land in the United States. These aspects are missing from the public narratives of politicians but are undoubtably valuable insights that can unravel the current structure of foreign land ownership in the United States and inform policy makers about the future of foreign land acquisition.

BACKGROUND

Over the past two years, numerous states have proposed legislation aimed at limiting foreign ownership. These proposed bills exhibit a range of intricacies and differentiate between individuals and corporations. In parallel, at the federal level, several proposed measures seek to exert control, prohibit, impose restrictions, or heighten oversight of foreign investments within the U.S. agricultural sector. The University of Arkansas National Agricultural Law Center splits the proposed measures of the 117th Congress (2021–2022) into four categories, some of which overlap (National Agricultural Law Center, 2023a). The proposed bills either (1) restrict or prohibit foreign ownership/investment in U.S. real estate for all foreign countries or a subset of countries; (2) amend the AFIDA to require the Secretary of Agriculture to make land purchase reports publicly available or tighten reporting requirements by requiring foreign entities reporting leases 5 years or more as opposed to 10-year-or-more leases; (3) prevent foreign participation in U.S. government farm programs or access to credit or financial services offered by the Farm Credit System; or (4) add the Secretary of Agriculture to the Committee on Foreign Investments in the United States (CFIUS).

Seventeen states have some kind of restrictions on foreign ownership of land, but each state's restrictions vary based on the definition of agriculture or farming, restrict certain kinds of foreign owners, or allow foreign owners to only purchase up to a certain amount of agricultural land. Several states, such as Iowa, already had restrictions on corporate land ownership that affects both foreign and U.S. companies (National Agricultural Law Center, 2023b). From 2021 through 2022, 12 states (Alabama, Arizona, Arkansas, California, Indiana, Iowa, Mississippi, Missouri, Oklahoma, South Carolina, Tennessee, and Texas) have proposed legislation that seeks to restrict certain foreign investments in real property and agricultural land located within the boundaries of their state. In 2023, this momentum persisted, with the majority of states either already having or planning to propose similar legislation (National Agricultural Law Center, 2023a). Based on the recent flurry of activity, it is reasonable to expect that federal and state governments will propose and enact even more measures in the near future.

Notably, in April 2023, Arkansas implemented legislation that imposes restrictions on specific foreign investments in land within the state. Put more precisely, the law introduced two distinct prohibitions: the first barring a prohibited foreign party (PFP) from acquiring agricultural land and the second prohibiting any acquisition of real property within the state by a “prohibited foreign-party-controlled business” (National Agricultural Law Center, 2023d). On October 17, 2023, Arkansas’s Attorney General ordered a subsidiary of Syngenta Seeds, a company ultimately owned by a Chinese state-owned entity, to divest its ownership interest in about 160 acres of agricultural land due to the restriction prescribed under the newly enacted foreign ownership law. As a result, Arkansas became the first in the nation to enforce a state law banning certain foreign entities from owning agricultural land (National Agricultural Law Center, 2023d; Associated Press, 2023).

In addition to general legislation affecting foreign land ownership, the recent strategic classification of “adversary” countries holds significant implications within the realm of foreign land ownership in the United States. As of June 2023, the U.S. Department of Commerce (DOC) has officially designated China, Russia, Cuba, Venezuela, Iran, and North Korea as “foreign adversaries” (National Agricultural Law Center, 2023a). Notably, as of March 2023, 14 states have proactively enacted some kind of legislative measures aimed at barring entities affiliated with these countries from purchasing agricultural land in the United States (Tesfaye, 2023). For example, Iowa has banned the Chinese government as well as any persons or entities from China from acquiring any real properties located in the state. Concurrently, several other states are proposing similar prohibitory measures. This trend appears to be driven by the escalating tension between Washington and Beijing, as well as a confluence of other international events, which result in increasing concerns about national security. The deteriorating U.S.-China relationship, in particular, has amplified debates surrounding Chinese holdings of U.S. agricultural land and concerns about national security of the U.S. food supply chain.

DATA AND METHODS

Enacted by Congress in 1978, the AFIDA is a federal law that requires foreign entities (individuals, businesses, and governments) to report transactions involving agricultural land to the USDA Farm Service Agency. Thus, a foreign entity that acquires, holds, transfers, or disposes of an interest in agricultural land located within the United States is required to disclose certain information concerning such transactions, investments, and acquisitions. The AFIDA database provides disclosed information about the foreign entities that hold U.S. agricultural land, including the name of the foreign entity, nationality, location, date of acquisition, type of interest, acquisition methods, land use (crop, pasture, forest, and other agriculture), parcel acreage, and more. Specific details about the information can be found in the Farm Service Agency form (FSA-153).

Here, we provide specific details about what variables we used in this research and the methods utilized for analysis. Specifically, our study incorporates several key variables: for acreage, “Number of Acres” denotes total acres acquired by a foreign entity, whereas “Crop,” “Pasture,” “Forest,” and “Other Agriculture” further separate the total acreage by general land usage. For location, we used “State” to categorize each foreign entity into one of the 10 USDA Agricultural Production Regions described in Cooter et al. (2012). Additionally, for a more granular geospatial analysis, “County” and “FIPS” serve as vital tools, enabling the creation of multiple county-level maps to augment the spatial dimension of our research. We also use “Country” to classify all foreign entities into three overarching categories: “US Allies,” “Adversaries,” and “Neutral.” For ownership structure, “acquisition method” signifies the recorded status at the time of land purchase, whereas “type of interest” encapsulates current ownership status. This enables us to distinguish foreign entities with either whole ownership or long-term leases, with specific emphasis on the latter.

In addition to the variables mentioned above, “Owner Name” shows the precise name of the foreign entities, so we applied keyword inclusion with Boolean conditions to search and classify entities with ties to energy or natural resource sectors. This categorization yields seven distinct categories: “forestry,” “solar energy,” “wind energy,” “metal,” “natural resources,” “other energy,” and “not energy.” Specifically, entities featuring keywords such as “timber,” “wood,” or “forest” are categorized as “forestry”; those with “solar” are designated as “solar energy”; entities containing “wind” are categorized as “wind energy”; those featuring items like “copper,” “metal,” or “mineral” fall under “metal”;

entities referencing “resource” or “natural resource” are classified as “natural resource”; those incorporating “energy” are categorized as “other energy”; while entities not conforming to any of these keyword criteria are grouped under “not energy.”

RESULTS

Current Situation

Figure 1 provides a comprehensive depiction of foreign-held farmland in the United States, categorized by its current land use as of the year 2020. The visual representation underscores some noteworthy spatial patterns: (1) foreign-held pastureland is generally located in the Western United States; foreign-held forest is predominantly distributed in the Northeast, Southeast, and Northwest; and (3) foreign-held cropland displays a relatively more dispersed spatial allocation when compared with the previous two categories.

We were also able to calculate the percentage of privately held cropland held by all foreign owners as of the year 2020 using data from the AFIDA and the National Agricultural Statistics Service. Figure 2 encapsulates the percentages, shedding light on the extent of foreign entity presence in each county. High percentages are evident in numerous counties located within the Mountain and Southern Plains regions. In contrast, the Corn Belt, which is traditionally renowned for its good agricultural productivity, exhibits comparatively lower percentages. It is important to acknowledge a limitation associated with this visualization. The total acreage of private cropland varies considerably across different counties. Consequently, regions with higher percentages do not necessarily correlate with higher acres of foreign-held cropland. Nevertheless, it remains a reasonable inference that foreign presence in the states located in Mountain and Southern Plains regions is generally more pronounced when compared to the Corn Belt region. Additionally, our analysis reveals that 648 counties exhibit 0% of foreign-held cropland, with an additional 774 counties featuring missing data but possessing a high likelihood of also reporting 0%. In these counties, the influence of foreign investors on privately held cropland is minimal.

Long-Term Lease vs. Ownership

An important aspect of foreign land acquisition pertains to the type of ownership structure employed. Taylor et al. (2023) highlight a salient trend: the majority of recent land acquisition by foreign entities leans heavily toward long-term leases rather than whole ownership. The AFIDA requires respondents to specify one of six ownership structures for the land they have acquired: (1) whole ownership; (2) partial ownership; (3) life estate; (4) trust beneficiary; (5) purchase contract; and (6) other (as per FSA-153). Category 6 mainly consists of long-term leases of 10 years or longer. We label the data from category 6 as “leased” versus the amalgamation of the other five categories, collectively termed “owned.”

Figure 3 unveils a compelling representation of this distinction via three-by-three maps, where each row corresponds to a specific year (2000, 2010, and 2020), and each column stands for a category of ownership type (all data, owned, or leased). We can observe the noticeable increase of foreign-held farmland by long-term lease from 2000 to 2020, as shown in the third column. This graphical depiction provides further empirical evidence affirming that leasing has emerged as the primary catalyst propelling the growing foreign interests in U.S. farmland from 2000 and 2020.

Energy and Natural Resource Company

According to Taylor et al. (2023), the impetus behind the acquisition of U.S. land in recent years predominantly centers on renewable energy production. By scrutinizing the names of the foreign entities, we can glean valuable insights into the intended purpose of their land usage. Our categorization process classified these entities into seven categories by the inclusion of specific keywords: (1) forestry, (2) metal, (3) natural resources, (4) other energy, (5) solar energy, (6) wind energy, and (7) not energy. As depicted in Figure 4, most of the land leased by foreign entities is used for wind and solar energy development, constituting a substantial 81.85% share, whereas the land held in whole ownership focuses more on wood and timber production and other non-energy-related activities.

When we combine the revelation that a significant proportion of recently acquired land by foreign entities is held under long-term leases, coupled with the significant presence of wind and solar energy development within the leased category, a compelling narrative emerges. It strongly suggests that the recent foreign investment landscape in U.S. farmland is primarily geared toward energy development, rather than agricultural or food production.

U.S. Allies vs “Adversary” Countries

The pie chart in Figure 5 illustrates a stark contrast in foreign interests in U.S. agricultural land. We can see that U.S. allies comprise a substantial majority, accounting for 87% of foreign interests, whereas the combined holdings of "adversary" countries represent 1% of foreign interests. Among allies, Canada, the Netherlands, Italy, the United Kingdom, and Germany emerge as the top five investors, collectively holding an impressive 72.15% of all foreign-owned farmland. Canada stands out as the largest owner of foreign-held U.S. agricultural land, owning 12,361,087 acres or 36.55% of the total foreign-held land. In contrast, within the category of "adversary" countries, China owns a relatively modest 352,139 acres, constituting a mere 0.92% of all foreign-held farmland.

Table 1 provides a more detailed comparison between the top five U.S. allies and the "adversary" countries by separating the total acreage held in one of the 10 agricultural production regions (USDA Farm Production Regions; Cooter et al., 2012). We can see that the top five countries have acquired substantial tracts of land across all 10 regions. Conversely, both the acreage held and the overall presence of the "adversary" countries in many of the regions are significantly lower than that of the U.S. allies.

DISCUSSION

Foreign Ownership of Agricultural and Food Processing Facilities and CAFOs

Beyond concerns about foreign entities, particularly those from China, acquiring U.S. farmland, there is a growing apprehension regarding foreign ownership extending to agricultural processing facilities and Concentrated Animal Feeding Operations (CAFOs). This broader spectrum of foreign ownership could raise potential threats to the domestic food supply chain and local communities.

In recent years, one of the most noteworthy instances of foreign acquisition in the American food industry was the 2013 purchase of Smithfield Foods by the Chinese company WH Group for $4.7 billion (Schneider and Dennis, 2013). This transaction resulted in the formation of the world's largest pork producer through the amalgamation of the two entities. Previously known as Shuanghui, WH Group is purported to have received subsidies from the Chinese government. Significantly, this acquisition stands out as the largest Chinese takeover of an American company to date.

Brazilian companies are also important players in the American food system. Notably, JBS, a meatpacker company with affiliations to the Brazilian government, acquired Swift Foods Co. in 2007 (Jelmayer, 2007) and purchased the controlling stake of Pilgrim's Pride in 2009 (ABC News, 2009; Thomas, 2022). Furthermore, Marfrig Global Foods, another Brazilian meatpacker company, has 31% ownership of the National Beef Packing Company. The latter, ranking as the fourth-largest beef processor in the United States, is presently predominantly owned by foreign entities, with 80% foreign ownership (Walljasper, 2019). These acquisitions and foreign-heavy ownership structures have raised alarms among local communities and legislators.

This issue was also brought up during a recent hearing titled "Foreign Ownership in U.S. Agriculture" by the Senate Agricultural Committee, where Senator Cory Booker expressed apprehensions about multiple facets of the food system falling under the control of foreign corporations, encompassing seeds, meat processing, and grocery stores (Rapoza, 2023).

The prevailing concern revolves around the potential risk to U.S. food security, as increased foreign ownership could pave the way for the introduction of lower-quality food products into American households. For example, the USDA temporarily stopped the import of Brazilian beef in 2017 due to public health concerns, sanitary conditions, and animal health issues (Walljasper, 2019; Phillips, 2017).

This paper does not furnish a comprehensive analysis of the existing structure of foreign ownership in agricultural and food processing facilities, including CAFOs. Nevertheless, it is important to underscore that this facet is of equal significance to that of agricultural land ownership. The lack of studies in this regard opens avenues for future research to delve into this crucial aspect, thereby addressing the complexities associated with foreign ownership in food processing facilities and CAFOs and how that might affect national security.

Location and Land Use

The geographical location and land use purposes of foreign interests in the United States also raise public concerns for national security. Some argue that AFIDA data lacks transparency and accuracy (Tesfaye, 2023; National Agricultural Law Center, 2023c), and others suggest that the specific locations of the foreign-held land and the purpose of the purchases might have more significant impact on national security. However, currently we do not have information on the specific details of the underlying purposes of these acquisitions and their accurate proximity to critical security facilities, such as government agencies and military bases. Nonetheless, we can analyze the TIGER/Line and Rural-Urban Continuum data in tandem with AFIDA data to share preliminary insights into this matter. This could serve as a foundation for future studies, providing a starting point to delve deeper into issues related to national security, location, and land use purpose.

We acquired TIGER/Line military installations data from the U.S. Census Bureau, encompassing location information on all 536 military bases in the U.S., which was subsequently merged with the AFIDA database. The merged data, aggregated by the USDA farm production region, culminated in the creation of Appendix Figures A and B. Figure A illustrates the acreage of foreign-purchased land situated within counties that also house military installations, while Figure B represents the number of counties with foreign-held agricultural land that also contains military installation. Depicted in red, foreign-owned land coexisting with military bases within the same counties is observed across all major regions. A particularly noteworthy observation is the Pacific region (encompassing California, Oregon, and Washington), which stands out with the highest percentage of foreign-held agricultural land located in counties that have military installations.

In our analysis, we also incorporated the Rural-Urban Continuum data obtained from the USDA's Economic Research Service (ERS). This dataset employs a classification scheme that categorizes counties based on their level of urbanization, assigning each county a code ranging from 1 to 9. Higher numerical codes indicate a greater degree of urbanization for the respective counties. In Figure C, we categorized foreign-held land based on the level of urbanization in the respective counties and aggregated this data by USDA farm production region. We can see that in the regions of the Northern Plains, Northeast, Mountain, and Lake, a higher share of foreign purchased land is in more urbanized regions.

CONCLUSIONS AND POLICY IMPLICATIONS

This article presents a comprehensive analysis of the landscape of foreign land ownership in the United States utilizing data from the AFIDA. Our investigation reveals that over the past two decades, while foreign interests in U.S. agricultural land have demonstrated a steady increase, a significant portion of the recently acquired farmland by foreign entities is held under long-term leases rather than in full ownership. Furthermore, our findings indicate that the primary acquirers of agricultural land are energy development and natural resource entities, as opposed to entities primarily engaged in agricultural or food production. This distinction holds particularly true for those entities holding long-term leases. Specifically, the emergence of wind and solar energy farms represents a notable trend of the recent foreign investment in U.S. agricultural land, and their effect on the U.S. food supply chain is likely limited. Another crucial aspect that has often been overlooked is the distribution of foreign-held farmland among "adversary" countries and U.S. allies. Notably, "adversary" countries hold a mere 1% of all foreign-held farmland, with U.S. allies accounting for a substantial 87% of said holdings. The historical presence of "adversary" countries in the U.S. agricultural land has been minor, and our analysis suggests that this trend is likely to persist in the future, given how more states have recently enacted or are proposing for prohibiting or limiting these countries from obtaining U.S. farmland.

This study is subject to several limitations that warrant discussion. First, due to the absence of precise information regarding the intended land usage within the AFIDA dataset, we resorted to categorizing foreign entities (energy or natural resource) based on the presence of specific keywords in the entities' names. It is important to acknowledge that this approach may not comprehensively capture the actual land usage intentions of all these entities, which results in some level of uncertainty. Second, concerns have been raised by various stakeholders regarding the accuracy, transparency, and reliability of the AFIDA data. Notably, members of the House of Agricultural Committee (Tesfaye, 2023), U.S. House Republicans (National Agricultural Law Center, 2023c), and other policy makers have expressed reservations about the AFIDA. They argue that the data may suffer from potential underreporting of foreign ownership of agricultural land, raising doubts about its completeness and accuracy. If these speculative concerns are indeed validated, there exists a risk that the findings presented in this study could be compromised by the quality of the underlying data.

As new data becomes available in the future, prospective research endeavors could extend the scope of this study to encompass the present state of foreign ownership within the broader food supply chain, incorporating areas like CAFOs. Additionally, there is considerable potential for investigations into the role of location and land use in this context. For instance, a quantitative exploration of proximity to military installations could be undertaken when relevant data becomes available. Undertaking such studies would not only contribute to the understanding of foreign ownership within the U.S. food supply chain but also provide invaluable insights into policy considerations regarding national security. The outcomes of such research endeavors could offer perspectives for the development of policies safeguarding both economic interests and national security in the context of foreign ownership in critical sectors.

Future research endeavors also hold promise in shedding light on the evolving landscape of foreign ownership of U.S. agricultural land. These future studies may be directed toward conducting rigorous impact evaluations, specifically focusing on the surge in legislative activities that have marked 2023. A particular area of interest lies in assessing the effectiveness of these legislative efforts, especially concerning "adversary" countries such as China. Such analyses could offer invaluable insights into the practical implications of the regulatory measures on Chinese entities aspiring to acquire or currently possessing U.S. farmland. Furthermore, it is prudent to consider the potential comparative dimension of these investigations. Such a comparative approach would enable a longitudinal assessment of the impact of legislative actions and policy changes on the structure of foreign ownership within the United States agricultural sector. These future research trajectories hold the promise of enriching our understanding of the intricate dynamics that underlie foreign land acquisition in the United States, offering a deeper comprehension of the consequences of policy interventions in this domain.

FOOTNOTES

1 24 States: Alabama, Arkansas, Florida, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Montana, Nebraska, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Utah, Virginia, and Wisconsin.

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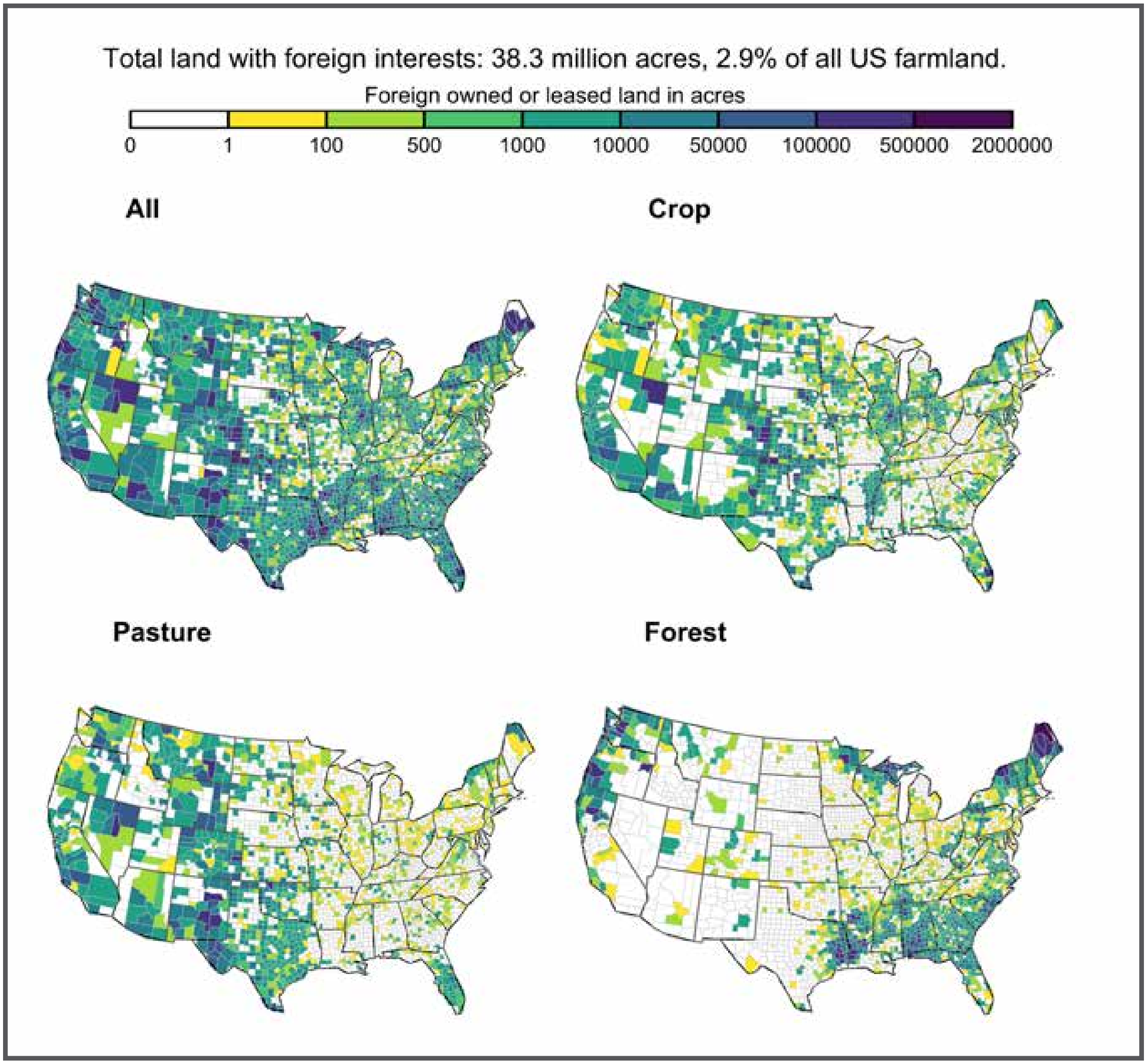

Figure 1. Foreign ownership of U.S. farmland by all countries as of 2020

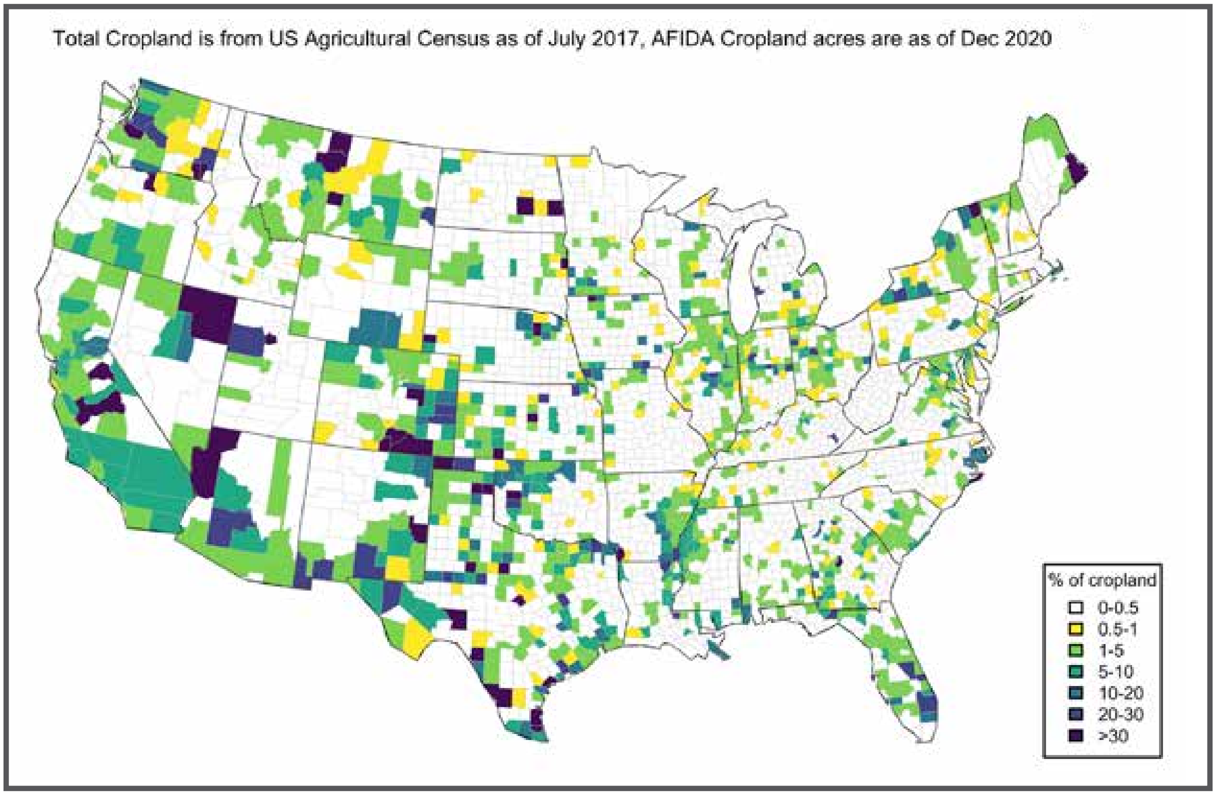

Figure 2. Percent of privately held cropland held by all foreign owners as of 2020

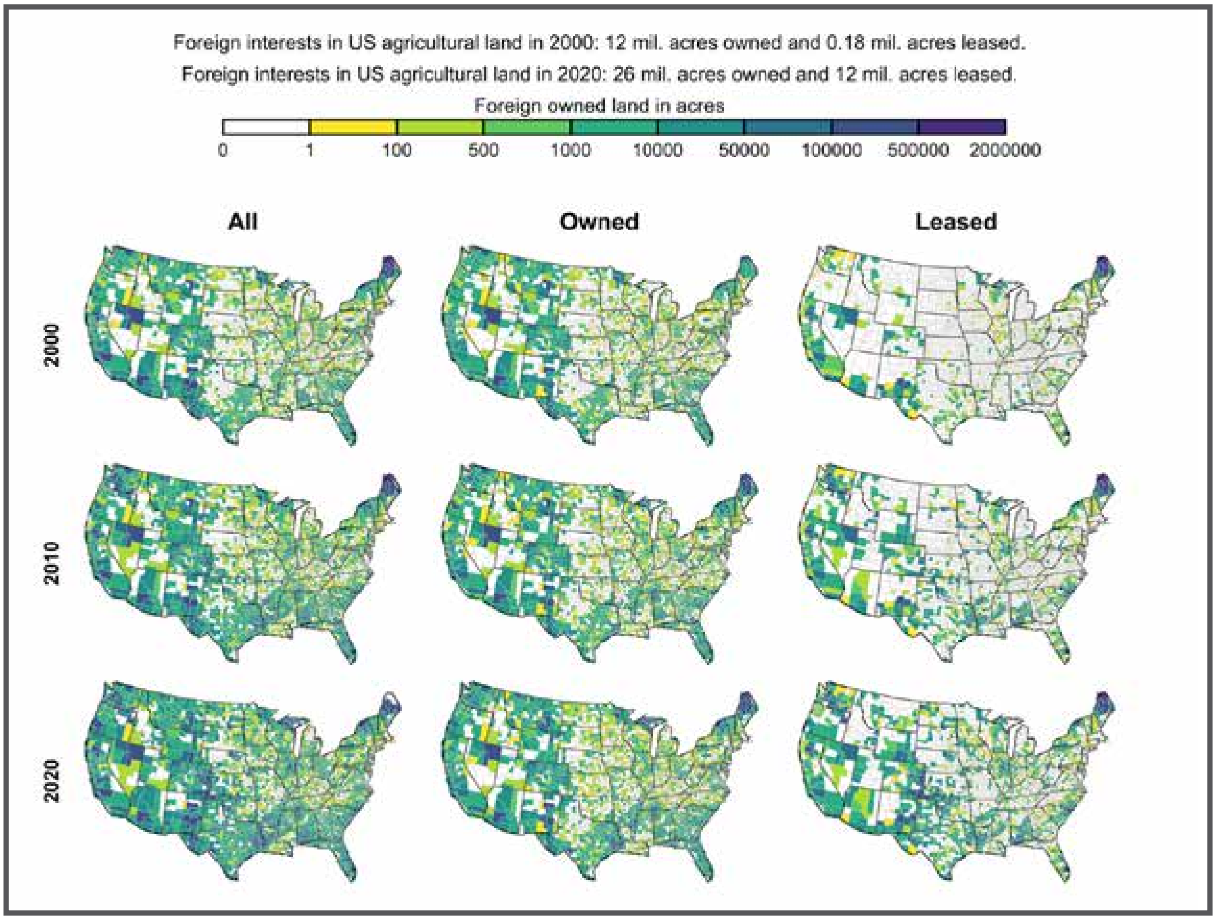

Figure 3. Foreign interests in U.S. farmland by all countries as by 2000, 2010, and 2020

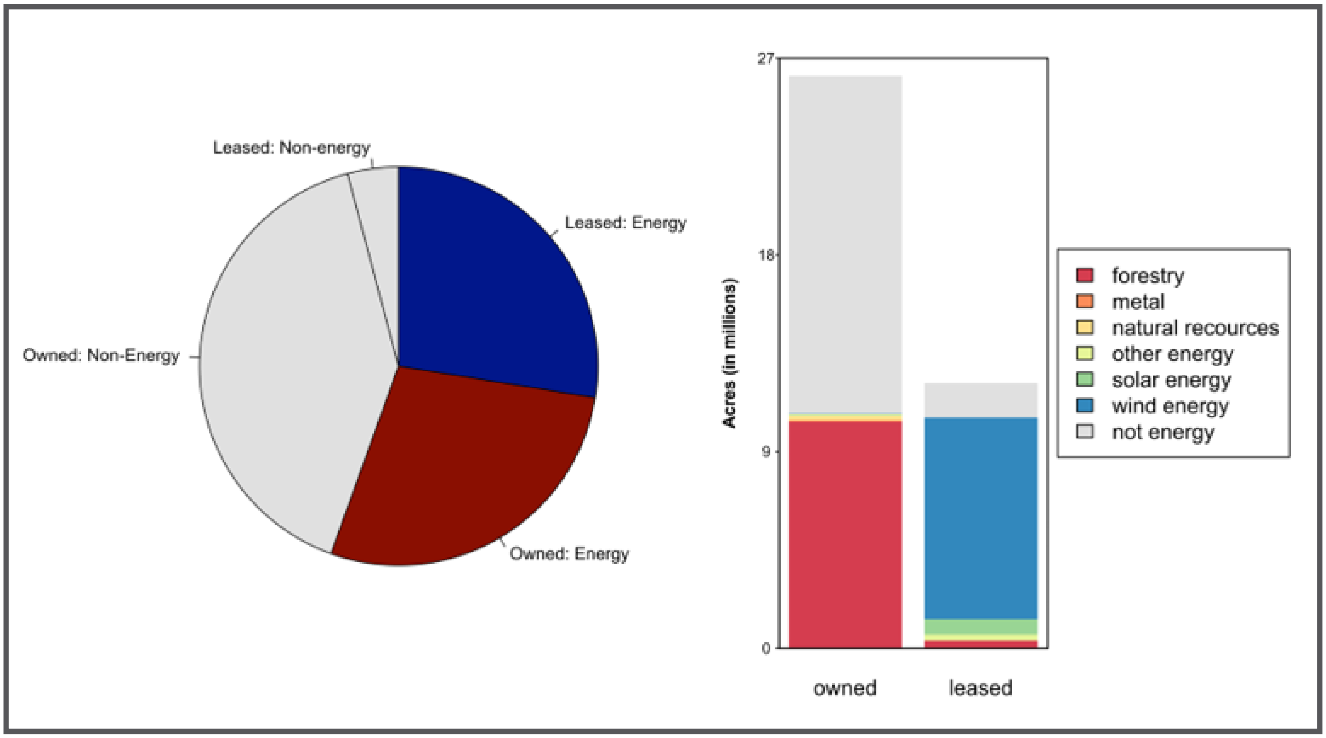

Figure 4. The significance of energy companies in foreign interests in U.S. farmland

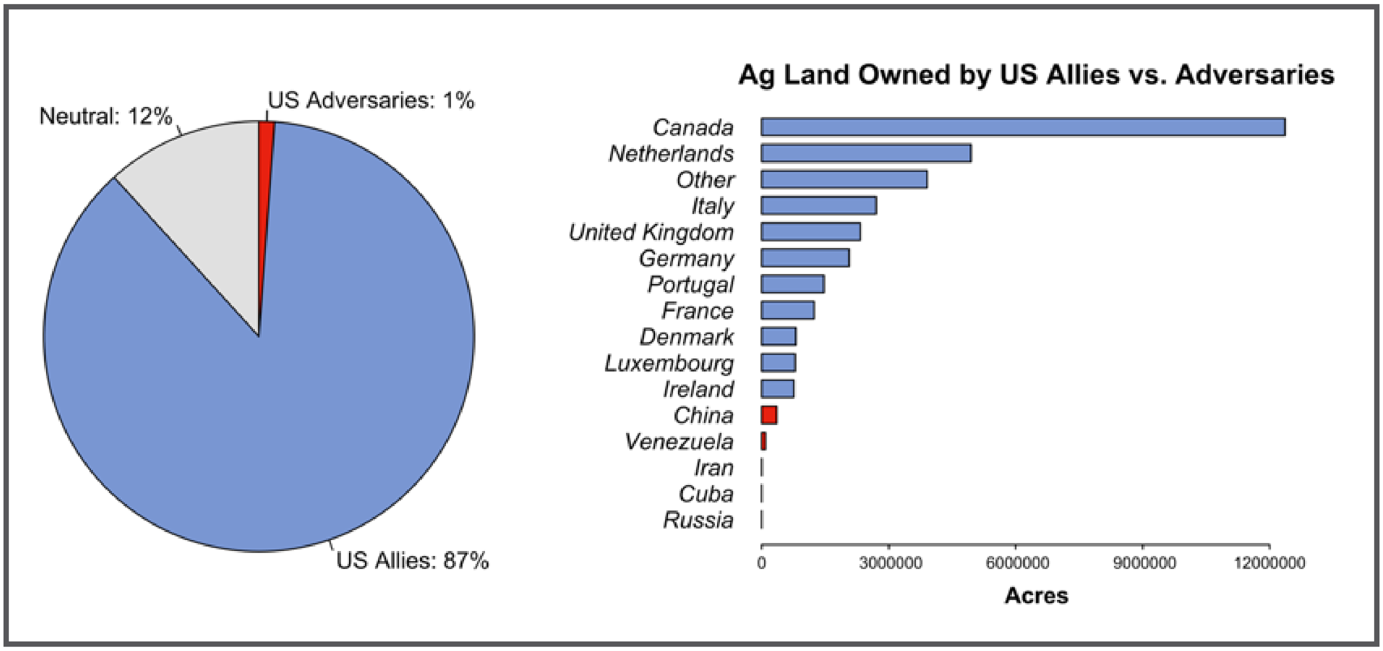

Figure 5. U.S. farmland owned or leased by U.S. allies versus U.S. “adversaries”

Table 1. Foreign Interests in U.S. Farmland by Foreign Country and USDA Farm Production Region.

	US Allies					Adversaries				
	Canada	**Netherlands**	**Italy**	**United Kingdom**	**Germany**	**China**	**Russia**	**Venezuela**	**Iran**	**Cuba**
Appalachia	163963	472156	59859	127847	84247	63294	11	2380	428	0
Corn Belt	514078	116262	602967	134904	271725	43936	0	14247	457	0
Delta	685229	1077146	65926	183777	163106	108	0	0	0	0
Lake	482086	467284	187721	113301	48866	0	0	0	0	0
Mountain	1586880	199151	319202	528149	445635	47770	0	20835	0	0
Northeast	3313311	358519	4771	137428	100562	2936	761	3513	788	0
Northern Plains	981433	23483	697491	118329	64605	0	0	0	169	0
Pacific	1258951	357190	12496	658770	125353	13589	40	1500	1507	0
Southeast	627414	1432449	23032	160097	395669	16729	0	46006	11	10
Southern Plains	2477418	403923	729406	164102	353102	163288	10	1137	964	838
Total	12090763	4907565	2702871	2326704	2052870	351651	822	89618	4324	848

Note:
USDA Farm Production Regions (Cooter et al., 2012)
Available at: https://www.researchgate.net/figure/USDA-Farm-Production-Regions_fig2_235609824

APPENDIX

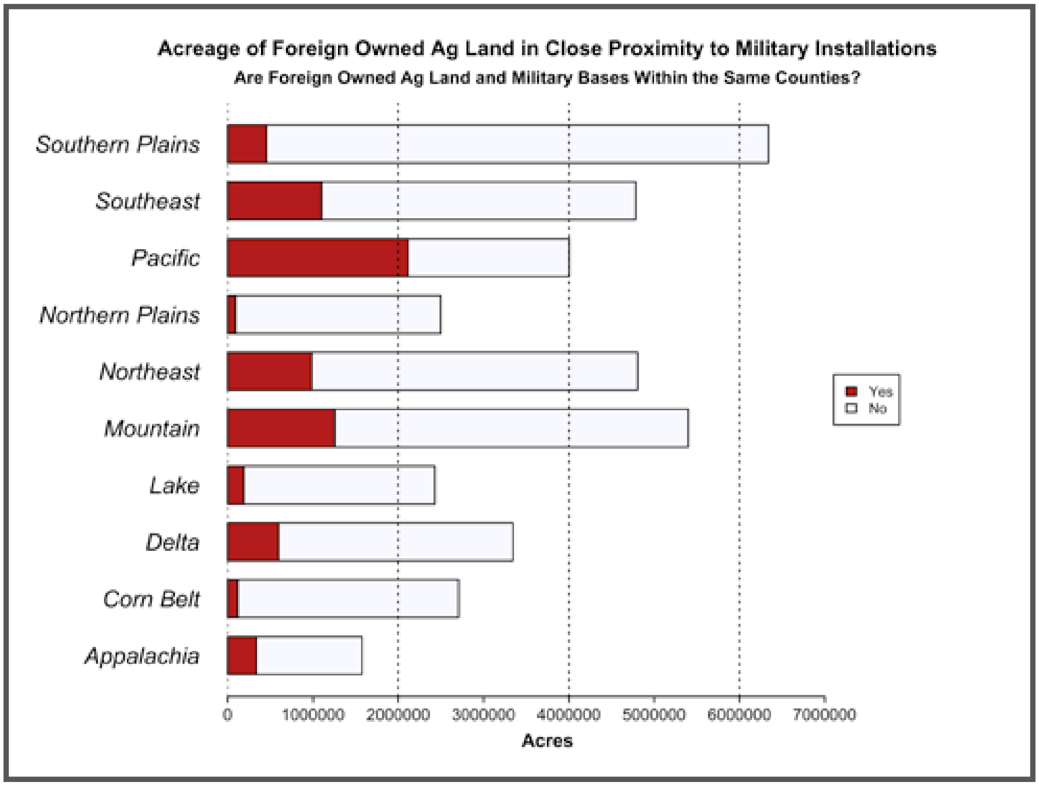

Figure A. Foreign interests by counties with or without military installations

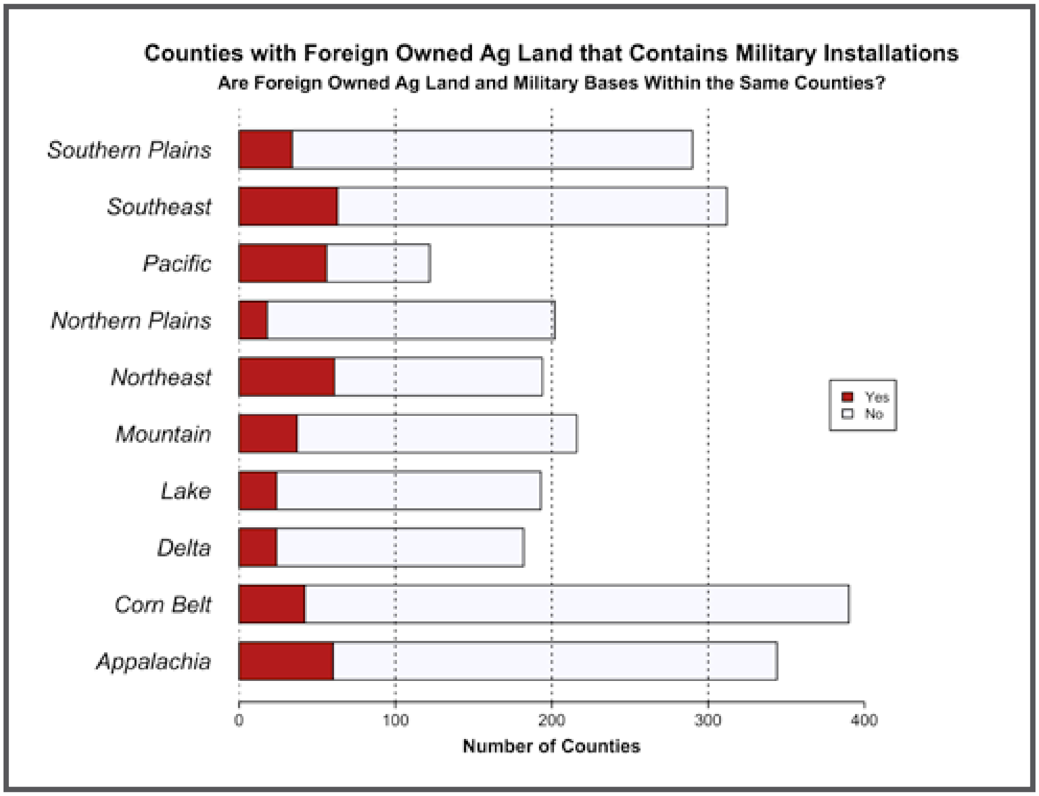

Figure B. Counties with foreign-owned ag land that contains military installations

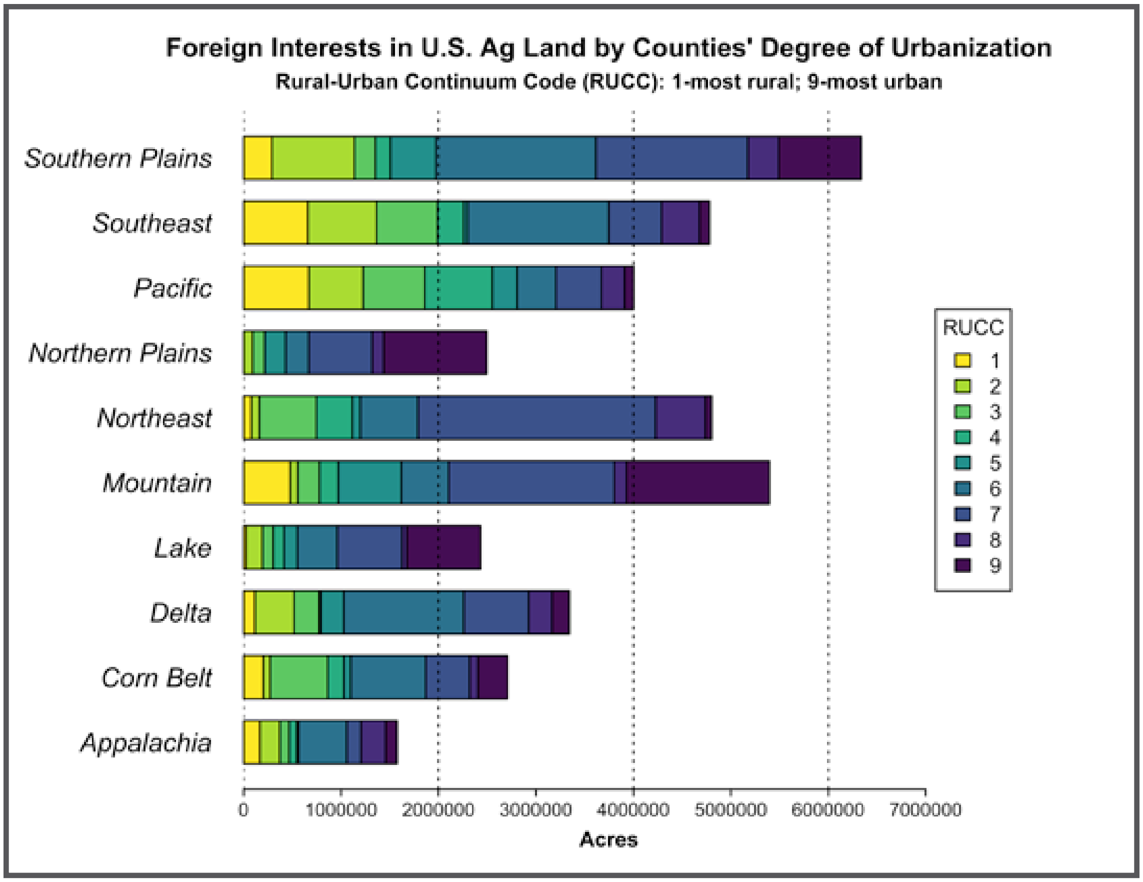

Figure C. Foreign interests in U.S. ag land by degree of urbanization

Submission Guidelines

JOURNAL OF THE ASFMRA

The *Journal of the ASFMRA* is an open-access online journal published each year by the American Society of Farm Managers and Rural Appraisers. The *Journal's* editorial board consists of the editor and members of the ASFMRA Editorial Task Force, which includes academic and professional members of the ASFMRA. It is a refereed journal, with the Editorial Task Force serving as peer reviewers.

The *Journal of the ASFMRA* seeks to publish manuscripts that discuss cutting-edge farm management, rural appraisal, and/or agricultural consulting practices, as well as recent research projects whose findings are relevant to professional farm managers, rural appraisers, and agricultural consultants. Academics and industry professionals are encouraged to contribute their expertise by submitting manuscripts for publication. The *Journal* seeks to be the first resource that academic and industry practitioners turn to for state-of-the-art information on the rural property professions.

OBJECTIVES

The objectives of the *Journal* are to:

1. Present papers relevant to farm managers, rural appraisers, agricultural consultants, academics, students, and others interested in the rural property professions.

2. Encourage practical problem-solving contributions highlighting established and cutting-edge farm management, rural appraisal, and agricultural consulting principles and practices.

3. Provide academic authors an opportunity to publish their practical research, and industry professionals an outlet to share their "from the field" experience, in order to reach a broad audience.

AUTHOR GUIDELINES FOR SUBMITTING MANUSCRIPTS

To submit a manuscript for publication consideration in the *Journal of the ASFMRA*, please send all required materials as email attachments to Publications@asfmra.org, using the following guidelines to prepare the submission:

1. **Cover Letter.** In a cover letter accompanying the manuscript, (a) indicate why the manuscript would interest *JASFMRA* readers; (b) certify that the material in the submitted manuscript (or modification thereof) has not been published, is not being published, and is not being considered for publication elsewhere; and (c) stipulate that the material in the manuscript, to the best of the author's knowledge, does not infringe upon other published material protected by copyright.

2. **Title Page.** On a separate page, provide the title of the manuscript and author(s)' name(s) centered and in boldface type. At the bottom of the same page, provide authors' title(s); institutional affiliation(s); and acknowledgments of colleague reviews and assistance, and institutional support, as appropriate. Please provide the corresponding author's address, phone number, and e-mail address. Do not place the name(s) of the author(s) on the first page of the text.

3. **Abstract.** Include an abstract of 100 words or fewer.

4. **Manuscript Title.** Manuscript titles should not exceed ten words, should encompass the topic of the paper, and should be designed to attract potential readers.

5. **Style, Grammar, and Punctuation.** The *JASFMRA* uses *The Chicago Manual of Style* by the University of Chicago Press, and *Webster's Third New International Dictionary* for style, format, and spelling.

6. **Manuscript Format Guidelines.** Manuscripts should be approximately 5,000 words in length or fewer, not counting the references or footnotes. Manuscripts must be submitted as Microsoft Word documents, double-spaced using 12-point Times New Roman font. Please use left justification and allow 1" margins on all sides. All pages and lines must be numbered, with line numbers running consecutively throughout the manuscript.

7. **Footnotes.** Number footnotes consecutively throughout the manuscript. Combine all footnotes on a separate page immediately following the manuscript text, rather than at the bottom of manuscript pages.

8. **References/Text Citations.** In a reference section immediately following the footnotes page, list all works cited in the text, alphabetized by author last name. Refer to *The Chicago Manual of Style* for formatting. For within-text citations (either parenthetical or as part of narrative), spell out up to three author last names; use first author's name followed by "et al." for works with four or more authors. When citing a direct quotation, include page number(s) from the author's work. List complete URLs for online sources.

9. **Figures and Tables.** Place each table, chart, figure, and/or photo on a separate page within the manuscript at its first mention. Include a short, self-contained title/caption for each. Please also include a separate Microsoft Excel version of each table and chart, and a separate high-resolution image for each figure or photo (.pdf, or .jpg format).

10. **Math/Equations.** Use only essential mathematical notation with equations consecutively numbered throughout the text. When displaying equations, place equation number within parentheses at flush-left margin and center the equation. Use italic type for all variables, both within equations and within the narrative.

11. **Submission Deadline.** In general, September 15th of each year is the deadline to submit a manuscript for publication in the following year's Journal.

12. **The Editorial Review Process.**

    a. The Chair of the ASFMRA Editorial Task Force, serving as Editor, assesses the initial suitability of articles submitted.

    b. Authors of submissions considered to be potentially suitable for the *JASFMRA* will be notified and their paper sent to three members of the ASFMRA Editorial Task Force, who will review the article for the Editor.

    c. Unsuitable articles are returned to the authors with a short note of explanation from the Editor. Failure to adhere to the Manuscript Format Guidelines will be cause for the manuscript to be returned to the authors.

    d. The review process is double-blind: The identity of the author(s) remains anonymous to the reviewer and vice versa.

    e. Following review, authors may be asked to resubmit their article in revised form for additional review.

    f. Upon completion of the review and editorial processes, authors will be notified of the Editor's decision regarding publication along with explanatory feedback, including reviewers' reports.

    g. Decisions on submitted manuscripts will be made following the Editorial Task Force's meeting at the ASFMRA Annual Conference each November, with notifications generally sent to corresponding authors by early December. The decision of the Editor is final.

13. **Publication Costs.** Authors submitting manuscripts are expected to assume obligation for payment of page charges at the time their manuscripts are published. Current page charges are $95/printed page for non-members and $80/page for ASFMRA members.

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