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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 2023 issue of the *Journal of the ASFMRA*. We received a significant number of manuscript submissions for this year's issue, and the fourteen 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.

Last year, select authors featured in the 2022 issue of the *Journal* were invited to present their papers at a special session at the 2022 ASFMRA Annual Conference. Thanks to extremely positive feedback, I am happy to announce that we will once again host a *Journal*-focused session at the upcoming 2023 ASFMRA Annual Conference, featuring select authors from this current issue.

The Editorial Task Force and I are also excited to announce that plans are in the works for a rural appraisal-focused special issue of the *Journal*, with an anticipated 2024 publication date. This will be the first of what we hope will be many special-topics issues of the *Journal*, which will complement our regular annual issue.

As I conclude my second 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 pursue new initiatives to elevate the visibility and impact of the *Journal*. I hope to see you in Nashville in November 2023 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*. I look forward to what the future holds.

Maria A. Boerngen, Ph.D.
Chair, ASFMRA Editorial Task Force and Editor, *Journal of ASFMRA*

2022–23 Editorial Task Force

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Suitable Fieldwork Days Required to Plant Arkansas Rice Crop

By Bayarbat Badarch and K. Bradley Watkins

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Abstract

This paper examines the number of acres planted per fieldwork day and the number of fieldwork days available for planting the entire rice crop in Arkansas using Arkansas's crop progress and condition report data from 1981 to 2022. The average maximum acres planted per suitable fieldwork day in Arkansas rice crop is 58,926, and the average minimum number of suitable fieldwork days required to plant the entire Arkansas rice crop is 23. The average number of weekly fieldwork days for Arkansas's optimum rice planting window (late March through the third week of May) is 4.5 days.

INTRODUCTION

The number of days available to plant rice in Arkansas during the planting season will depend on spring weather conditions each year. Different spring weather every year can make planting decisions difficult for rice producers. Weather dictates the number of days suitable for planting a crop and can lead to a shortened planting window or later planting dates. For instance, in spring 2013, 2019, 2020, and 2022, Arkansas crop producers had excessive rainfall that affected the timing of rice planting and shortened the available planting window. In 2013, 2019, and 2020, Arkansas experienced record-high numbers of rice-prevented planting acres due to excessive rainfall and flooding (Watkins and Gautam, 2021).

A shorter planting window caused by extreme weather variability can negatively affect crop yield potential. Extreme weather events such as excessive spring rainfall and cooler-than-average temperatures can reduce the number of suitable fieldwork days available to producers and push rice planting to later dates. The *Arkansas Rice Production Handbook* indicates that rice planted early generally has larger yields relative to rice planted later and recommends optimum planting dates ranging from March 28 to May 20 in eastern Arkansas (Hardke et al., 2021). Planting rice outside of these dates can significantly reduce rice yields. A late planting season can also lead to delayed harvest in the fall, where rain and dew could lead to reduced rice kernel quality and more considerable drying costs associated with the late harvest (Lu et al., 1995). Technological advances have occurred over time to speed up the planting of rice. For example, grain drills have grown in width over time, allowing more acres to be planted per hour. Planting is one of the fastest machinery operations conducted during the production season. The problem is not so much the speed of planting the rice crop but the ability to enter the field to plant rice in a timely manner.

In addition, crop insurance can also affect planting decisions by dictating when rice may be planted for producers to receive crop insurance or by providing key final planting dates to ensure producers receive the full revenue guarantee. The earliest rice may be planted in Arkansas to receive crop insurance is April 1.

The final planting date for rice to receive the full revenue guarantee in Arkansas is May 25, and the late planting period ends 15 days after the final planting date (June 9). During the late planting period, the revenue guarantee declines by 1% daily (USDA RMA, 2023).

Rice producers purchase revenue protection (RP) and yield protection (YP). However, they tend to purchase these products at lower coverage levels relative to corn and soybean producers in the Corn Belt due to rice being an irrigated crop. They see irrigation as "insurance" against yield risk. The main risks rice producers face are those associated with price variability and those associated with increased input expenses, particularly those related to fossil fuels (irrigation energy expenses, fertilizer, diesel fuel for machinery operations). A large number of rice acres are covered by catastrophic insurance (Mane and Watkins, 2015). Rice producers purchase crop insurance primarily for prevented planting coverage, downed rice endorsement, and replanting coverage. Rice producers often choose YP at 50% buy-up coverage over catastrophic insurance (also 50% yield coverage) due to a larger prevented planting revenue guarantee for the former and because the downed rice endorsement and replant coverage are not available for catastrophic insurance but are available for YP (and for RP). Government payments do not play a role in the rice planting decision, as payments received by rice producers are decoupled. Rice producers accept payments on rice base acres regardless of whether rice or some other crop is planted. Market conditions determine what will be planted on rice base acres (rice, soybeans, or corn), but the planting decision itself is not affected by government programs.

Most farmers grow more than one crop because of crop rotation, diversification, and profitability. However, planting multiple crops on a tight spring schedule can be hectic and challenging. Therefore, reviewing the historical planting progress data for rice crops and figuring out essential metrics that bring imperative knowledge on rice planting decisions for producers is the goal of this paper. This paper aims to estimate the minimum number of days required to plant the Arkansas rice crop based on historical data. We also want to compare the year-to-year variability associated with this number and the likelihood of having sufficient suitable fieldwork days available for planting a rice crop on time. We base our analysis on weekly crop progress and condition report data and annual rice planted acreage data collected from USDA NASS for 1981–2021. This information will give rice producers better information for planting future rice crops.

LITERATURE REVIEW

A handful of research articles have been done using historical weekly crop progress and condition report data collected from USDA NASS (Irwin, 2022; Massey, Carpenter, and Gerlt, 2022; Shockley and Mark, 2017; Griffin and Kelley, 2011; Enz, Helm, and Brenk, 1991). Each article focused on suitable fieldwork days for a specific time frame (planting and harvesting), but their research objectives and study regions differed, which makes them unique from each other. Therefore, reviewing some of them and discussing their significant findings in this section is worthwhile.

Irwin (2022) evaluated Illinois's historical corn planting progress data from 1980 to 2021. This paper showed the maximum number of acres of corn planted in Illinois per suitable fieldwork day, the minimum number of fieldwork days required to plant the Illinois corn crop, and the distribution of suitable fieldwork days available per week in the spring for planting the corn crop. The research found no significant trend in the maximum corn acreage planted per suitable fieldwork day, with an average of 800,000 acres per day. This means, on average, the maximum planting rate per suitable day has not increased or decreased over time at the state level. Moreover, no significant trend was found for the minimum days required to plant corn for the entire state, averaging around 14 days. The average number of suitable fieldwork days in Illinois during April and May was estimated at 3.6 per week. These quantitative findings are beneficial for referencing the Illinois corn planting progress when massive weather disruptions happen in the future. Corn producers can compare their numbers to state averages and plan their planting progress according to the critical dates, mainly for crop insurance purposes. Due to most of the rice crops in Arkansas being irrigated, the different protection programs' coverage levels may not be relatively the same as the coverage levels for corn and other crops in the various regions; however, the final planting date for rice crop is a significant decision-making factor in Arkansas.

Massey, Carpenter, and Gerlt (2022) focused on Missouri's suitable fieldwork days from 1977 to 2017. This paper quantified probabilities for the number of fieldwork days available during the April–May period (planting) and the September–October period (harvest). The paper also quantified the average weekly fieldwork days for the state and the state's NASS reporting districts. Missouri farmers may use data from this study to calculate better machinery needs for completing planting and harvesting operations.

Shockley and Mark (2017) conducted similar research on Kentucky's suitable fieldwork days from 1996 to 2016. The paper estimated the percentile in three criteria (15% for bad year, 50% for median year, and 85% for good year). The paper also provided graphical comparisons of the estimated days suitable for fieldwork for corn and soybean crops in Kentucky for bad, median, and good years. The authors stated that farmers might use the data to calculate machinery capacity requirements for farming operations.

Griffin and Kelley (2011) evaluated historical Arkansas suitable fieldwork days. Their data covered from 1975 to 2009 and focused on the likelihood of specific numbers of days suitable for fieldwork for rice, soybeans, and cotton during each respective crop's planting season. The authors also reported the expected days suitable for fieldwork for typical planting windows for rice, soybeans, and cotton. They found that 18.1, 28.3, and 13.2 fieldwork days were available for planting rice, soybeans, and cotton, respectively, during an average year. In bad years, the number of fieldwork days available shrunk to 12.4, 18.4, and 8.8 days for planting rice, soybeans, and cotton, respectively.

Potential fieldwork days were researched in North Dakota in the early 1990s. Enz, Helm, and Brenk (1991) found that the number of suitable planting days in North Dakota averaged around 25 days; however, it varied widely from one region to another and one year to another. Moreover, the southeastern region has the advantage of rapid increase of days due to its suitability in the early spring, early snowmelt, ground thaw, and warmer temperature. This paper's most interesting statement was that the cost of additional or scaled planting equipment necessary for a worst-case scenario is much greater than yield reductions associated with late planting. In other words, adding capital investment to the planting operation can put a massive burden on farm finances compared with low crop yield from late planting.

The papers we reviewed in this section utilized their selected states' or regions' crop progress and condition data, but each paper had its objectives and purposes. Our paper also uses crop progress and condition data; however, it focuses on estimating the number of acres planted per fieldwork day and the number of days available for planting the entire rice crop in Arkansas.

METHODOLOGY

This paper follows the procedures used by Irwin (2022). We base our analysis on weekly USDA crop progress and condition report data for rice in Arkansas (USDA NASS, 2022a) along with Arkansas rice planted acreage data for the period between 1981 and 2022 (USDA NASS, 2022b), supplemented by Arkansas days suitable for fieldwork data from Griffin (2009).

Based on Irwin (2022), our estimation procedures are as follows:

1. We estimate the maximum Arkansas rice acres planted per suitable fieldwork day for each year by multiplying each week's rice planting progress percentage for a given year by the total rice acreage planted each year, summing the two peak weekly acreages, and dividing them by their respective sum of suitable fieldwork days.
2. We calculate the minimum number of suitable fieldwork days required to plant the rice crop each year by dividing the total planted rice acres by the estimated maximum rice acres planted per suitable fieldwork day.
3. We calculate a frequency distribution to determine historical probabilities for the number of available suitable fieldwork days per week during the week 13 (the last week of March) through week 20 (the third week of May) planting window in Arkansas.

Figure 1 presents Arkansas's 2020 rice planted acres by county. Approximately 95% of the rice acres are planted in eastern Arkansas, with the most significant area being northeast Arkansas, east-central Arkansas, and southeast Arkansas. Some rice acres are planted in the Arkansas River Valley and along the Red River in southwest Arkansas.

RESULTS AND DISCUSSION

Descriptive statistics for the data used in this paper are presented in Table 1. A couple of observations can be gleaned from Table 1. First, the mean number of rice planting days per week for 2011–2022 is numerically smaller than the mean number of rice planting days per week for the other periods presented in the table. The 2011–2022 period experienced episodes of extreme precipitation and flooding and resulted in record levels of prevented planting rice acres for the years 2013, 2019, and 2020 (Watkins and Gautam, 2021). Thus, the average number of days available per week for planting rice is smaller for this period relative to previous periods presented in Table 1. Second, the mean percents of rice acres planted by the end of April are smaller for the 1981–1986 period (29%) and 1987–1998 period (45%) than for the 1999–2010 and 2011–2022 periods (66% and 56%, respectively), implying rice was planted later in the 1980s and 1990s than in the most recent couple of decades. Based on a conversation with Jarrod Hardke, Rice Extension Agronomist for the University of Arkansas System Division of Agriculture, the earlier planted rice in the 2000–2022 years is mainly due to improvements in seed drill technology (more uniform seed depth and seed placement in furrows). The broader adoption of fungicide and insecticide seed treatment has allowed rice to be planted much earlier in recent decades. In addition, previous studies have shown that early rice planting brings higher yields regardless of seed variety. Due to irrigation technology adaption in the rice acres, most producers can manage the rice yield and plant rice early to some degree.

The maximum rice acres planted per suitable fieldwork day in Arkansas from 1981 to 2022 are presented in Figure 2. The variation in maximum rice acres planted per suitable fieldwork day is noticeably different from year to year, specifically between 2000 and 2014. This variation implies that weather conditions change the number of suitable fieldwork days available for planting rice every spring, which impacts planting progress each year. Therefore, it isn't easy to project what next spring will bring us and what to expect in the next planting season. Based on the graph, the trend for maximum planted rice acres in Arkansas has not noticeably changed over the study period, meaning there is no significant upward or downward trend. Overall, the average stays around 58,926 acres per suitable fieldwork day. Gautam and Watkins (2021) found the trend of total rice acres was reasonably consistent in the past eight census years, staying at around 1.3 million acres since 1982. Irwin (2022) also found no significant trend in Illinois's maximum corn acres planted per suitable fieldwork day from 1980 to 2021.

The minimum suitable days required to plant rice in Arkansas are presented for the period 1981–2022 in Figure 3. In other words, we answer the question of the minimum number of days rice producers need to plant the rice crop in Arkansas each year. Noticeably, the minimum number of days varies greatly by year due to variations in weather, especially between 2000 and 2020. The long-term average number of days needed to plant the rice crop stays at around 23 days, with no significant trend up or down in the past 42 years. Thus, a minimum of 23 suitable fieldwork days are generally needed on average to plant the entire Arkansas rice crop based on historical data. Irwin (2022) also found no significant trend in the minimum number of fieldwork days required to plant the corn crop in Illinois using data from 1980 to 2021. He concluded that at least 14.3 days were needed on average to plant the corn crop in Illinois. Griffin and Kelley (2011) estimated 18.1 days were available for rice planting between April 11 and May 9 from 1975 to 2009 during average years. Our number is likely a bit higher because the Griffin and Kelley estimate is not based on planting all rice acres in a growing season as is our number but rather represents the number of suitable fieldwork days available on average for a specific planting window (April 11 through May 9). In addition, the rice planting in Arkansas today can be much earlier than the early date used by Griffin and Kelley in 2011 (April 11) due to improvements in grain drill seed placement and increased usage of fungicide and insecticide seed treatment that have occurred over time, as mentioned earlier in our paper.

The number of minimum days available for planting the rice crop varies significantly from year to year due to weather conditions, as shown in Figure 3. The years 1985, 2003, 2007, 2011, 2013, and 2019 all have minimum suitable fieldwork days for planting rice in excess (plus one standard deviation or more) of 23 days. In 1985 and 2007, rice planting was delayed due to unusually cooler temperatures in the early spring. In years 2003, 2011, 2013, and 2019, we had excessive rainfall in spring months at most locations in eastern Arkansas. Alternatively, years experiencing warm, dry weather in the spring (1982, 1992, 1993, 1994, 2002, 2005, and 2017) all had minimum suitable field days for planting rice below 23 days (minus one standard deviation or more). Thus, it makes sense why some years require more suitable fieldwork days to plant the rice crop than others.

The historical distribution of suitable fieldwork days per week for rice in Arkansas from week 12 (late March) through week 20 (the third week of May) is presented for the period 1981–2022 in Figure 4. As expected, there is a wide range in the number of suitable fieldwork days per week, reflecting extremes in weather. For instance, there is a 23% chance of either one, two, or three suitable fieldwork days occurring per week and an almost 50% chance of either five, six, or seven fieldwork days occurring per week. The average number of suitable fieldwork days per week is 4.5. Rice producers may use this information to estimate the number of days available to complete rice planting in years when rice planting has been delayed due to extreme weather. For instance, if most of a producer's rice acres have not been planted by the end of April due to weather conditions, the rice producers have roughly three weeks left to complete rice planting within the optimal planting window. Assuming the average of 4.5 suitable fieldwork days over the next three weeks, the rice producer would expect to have approximately 13.5 days available to plant the remaining rice acres. The producer then can decide to plant rice or other crops (e.g., soybeans or cotton) based on the economic feasibility.

SUMMARY AND CONCLUSION

Planting windows shortened due to cool weather and excess rainfall in the spring can result in later planting of rice, potentially later rice harvests, and ultimately lower rice yields, reduced rice quality, and reduced profitability. In this paper, we review Arkansas's historical rice planting data for 1981–2022 and quantify critical statistics related to timely rice planting in Arkansas to provide helpful insights to rice producers. The conclusions of our analysis are as follows:

1. The maximum rice acres planted per suitable fieldwork day in Arkansas during the past 42 years has not markedly changed. The overall average is 58,926 rice acres planted per suitable fieldwork day over the study period. The maximum fluctuates yearly due to weather conditions, varying between 35,000 and 94,000 acres per suitable fieldwork day. However, there is no indication of an upward or downward trend in the peak rate of rice planting per suitable fieldwork days in Arkansas.

2. The minimum number of suitable fieldwork days necessary to plant the entire rice crop in Arkansas has historically averaged around 23 days but ranges from 17 to 34 days. It is plausible that excessive precipitation has played the most prominent role in the upper variation of this number. No linear trend exists in the data, suggesting that the minimum number of suitable fieldwork days required to plant the Arkansas rice crop has remained steady over the 23 days on average.

3. Our data indicate that the variation around the means of the previous two statistics has been more pronounced over the past couple of decades (2000–2022). Untimely or extreme precipitation events have significantly delayed impacts on the timing of rice planting during the 2000 and 2022 period relative to the 1980s and 1990s, and our data bear this out.

4. The weekly average number of suitable fieldwork days per week is 4.5 from week 12 (the last week of March) to week 20 (the third week of May) over the study period. However, a wide range of probabilities exists in the number of suitable weekly fieldwork days for the given planting window. Historically over the 42 years, the likelihood of having only one, two, or three suitable fieldwork days per week is 23%, whereas the likelihood of having either five, six, or seven suitable fieldwork days per week is almost 50% during the given planting window.

A shortcoming of this study is that Arkansas crop progress and condition report data are reported only for eastern Arkansas as a whole rather than for specific regions in eastern Arkansas. Due to changing weather conditions, the number of weekly fieldwork days would vary somewhat when moving from south to north. Crop progress and condition data by USDA NASS crop reporting district rather than for eastern Arkansas as a whole could have added accuracy to our analysis if such data were available. This study found no significant trend over time in the number of suitable fieldwork days required to plant the rice crop but did find considerable variation around the mean due to weather. Thus, a potential topic of further study would be to better regress suitable fieldwork days against precipitation and temperature to understand the impacts of weather on available fieldwork days. Finally, our analysis has focused exclusively on rice planting progress in Arkansas. Other crops, such as soybeans, cotton, and corn, are commercially grown in eastern Arkansas, and it would be interesting to investigate their planting progress numbers. Thus a natural extension of this study would be to apply a similar analysis to these other essential crops grown in Arkansas.

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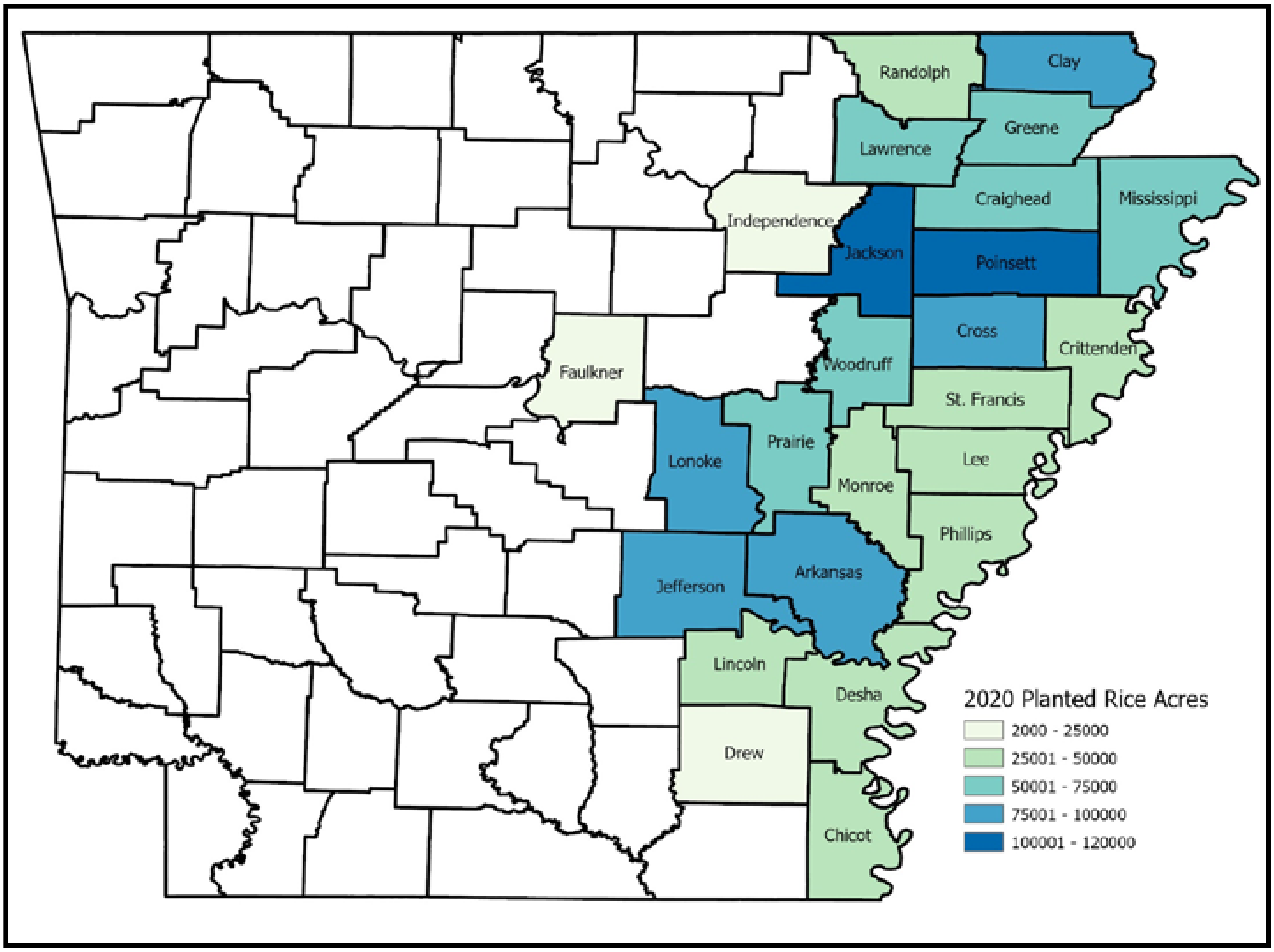

Figure 1. Arkansas planted rice acres in 2020

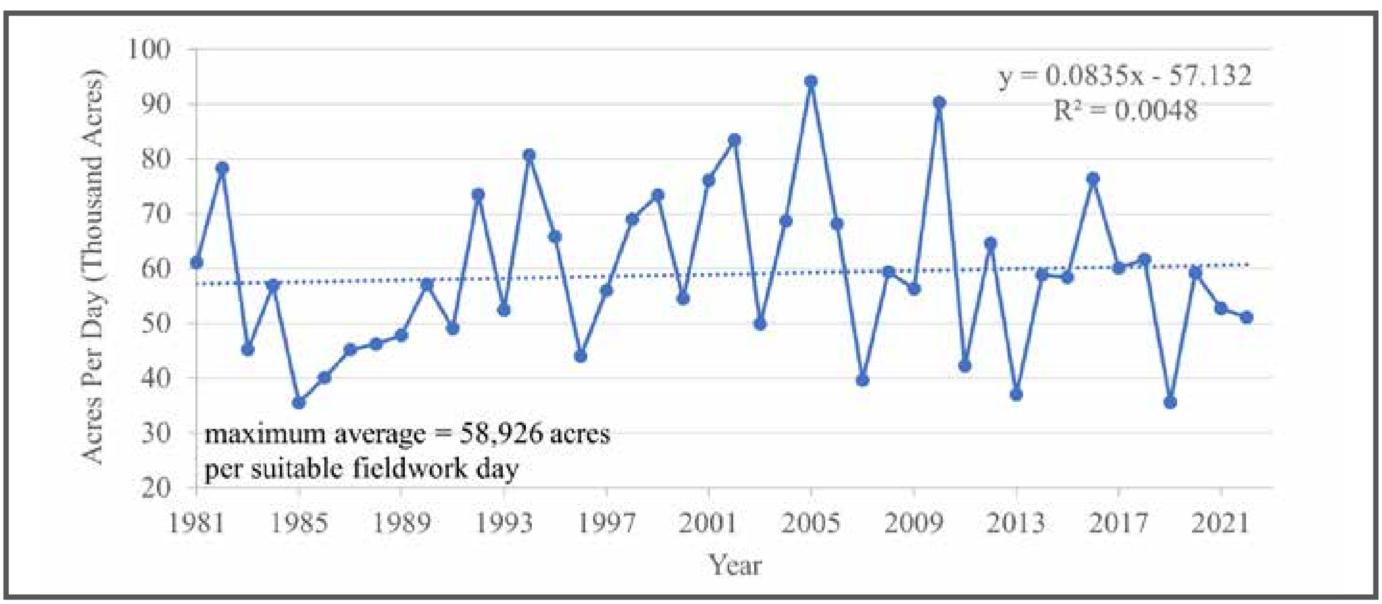

Figure 2. Maximum rice acres planted per suitable fieldwork days in Arkansas, average of two peak weeks, 1981–2022

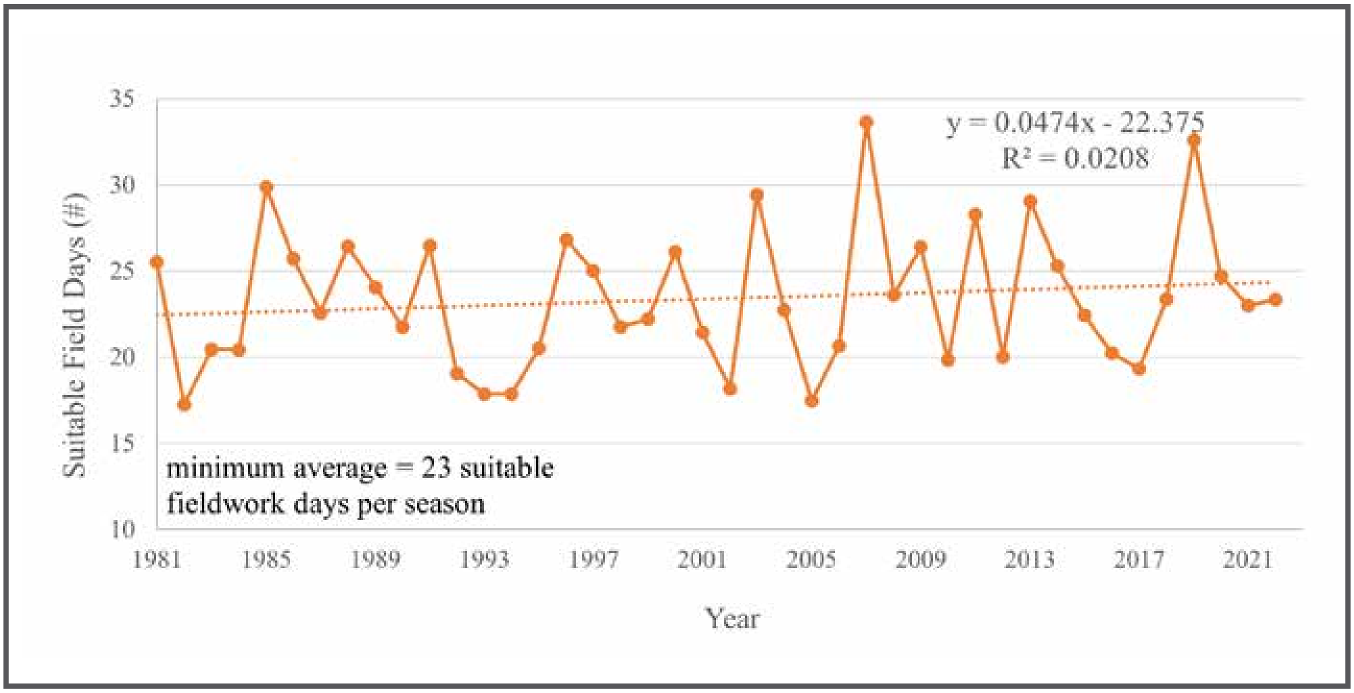

Figure 3. Minimum suitable fieldwork days required to plant rice in Arkansas, 1981–2022

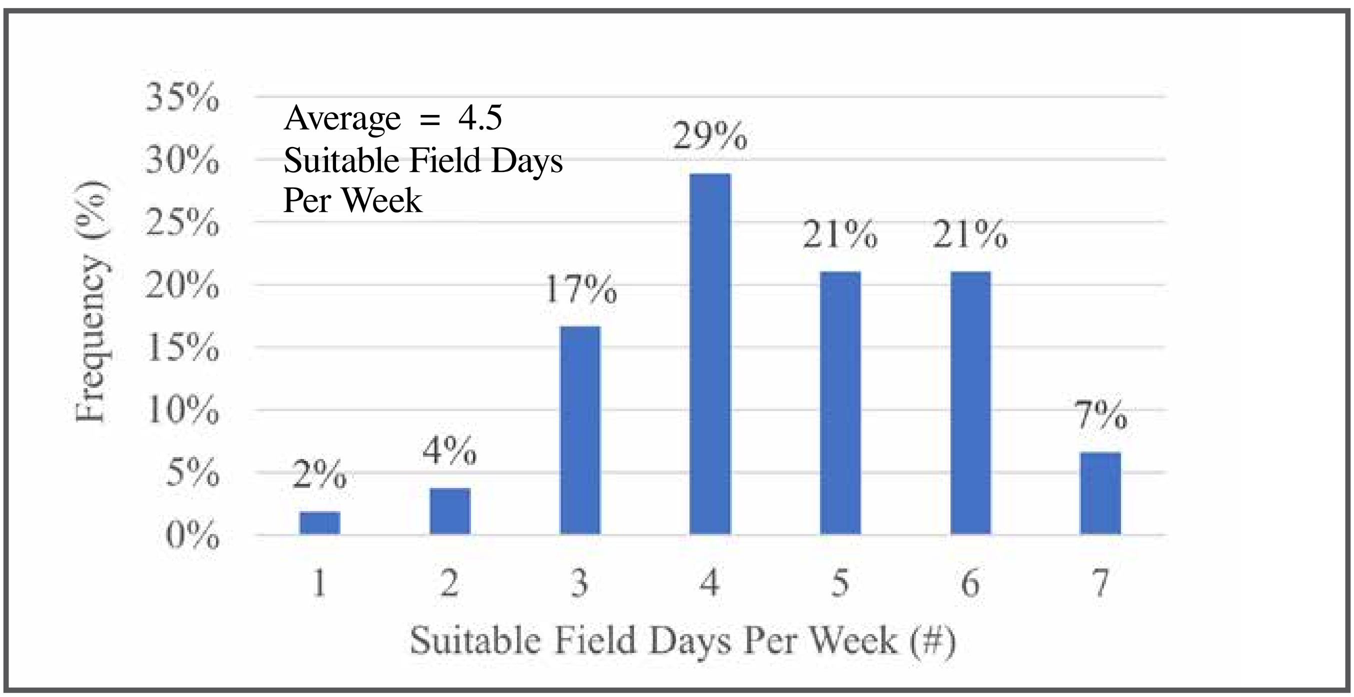

Figure 4. Distribution of suitable fieldwork days per week for rice in Arkansas, last week of March through the third week of May, 1981–2022

Table 1. Descriptive Statistics for Arkansas Rice Planting Days Per Week, Planted Acres Percent, and Total Planted Acres, 1981–2022								
	Mean		St. Deviation		Minimum		Maximum	
Period	Rice Planting Days per Week[a]	Percent Acres Planted[b]	Rice Planting Days per Week	Percent Acres Planted	Rice Planting Days per Week	Percent Acres Planted	Rice Planting Days per Week	Percent Acres Planted
1981–1986	4.61	29%	1.24	14%	2.00	14%	7.00	48%
1987–1998	4.85	45%	1.30	22%	3.00	9%	7.00	78%
1999–2010	4.65	66%	1.33	17%	1.20	37%	7.00	90%
2011–2022	4.04	56%	1.40	22%	0.60	33%	7.00	92%
1981–2022	4.50	52%	1.37	23%	0.60	9%	7.00	92%
Acres Planted	1,342,357		191,780		925,000		1,791,000	

[a]*Rice Planting Days per Week* represents the number of suitable field days per week available for planting rice during the week 12 through week 20 planting window (roughly the last week of March through the third week of May).

[b]*Percentage Acres Planted* represents the accumulated percentage of rice acres planted through week 17 (roughly by the end of April).

Coping with Delayed H-2A Worker Arrivals during the Pandemic



By Cesar L. Escalante, Watson L. Cowart, and Vanessa P. Shonkwiler

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Abstract

Agricultural demand remains essential under all economic conditions. The recent pandemic is a case in point when the farm sector's real concern was not declining market demand but rather supply chain disruptions, such as the constrained mobility and availability of needed foreign contractual workers. Enforced border entry restrictions and strict screening procedures disrupted the flow of arrivals of foreign workers with approved H-2A visas. A survey was conducted among southeastern U.S. farms with approved H-2A petitions to verify if there were any H-2A labor supply disruptions during the pandemic. Results indicate that more than half of H-2A workers arrived 3 to 5 weeks later than expected. Popular farmers' coping strategies include maximizing family labor contributions, reducing off-farm employment hours, and resorting to less labor-intensive production alternatives.

BACKGROUND

Even as the COVID-19 pandemic's social distancing mandates substantially slowed down overall economic activity, the farm sector was poised to thrive better than other industries since farm products comprise essential goods that consumers normally prioritize in their purchase decisions at all times. Hence, the farm sector's real concern during the pandemic was not a decline in overall demand for its goods and services. Instead, it had to contend with price-related shocks and supply chain disruptions that could have been partially driven by, among other factors, the mobility and availability of the needed labor force to sustain farm operations during the pandemic (Smith and Glauber, 2020).

The existence of labor availability concerns under a period of economic contraction is counterintuitive since economic downturns are usually associated with worsening unemployment conditions. In early 2020 analysts feared that the global economy would plunge into its worst recession since World War II (Felsenthal, 2020). When social mobility constraints were in full force at that time, unemployment levels were not only high, but sectoral unemployment trends were also reversed and deviated from historical patterns. The farm sector's rates exceeded non-farm sector levels by 6% and 7.5% in March and April 2020, respectively (U.S. Bureau of Labor Statistics, 2021).

The market demand/labor supply gap was quite difficult to reconcile. If prevailing market conditions compelled farms to at least remain actively in business, if not expand, during the pandemic, then plenty of employment opportunities in farms awaited the sector's growing unemployed labor force. However, such economic logic is defied by the U.S. farm sector's employment realities usually characterized by high labor turnovers in favor of non-farm employment that persists in any macroeconomic setting (Luo and Escalante, 2017). For instance, during the Great Recession of the late 2000s, empirical evidence indicates an even more pronounced interindustry migration of workers as domestic workers abandoned the farm sector to seek employment in non-farm industries. At that time, farm businesses had to rely mostly on undocumented workers, who had nowhere else to go, given their inflexible employment options (Luo and Escalante, 2017).

Labor input substitution strategies through increased mechanization of farm operations may be a viable alternative to lessen dependence on farm labor inputs. However, smaller farm businesses find the capital cost outlay requirement of this alternative quite unaffordable (Escalante, Kostandini, and Mykerezi, 2014). Even as most U.S. farm enterprises, especially the larger farm businesses, have considered transitioning into semi- to fully mechanized operations, certain operations—such as fruit, vegetable, and horticultural production—still remain more labor-intensive as their labor wage bills account for more than 40% of their variable costs (Williams and Escalante, 2019; Calvin and Martin, 2010).

Thus, given the unreliable domestic labor force and lack of labor-substitution alternatives, the farm sector—especially the more labor-intensive farm enterprises—had to rely on contractual foreign labor supplied by the government's H-2A guest farm worker visa program when it needed workers during the pandemic. Since the launching of more aggressive immigration controls at the federal and (certain) state levels in the 2000s that effectively deported many undocumented farm workers and punished the employers that hired them (with prison terms and fines), the H-2A program remains the only legitimate option for farm businesses to hire contractual foreign workers as replacement farm workers. The program's importance in supplying the needed farm labor inputs has actually grown in recent years. In 2019 it accounted for more than 27.4% of the farming sector's total hired workers—a significant jump from about 7% ten years ago. When pandemic conditions kicked in, the government promptly released regulations to ensure continued availability of H-2A workers. These federal policies include the temporary final rule, the exclusion of H-2A visas from the federal list of suspended visa processing activities at consular offices, and granting essential travel status to H-2A–related travels.

An earlier *Choices* article (Escalante, Luo, and Taylor, 2020) analyzes national data on approved H-2A worker petitions from the United States Department of Labor (DOL) and H-2A visa approvals from the U.S. Department of State's Bureau of Consular Affairs. The article contends that the H-2A program managed to maintain an increasing trend in petition and visa approval levels even during the early period of the pandemic. The article, however, raises the issue of timely arrivals of H-2A visa holders as stricter border restrictions, medical screenings, and other entry regulations were being enforced, in addition to heightened fears and paranoia at the Mexican border that dealt with sudden outbreaks of coronavirus infections. As overall port entry and border crossing data in April 2020 registered an overall decline of about 96%, there seemed to be a higher likelihood that an impending farm labor supply gap was brewing as many U.S. farms faced the uncertainty of timely arrival of H-2A workers they were expecting to provide the much needed labor support during the 2020 spring season when most of the crops surveyed are being planted.

THE H-2A FARM EMPLOYERS' SURVEY

This article provides a reality check by presenting actual farm-level information on arrival status of expected H-2A workers during the crucial phases of the 2020 planting season in the southeastern United States. A survey was conducted among farmers in Georgia, North Carolina, and Florida—coincidentally among the top five H-2A state patrons over the past several years. The survey instrument was distributed via email to farms with approved H-2A farm labor certifications in the last quarter of 2019 as per the DOL disclosure database.

Of the 573 farms in these three states with approved H-2A labor petitions, some utilized hiring agencies, whereas others did not list email addresses. After accounting for these, 399 potential respondents were contacted and a response rate of over 12% was realized. The participating farms had an average farming experience of about 12 years and operating an average of 1,663 acres. Vegetable farms comprise 42.1% of the study's sample, with the rest engaged in fruit, grain, field crop, and herb production.[1]

The survey's questionnaire addressed two major issues. First, the farmers were asked about the arrival status of the H-2A workers they were certified to hire and expected to work during their 2020 planting season. These contracted foreign workers were expected to have been covered by the approved foreign worker certifications granted by DOL in late 2019 and the working visas released by the U.S. Department of State in early 2020. Historically, H-2A visa approvals usually peak around mid-March, followed by worker arrivals in April when planting season for certain farm production regions starts (Echavarri, 2020; da Silva, 2020). The survey questions capture the arrival status of H-2A workers in each stage of the entire farm production process commencing with the pre-production stage, followed by the planting and processing stages, and culminating in the harvesting phase.

The latter section of the survey was designed with the assumption that H-2A workers were indeed late in their arrivals at their employers' farms and for their designated farm work assignments. Farmer respondents were asked to validate and evaluate several business strategies that were adopted to remedy the impending temporary H-2A labor shortage. The survey participants then provided estimates of any business losses associated with each business strategy. Extra attention was devoted to the coping strategy that involves hiring of temporary domestic worker replacements.

H-2A Workers' Arrival Status

Table 1 provides a summary of relevant worker arrival statistics for each category of farm work responsibility pre-agreed with the contracted H-2A workers. Survey results indicate that the highest percentage of late H-2A workers was recorded in the pre-production phase, where only 34% of the average pre-processing H-2A labor complement of 66 workers arrived on time. Understandably, the earliest phase of the planting season stood to be plagued with more delays in worker arrivals at a time when the enforcement of much stricter entry regulations and screenings at U.S. ports of entry was also in its early stages. During this time, enforcers and travelers alike had yet to fully grasp the uncertainty of the pandemic and the reasonable extent of severity needed in enforcing the entry regulations.

Planting and processing, which could be simultaneous activities for basic production farms and value-added agribusinesses, reported late worker arrivals comprising 33% and 58%, respectively, of their expected manpower complement. Harvesting operations that occur later in the production stage experienced a 45% delay in worker arrivals, although this category had the shortest period of lateness at only 3.4 weeks. H-2A workers assigned to perform processing work recorded the longest arrival lag at almost 5 weeks of delay. Pre-production and planting H-2A workers were about 4 weeks late in arrival.

Business Coping Strategies

Now that the pandemic's effect on H-2A workers' availability has been quantified in terms of the number of worker arrivals and duration of delay, the more pressing concern has been maintaining operating sustainability. Even during the pandemic, the farm sector remained an essential provider of basic necessities, hence consumer demand for farm goods and services remained high. In order to take advantage of such market opportunities, farms were compelled to explore alternative business strategies to keep their operations afloat and responsive to market demands. The latter part of the survey questionnaire was devoted to business strategies designed to mitigate the effects of the temporarily absent H-2A workers.

Table 2 lists the popular strategies employed by the respondent farms. Based on the collected inputs, the more common tendency among farmers was to initially explore internal sources of replacement labor. More than half of the farmers (62.5%) relied on family members as temporary replacement workers, whereas part-time farmers either reduced their off-farm employment time (52.9%) or resigned from their non-farm positions (50%).

Other farms resorted to downsizing (41.2%), which most likely led to foregone business opportunities in a promising market environment. Almost a quarter of the respondents considered modifying their production methods in favor of those alternative plans that are less labor-intensive (23.5%).

In terms of the economic repercussions of these coping strategies, adverse effects on business returns were relatively smaller when the farm operator fully devoted their personal time and attention to the operations by quitting off-farm employment. This strategy was estimated to have caused only a 4.3% reduction in farm business returns. The family labor option resulted in the second lowest income reduction of 8.9%. All the other strategies registered business return reductions of more than 20%.

Domestic Hiring Alternative

In Georgia, the unemployment rate in March 2020 was 3.6%. After the declaration of a national emergency by President Trump, along with the passage of the

Coronavirus Aid, Relief, and Economic Security (CARES) Act that increased unemployment benefits (Petrosky-Nadeau and Valletta, 2021), the rate skyrocketed to 12.5% in April 2020 (U.S. Bureau of Labor Statistics, 2021). Florida and North Carolina registered the same trend from March to April as their unemployment rates grew from 4.9% and 3.9% to 14% and 13.5%, respectively (U.S. Bureau of Labor Statistics, 2021).

Such were the prevailing labor market conditions faced by Georgia, North Carolina, and Florida farmers who turned to the domestic labor pool for temporary fillers of farm positions reserved for the delayed H-2A workers. In this study's survey, 30% of the participants considered the domestic hiring alternative. Table 3 includes a tabulation of the farmers' assessment of their domestic hiring experiences. Initially, the farmers provided an estimate of their own farms' labor force deficiency expected to be filled in by domestic workers. On average, farmers expected an estimated average labor shortfall of 55%. Moreover, drawing from these farmers' previous experiences with domestic workers who actually showed up for work on their farms, they estimate a labor output efficiency shortfall of about 47%. Evidence from farmers validates that local workers usually lack motivation and drive to be as efficient in their farm work performance as contracted foreign workers.

In terms of their actual hiring experiences, farmers were asked to use a 5-point scale to rate the level of difficulty in their hiring experiences (where 1 represents the least amount of difficulty and 5 is the hardest). Results indicate an average difficulty rating of 3.7 experienced with regard to domestic workers' availability. This result is consistent with those obtained in earlier studies on the farmers' domestic hiring predicaments during the Great Recession of the late 2000s (Luo and Escalante, 2017; Escalante, Wu, and Li, 2016), which are substantiated with anecdotal evidence provided by the farmers themselves (Escalante, Perkins, and Santos, 2011). In terms of labor productivity gaps, an average difficulty rating of 4.0 was assessed by the survey respondents, which confirms their initial expectations that indeed it was too difficult to elicit an acceptable level of work productivity among domestic workers they hired.

Moreover, the farmers also provided estimates of production shortfalls associated with domestic labor employment. According to them, the use of significant time and resources in recruiting local workers to work on their farms translated to about 60% business opportunity loss. When other farmers have succeeded in their domestic hiring campaigns, opportunity losses of about 53% were still realized as the local workers' output productivity proved to be substantially below levels realized by the contracted H-2A workers.

Farms' Resilience during the Pandemic

Prior to the onset of the pandemic, the U.S. farm sector had already been plagued with operating challenges, including the repercussions of tariff wars and weather-related disturbances. These translated to higher production costs and constrained profit margin potentials, which, in turn, could have led to lower capital investments and higher leverage conditions (Johansson, 2021). Prior to the enforcement of pandemic-induced social mobility constraints in early 2020, U.S. consumers were registering a stable growth in food expenditures that was allocated approximately evenly among retail (supermarket and grocery sales) and food service (such as restaurants and schools) outlets (Felix et al., 2020). In the early lockdown period of the pandemic, consumers primarily turned to retail suppliers as food service sales declined. An initial frenzy of panic buying led to empty shelves at groceries and supermarkets as the shortage affected many categories of consumer goods (Kam, 2020).

The shortages were expected to create a serious, sustained food crisis, but as one expert summarizes the situation, the condition was "more dramatic, but not emblematic" as the farm sector proved to be resilient enough to remedy the issue (Kam, 2020). Naturally, the recovery among farms was not sector-wide. The meat processing industry turned out to be its weakest link through some serious blows on the health conditions of its workers, whereas its fruit and vegetable operations "remained relatively unscathed" (Kam, 2020).

Most shortages during the pandemic proved to be temporary in nature. Average stock-out rates (whereby retailers run out of goods to sell) rose from its pre-pandemic rate of 14% in 2019 to about 35% in May 2020 (Cavallo and Kryvtsov, 2021). The rate would revert to its pre-pandemic level in November 2020 and would continue to decline thereafter (Cavallo and Kryvtsov, 2021).

CONCLUSIONS

This article serves as an exposition on how a sample of farms in the southeastern United States have managed to overcome the odds of business disruptions due to a temporarily handicapped labor force. The results of our study indicate that a 4- to 5-week absence of H-2A workers, on whom rests the steady and effective operation of the farming business, can actually lead to some opportunity losses. As this article validates the farmers' continued frustrations over the unreliability of domestic labor options—usually dissatisfied with the relatively inferior remuneration package of farm work vis-à-vis non-farm jobs that inadequately compensates the riskier, more taxing nature of tasks (Luo and Escalante, 2017; Martin, 2016; Escalante, Perkins, and Santos, 2011; Escalante and Santos, 2011), business setbacks caused by H-2A workers' delayed arrival can be mitigated only partially by certain alternative business coping strategies that farmers resorted to while they waited for their foreign workers to arrive.

This study's results only confirm the farm sector's reliance on contracted foreign workers, whose temporary absence can threaten the sustainability of farm operations. Even as the patronage of the H-2A farm labor hiring alternative has increased in recent years, the program's current utilization level is far from ideal (hovering around only 25% of the country's hired farm labor force) and farmers continue to clamor for program reforms. Thus, by providing additional empirical support to the farms' strong dependence on H-2A labor, especially during more difficult economic periods, this article supports the demands for continued evaluation of the program until its implementing guidelines and policies are able to fairly ensure the promotion of economic welfare on both workers' and farm employers' sides.

FOOTNOTE

1 Recent legislative efforts address current H-2A programs' bias toward crop operations. H-2A utilization trends indicate that crop farms accounted for 80% to 90% of H-2A workers hired since 2010 (Castillo et al., 2021). Conversely, livestock farms accounted for only 4% to 8%. This can be partially attributed to the livestock production cycle because even while certain livestock operations have high labor requirements, the industry's demand for year-round labor cannot be filled by seasonal, temporary H-2A work contracts.

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Table 1. H-2A Workers' Actual Arrival Status, 2020 Planting Season, Georgia, Florida, and North Carolina Farms				
H-2A Worker Petitions and Arrival Status Measures	**H-2A Workers' Farm Work Assignments**			
	Pre-Production	**Planting**	**Processing**	**Harvesting**
Approved H-2A Workers Petitioned, per farm	65.86	39.40	52.25	79.44
Average Number of H-2A Workers Arriving Late	43.70	12.93	30.40	35.85
Percent of Late H-2A Workers, per work category	66.35	32.82	58.18	45.13
Average Number of Weeks Late	4.33	4.14	4.75	3.40

Source: 2021 H-2A Labor Hiring During the Pandemic Survey, Department of Agricultural & Applied Economics, University of Georgia.

Table 2. Business Coping Strategies and Effects of Late/Absent H-2A Workers of Georgia, North Carolina, and Florida Farms, Spring 2020		
Business Strategies	**Percent of Adopters**	**Average Effect on Business Returns**
Relied More on Family Members for Labor	62.50%	–8.89%
Reduced Off-Farm Working Time	52.94%	–20.00%
Quit Off-Farm Job	50.00%	–4.29%
Reduced Scale and Amount of Production	41.18%	–20.83%
Changed Production Plans to Commodities that Require Less Labor	23.53%	–21.67%

Source: 2021 H-2A Labor Hiring During the Pandemic Survey, Department of Agricultural & Applied Economics, University of Georgia.

Table 3. Domestic Hiring of Replacement for Late H-2A Workers in Georgia, North Carolina, and Florida, Spring 2020		
Domestic Hiring Parameters	**Domestic Workers' Availability**	**Available Domestic Worker's Output Productivity**
Expected Deficiency (Before Hiring), percent	54.67	46.50
Level of Difficulty (5-point scale where 5 is hardest)	3.71	4.00
Estimate of Actual Effect on Business Returns due to Hiring Decisions, percent	–60.40	–52.83

Source: 2021 H-2A Labor Hiring During the Pandemic Survey, Department of Agricultural & Applied Economics, University of Georgia.

Managing through Drought with the Livestock Forage Disaster Program



By Allison E. Wilton, Bart L. Fischer, and Joe L. Outlaw

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Abstract

Production agriculture is an inherently risky business. For livestock producers in particular, drought is one of the most common disasters they face. While the Livestock Forage Disaster Program (LFP) was permanently funded by Congress in the 2014 Farm Bill to help livestock producers manage these risks, producers still face a number of management decisions that impact their bottom line. In this study, we examine the interaction between LFP and various alternative management strategies using simulation analysis. We find that LFP does not fully offset the losses incurred due to drought—regardless of management strategy—particularly in the case of longer-term drought.

BACKGROUND

Production agriculture has always been a risky business. Livestock production is particularly vulnerable to regional weather events, with drought being one of the most common. While Congress has provided livestock producers with a number of risk management tools—ranging from the Livestock Forage Disaster Program (LFP) to the Pasture, Rangeland, and Forage (PRF) insurance policy—producers still face several management decisions that greatly affect their bottom line (Fischer, Benavidez, and Hagerman, 2022). In this study, we explore the interaction between LFP and the management decisions made by cattle producers.

Although cattle producers historically have not had a robust safety net, much has changed over the past decade. One of the more notable changes was the permanent funding provided for LFP in the 2014 Farm Bill. LFP provides financial assistance to livestock owners who have suffered a loss of forage due to qualifying drought during the county's normal grazing period (USDA, 2019). Producers are eligible for monthly payments based on severity and length of drought. LFP payment rates are based on monthly feed costs incurred by producers, and the number of monthly payments a producer is eligible to receive is based on county drought ratings from the U.S. Drought Monitor and the length of time the county has been in drought. Producers with eligible livestock that have been in counties in:

- D2 drought for at least eight consecutive weeks are eligible for one monthly payment
- D3 drought at any time are eligible for three monthly payments
- D3 drought for at least four weeks or in D4 at any time are eligible for four monthly payments
- D4 drought for four weeks, including non-consecutive weeks, are eligible for up to five monthly payments

One month's payment for losses due to drought is 60% of either monthly feed costs of livestock owned or of the normal carrying capacity of the land, whichever is less. Notably, livestock sold due to drought in the two years before the current production year are eligible for 80% of the monthly payment rate. Monthly feed costs are calculated by:

$$\textit{Monthly feed cost} = \textit{30 days} \times \textit{feed grain equivalent} \times \textit{corn price per pound} \quad (1)$$

The feed grain equivalent is equal to 15.7 pounds of corn per day for an adult beef cow. Corn price per pound is determined by dividing (1) the higher of the simple average of the national monthly corn price per bushel for the 12-month period immediately preceding March 1 of the year for which the disaster assistance is calculated or for the 24-month period immediately preceding that March 1 by (2) 56. For context, the monthly payment rate for adult beef cattle in 2022 was $47.29. Producers cannot receive LFP payments for more than five months for the "same kind, type, and weight range of livestock" (USDA, 2019). The 2018 Farm Bill maintained an annual payment limit for LFP of $125,000 per person or legal entity, disregarding any other program, for 2019 and subsequent years.

Although a number of risk management tools are available, producers must make a litany of decisions when managing a cattle ranch. Specifically, during times of drought, management decisions are critical to the continued operation of the business. Although there are several different options that a ranching operation could utilize in the case of a drought, three of the more popular scenarios are:

- **Purchasing supplemental feed**—During short periods of drought, producers may choose to purchase feed to supplement scarce forage. This feed may be in the form of forage (alfalfa or grass hay), protein (dried distillers' grains or cubes), or both. The amount of feed needed will depend on the severity of the drought, the body condition of the herd, and the dietary nutrients being supplemented (Carpenter and Hart, 2021). There are a few drawbacks to this scenario. The longer the drought persists, the more severe it becomes; thus, purchasing feed becomes significantly more expensive as the forage does not replenish and eventually ceases to exist, perhaps with irreparable damage to soil conditions (van de Koppel and Rietkerk, 2000). This strategy is normally used until it rains, or until the producer decides to adopt one of the other strategies.
- **Reducing stocking rates (culling)**—Díaz-Solís et al. (2009) and Bidwell and Redfearn (2020) emphasize that in drought, stocking rates must be reduced. When reducing the stocking rates, Carpenter and Hart (2021) posit that open cows should be culled first, followed by lactating females in poor body condition, as they likely won't calve again.
- **Relocation**—During prolonged drought, this strategy calls for moving cattle to a pasture outside of the drought area to ride out the drought. Several considerations need to be made when using this strategy: the construction of a pasture lease or rental agreement, restrictions if crossing state or county lines, and biosecurity measures if cattle are moved to a feedlot (Rasby, 2009; McCollum, 1999). If cattle are fed in confinement, as in a feedlot, less total feed would be required as less energy is spent and the feed is more energy dense than forage; however, these cattle would not be eligible for LFP payments, as cattle fed in confinement are ineligible for LFP.

With drought ravaging more than half of the United States in 2022, it's absolutely vital that livestock producers use all of the tools at their disposal. Doing so requires examining the interaction between LFP and the management decisions made by cattle producers. While that is the focus of this study, our analysis also highlights shortcomings of LFP that can help inform policy makers as they negotiate the next farm bill.

METHODS

To analyze the interaction between LFP and the various management options listed above, we utilize a case study ranch. The Agricultural and Food Policy Center (AFPC) at Texas A&M University maintains 94 representative crop, livestock, and dairy farms in 30 different states, 10 of which are cow-calf operations. Information used to simulate the economic activity on these operations is developed through a consensus-building interview process with a panel of producers. Projected prices and input inflation rates are provided by the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri. Financial statements are provided to the panels for their respective operations, and they are asked to verify the accuracy of the simulated results for each year and for a five-year projection (Outlaw et al., 2021). The King County Ranch (TXRB400, shown in Figure 1) was chosen for this study, in part because cattle are the primary enterprise on the operation. Additionally, the ranch is in the heart of the area affected by the 2011–2015 drought and was eligible for five months of LFP payments in 2022 due to prolonged D4 drought (Figure 2).

For the case study ranch, we project the financial health of the operation for five years, beginning with 2022. We calculate the expected net present value (NPV) for the five scenarios highlighted in Table 1: baseline during a normal year; feeding, culling, and relocating during a three-year drought with LFP payments; and relocating during a three-year drought without LFP payments. Although LFP payment rates were calculated using the formula above—using monthly average prices over a one- and two-year period—this study simply uses annual averages provided by FAPRI. The ranch is organized as a corporation, and the tax implications of each scenario are incorporated accordingly.

Stochastic simulation was used to account for risk in projected revenues and costs to give a full picture of the risks facing the operation. The ranch was assumed to already be in D4 drought and eligible for the maximum five months of payments (consistent with reality in King County in 2022). We also assume that the drought persists for three years as noted in Table 1. In both the feeding and culling scenarios, the rate of feed purchased is assumed to increase as forage is depleted. For the cull scenario, after a year of drought, 25% of the herd was culled, and the following year, another 25% was culled. After the drought ended in the third year, 25% of the original herd size was bought back, and in the fifth year, the remaining 25% was purchased to bring the herd back to its original size. The relocation scenarios followed the same structure as the culling scenario, except cattle were relocated instead of sold.

FINDINGS

Figure 3 illustrates the expected NPV for the ranch under each scenario. LFP payments are triggered only in years of drought; for example, when the ranch was buying back cattle or bringing cattle back to the original ranch area, LFP payments were received only for cattle sold due to drought. Of all the strategies employed during a three-year drought, relocation with LFP payments had the highest expected NPV, followed by culling and feeding, respectively. Even with LFP payments not factored in, the expected NPV for the relocation scenario is higher than feeding through a three-year drought with LFP. Perhaps most importantly, LFP does not restore the ranch to the baseline outlook regardless of the management approach chosen. And, in the case of feeding through the drought—which many ranches may try to do as they endeavor to hold on to precious seedstock—LFP falls the shortest in terms of helping offset the costs incurred by the ranch. This shortfall grows even more pronounced as drought persists.

Figure 4 illustrates the cumulative distribution functions (CDFs) for NPV for all five scenarios. CDFs provide a depiction of the full range of possible outcomes—and the risk associated with each—for each scenario. Out of all scenarios (other than the baseline), relocation with LFP provides a consistently larger expected NPV. When the management response is to feed through the drought, there is a greater than 20% chance that the NPV will be negative, despite LFP payments. Culling in response to the drought results in an 8% likelihood that the NPV will be negative; by contrast, with relocation including LFP, NPV is negative only 0.2% of the time. To provide context, without LFP payments factored in, the relocation scenario results in negative NPV 16% of the time. Naturally, the success of relocation is highly dependent on diesel prices, hauling rates, and management expenses, as well as on finding a location outside of the drought region to which the cattle can be moved. In the case of TXRB400, relocation was the option used during the drought of 2012; this analysis utilized the same alternate location.

CONCLUSIONS AND SUMMARY

When facing drought, agricultural operations must make critical management decisions to ensure the viability of the operation. With LFP payments included, the optimal option for this ranch was to relocate cattle to an area outside of the region affected by drought. The next best option was to cull the herd and buy it back after the drought had ended. Although the purpose of LFP is to compensate for supplemental feed, feeding through the drought proved to be the most expensive option, despite the inclusion of LFP payments.

Although LFP provides a safety net for livestock producers, it does not make them whole, regardless of the management strategy used. If LFP is revisited in the next farm bill, policy makers may wish to consider increasing payment rates, particularly for operations facing long-term drought. The results also highlight the need for additional research—for example, exploring incorporating the cost of additional feedstuffs such as hay into the LFP calculations, expanding the number of payments beyond five months for prolonged drought, and examining interactions with other risk management tools such as PRF.

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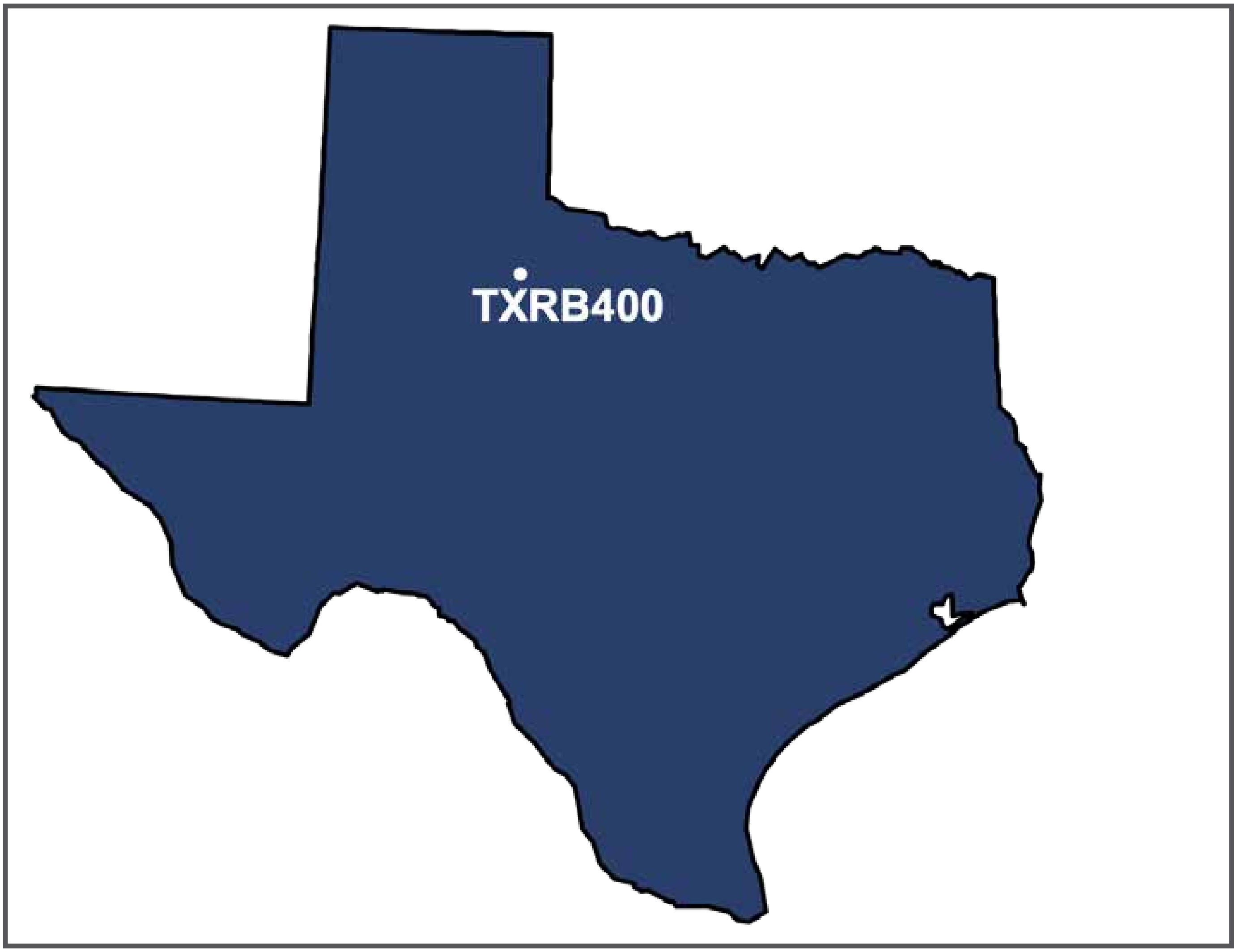


Figure 1. AFPC representative ranch location

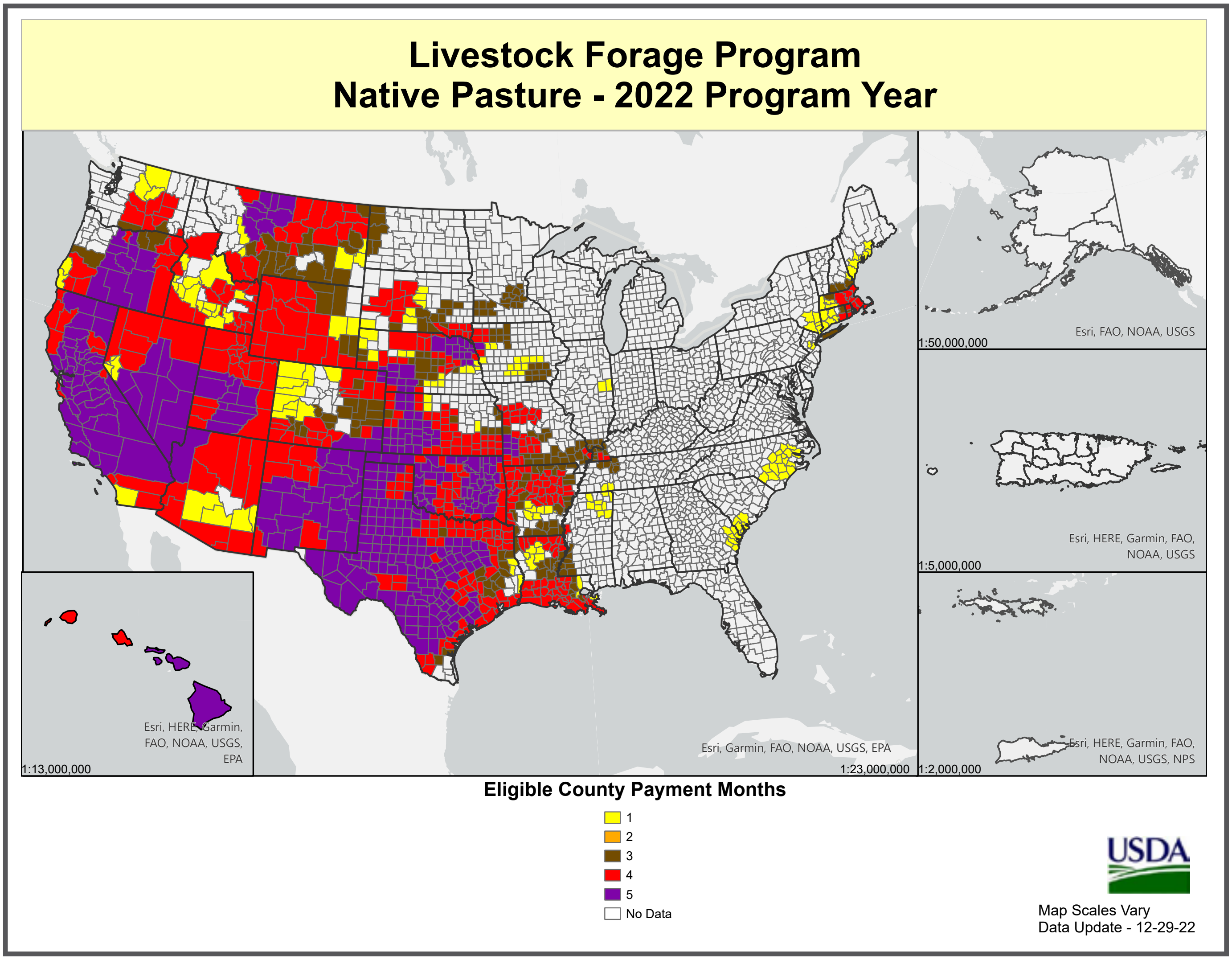


Figure 2. LFP native pasture payment months by county—2022 program year. (Source: https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Disaster-Assist/LFP-Maps/2022/native_pasture_2022.pdf.)

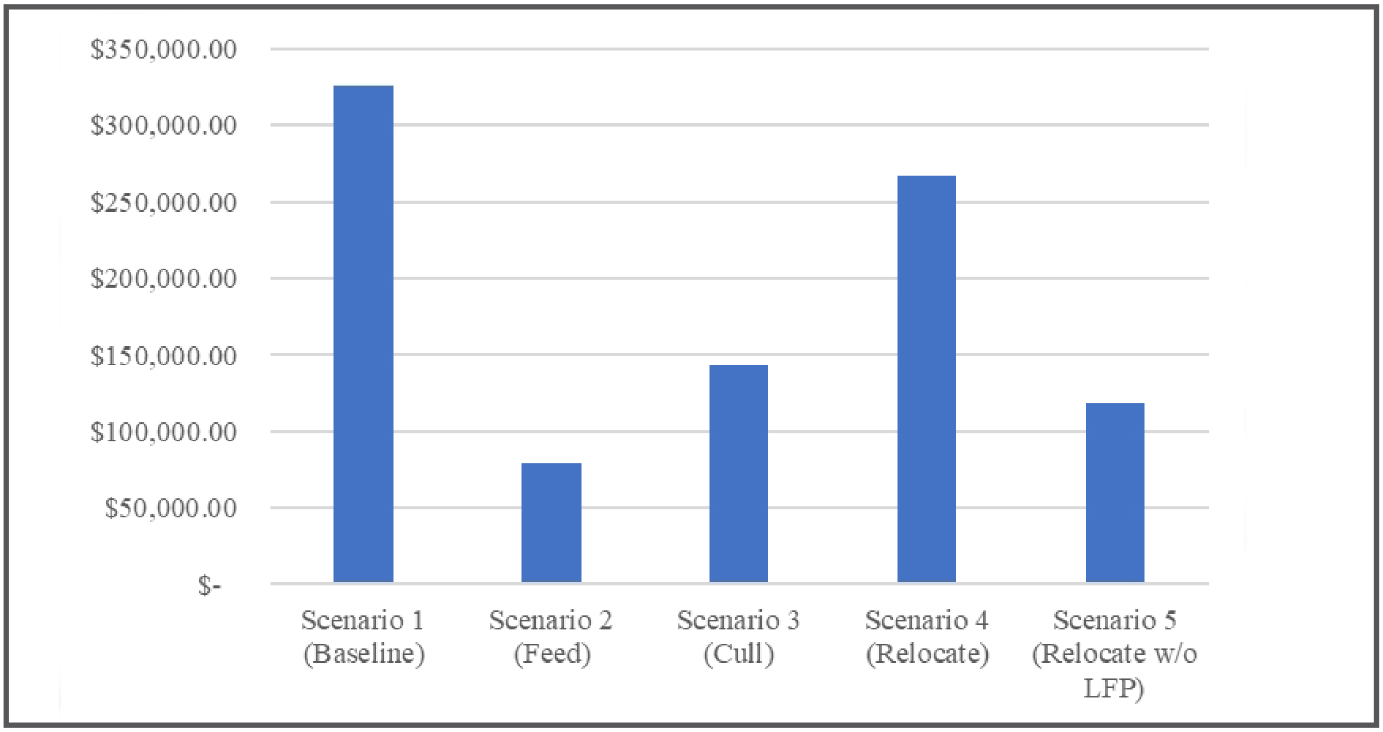


Figure 3. Expected NPV for various drought management scenarios

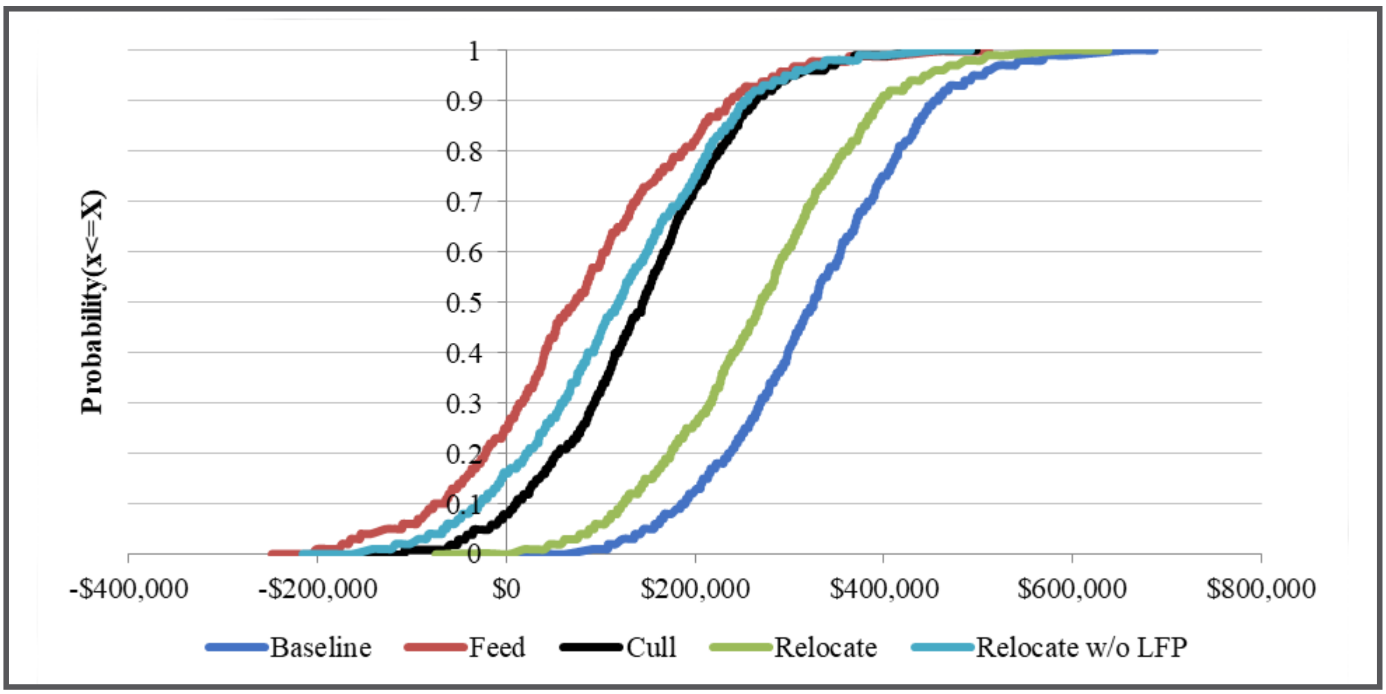
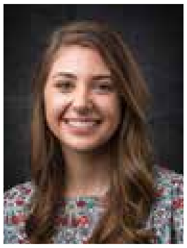
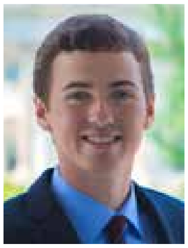


Figure 4. NPV CDF for various drought management scenarios

Table 1. Description of Scenarios					
Scenario	1	2	3	4	5
Drought Length (Years)	0	3	3	3	3
Management Response	N/A	Feed	Cull	Relocate	Relocate
LFP Payments	No	Yes	Yes	Yes	No

STAX and SCO: Finding Their Place in the Farm Safety Net


By Natalie A. Graff, Henry R. Nelson, Joe L. Outlaw, Bart L. Fischer, and Henry L. Bryant

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Abstract

The Stacked Income Protection Plan (STAX) for upland cotton and the Supplemental Coverage Option (SCO) are area-wide crop insurance tools that serve as complements to individual crop insurance policies. Consideration of STAX and SCO requires producers to make tough decisions regarding other safety net programs: Agriculture Risk Coverage-County (ARC-CO) and Price Loss Coverage (PLC). This article describes STAX and SCO and shows how they work in relation to ARC-CO and PLC, using an example cotton farm in Texas. The example farm models the impact of safety net decisions on 2022 crop year payments and provides insight into producer decisions.

INTRODUCTION

The 2014 Farm Bill established Agriculture Risk Coverage (ARC) and Price Loss Coverage (PLC) as Title I commodity programs and allowed producers to decide in which program to enroll base acres on a commodity-by-commodity basis. ARC and PLC were continued by the 2018 Farm Bill. Producers were allowed to make an annual election between the two programs, beginning with the 2021 crop year. ARC is offered at the individual farm level (ARC-IC) and at the county level (ARC-CO). Both provide revenue-based support; to date, utilization of ARC-CO far exceeds that of ARC-IC. ARC-CO provides shallow-loss protection and provides a payment when actual county revenue falls below the county benchmark revenue. PLC protects against deep losses and provides a payment when the marketing year average (MYA) price falls below the statutory reference price. Prior to the March 15 deadline for commodity program sign-up, a series of *Southern Ag Today* (SAT) articles addressed producers' 2022 farm safety net decisions. In the first article, Fischer and Raulston (2022) pointed to the price outlook and speculated that neither ARC nor PLC were likely to pay due to the expectation of high commodity prices. The next two SAT articles discussed alternative safety net programs for producers to consider for 2022: the Stacked Income Protection Plan (STAX) for upland cotton and the Supplemental Coverage Option (SCO) for all Title I covered commodities (Fischer and Outlaw, 2022; Outlaw and Fischer, 2022).

STAX and SCO are area-wide crop insurance tools and serve as complements to individual crop insurance policies. The SAT articles offered STAX and SCO as shallow-loss alternatives to ARC-CO and pointed out that STAX and SCO take advantage of price elections on crop insurance (generally higher than MYA prices used for ARC-CO), resulting in higher coverage. Consideration of STAX and SCO required producers to make tough decisions regarding ARC-CO and PLC. Producers cannot purchase STAX coverage if they enroll seed cotton base acres in ARC-CO or PLC; additionally, producers may purchase SCO coverage only if they enroll base acres in PLC (but not ARC-CO). Since these tools (ARC-CO, STAX, and SCO) are all area-wide supplements to individual crop insurance policies, producers are required to make a choice between them. Producers incur premium costs with STAX and SCO, whereas ARC-CO is free. However, careful consideration is needed. This article will show that under some possible market outcomes, producers may be better off with STAX or SCO. The decision producers make is important because market conditions dictate which programs are more likely to pay in a given year, and farm program payments have a large impact on a producer's bottom line. The objective of this article is to describe STAX and SCO and show how they work in relation to ARC-CO and PLC using an example cotton farm in the Southern High Plains of Texas. The example farm will be used to model the impact of safety net decisions on payments for the 2022 crop year and provide insight into producer decisions. There are many acronyms used throughout this article; these are listed and defined in Table 1.

BACKGROUND

STAX, SCO, ARC-CO, and PLC were all established in the 2014 Farm Bill and reauthorized in the 2018 Farm Bill. STAX is an area-based revenue insurance policy available only for upland cotton. STAX can be purchased on its own or with a companion crop insurance policy, such as Revenue Protection (RP) or Yield Protection (YP). STAX provides coverage for up to 20% of the adjusted expected area revenue. Figure 1 illustrates STAX coverage and the difference in deductible with and without STAX. Producers select both of the following:

- A protection factor between 80% and 120% (in 1% increments) to determine the adjusted expected area revenue (equal to the product of the protection factor and the expected area revenue).
- An area loss trigger between 75% and 90% (in 5% increments) to determine the STAX coverage range (equal to the difference between the area loss trigger and the higher of the coverage level of the companion policy and 70%). For example, if a producer chooses an area loss trigger of 90% and the coverage level of the companion policy is 75%, then the STAX coverage range is equal to 15%. With the same 90% area loss trigger, if the coverage level of the companion policy is less than or equal to 70%, then the STAX coverage range is equal to 20%.

STAX begins to pay when the *actual area revenue* drops below the *area loss trigger* percentage of the *expected area revenue*, down to the low end of the *coverage range*. The *expected area revenue* is the expected area yield, multiplied by the higher of the projected price and the harvest price. The *actual area revenue* is the product of the actual area yield and the harvest price. The amount of *STAX protection* (1) and the *STAX indemnity* (2) are calculated as follows (FCIC, 2021):

$$\textit{STAX protection} = \textit{expected area revenue} \times \textit{protection factor} \times \textit{coverage range} \qquad (1)$$

$$\textit{STAX indemnity} = \textit{STAX protection} \times \min\left(\frac{\max\left(\textit{area loss trigger} - \frac{\textit{actual area revenue}}{\textit{expected area revenue}}, 0\right)}{\textit{coverage range}}, 1\right) \qquad (2)$$

The expected and actual area yields are reported by the U.S. Department of Agriculture's Risk Management Agency (RMA); projected and harvest prices are determined in accordance with the Commodity Exchange Price Provisions (CEPP); and the protection factor and the area loss trigger are selected by the producer.

If a producer purchases STAX, they are not eligible to sign up for ARC or PLC on the upland cotton base acres on the farm (FCIC, 2021). Historically, STAX was unpopular for a couple of reasons: (1) producers preferred PLC, which has paid each year since 2018; and (2) some producers thought area yields were too low, which made a payment less likely. For 2022, the high upland cotton futures prices during the price discovery period means more protection can be garnered with STAX than with ARC-CO or PLC, which utilize MYA prices to determine payments. A producer also must make a choice between STAX and SCO because STAX and SCO cannot be purchased together for the same crop and on the same acres.

SCO is also an area-based policy that provides additional coverage on top of an underlying crop insurance policy. SCO can be purchased only as an endorsement to the underlying policy; unlike STAX, it cannot be purchased on its own. Figure 2 illustrates SCO coverage in relation to an underlying policy. SCO was first available in the 2015 crop year for some major crops (spring barley, corn, soybeans, wheat, sorghum, cotton, and rice) in select counties but was expanded in 2016 to include additional counties and crops. The underlying policies eligible for an SCO endorsement include YP, RP, RP with Harvest Price Exclusion (RP-HPE), and Actual Production History (APH). SCO coverage follows the coverage of the underlying policy (i.e., if a producer chooses RP, then SCO covers revenue loss, and if a producer selects YP, then SCO covers yield loss). The underlying policy also determines the coverage range and the amount of protection for SCO. The SCO coverage range is the difference between 86% and the coverage level of the underlying policy. This study analyzes SCO as an endorsement to an RP policy; therefore, the following SCO descriptions and calculations assume an underlying RP policy. *SCO protection* is determined using individual *expected crop value*—which is based on a producer's individual *approved yield*—unlike STAX, which uses expected area revenue. Producers select a *coverage percentage*, between 50% and 100% (in 1% increments), which allows them to customize their amount of coverage. Calculations for *expected crop value* (3) and *SCO protection* (4) are as follows (RMA, 2022b):

$$\textit{Expected crop value} = \textit{approved yield} \times \max(\textit{projected price}, \textit{harvest price}) \tag{3}$$

$$\textit{SCO protection} = \textit{expected crop value} \times \textit{coverage percentage} \times \textit{coverage range} \tag{4}$$

While the underlying policy pays an indemnity when an individual loss occurs, an SCO indemnity is triggered by an area-level loss. SCO begins to pay when the *actual area revenue* falls below 86% of the expected area level, down to the coverage level of the underlying policy. The *SCO indemnity* (5) is calculated as follows:

$$\textit{SCO indemnity} = \textit{SCO protection} \times \min\left(\frac{\max\left(0.86 - \frac{\textit{actual area revenue}}{\textit{expected area revenue}}, 0\right)}{\textit{coverage range}}, 1\right) \tag{5}$$

SCO limits a producer's farm program decisions: SCO and ARC-CO cannot be elected for the same crop on a farm; however, producers can enroll the same acres in both SCO and PLC. Given high commodity futures prices during price discovery for 2022, SCO provided significantly more revenue protection than ARC-CO, which uses MYA prices to determine revenue benchmarks. Therefore, some producers may have found SCO to be a more favorable shallow loss revenue protection option than ARC-CO. Again, SCO and STAX cannot be purchased for the same crop on the same acres.

ARC-CO payments are triggered when the actual county revenue is less than the ARC-CO revenue guarantee for a covered commodity in a specific county (FSA, 2019). Actual county revenue is determined by the MYA price and the county yield. The ARC-CO revenue guarantee equals 86% of the previous five-year Olympic average of national MYA prices (benchmark price), multiplied by the five-year Olympic average of county yields (benchmark yield). When an ARC-CO payment is triggered, the payment is equal to the difference in the actual county revenue and the ARC-CO revenue guarantee, multiplied by 85%, multiplied by base acres (not to exceed 10% of the previous five-year Olympic average of national MYA prices, multiplied by the five-year Olympic average of county yields).

PLC payments are triggered when the current year MYA price is less than the reference price for a covered commodity (FSA, 2019). Reference prices are established in each farm bill. If a PLC payment is triggered, the payment is equal to the difference in the MYA price and the higher of the loan rate or reference price, multiplied by the PLC payment yield, multiplied by 85%, multiplied by base acres. Each covered commodity on each individual farm has a unique PLC payment yield and number of base acres. For cotton, ARC-CO and PLC programs cover seed cotton (combination of cotton lint and cottonseed) price and yield, whereas the insurance policies cover cotton lint only. For ARC-CO and PLC purposes, the cotton lint yield multiplied by 2.4 equals the seed cotton yield.

To recap, enrollment in STAX makes a producer ineligible for ARC-CO, PLC, and SCO on seed cotton base acres on a farm. Enrollment in SCO makes a producer ineligible for ARC-CO. Therefore, cotton producers have the following options:

- Purchase STAX (upland cotton only), with or without a companion policy;
- Purchase SCO, with an underlying policy, and enroll base acres in PLC; or
- Enroll base acres in ARC-CO.

The subsequent sections illustrate these options on an example representative cotton farm in Texas and analyze the impact of producer decisions on farm safety net payments.

METHODOLOGY AND DATA

This section describes the representative cotton farm used to model impacts of program decisions on safety net payments for several scenarios of price and yield realization. First, the characteristics of the farm and associated safety net program parameters are described. Next, the scenarios of price and yield realizations used to calculate payments are presented, followed by the necessary assumptions and data sources. Finally, this section describes the safety net payments that are calculated for each scenario and reported in the results section.

Dawson County Cotton Farm

This farm is representative of farm operations in Dawson County, a major cotton production county in the Southern High Plains of Texas. The farm grows dryland upland cotton. The farm purchases an RP policy for cotton, which will serve as the companion policy for STAX and the underlying policy for SCO. Safety net program parameters that remain constant for each scenario include:

- STAX/SCO expected area lint yield (RMA, 2022b): 209 lbs/acre
- STAX/SCO projected cotton lint price (RMA, 2022b): $1.03/lb
- Assumed STAX protection factor: 120%
- Assumed STAX area loss trigger: 90%
- Assumed SCO coverage percentage: 100%
- PLC seed cotton yield (expected yield multiplied by 2.4): 501.6 lbs/acre
- PLC seed cotton reference price (FSA, 2022a): $0.367/lb
- ARC-CO seed cotton benchmark price (FSA, 2022c): $0.367/lb
- ARC-CO seed cotton benchmark yield (FSA, 2022c): 621.39 lbs/acre
- ARC-CO seed cotton revenue guarantee (86% of benchmark price multiplied by benchmark yield): $192.12/acre
- Assumed RP individual farm approved lint yield: 209 lbs/acre

The assumed STAX protection factor, STAX area loss trigger, and SCO coverage percentage values that were chosen are the common choices among area producers for these parameters.

Scenarios

Six alternative price/yield scenarios of 2022 price and yield realizations were imposed on the farm to demonstrate how each would affect estimated payments from RP, STAX, SCO, ARC-CO, and PLC. Table 2 describes each scenario and shows the actual individual farm yield, actual county yield, harvest price, and MYA price assumed for each scenario.

The baseline actual county yield and individual farm yield used for cotton are assumed to be equal to the STAX/SCO expected area yield (209 lbs/acre). For the low county yield and low individual farm yield scenarios, a yield loss of 50 pounds per acre is assumed (159 lbs/acre). The baseline harvest price used for cotton ($1.03/lb of lint) is equal to the 2022 projected price. The low harvest price is the average of the harvest prices from the previous 5 years ($0.77/lb of lint), which is 25% lower than the baseline price.

Recall that the harvest (lint) price is used to determine RP, SCO, and STAX payments, but ARC-CO and PLC use MYA (seed cotton) price to determine payments. When cotton was reintroduced as a covered commodity in the Bipartisan Budget Act of 2018, both cottonseed and lint were designed to be covered under the name "seed cotton" for Title I programs (Schnepf, 2018). Therefore, the *seed cotton MYA price* (6) consists of both lint price and cottonseed price, weighted by production:

$$Seed\ cotton\ MYA\ price = (\frac{lint\ lbs.}{total\ lbs.}) \times lint\ price + (\frac{cottonseed\ lbs.}{total\ lbs.}) \times cottonseed\ price \quad (6)$$

where total pounds equals the sum of lint pounds and cottonseed pounds. The MYA seed cotton price used for the baseline price scenarios ($0.4923) is the most recent 2022 national MYA price projection from USDA's World Agricultural Supply and Demand Estimates (WASDE) (FSA, 2022b). For the low-price scenarios, a reduction in the baseline MYA seed cotton price is assumed to be proportional to the difference in the baseline and low harvest price (25%). However, simply multiplying seed cotton MYA price by –0.25 does not result in a proportional change because harvest price consists only of lint price, whereas seed cotton price is made up of cottonseed and lint prices. Instead, a new (low) seed cotton MYA price ($0.3872) is achieved by decomposing the equation for *seed cotton MYA price* into its component parts, solving for the unknown (*cottonseed price*[1]), and reconstructing the equation using a new *lint price* (the WASDE-reported price, $0.97, reduced by 25%).

Safety Net Payment Analysis

The study utilizes the farm characteristics, program parameters, and price and yield realizations described above to analyze, for each scenario, the RP net indemnity for various coverage levels (50% to 85%, in 5% increments) and the following three safety net options, of which producers can select one:

- STAX net indemnity
- SCO net indemnity plus PLC payment
- ARC-CO payment

To calculate net indemnities, the study utilizes premium data for 2022, publicly available from RMA.

RESULTS

Results for all payments are reported on a per-acre basis. Tables 3–8 show net indemnities for RP, STAX, and SCO, for varying levels of RP coverage, along with the payment for ARC-CO and PLC. Table 3 is the baseline scenario where county and individual yields are equal to the expected area yields, and the harvest price and MYA prices are equal to the respective projected prices. Note that no indemnities are being paid out in Scenario 1 because there is no price or yield loss. Therefore, the negative values are the premiums paid for each policy.

Table 4 shows the results for Scenario 2 where the baseline yields are held constant, but harvest price and MYA price projections decrease. The RP net indemnity is still negative, but there is some indemnity paid for the higher coverage levels. With the price loss, STAX and SCO both result in a positive net indemnity regardless of the RP coverage level. It is worth noting, even with a 25% price drop from the current MYA price projection for cotton lint, that the resulting seed cotton MYA price is still not low enough to trigger a PLC payment.

In Table 5, Scenario 3 maintains baseline prices and baseline actual county yield but experiences an individual yield loss. When a producer experiences a yield loss, but the county does not, neither STAX and SCO nor ARC-CO payments are impacted because they are not dependent on individual yield. In this scenario, only RP is affected; net indemnities remain negative.

Table 6 contains results of Scenario 4 where the farm experiences low prices and an individual yield loss. With an individual yield loss and lower prices, RP net indemnities are positive for coverage levels between 65% and 85%. Given the levels of price and individual yield loss in Scenario 4, the optimal policy bundle is RP, with 75% coverage, and STAX. This combination nets over $56 per acre.

Table 7 shows results from Scenario 5, where baseline prices are maintained and the individual farm realizes baseline yields, but a yield loss occurs at the county level. The decrease in actual county yield affects STAX and SCO and ARC-CO payments. Since these three options can be chosen only independently of one another, the optimal choice for Scenario 5 is 50% RP with STAX. When the individual farm does not experience yield loss, an RP indemnity is not triggered, and for any RP coverage level at or below 70%, the STAX coverage is the same. Therefore, when county losses are more likely than individual loss, producers may choose a lower RP coverage level to lower the RP premium and allow for maximum STAX coverage (20%).

Results for Scenario 6 are reported in Table 8. County yield loss is combined with low prices, while the individual farm experiences baseline yields. The maximum ARC-CO payment is triggered and STAX and SCO net indemnities are positive for each level of RP coverage chosen. RP net indemnities are negative since individual yield loss did not occur. Again, the price loss is not great enough to trigger a PLC payment. The optimal producer choice in this scenario is 55% RP with SCO. The same justification from Scenario 5 can be offered for Scenario 6: Choosing a lower RP coverage level and allowing an area-based policy to provide more coverage in the event of a county yield loss results in a higher net indemnity. Note that the only difference between Scenarios 5 and 6 is the price realization (baseline price is used in Scenario 5; low price is used in Scenario 6), and the optimal program choice switches from STAX to SCO for lower RP coverage levels.

Results Summary

Table 9 provides a summary of the preferred option for each scenario. Note that the preferred option (highest net benefit or lowest net loss) changes across scenarios. Both the insurance and farm programs (ARC-CO/PLC) are producer safety net programs that provide a benefit only when a loss (yield, price, or both) occurs.

It is not realistic that a producer would farm dryland cotton in Dawson County, Texas, without crop insurance—which means the results from Scenarios 1 and 3 minimized losses but provided very little protection for the farm. Price declines during the crop year or at harvest are a real possibility each year. Note that PLC never triggered, and ARC-CO only triggered more than a few dollars per acre in Scenario 6. Even in this scenario, the benefits for ARC-CO are lower than the net benefits from buying all but the highest level of STAX and 50% to 70% SCO. The scenarios that included a price decline (2, 4, and 6) showed that RP and either STAX or SCO were preferred to ARC-CO or PLC. Note that this study has the luxury of hindsight, which results in the 50% RP coverage level being the optimal choice. Although this study assumed a 50-pound loss in low-yield scenarios, a dryland cotton farm in Dawson County could easily have a much greater yield loss. Incorporating risk by projecting stochastic yields for the future year would likely predict a higher optimal coverage level.

These results support what producers in Texas are currently doing in 2022, which is foregoing signing up for ARC-CO or PLC in favor of purchasing revenue insurance and one of the shallow loss area plans (STAX or SCO). With seed cotton prices starting the year very high and a high insurance price, producers were not anticipating much if any ARC-CO/PLC payments. Further, even after paying premiums the shallow loss insurance products would be better than ARC-CO.

CONCLUSION

Producers and landowners face many decisions within the current farm safety net, and the recent drastic changes in commodity prices have shifted which programs provide the most protection for each crop. The example farm used to model the impact of safety net decisions on payments for the 2022 crop year showed that in the event of a price or yield loss, STAX and SCO were likely advantageous for producers over ARC-CO or PLC.

These results comport with what many producers in Texas did in 2022: forgo signing up for ARC-CO or PLC in favor of purchasing revenue insurance and one of the shallow loss area plans (STAX or SCO). With seed cotton prices starting the year very high and a high insurance price, producers were not anticipating much, if any, ARC-CO/PLC payments. Further, even after paying premiums, the shallow loss insurance products were better than ARC-CO in the event of a yield loss. Understanding the program dynamics of STAX and SCO, programs that were previously unpopular, and the climate that led to them being useful in 2022 will help producers make decisions going forward.

FOOTNOTE

1. Projections for seed cotton MYA price and lint MYA price are reported by WASDE. Projections for lint and cottonseed pounds of production are reported by the National Agricultural Statistics Service (NASS). Therefore, the unknown in the equation—cottonseed MYA price—can be solved.

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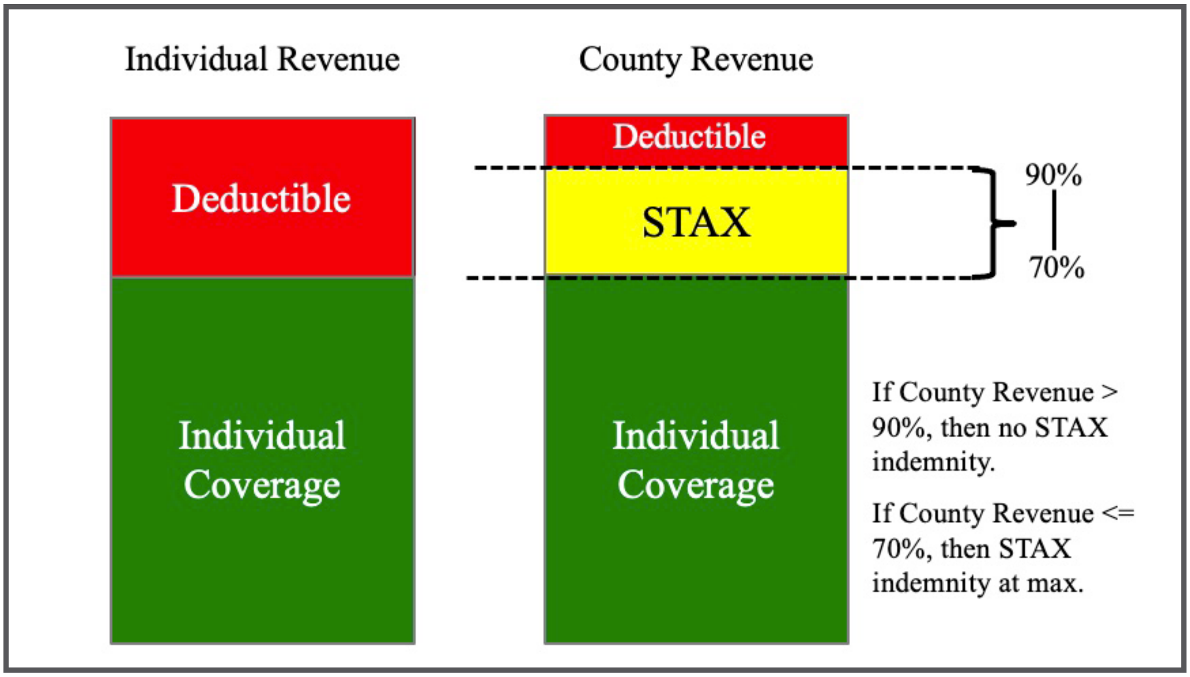

Figure 1. STAX coverage

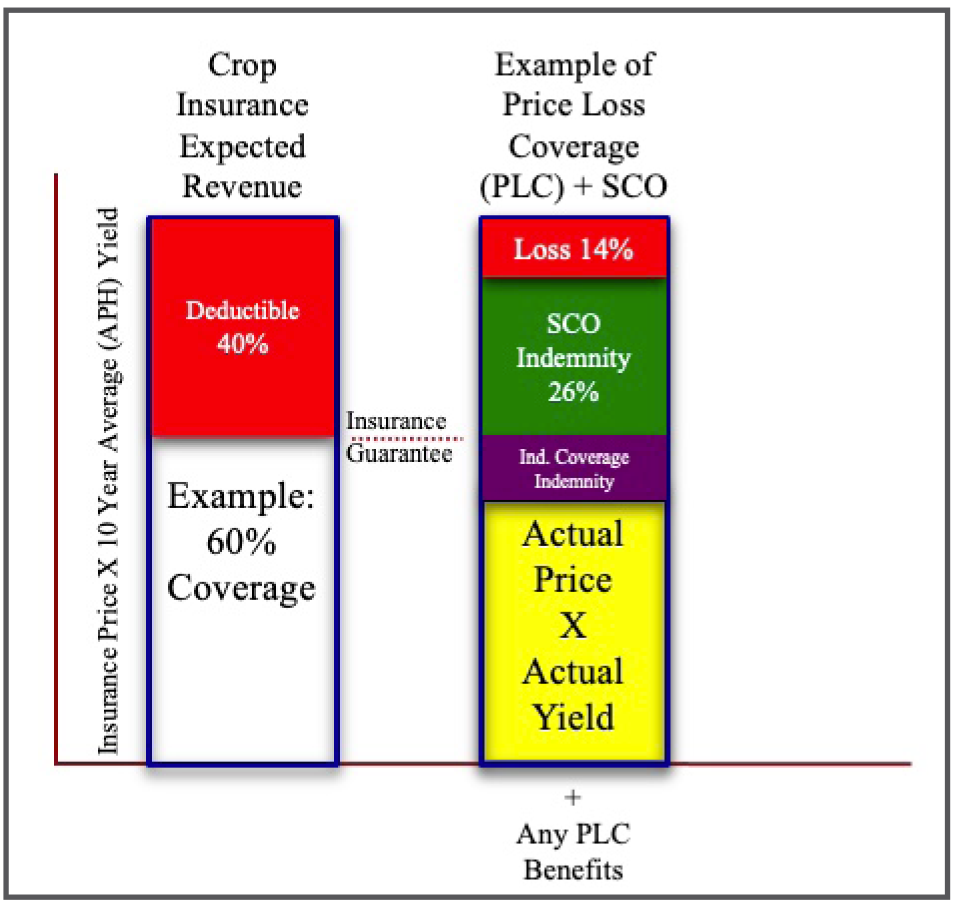

Figure 2. SCO coverage

Table 1. Acronyms	
Acronym	**Definition**
ARC	Agriculture Risk Coverage
ARC-CO	Agriculture Risk Coverage-County
ARC-IC	Agriculture Risk Coverage-Individual Coverage
APH	Actual Production History
CEPP	Commodity Exchange Price Provisions
FCIC	Federal Crop Insurance Corporation
FSA	Farm Service Agency
MYA	Marketing Year Average
NASS	National Agricultural Statistics Service
PLC	Price Loss Coverage
SAT	*Southern Ag Today*
SCO	Supplemental Coverage Option
STAX	Stacked Income Protection Plan
RMA	Risk Management Agency
RP	Revenue Protection
RP-HPE	Revenue Protection with Harvest Price Exclusion
WASDE	World Agricultural Supply and Demand Estimates
YP	Yield Protection

Table 2. 2022 Price and Yield Realization Scenarios for Dawson County Cotton Farm

Scenario	Scenario Description	Actual Farm Yield, lbs/acre	Actual County Yield, lbs/acre	Harvest Price, $/lb (Lint)	MYA Price, $/lb (Seed Cotton)
1	Baseline prices, Baseline yields	209	209	$1.03	$0.4923
2	Low prices, Baseline yields	209	209	$0.77	$0.3872
3	Baseline prices, Low farm yield, Baseline county yield	159	209	$1.03	$0.4923
4	Low prices, Low farm yield, Baseline county yield	159	209	$0.77	$0.3872
5	Baseline prices, Baseline farm yield, Low county yield	209	159	$1.03	$0.4923
6	Low prices, Baseline farm yield, Low county yield	209	159	$0.77	$0.3872

Table 3. Scenario 1: Baseline Prices and Yields					
RP Coverage Level	Net Indemnity, $			Farm Program Payment, $	
	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	(9.16)	(16.83)	–	–
55%	(6.22)	(9.16)	(14.87)	–	–
60%	(7.04)	(9.16)	(12.87)	–	–
65%	(7.93)	(9.16)	(10.64)	–	–
70%	(9.83)	(9.16)	(8.34)	–	–
75%	(14.08)	(7.03)	(5.88)	–	–
80%	(23.94)	(4.78)	(3.26)	–	–
85%	(42.06)	(2.44)	(0.55)	–	–

Table 4. Scenario 2: Low Prices, Baseline Yields					
RP Coverage Level	Net Indemnity, $			Farm Program Payment, $	
	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	30.22	7.37	1.62	–
55%	(6.22)	30.22	9.33	1.62	–
60%	(7.04)	30.22	11.33	1.62	–
65%	(7.93)	30.22	13.56	1.62	–
70%	(9.83)	30.22	15.86	1.62	–
75%	(13.56)	31.72	17.80	1.62	–
80%	(12.65)	21.05	9.66	1.62	–
85%	(20.01)	10.48	1.60	1.62	–

Table 5. Scenario 3: Baseline Prices, Low Farm Yield, Baseline County Yield					
RP Coverage Level	Net Indemnity, $			Farm Program Payment, $	
	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	(9.16)	(16.83)	–	–
55%	(6.22)	(9.16)	(14.87)	–	–
60%	(7.04)	(9.16)	(12.87)	–	–
65%	(7.93)	(9.16)	(10.64)	–	–
70%	(9.83)	(9.16)	(8.34)	–	–
75%	(14.08)	(7.03)	(5.88)	–	–
80%	(15.49)	(4.78)	(3.26)	–	–
85%	(22.85)	(2.44)	(0.55)	–	–

Table 6. Scenario 4: Low Prices, Low Farm Yield, Baseline County Yield					
	Net Indemnity, $			Farm Program Payment, $	
RP Coverage Level	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	30.22	7.37	1.62	–
55%	(6.22)	30.22	9.33	1.62	–
60%	(0.31)	30.22	11.33	1.62	–
65%	9.57	30.22	13.56	1.62	–
70%	18.43	30.22	15.86	1.62	–
75%	24.94	31.72	17.80	1.62	–
80%	25.85	21.05	9.66	1.62	–
85%	18.49	10.48	1.60	1.62	–

Table 7. Scenario 5: Baseline Prices, Baseline Farm Yield, Low County Yield					
	Net Indemnity, $			Farm Program Payment, $	
RP Coverage Level	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	26.81	4.53	7.02	–
55%	(6.22)	26.81	6.49	7.02	–
60%	(7.04)	26.81	8.49	7.02	–
65%	(7.93)	26.81	10.72	7.02	–
70%	(9.83)	26.81	13.02	7.02	–
75%	(14.08)	28.94	15.48	7.02	–
80%	(23.94)	21.05	9.66	7.02	–
85%	(42.06)	10.48	1.60	7.02	–

Table 8. Scenario 6: Low Prices, Baseline Farm Yield, Low County Yield					
	Net Indemnity, $			Farm Program Payment, $	
RP Coverage Level	RP	STAX	SCO	ARC-CO	PLC
50%	(5.51)	42.50	45.87	22.81	–
55%	(6.22)	42.50	47.83	22.81	–
60%	(7.04)	42.50	43.10	22.81	–
65%	(7.93)	42.50	34.57	22.81	–
70%	(9.83)	42.50	26.10	22.81	–
75%	(13.56)	31.72	17.80	22.81	–
80%	(12.65)	21.05	9.66	22.81	–
85%	(20.01)	10.48	1.60	22.81	–

Table 9. Summary of Preferred Options for Each Scenario			
Scenario	**Scenario Description**	**Producer Choice**	**Net Benefit**
1	Baseline prices, Baseline yields	Either ARC-CO or PLC	$0
2	Low prices, Baseline yields	STAX @ 75%	$31.72
3	Baseline prices, Low farm yield, Baseline county yield	Either ARC-CO or PLC	$0
4	Low prices, Low farm yield, Baseline county yield	RP @ 75% and STAX	$24.94 + $31.72 = $56.66
5	Baseline prices, Baseline farm yield, Low county yield	RP @ 50% and STAX	–$5.51 + $26.81 = $21.30
6	Low prices, Baseline farm yield, Low county yield	RP @ 50% and SCO	–$5.51 + $45.87 = $40.36

Alternative Public Land Management Policy Impacts: Ranch and County Level

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Abstract

A dynamic Monte Carlo linear programming model of a cattle ranch in Elko County, Nevada, provided a range of assets under management (AUM) valuations under alternative reductions in public land grazing permits. Employing these ranch level results into a county level input-output model, we derived a range of county economic, employment, and household income impacts for alternative public land policies. Estimation as to possible ranges in AUM valuations and county level economic impacts provides information to policy makers not only during periods of average economic condition but also under unfavorable economic conditions. Here Manski's credible interval scoring was employed for policy analysis.

INTRODUCTION

Almost one-third of total U.S. acreage is administered by the federal government. Of total federal land acreage, approximately 92.4% in 2015 was located in the 13 western states. Not only are most public lands located in the West, the federal government is also the dominant landowner of these lands (Table 1). Because of this vast public land management of the western lands, the federal government plays an important role in economic activity of rural western states' economies.

For the state of Nevada, approximately 83% of the total land area was federal land in 2018 (Table 2). A much smaller percentage, only 0.37%, was state lands. Over 85% of total county land acreage is under federal ownership in the Nevada counties of Nye, Esmeralda, Lander, Lincoln, and White Pine. Figure 1 shows the public lands within the state of Nevada. These seven Nevada counties have 54.87% of all federally owned land and make up 49.64% of the state's total land acreage (U.S. Census Bureau, 2022). Within the seven-county area in 2021, the metropolitan city of Las Vegas is located within Clark County. Clark County's population has 72.86% of the state's total population. Adding the six other rural counties, this seven-county area has 74.20% of the state's total population (U.S. Census Bureau, 2022). Elko County, Nevada, is in northeastern Nevada and has 74% of its land under federal administration.

Over the past few decades, rural residents have often come into conflict with urban residents, resource managers, and public lands stakeholders over perceived acceptable land uses. Many diverse users actively utilize these lands for both recreational and commercial activities such as fishing, camping, hiking, hunting, boating, grazing, logging, and mining. Many times, the multi-use nature of these activities includes overlap, and sometimes conflict, between them. Importantly, the landscapes also provide critical ecosystem services related to water quality, air quality, and wildlife habitat along with a host of other functions.

One of the most sensitive resource management topics in these landscapes has been the reduction of animal units in public lands grazing (Pearce et al., 1999). Federal resource managers are faced with multiple objectives with multiple use lands. On one hand, they are required to keep multiple use federal lands within environmentally acceptable limits. Some interest groups also advocate for removal of livestock from public lands because they define grazing of public lands as an adverse and unnecessary use of western landscapes. On the other hand, there are families and communities in the West whose livelihoods depend on livestock grazing in public lands, with livestock production remaining as a core sector of commerce.

Many rural counties have strong ties to the livestock industry, which help to provide economic stability and a rural lifestyle to their families (Pearce et al., 1999; Boyd, Beck, and Tanaka, 2014; Davies, Bates, and Boyd, 2016). Although numerous western rural county economies continue to diversify, the livestock industry provides not only economic stability for many communities (Boyd, Beck, and Tanaka, 2014) but also ecological and landscape functions to manage increased wildfire risk (Davies et al., 2016).

The Bureau of Land Management (BLM), U.S. Forest Service (USFS), and National Park Service (NPS) policy decisions in recent decades have resulted in a consistent downward trend in the amount of alteration of the planned grazing in the West (Pearce et al., 1999). These previous and ongoing grazing reductions have impacted livestock operations, associated rural economies, and rural communities' social cohesion.

Public land management policies are often completed by using average values of key decision variables. This type of policy evaluation under certainty assumptions has been criticized by many, such as Manski (2013). Manski would argue that constructing and analyzing public policies such as public land management policies under a deterministic framework often ignores economic, social, and climate variabilities. He would classify deterministic modeling as "incredible certitude" analysis providing only a point estimate of key output variable such as net present value (NPV) or value of an animal unit month (AUM). However, "credible interval scoring" provides a probability distribution of key output variables, which is necessary for effective and efficient public land management policy analysis (Pouliquen, 1970; Reutlinger, 1970; Hardaker et al., 2004). Pouliquen states that the benefits of Monte Carlo modeling are that it provides decision-makers the extreme values of key operating variables and their relative probabilities along with a weighted estimate of the relationships between unfavorable and favorable outcomes. In addition to risk analysis and how variabilities in output and input prices could affect business operations, Pouliquen would suggest that Monte Carlo analysis could be used to analyze alternative public land management policies. In addition, results of a ranch level Monte Carlo model can be coupled with a county input-output model to derive countywide impacts from changes in public land management policies.

In this paper, the economic impacts of reducing grazing permits on a livestock-dependent county that relies heavily on public lands for seasonal grazing will be estimated. A multi-period Monte Carlo linear programming model will be employed to derive ranch level impacts from alternative grazing permit scenarios. From results of the multi-period Monte Carlo linear programming model and the county input-output model, countywide impacts such as economic activity, employment, and labor income from alternative public land management policies will be derived. Specific objectives include:

- To complete an overview of the study area of Elko County, Nevada
- To discuss the ranch level multi-period Monte Carlo linear programming model
- To discuss the validation and verification of the Elko County IMPLAN input-output model
- To present results of the analysis of alternative public land management policies over a range of possibilities or Manski's interval scoring

STUDY AREA

The study area for this paper is Elko County, Nevada. Elko County is in northeastern Nevada. The economy of Elko County is based on natural resource industries and specializes in economic sectors related to natural resource industries. To show this specialization, an analytical statistic called location quotient is used. A location quotient for this study is computed as an economic sector's share of Elko County's total employment divided by the economic sector's share of the national employment. Table 3 shows the gold and silver mining sector with a location quotient of 452.85, which means Elko County's proportional share of total county employment in the gold and silver mining sector is 541.36 times the national share and that Elko County's animal production sector location quotient of 2.55 is 4.67 times the national proportionate share. These two sectors are the export sectors for this county. Most of the federal land is rangeland and is used for livestock grazing by private landowners holding grazing permits and leases.

Dating back to the 1990s, a substantive number of BLM acres and permits have been under review and challenged by additional constraints. The overall management pattern occurring in recent decades yields a reduction in AUMs by the BLM on many of Elko County's public land allotments. Most ranches in northeastern Nevada rely on a matrix of public and private lands that include the ability to rotate cattle through lower and higher elevation areas to follow forage availability with the seasons.

Reduction in grazing permits puts ranchers' economic activities and counties' economies at risk. Stemming primarily from the overall permit loss, the reduction of AUMs of public forage available reduces the profitability of the livestock industry and puts at risk the economic activities across all sectors that are generated by the livestock industry. In addition, AUM reduction increases litigations, uncertainty, and risk faced by ranchers. To estimate the economic impacts of potential losses of AUMs, a multi-period Monte Carlo linear programming model will be developed to estimate AUM values from grazing allotment reductions at the ranch level. Afterwards applying the IMPLAN microcomputer input-output model algorithm, total economic impacts from reductions in public land grazing on the Elko County economy can be estimated.

Federal grazing plays a large role in Elko County agricultural production. According to the 1997 Census of Agriculture, 177 ranches held grazing permits or approximately 41% of total agricultural operations in Elko County (436) in 1997 and 68% of operations with a beef cow inventory (262) in 1997. Of these ranches, 144 held grazing permits with the BLM, 61 held grazing permits with the USFS, and 16 held permits with other types of landowners. Note that some owners had grazing permits with more than one type of agency.

Current data on the number of available AUMs was collected from Elko County regional offices of the BLM, USFS, and U.S. Fish and Wildlife Service. Table 4 displays the data. Total permitted AUMs in Elko County in 2017 were estimated to be 847,058, with 85% of the total permitted AUMs on BLM lands and the remaining 15% on USFS land. A small amount of grazing was permitted on the Ruby Lake National Wildlife Refuge. Actual AUMs used were less than the permitted amount and vary from year to year. Another study of Elko County grazing estimated that as much as 49% of total AUMs used by the cattle industry were provided by federal grazing land (Torell, Garrett, and Ching, 1981). In addition to being a large portion of total AUMs, often the timing of forage availability on federal lands increases their importance to the ranch operation. Because of the seasonal factors, several studies have found that the value of an AUM from federal lands is greater than the value of AUMs from other sources (Torell, Garrett, and Ching, 1981; Torell et al., 2002a).

ELKO COUNTY RANCH MODEL

The Elko multi-period ranch model was developed to exemplify range cattle operation in the Elko-Eureka area of Nevada. The ranch runs a 700 cow-calf operation utilizing a mixture of private and public rangelands during the grazing season and private hay meadows to produce winter feed and aftermath grazing in the fall. Cattle are turned out in early April and return to private lands in early October.

A multi-period linear programming model is employed and has been used to derive impacts of federal land policies (Torell et al., 2002b; Rimbey et al., 2003; Taylor et al., 2004; 2005), evaluations of drought management strategies (Torell, Murugan, and Ramirez, 2010; Bastian et al., 2009; Ritten et al., 2010), grazing management assessments (Stillings et al., 2003; Tanaka et al., 2007), juniper control (Aldrich et al., 2005), and wildfire impacts (Maher, Tanaka, and Rimbey, 2013). The NPV of discounted annual returns is maximized over a 40-year time span subject to linear constraints that define resource limitations and resource transfers between years. Figure 2 shows the general structure of the multi-period linear programming model (Torell et al., 2014).

The model maximizes the present value of net returns. Results also account for off-ranch income and fixed costs (e.g., mortgage payment) that do not change over time. Variable production costs include animal production expenses plus feed costs and costs that vary with level of production, such as labor, veterinary costs, etc.

Livestock prices generally influence annual ranch income and optimal production. A Monte Carlo analysis was employed to consider the effects of beef price variations on ranch returns and optimal production strategies. Different beef cattle prices were generated for each of 100 model iterations over a 40-year planning horizon using beef cattle cycle and trends. The Monte Carlo multi-period linear programming model is superior to the deterministic multi-period linear programming model.

Manski (2013) would argue that constructing and analyzing public land management policies under a deterministic framework often ignores price and cost variabilities. Manski would classify deterministic modeling as "incredible certitude" analysis providing only a point estimate of key output variable such as NPV or value of an AUM. However, "credible interval scoring" provides a probability distribution of key output variables, which is necessary for effective and efficient public land management policy analysis (Pouliquen, 1970; Reutlinger, 1970; Hardaker et al., 2004). Pouliquen indicates that the benefits of the Monte Carlo multi-period linear programming model are that it provides public land decision-makers the extreme values of key operating variables and their relative probabilities along with a weighted estimate of the relationships between unfavorable and favorable outcomes. In addition to risk analysis and how variabilities in livestock prices affect livestock operations, Pouliquen would suggest that complete multi-period Monte Carlo linear programming analysis could be used to analyze alternative public land management policies. In addition, results of the ranch level multi-period Monte Carlo linear programming model can be coupled with a county input-output model to derive countywide impacts from changes in public land management policies. Often county impacts from changes in grazing permits are estimated using average value of AUMs. For understanding the potential impacts of grazing reductions on a county economy, ranges of AUM values should be used to estimate the range of county-wide impacts that could occur from public land management policies.

Verified and Validated Elko County Input-Output Model

Estimation of the economic, employment, and household income impacts of changes in the Elko County economy from changes in public land management policies will be derived from employing an input-output or interindustry model. Interindustry analysis was developed by Wassily Leontief in the late 1930s to represent the interdependencies between different economic sectors in a study area (1936). Interindustry analysis shows how economic sectors are linked together by sales and purchases between other economic sectors. Since its inception, the framework of interindustry models has continued to be improved and is one of today's most applied analytical techniques in economics (Baumol, 2000). The advantage of interindustry analysis is its ability to provide an easy to understand, transparent, and detailed picture of economic structure of a study area's economy at a point in time. Another advantage is that interindustry models do not incorporate any behavioral equations of individuals or businesses, so it is politically and ideologically neutral (Foran, Lenzen, and Dey, 2005).

One of the most used secondary input-output models is IMPLAN. Originally developed by the USFS, IMPLAN is now a private modeling company (IMPLAN, 2021). The two major components of IMPLAN are its data files and software. The desktop database includes information on 528 different economic sectors, along with a national input-output model to derive regional or county level input-output models. The IMPLAN model is reasonably flexible, allowing users to verify and validate data used in county model development.

However, there must be the verification and validation of dataset used for developing IMPLAN models as outlined by Willis and Holland (1997). The first step is to download the IMPLAN model data from the industry detail file, which has sectoral employment. The second step is to download quarterly census of employment and wage data for the study area from the Nevada Department of Employment, Training, and Rehabilitation's (DETR's) employment data by the North American Industry Classification System (NAICS). Using IMPLAN user supplied crosswalk tables, the NAICS sectors and employment levels are redefined into IMPLAN economic sectors.

After creating the IMPLAN economic sectors, employment data for the same year as the IMPLAN data and model is downloaded from Bureau of Economic Analysis Regional Economic Information System (BEA REIS). The BEA REIS employment data will have employee and proprietor data. The data will show employment by two-digit NAICS code that can be cross-referenced with and redefined into the IMPLAN economic sectors defined above. Therefore, using data from the state employment offices, proportional values of each sector to each two-digit IMPLAN sector can be estimated. Willis and Holland (1997) suggest reclassifying certain sectors in a way that intuitively makes more sense to the public. By using procedures outlined by Willis and Holland (1997) and DETR and BEA REIS data, county level input-output models for this analysis are verified and validated.

RESULTS

As noted by Gardner (1997, 11), "the Animal Unit per Month permit's value represents the capitalized value expected future differences between fee (and non-fee grazing costs) and value of forage." To derive the value of grazing permits as grazing permits are reduced or eliminated, the multi-period Monte Carlo linear programming model was used to derive 40 years of discounted returns to estimate an income-based grazing permit value.

Rimbey, Torell, and Tanaka (2007) and Torell, Dixon, and McCollum (2012) found that highly federal land–dependent ranches had estimated permit values ranging from approximately $100 to $350 per AUM. These values were similar to capitalized return reductions estimated by Torell et al. (2014).

Using the Monte Carlo multi-time period model, a distribution of value of AUM permits for a 25% reduction, 50% reduction, and 75% reduction is shown as a "credible interval scoring"—not from a deterministic livestock price, which is "incredible certitude" result. Figure 3 shows that the value of an AUM permit from a 25% reduction in Elko County varies from $202.22 per AUM to $245.49 per AUM, with average value of $226.25 per AUM. Figure 4 shows that the value of an AUM permit from a 50% reduction in Elko County varies from $213.47 per AUM to $258.67 per AUM, with average value of $240.40 per AUM. Figure 5 shows that the value of an AUM permit from a 75% reduction in Elko County varies from $226.27 per AUM to $268.02 per AUM, with average value of $251.29 per AUM.

The results from the Elko County ranch model show that, in terms of ranch production, one AUM of federal grazing can potentially generate on average from a 25% reduction in AUM permits of $226.25 per AUM, with a low value of $202.22 per AUM and a high value of $245.49 per AUM. A 50% reduction in AUM permits yields an average of $240.40 per AUM, a low value of $213.47 per AUM, and a high value of $258.67 per AUM. In contrast, a 75% reduction in AUM permits yields an average value of $251.29 per AUM, a low value of $226.27 per AUM, and a high value of $268.02 per AUM. This assumes that since federal AUMs are part of an overall grazing system, a change in federal grazing affects the optimal use of the rest of the forage resources.

From Table 4, the regional impacts from a change in public AUMs can be seen. If using only the average AUM value for 25% reduction, the results would show decline in economic activity of $47,911,718, loss of 463 jobs, and reduction of labor income of $9,566,237. However, deriving a range of AUM values for a 25% reduction in AUM permits shows economic activity decrease ranging between $42,823,017 and $51,986,067, with loss of employment ranging between 414 jobs and 502 jobs and loss of labor income ranging between $8,550,208 and $10,379,737. This shows that using only average impacts does not give a true picture of AUM reduction impacts. Table 4 shows that analysis of impacts of reductions in AUMs on public lands should be analyzed by credible interval scoring.

CONCLUSION

This paper provided an initial experiment in investigating impacts of changes in public land management policies by employing a dynamic Monte Carlo linear programming model. Deriving a range of values for AUMs for alternative reductions in grazing permits provides information as to the range of impacts that could result. Also, using these ranges with interindustry analysis provides information as to the potential range of county economic, employment, and labor income impacts. As Hardaker et al. (2004) suggested in investigating ranges of potential policy results, deriving impacts at average does not yield suitable information. Estimation of potential ranges provides information as to possible policy impacts during not only average times but also times when the economy is low. Again, Manski's credible interval scoring could be employed in any regional policy analysis.

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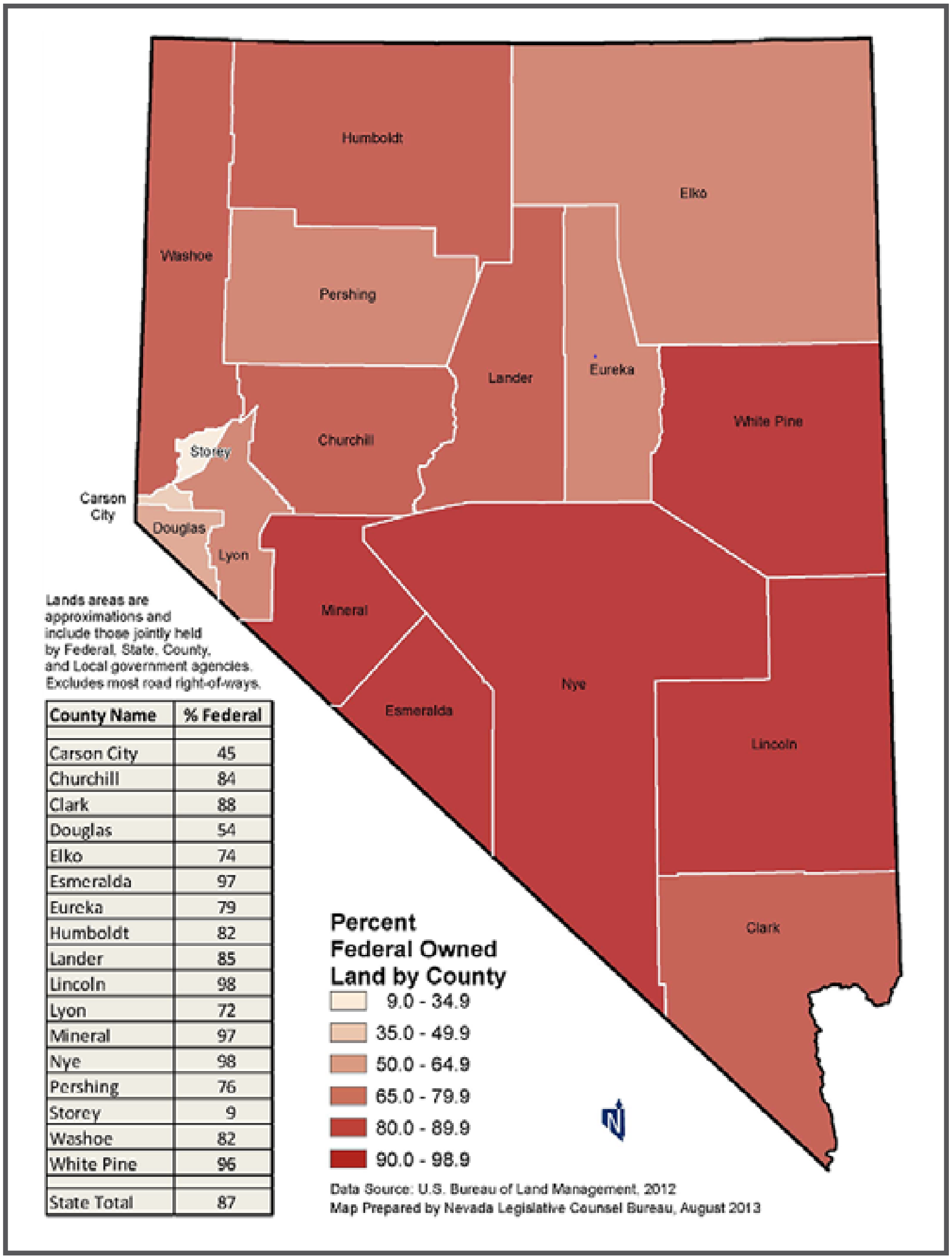

County Name	% Federal
Carson City	45
Churchill	84
Clark	88
Douglas	54
Elko	74
Esmeralda	97
Eureka	79
Humboldt	82
Lander	85
Lincoln	98
Lyon	72
Mineral	97
Nye	98
Pershing	76
Storey	9
Washoe	82
White Pine	96
State Total	87

Figure 1. Percent of total land under federal ownership by county in the state of Nevada. (Source: Nevada Legislative Counsel Bureau, 2013.)

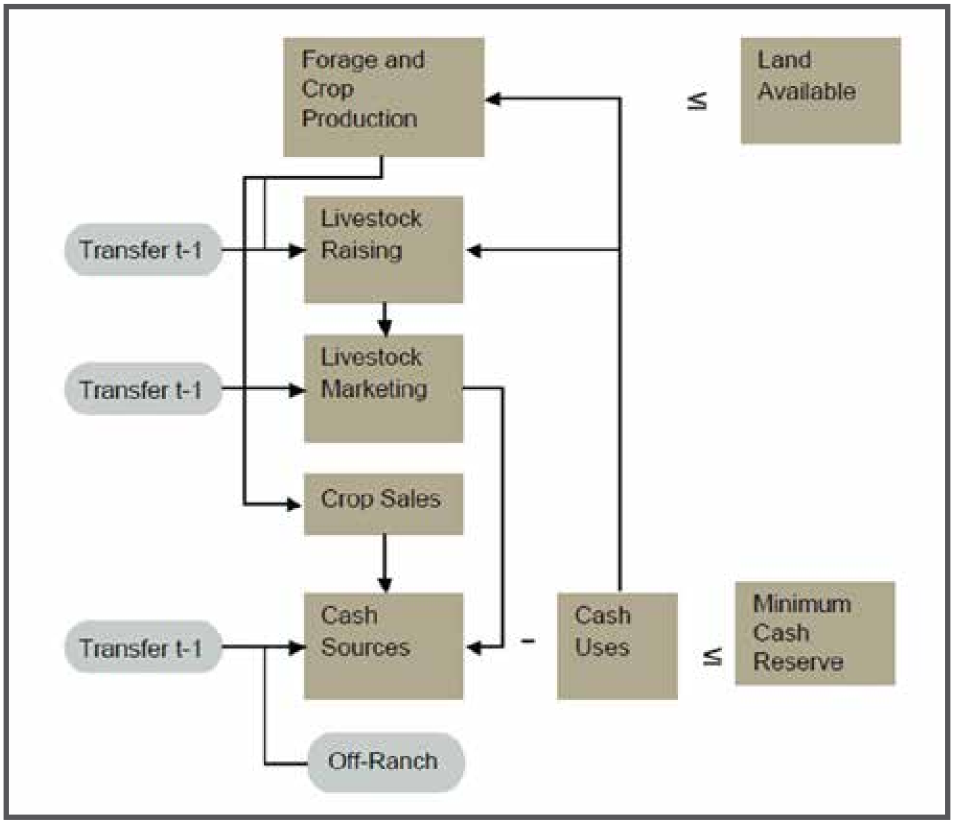

Figure 2. Schematic of multi-period linear programming model. (Figure adapted from Torell et al., 2014.)

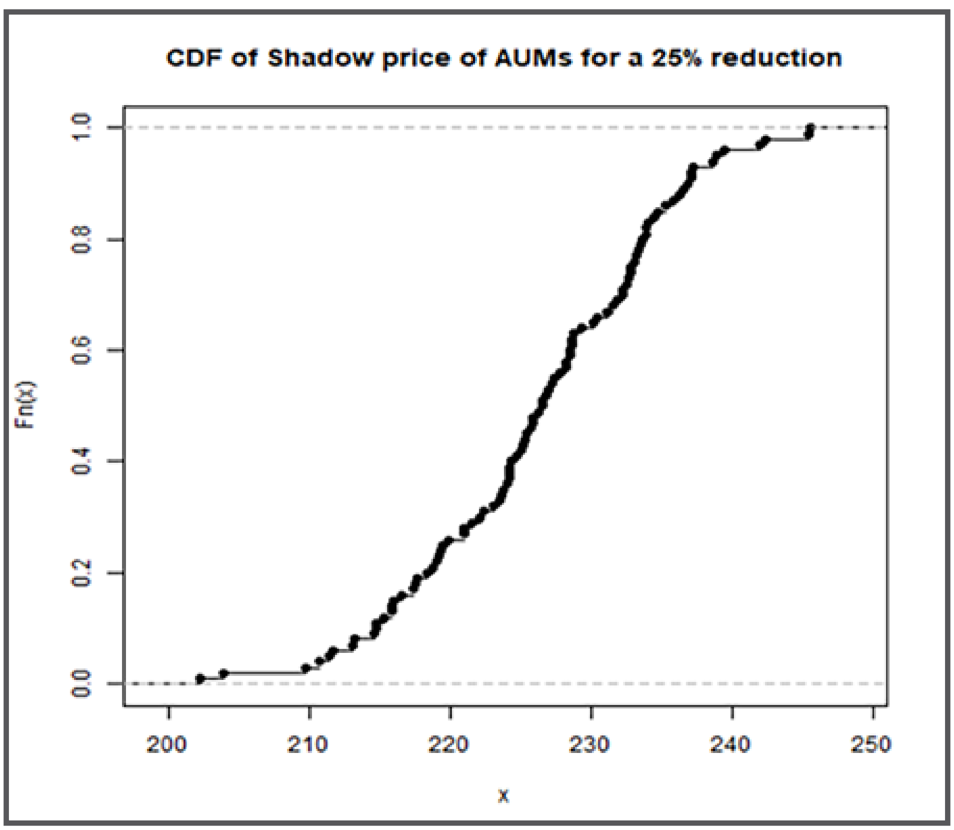

Figure 3. CDF of valuation of AUMs in Elko County from a 25% reduction in public land grazing permits

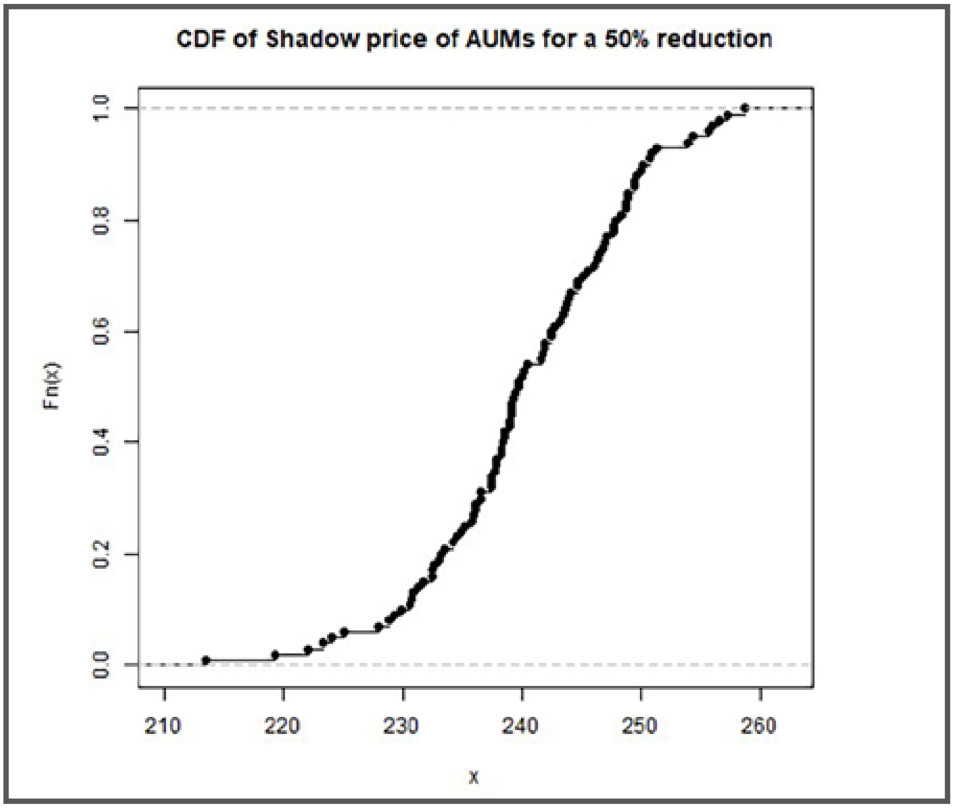

Figure 4. CDF of valuation of AUMs in Elko County from a 50% reduction in public land grazing permits

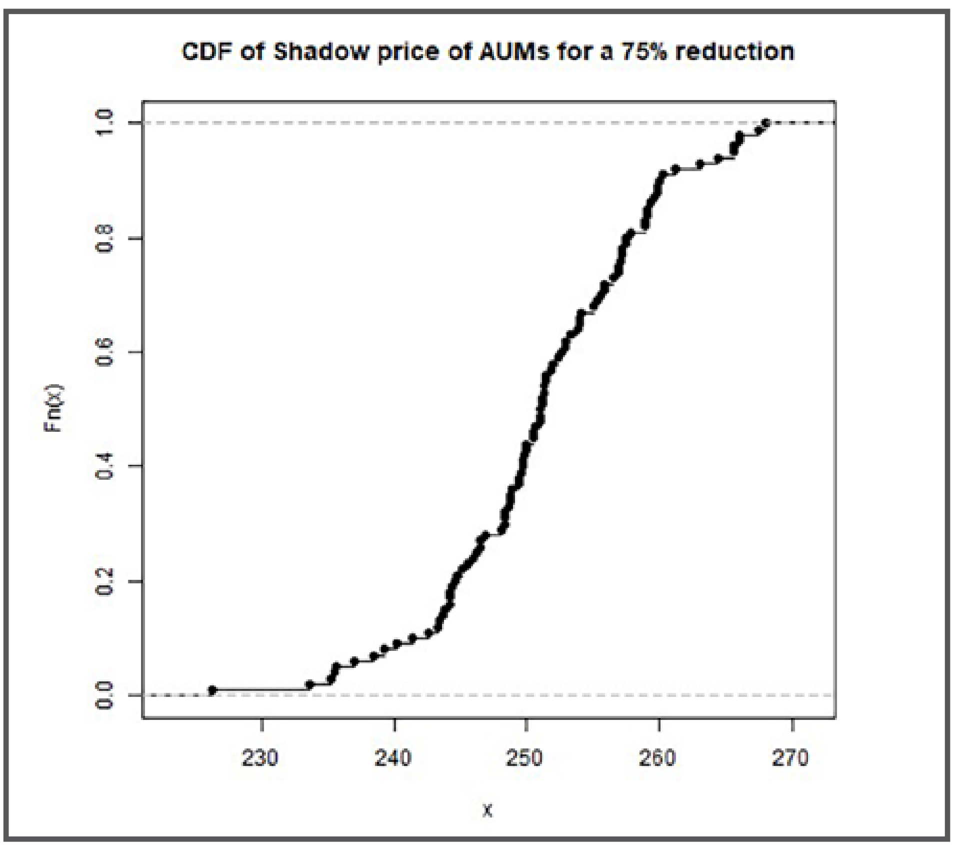

Figure 5. CDF of valuation of AUMs in Elko County from a 75% reduction in public land grazing permits

Table 1. Federal Lands in Western U.S. States

State	Total Acreage (acres)	Federal Lands (acres)	Percentage of Total Acreage That Is Federal
Alaska	372,792,373	222,412,794	59.66%
Arizona	72,951,915	30,346,513	41.60%
California	101,159,181	47,915,621	47.37%
Colorado	66,620,719	37,017,343	55.56%
Hawaii	4,116,516	2,132,873	51.81%
Idaho	53,494,867	33,547,324	62.71%
Montana	94,147,914	27,767,169	29.49%
Nevada	70,664,589	59,661,758	84.43%
New Mexico	77,819,693	26,283,866	33.78%
Oregon	62,053,174	32,273,753	52.01%
Utah	56,952,598	34,990,802	61.44%
Washington	43,212,988	12,565,361	29.08%
Wyoming	62,598,290	29,891,689	47.75%
TOTAL	**1,138,584,817**	**596,806,866**	**52.42%**
11 Contiguous Western States	761,675,928	372,261,199	48.87%
United States	2,303,091,014	632,461,561	27.46%

Source: Headwaters Economics, 2022.

Table 2. Federal and State Lands in Nevada								
County	Private Lands		BLM		Forest Service		Other Federal	
	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Carson City	38,310	38.07%	35,805	35.58%	15,326	15.23%	115	0.11%
Churchill	791,160	24.60%	1,997,934	62.14%	0	0.00%	366,147	11.39%
Clark	582,648	11.29%	2,631,068	51.00%	279,752	5.42%	1,534,950	29.75%
Douglas	142,009	30.08%	161,894	34.29%	83,041	17.59%	25	0.01%
Elko	2,844,111	25.83%	6,888,104	62.57%	1,067,810	9.70%	26,817	0.24%
Esmeralda	64,869	2.82%	2,160,499	94.06%	67,085	2.92%	3,704	0.16%
Eureka	565,004	21.12%	1,966,064	73.49%	144,104	5.39%	0	0.00%
Humboldt	1,096,813	17.74%	4,379,103	70.85%	289,555	4.68%	386,104	6.25%
Lander	537,034	15.20%	2,664,636	75.43%	296,542	8.39%	30,162	0.85%
Lincoln	142,447	2.09%	5,581,253	81.98%	29,467	0.43%	1,047,444	15.39%
Lyon	376,696	29.08%	562,602	43.43%	276,406	21.34%	59	0.00%
Mineral	99,825	4.09%	1,581,872	64.82%	375,347	15.38%	144,596	5.93%
Nye	305,785	2.63%	6,559,135	56.32%	1,963,183	16.86%	2,800,257	24.04%
Pershing	946,467	24.37%	2,907,584	74.88%	0	0.00%	15,668	0.40%
Storey	153,180	90.78%	15,146	8.98%	0	0.00%	0	0.00%
Washoe	683,420	16.32%	2,706,642	64.64%	108,710	2.60%	191,492	4.57%
White Pine	245,145	4.31%	4,515,194	79.31%	764,409	13.43%	90,189	1.58%
TOTAL	**9,614,923**	**13.59%**	**47,314,535**	**66.86%**	**5,760,737**	**8.14%**	**6,637,729**	**9.38%**

Table 2. Federal and State Lands in Nevada (Continued)								
County	Tribal Lands		State Lands		City, County, Other		Total	
	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Carson City	3,918	3.89%	4,062	4.04%	3,101	3.08%	**100,637**	**100.00%**
Churchill	52,401	1.63%	7,823	0.24%	0	0.00%	**3,215,465**	**100.00%**
Clark	79,143	1.53%	48,269	0.94%	3,126	0.06%	**5,158,956**	**100.00%**
Douglas	83,627	17.71%	1,496	0.32%	0	0.00%	**472,092**	**100.00%**
Elko	160,231	1.46%	22,413	0.20%	0	0.00%	**11,009,486**	**100.00%**
Esmeralda	0	0.00%	835	0.04%	0	0.00%	**2,296,992**	**100.00%**
Eureka	0	0.00%	0	0.00%	0	0.00%	**2,675,172**	**100.00%**
Humboldt	29,453	0.48%	0	0.00%	0	0.00%	**6,181,028**	**100.00%**
Lander	630	0.02%	3,476	0.10%	0	0.00%	**3,532,480**	**100.00%**
Lincoln	0	0.00%	6,669	0.10%	509	0.01%	**6,807,789**	**100.00%**
Lyon	50,911	3.93%	28,846	2.23%	0	0.00%	**1,295,520**	**100.00%**
Mineral	238,366	9.77%	298	0.01%	0	0.00%	**2,440,304**	**100.00%**
Nye	8,479	0.07%	10,263	0.09%	0	0.00%	**11,647,102**	**100.00%**
Pershing	6,018	0.15%	7,431	0.19%	0	0.00%	**3,883,168**	**100.00%**
Storey	320	0.19%	85	0.05%	0	0.00%	**168,731**	**100.00%**
Washoe	463,891	11.08%	20,586	0.49%	12,274	0.29%	**4,187,015**	**100.00%**
White Pine	70,488	1.24%	7,831	0.14%	0	0.00%	**5,693,256**	**100.00%**
TOTAL	**1,247,876**	**1.76%**	**170383**	**0.24%**	**19,010**	**0.03%**	**70,765,193**	**100.00%**

Source: Headwaters Economics, 2022.

Table 3. Location Quotient Values for Economic Sectors in Elko County, 2010 and 2019		
Sector	**2010**	**2019**
Crop Production	1.58	1.15
Animal Production	5.37	2.55
Other Agriculture	1.48	1.04
Gold and Silver Mining	492.5	452.85
Other Mining	2.52	1.59
Supportive Activities for Mining	17.89	107.84
Utilities	1.13	1.02
Construction	1.48	1.18
Manufacturing	0.13	0.14
Wholesale Trade	0.9	1.28
Retail Trade	0.99	1.02
Transportation and Warehousing	0.9	0.55
Information	0.37	0.8
Finance and Insurance	0.36	0.37
Real Estate and Rental and Leasing	0.56	0.77
Professional, Scientific, and Technical Services	0.39	0.43
Management of Companies and Enterprises	0.92	0.85
Administration and Support and Waste Management and Remediation Services	0.45	0.45
Educational Services	0.15	0.24
Health Care and Social Assistance	0.53	0.52
Arts, Entertainment, and Recreation	1.48	1.85
Accommodations and Food Services	3.94	1.63
Other Services (except Administration)	0.99	0.93
Government	1.03	1.04

Table 4. Range of Economic, Employment, and Labor Income Impacts from 25%, 50%, and 75% Reductions in AUM Permits in the Elko County Economy									
Result Types	**25% Reduction in AUMS**			**50% Reduction in AUMs**			**75% Reduction in AUMs**		
	Economic	**Employment**	**Labor Income**	**Economic**	**Employment**	**Labor Income**	**Economic**	**Employment**	**Labor Income**
Low	$42,823,017	414	$8,550,208	$90,410,736	873	$18,051,754	$143,747,860	1,388	$28,701,248
Average	$47,911,718	463	$9,566,237	$101,646,960	982	$20,295,221	$159,642,904	1,542	$31,874,913
High	$51,986,067	502	$10,379,737	$109,554,246	1,058	$21,874,020	$170,271,364	1,655	$33,997,032

Grower Production and Economic Efficiency in the Semi-Arid Southern Great Plains



By Lixia H. Lambert, Hannah E. Shear, and Jason Warren

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Abstract

Agricultural production competitions that focus on a single crop, relatively similar field conditions, and similar growing conditions can provide valuable information to extension educators, researchers, and growers on input and resource management. Using data collected from a grower competition in the Oklahoma panhandle, a semi-arid region, we estimated the relative production and economic efficiency scores for competing grower teams. Efficiency was measured using data envelopment analysis (DEA) procedures. Results show that comparatively lower fertilizer application rates and higher rates of irrigation generated the highest efficiency scores. Limited application of fertilizer and irrigation may achieve technical and cost efficiencies, but it is not an optimal decision if the producer's objective is to maximize profit.

INTRODUCTION

Sustainable irrigated agriculture in the Southern Great Plains semi-arid regions depends on how the producers manage scarce water resources and other inputs (Evett et al., 2020; Hansen et al., 2012; Parton, Gutmann, and Ojima, 2007). Agronomic and economic models and extension personnel provide producers with resources to identify when and how much inputs to apply to achieve economically optimal outcomes under different growing and prevailing market conditions. However, agricultural producers may not always make optimal input use decisions based on variability of commodity price, input costs, and yield, and their decision-making criteria varies across geographic locations, crop types, and a changing climate (Patrick et al., 1985).

In an effort to develop effective extension education materials to help agricultural producers make better decisions in semi-arid production regions, it is useful to first understand the farm management decisions currently made by producers. Analyzing producers' real-time decisions and the production and economic consequences will help extension educators and producers learn the impact of different management strategies on input use with respect to the region's growing condition, along with national input costs and output prices. As it has long been known, comparison to a neighbor's operation can lead to better decision-making (Baker, 1971). A well formulated and designed producer contest is expected to provide participants the opportunity to observe the impact of different management decisions and glean some understanding from the choices made by others due to site similarities.

Agricultural production contests with a single crop, relatively similar field conditions, and similar growing conditions can be useful in proving information to producers about their operations and encourage them to identify best resource management practices among their peers (Sheremeta, 2013; Henry et al., 2022). This type of contest has a long history of implementation in the United States, with many commodity organizations hosting annual yield competitions. For example, the National Corn Growers Association hosts the annual national corn yield contest and the National Wheat Foundation has a national wheat yield contest. Although yield is one of the most important engineering and agronomic factors that affect producers' revenue, maximum production does not necessarily (if ever) guarantee maximum profits, given fluctuations in input costs and commodity prices. A competition focused on both profit maximization and production efficiency is more reflective of the production environment while also being more applicable and useful for farm management analyses. Evaluating producer decisions regarding input management decisions in terms of production and economic efficiency could be a potentially compelling indicator to producers as they adjust their management protocol.

This research analyzed data collected from a grower competition in the Oklahoma panhandle region. Details of the competition are discussed along with summary information in the data and methods section. The production and economic efficiency are calculated using data envelopment analysis (DEA) (Chavas and Aliber, 1993; Färe, Grosskopf, and Lovell, 1985; Coelli et al., 2005). This method allows for a relative comparison of the producers with respect to their production and economic efficiencies. The data collected is from the 2019 competition, but further analysis simulating output price distributions was utilized to determine the impact on the producers' economic efficiency under different fertilizer costs.

METHOD AND DATA

2019 Testing Ag Performance Solutions in Oklahoma

Testing Ag Performance Solutions (TAPS) was created in 2017 in Nebraska by a team of researchers at the University of Nebraska–Lincoln's West Central Research, Extension, and Education Center as a sprinkler corn farm management competition. Producers can "win" the TAPS competition in one of three ways: most profitable producer, highest input efficiency, and greatest grain yield. Recognizing the top teams for being the most profitable and the most efficient with input use is what makes this farm management competition more similar to the environment in which producers operate outside of the TAPS competition.

Oklahoma State University's first TAPS annual sprinkler irrigated corn farm management competition was established and conducted in 2019 at the McCaull Research and Demonstration Farm in Eva, Oklahoma. Six farms, a team of university extension specialists, and an Oklahoma State University student team participated in this competition (Table 1). Teams A–F are farmers, Team G is the team of extension specialists, and Team H is a student team. Each team competed for three prize places: first place goes to the most profitable team, second place goes to the team with the highest input efficiency, and third place goes to the team with the greatest corn yield.

Each team was randomly assigned to a set of four experiment-sized plots, totaling about 1.2 acres. Teams made decisions as they would on a real Oklahoma panhandle irrigated corn farm, with control over N fertilizer and irrigation only. University personnel carried out each team's production management decisions. All other management decisions and field maintenance, such as pesticide use and residue management, were fixed and carried out by the same university personnel to ensure uniformity. Although participants were encouraged to observe and monitor their plots, install their own equipment, and/or collect additional data from their plots throughout the growing season at their own expense and risk, they were not permitted to change, modify, alter, or add to any of the competition management protocols. This includes the use of additional inputs of any kind, such as fertilizers, biologics, herbicides, and additives.

Communication between each team and university personnel occurred through the competition website, on which each team's production decisions were tracked. University personnel regularly took photos and collected data for each team and shared the information only with team members. Other photos and ancillary data, including weather, growth stage advancement, and data collected by soil water sensor and aerial photographs, were posted to the website as they were collected and made accessible to all teams.

Data

To calculate the production and economic efficiency, we used data only on irrigation and nitrogen fertilizer management because each team was obligated to decide on these inputs, whereas other inputs and practices such as insurance were deemed optional. The amounts of pre-plant, side-dress, and in-season nitrogen fertilizer are in the forms of UAN 32% as fertigation and anhydrous ammonia 82% for pre-plant and side-dress. Pre-plant nitrogen decisions were submitted by March 10, 2019. Fertigation nitrogen was applied at four vegetation stages: V1 (Stage 1 thereafter), V12 (Stage 2 thereafter), VT/R1 (Stage 3 thereafter), and R2 (Stage 4 thereafter).[1] Maximum application amount for pre-plant and side-dress was 300 pounds per acre and for each fertigation event was 30 pounds per acre (i.e., total possible fertigation amount was 120 pounds per acre). A pre-season soil report was made available on the website by the competition's kickoff in March. Decisions on the amount of fertilizer in pre-plant, side-dress, and fertigation at each stage by each team are presented in Table 2. Teams A–F applied 30–60 pounds of fertilizer for side-dress, whereas Teams G and H did not apply any side-dress. Teams A and D did not apply any pre-plant fertilizer, whereas Teams B, F, G, and H applied more than 100 pounds per acre of pre-plant fertilizer. Most teams applied fertigation in Stages 1–3, except Team B did not apply fertigation in Stage 1 and Teams C and F omitted fertigation in Stage 4 (Table 2). In 2019, the year of competition, the unit cost for UAN 32% was $0.135 per pound and $0.305 per pound for anhydrous ammonia 82% (Table 3). Both fertilizer prices increased dramatically in 2021.

Each team's decision on irrigation application from June to September is presented in Table 4, including irrigation rate in the second half of June (weeks 3–4), the first (weeks 1–2) and second half (weeks 3–4) of July and August, and the first half (weeks 1–2) of September. From June to August, all teams applied irrigation to their crop, with lower amounts in June and increased amounts in July and August. All teams except Team H did not apply irrigation in September. Team A applied the most irrigation water at 17.31 inches, whereas Team C applied the least with 13.74 inches. Cost of irrigation is set to $6 per inch for the competition.

Yield and Commodity Price

The observed corn yield and received corn prices from each team field were recorded (Table 5). Team A had the highest yield (207 bushels per acre) and received the highest price ($4.64 per bushel). Teams A, B, and D had the chance to market their corn at a higher price than other teams. The market price for corn is $3.93 per bushel, which we used for teams that were not able to sign a contract for marketing their product.

We also simulated corn prices following a triangular distribution. Historical corn prices from 1995 to 2019 were inflated using 2019 as base year and detrended to obtain the minimum ($3.63 per bushel), maximum ($6.65 per bushel), and median ($4 per bushel) of the triangular distribution. The histogram of the 1,000 simulated price samples is presented in Figure 1. This simulated price, along with nitrogen prices in 2019, 2020, and 2021, were used to estimate the expected profit efficiency for each team given their input management practices and output levels in 2019. This procedure introduces input and output market uncertainty into the analysis.

Production and Economic Efficiency Ranking Using DEA Approach

We used the DEA approach proposed by Färe, Grosskopf, and Lovell (1985) to measure each team's relative production and economic efficiency. In DEA, an efficiency frontier is benchmarked using observed teams' behavior. Teams that are 100% efficient fall on this frontier, whereas teams that are less than 100% efficient fall below this frontier, with some closer to the frontier than others. A first advantage of the DEA approach is that it does not impose parametric restrictions on the underlying technology (Chavas and Aliber, 1993). A second advantage of this procedure is that a team's performance can be evaluated relative to other teams. The approach proposed by Färe, Grosskopf, and Lovell (1985) allows for the measurement of overall, allocative, purely technical, and scale efficiency. The goal of DEA in this research is to identify the "best" team among all participating teams, given managerial decisions.

Using DEA, we estimated production efficiency by calculating team technical efficiency (TE) scores under variable return to scale (VRS) and constant return to scale (CRS), and we estimated economic efficiency by calculating team cost efficiency (CE) scores and profit efficiency (PE) scores. PE scores are estimated with respect to fertilizer prices from 2019 to 2021 and simulated output prices to incorporate market uncertainty.

The TE score measures the proportional decrease in input quantity necessary to produce the same amount of output (Equation 1), whereas the CE score measures the ratio of minimum costs to observed cost for each team (Equation 2). Given the price on both inputs (fertilizer and irrigation) and output (corn), the PE score measures the ratio of each team's observed profit to the maximum profit (Equation 3). The measures are:

$$TE = \frac{\text{Optimal Input per Output}}{\text{Observed Input per Output}} \quad (1)$$

$$CE = \frac{\text{Minimum Cost}}{\text{Observed Cost}} \quad (2)$$

$$PE = \frac{\text{Observed Profit}}{\text{Maximum Profit}} \quad (3)$$

The efficiency scores, TE and CE, range from 0 to 1. If the score is 1, it means the team reached the highest performance among the competition participants. The PE score is not bound by 0 and 1 because profit level can be negative. These efficiency scores inform us which team is the most efficient and how well other teams are doing relative to the best performed team with respect to productivity, cost, and profit criteria. The procedure of calculating scores for each team can be formulated as a linear optimization problem (Coelli et al., 2005). To analyze the efficiency of the eight teams, we formulated a set of eight linear optimization models. Details of the model formulation for technical, cost, and profit efficiency can be found in Coelli et al. (2005).

RESULTS

Production and Economic Efficiency in 2019

If looking only at the TE score, all teams have achieved their full technical potential under VRS in 2019 (Table 6). Except for Team D, the rest of the teams also reached full technical potential assuming CRS because Team D applied the lowest amount of fertilizer compared to other teams and the second lowest irrigation application during the growing season. Lower input levels also resulted in the lowest corn yield for Team D (87 bushels per acre).

With respect to CE score, only Teams A and D reached full efficiency in 2019 (Table 7). These two teams are among the lowest in fertilizer application, which positioned them to have the lowest costs on input mix if judging efficiency by comparing the measure to the lowest potential input costs with output level held constant. Given the 2019 fertilizer prices, the CE scores of Teams C and E ranked second and third with efficiency scores, 0.997 and 0.912, respectively (Table 7). Team B ranked lowest in this category, because Team B applied the highest amount of fertilizer (200 pounds of nitrogen) during pre-plant and was fourth highest in irrigation (15.22 inches per acre). Although higher levels of fertilizer and irrigation were used by Team B, the 192 bushels per acre of corn produced by Team B was not the highest yield.

Changing fertilizer prices affected rankings in CE scores. Teams A and D were always fully efficient with respect to the input mix that minimized costs from 2019 to 2021 (Table 7). When facing a lower anhydrous ammonia price in 2020, Team C was also fully efficient, and the CE scores of other teams increased as well. In 2021, fertilizer prices increased substantially for both anhydrous ammonia and UAN32 (Table 3), under which the CE scores decreased from 2020 for all teams except A and D.

The PE scores and ranking show that only Team A was fully efficient in terms of maximizing profit, given the 2019 input prices and corn selling price at $4.64 per bushel (Table 6). Team A used the lowest fertilizer application rate and highest amount of irrigation water, and they achieved the highest yield (207 bushels per acre) among all the teams. Team E ranked second in PE scores and its output yield is also second to highest. It is not surprising that Team D has the lowest PE score because of its low output level, although its fertilizer input cost is also the lowest. The lack of irrigation water may have prevented the yield.

Although Team B applied the highest amount of fertilizer during pre-plant period, its yield is not the highest. Lack of irrigation might be the reason. Team B applied much less irrigation compared with Team A except for irrigation during the second half of June. Team E ranked second on profit efficiency, with a score of 0.901. Both Teams E and B have the second highest yield (192 bushels per acre), but Team E applied much less fertilizer during pre-plant. Therefore, Team E has a lower cost than Team B in this regard. Teams G (extension specialist team) and H (student team) ranked fourth and fifth, respectively, with Team G applying more irrigation than Team H. Both teams applied the same amount of fertilizer over pre-plant, side-dress, and fertigation stages.

Expected Profit Efficiency Under Input and Output Price Uncertainty

The expected profit efficiency (EPE) scores under 2019, 2020, and 2021 fertilizer prices and simulated output prices are presented in Table 8. The cost of irrigation is assumed the same in these years at $6 per inch of water applied. The EPE scores reflect the efficiency level of each team when facing exactly the same input and output price uncertainty under the assumption that individual producers are price takers. Results show that Team A achieved full efficiency on EPE across the board, whereas Team D's EPE scores were the lowest. With respect to different fertilizer prices, the EPE ranking was consistent, but the value of scores decreased when fertilizer prices were high in 2021 since fertilizer prices affect the overall profit level. Low input level may result in cost efficiency, but it can hurt the team's profit level. For example, Team D is fully efficient in CE but remains last in EPE. Teams E and B ranked second and third in EPE, but Team B ranked last in CE scores, indicating that Team B can achieve the same profit level with reduced application of fertilizer in pre-plant period.

CONCLUSIONS

Increasing crop productivity and profitability and improving resource use efficiency is the ultimate goal for producers. Producers make decisions based on growing conditions (such as weather information and soil conditions), resources (such as water), market conditions (input and output prices), technology adoption, available tools for uncertainty and risk management, and their personal experience and knowledge in farming. In an effort to help agricultural producers make better production decisions, we used a grower contest to improve our understanding and provide quantitative evaluations on producer input management behaviors, ultimately allowing extension personnel to see the production and economic return gaps between different decision strategies.

This research uses data collected from the Oklahoma State University TAPS program's irrigation corn competition hosted in 2019, where producers competed for maximum profitability and optimal input (irrigation and fertilizer) management. Production and economic efficiency are calculated using the DEA approach. We calculated technical, cost, and profit efficiency scores under each team's received input and output prices, as well as the input prices in 2020–2021 and simulated output prices.

What we learned from the ranking of efficiency scores of this producer competition is that comparatively lower fertilizer application rates and higher use of irrigation produce better efficiency scores. This was especially true for Team A. Among all the teams, Team A was fully efficient in all measures in 2019, with the lowest amount of fertilizer and the highest amount of irrigation water application. This same team also achieved the highest corn yield among all teams in the competition. The combination of inputs and output also sustained Team A under the high fertilizer prices of 2021 and uncertainty in commodity price, to maintain efficiency.

Another finding is that low fertilization and low irrigation could achieve a full score in technical efficiency and cost efficiency, but it will not necessarily be a good option if the producer's objective is to maximize profit level. In this study, Team D used the lowest amount of fertilization and the lowest rate of irrigation. This team's yield was also the lowest among all teams. With respect to cost efficiency, Team D's input-mix was fully efficient across low and high fertilizer prices. However, Team D's profit efficiency in 2019 and expected profit efficiency under uncertain output prices was the lowest among all teams. Team D's profit efficiency rankings also suggest the importance of sufficient irrigation water application during the growing season. Simultaneously decreasing water and fertilizer application could result in lower yields and missed profit targets.

Competition among producers with homogeneous physical growing conditions on soil and weather, as well as production technology, provides an ideal space to observe and evaluate each producer's decision on fertilizer and irrigation applications in Oklahoma's major irrigation agricultural area. Fertilization and irrigation are complementary inputs that are essential to producers in this region, where fertilizer prices have increased and groundwater is diminishing at an alarming rate. The results from the competition show that an optimal mix of these two inputs can increase productivity and producer profit, especially with high irrigation and low fertilization.

The limitations of this research are that (1) we focused only on the uncertainty of fertilizer prices and output prices, although the irrigation cost, especially energy cost, will also increase if the producers must go deeper into the well to withdraw groundwater for future irrigation; and (2) although the study shows the impact of commodity price and input price uncertainty on economic efficiency, more research is required to understand what kind of insurance options are available and how insurance will affect producers' efficiency scores. Future research should also consider different soil types that producers work with in the region.

FOOTNOTE

1. These are corn growth stages. At V1 (Stage 1), the plant is about 2 to 4 inches tall and seed is the plant's main energy source. By V12 (Stage 2), the plant reaches about 4 feet tall or more. Plant growth demand on nutrients and water is very high at this stage. VT/R1 (Stage 3) is a critical period for pollination and kernel development. At R2 (Stage 4), kernels are well formed and embryos are developed. (Source: https://www.dekalbasgrowdeltapine.com/en-us/agronomy/corn-growth-stages-and-gdu-requirements.html.)

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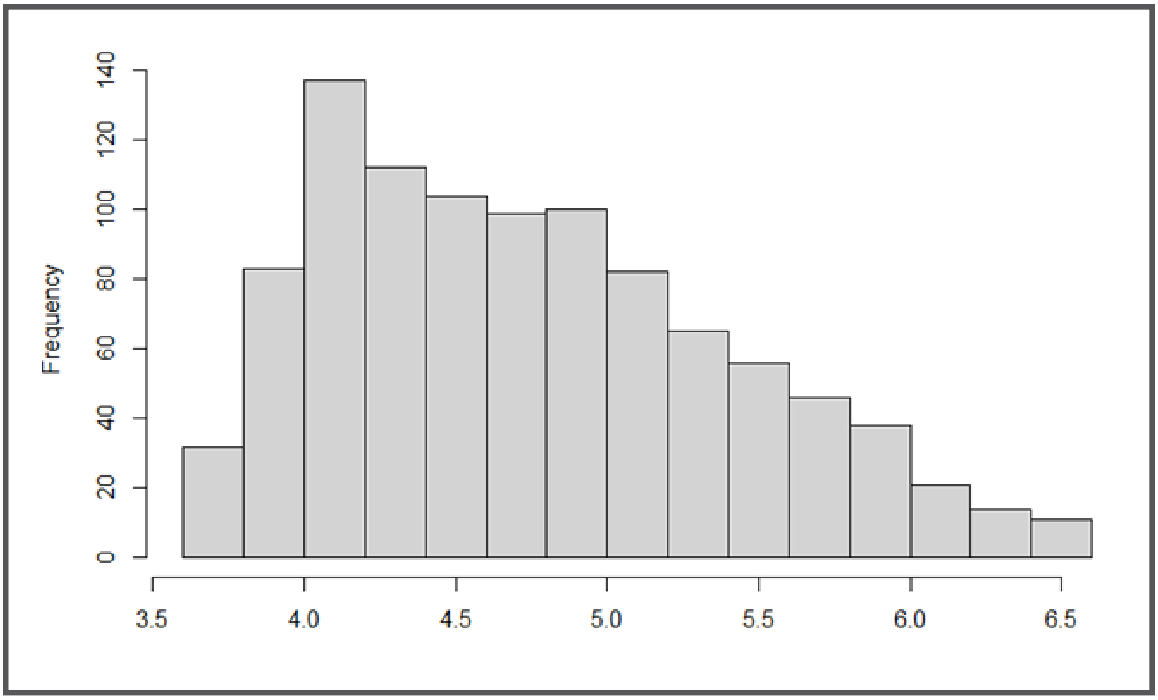


Figure 1. Histogram of simulated corn prices using triangular distribution

Table 1. Teams of Participants

Team	Description
A	Farmers
B	Farmers
C	Farmers
D	Farmers
E	Farmers
F	Farmers
G	Extension specialists
H	Student team

Table 2. Nitrogen Fertilizer Consumption at Different Stage of Production by Each Team (pounds per acre)

Team	Pre-plant	Side-dress	Fertigation				Total
			Stage 1	Stage 2	Stage 3	Stage 4	
A	0	30	30	30	30	30	150
B	200	30	0	0	15	20	265
C	50	50	30	30	30	0	190
D	0	30	30	30	30	30	150
E	50	60	30	30	30	30	230
F	120	30	30	30	30	0	240
G	100	0	30	30	30	30	220
H	100	0	30	30	30	30	220

Table 3. Nitrogen Prices

Item	Price ($/lb)		
	2019	2020	2021
Anhydrous Ammonia 82%	0.305	0.245	0.336
UAN32	0.135	0.138	0.261

Table 4. Each Team's Irrigation Water Application from June to September (inches per acre)

Team	June	July		August		September	Total
	Weeks 3–4	Weeks 1–2	Weeks 3–4	Weeks 1–2	Weeks 3–4	Weeks 1–2	
A	1.10	3.31	4.05	4.05	3.60	1.20	17.31
B	1.27	2.52	3.90	3.98	2.55	1.00	15.22
C	1.00	3.09	4.05	2.80	2.05	0.75	13.74
D	0.65	3.11	3.85	3.80	2.40	0.65	14.46
E	1.00	3.09	4.05	4.10	2.70	0.75	15.69
F	1.27	2.89	3.60	3.75	3.45	0.80	15.76
G	1.02	3.09	4.05	4.10	2.50	1.25	16.01
H	1.02	3.09	4.05	4.10	2.50	0.00	14.76

Table 5. Output Yield and Price Received by Each Team in 2019

Team	Yield (bu/acre)	Price Received ($/bu)
A	207	4.64
B	192	3.99
C	152	3.93
D	87	4.24
E	192	3.93
F	174	3.93
G	187	3.93
H	182	3.93

Table 6. Technical Efficiency (TE) and Profit Efficiency (PE) Under 2019 Input and Output Prices Received by Each Team

Team	TE (CRS)	TE (VRS)	PE (ranking)
A	1	1	1 (1)
B	1	1	0.862 (3)
C	1	1	0.697 (7)
D	0.776	1	0.348 (8)
E	1	1	0.901 (2)
F	1	1	0.778 (6)
G	1	1	0.859 (4)
H	1	1	0.841 (5)

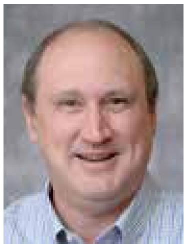
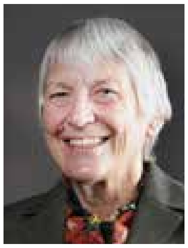
Table 7. Cost Efficiency (CE) Under Different Fertilizer Prices

Team	2019 Fertilizer Prices	2020 Fertilizer Prices	2021 Fertilizer Prices
A	1 (1)	1 (1)	1 (1)
B	0.757 (7)	0.825 (6)	0.807 (7)
C	0.997 (2)	1 (1)	0.997 (2)
D	1 (1)	1 (1)	1 (1)
E	0.912 (3)	0.930 (2)	0.893 (4)
F	0.810 (6)	0.846 (5)	0.835 (6)
G	0.849 (5)	0.885 (4)	0.873 (5)
H	0.891 (4)	0.929 (3)	0.911 (3)

Table 8. Expected Profit Efficiency (EPE) with Simulated Output Prices

Team	2019 Fertilizer Prices	2020 Fertilizer Prices	2021 Fertilizer Prices
A	1 (1)	1 (1)	1 (1)
B	0.873 (3)	0.890 (3)	0.876 (3)
C	0.704 (7)	0.708 (7)	0.697 (7)
D	0.355 (8)	0.355 (8)	0.340 (8)
E	0.905 (2)	0.909 (2)	0.897 (2)
F	0.789 (6)	0.799 (6)	0.785 (6)
G	0.867 (4)	0.875 (4)	0.865 (4)
H	0.848 (5)	0.856 (5)	0.846 (5)

Economic Analysis of Subsurface Tile Drainage Spacing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Abstract

This study examined the optimal tile drainage spacing using data for the 1984–2021 period for a drainage experiment in southeast Indiana. Four drainage spacings were compared: 16 feet, 33 feet, 66 feet, and 133 feet. Gross return per acre was highest for the 16-foot spacing. However, net return per acre was highest for the 66-foot spacing. The 66-foot tile drainage spacing also had a higher certainty equivalent of net returns and was the preferred drainage spacing using second-degree stochastic dominance (SSD). Sensitivity analysis related to the discount rate used, the cost of tile installation, and the useful life of the tile drainage system confirmed the attractiveness of the 66-foot spacing. The conceptual framework developed in this study would be useful when examining the feasibility of installing subsurface drainage in poorly drained soils in the U.S. Midwest.

INTRODUCTION

Using the 2017 Census of Agriculture, 56 million U.S. acres were reported as being drained by tile, which represented a 14% increase from the 2012 Census of Agriculture (USDA NASS, 2019). Moreover, according to Zulauf and Brown (2019), the share of acres that was drained in 2017 was greater than 20% in Iowa (53%), Indiana (49%), Ohio (49%), Illinois (39%), Michigan (38%), Minnesota (37%), and New York (20%).

There are numerous benefits associated with tile or subsurface drainage. These benefits may include improved timeliness of fieldwork, improved crop yields, increased infiltration, and reduction in sediment and nutrient losses (Skaggs and van Schilfgaarde, 1999; Kladivko, 2020; Kladivko and Bowling, 2021). Benefits primarily occur on soils classified as poorly or somewhat poorly drained. These soils comprise the majority of the tile-drained lands in the Midwest.

This paper utilized data from a long-term subsurface drainage project in southeast Indiana. Previous studies have examined various agronomic aspects of the drainage spacings used in this project. Kladivko et al. (2004) examined drain flow and nitrate N losses. Drain flow and nitrate N losses were greater for narrower drain spacings. Kladivko, Willoughby, and Santini (2005) examined corn growth and yield response to subsurface drain spacing associated with the project. Although the narrower spacings provided yield improvements in some years, average corn yields were not significantly different among treatments during the 10-year study period (i.e., first 10 years of the drainage project). Further insights into soil drainage and crop yields from the project can be found in Kladivko (2020). Drainage improved timeliness of fieldwork by 1 to 15 days and improved corn yields by 24 bushels per acre compared to the undrained control. However, soybean yields were not different across drainage spacings. In contrast, using data from the north central region of the United States, Mourtzinis et al. (2021) found that the average yield of soybeans with subsurface drainage was 8% higher than yields without subsurface drainage. Kladivko and Bowling (2021) compared nitrate N loads in surface waters for the first 15 years of the drainage project in southeast Indiana with those for the second 15 years. Drain flow and nitrate N losses were greatest for the 5-meter (16-foot) spacing and lowest for the 20-meter (66-foot) spacing. In contrast, nitrate N concentrations did not vary across drainage spacings.

Much of the previous literature on tile drainage has focused on agronomic and water quality aspects. Research that has examined the relationship between net return per acre and drainage spacing is limited. Skaggs, Youssef, and Chescheir (2006) developed a simulation model to determine the drainage spacing corresponding to maximum economic return. Specifically, the authors simulated 50 years of corn yields for four soils near Urbana, Illinois. Net returns were then computed using these yields, corn price, and tile installation cost assumptions. The optimal drain spacing ranged from 19 to 24 meters (62.3 to 78.7 feet) for three soils and 40 meters (131.2 feet) for the fourth soil.

The objective of this paper is to examine optimal tile drainage spacing using 1984–2021 data from a drainage experiment in southeast Indiana. Four drainage spacings were compared: 16 feet, 33 feet, 66 feet, and 133 feet. Analysis included comparisons of crop yields, gross return per acre, and net return per acre.

METHODS

Corn and soybeans were produced on an experimental field in southeast Indiana. Specifically, corn was produced in 24 of the 38 years during the sample period, and soybeans were produced in the other 14 years. Real gross return per acre was computed using marketing year average prices for Indiana (USDA NASS, 2022), crop yields, and the implicit price deflator for personal consumption expenditures (BEA, 2022).

Tile drainage is a long-term investment. Thus, economic analysis of tile or subsurface drainage typically compares added gross returns resulting from higher crop yields to the annual cost of the tile drainage system, which incorporates capital budgeting concepts such as the discount rate and the useful life of tile investment (Hofstrand, 2010). The equivalent annual cost (EAC) method can be used to estimate the annual cost of owning an asset over its useful life (Kenton and Kindness, 2020). Information pertaining to the discount rate, investment cost, and useful life of the drainage system was used to compute the EAC for each drainage spacing. The base case used a 6% discount rate, a cost of tile installation of $1 per foot, and a useful life of 30 years. Net return per acre for each drainage spacing was computed by subtracting EAC from gross return per acre. Sensitivity analysis examined whether the drainage spacing choice changed when a higher discount rate, higher tile installation cost, or longer useful life was assumed.

Before examining risk, t-tests were used to examine the difference in the means across drainage spacings for corn yields, soybean yields, gross return per acre, and net return per acre. Risk was incorporated using both expected utility analysis and stochastic dominance. Expected utility analysis was used to compute the certainty equivalent of net returns for each drainage spacing. The certainty equivalent incorporates average net returns, the variability of net returns, and downside risk. Essentially, the certainty equivalent of net return represents a risk-adjusted return. To calculate the certainty equivalent requires information pertaining to a utility function and risk aversion coefficients. The power utility function was used to compute certainty equivalents in this study. This utility function is often referred to as the constant relative risk aversion utility function and is widely used for modeling risk aversion in production agriculture (e.g., Liu et al., 2018). In addition to constant relative risk aversion, this utility function exhibits decreasing absolute risk aversion as wealth increases. A relative risk aversion level of 3 was used in this study. This risk aversion level represents moderately risk-averse preferences (Hardaker et al., 2015).

Stochastic dominance was also used to examine the choice between drainage spacings. Stochastic dominance compares the entire cumulative distribution function of net return per acre (Hardaker et al., 2015). First-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) were utilized. FSD compares the risky alternatives (i.e., drainage spacings in this case) faced by decision-makers who have positive marginal utility, which implies that decision-makers prefer a higher net return per acre to a lower net return per acre. Alternatives included in the FSD set satisfy the criteria that more is preferred to less. FSD is typically not very discriminating. In other words, most activities or choices are typically part of the FSD set. SSD assumes that decision-makers are risk averse—or are concerned about the trade-off between average net returns and risk, measured using the variance of net returns or downside risk. Alternatives included in the SSD set satisfy the criteria that decision-makers are risk averse. SSD has more discriminatory power than FSD and reflects the fact the most decision-makers are risk averse.

DATA

Kladivko (2020) contains background information pertaining to the long-run drainage study in southeast Indiana. The study was conducted at the Southeast Purdue Agricultural Center (SEPAC) on Clermont silt loam soil. As noted by Kladivko (2020), most of the results garnered from the drainage project are generally applicable to other poorly drained soils. The drain spacing experiment consisted of three drain spacings plus an undrained control. Drains were installed at 5, 10, and 20 meters (16, 33, and 66 feet), with an "undrained control" spaced at 40 meters (133 feet). Because the soil is so slowly permeable, the 40-meter spacing was considered to be a good proxy for an undrained field. The drainage systems were installed in 1983, and crop yields were first collected in 1984.

Tile investment and cost per acre are very sensitive to drainage spacing. Tile investment was estimated using drainage spacing information and a tile installation cost of $1 per foot. Cost estimates included materials and installation costs. Costs would be higher for small and/or irregularly shaped fields. Tile investment per acre ranged from $332 for the 133-foot spacing to $2,738 for the 16-foot spacing. Tile investment cost was $1,327 per acre for the 33-foot spacing and $664 per acre for the 66-foot spacing. EAC for the base case scenario was computed using a 6% discount rate, an installation cost of $1 per foot, and a 30-year useful life. Note that the tile was installed close to 40 years ago at the SEPAC site. For the base case scenario, EAC was approximately $24 per acre for the 133-foot spacing, $48 per acre for the 66-foot spacing, $96 per acre for the 33-foot spacing, and $199 per acre for the 16-foot spacing. Obviously, crop yields would have to be substantially higher for the 16-foot spacing option for it to be preferred to the other drainage spacings.

Table 1 presents the summary statistics for the tile drainage site in southeast Indiana and the t-test results. Gross return per acre and net return per acre were adjusted for inflation using the implicit price deflator for personal consumption expenditures and are expressed in real 2021 dollars. Corn yield was significantly higher for the 16-foot spacing and significantly lower for the 133-foot spacing. Average corn yield for the 16-foot spacing was over 24 bushels per acre higher than that for the 133-foot spacing. Differences in soybean yields, on the other hand, were minimal. The gross return results were similar to the corn yield results. Gross return per acre was significantly higher for the 16-foot spacing and significantly lower for the 133-foot spacing. As noted above, cost increases as drainage spacing narrows. This fact helps explain the net return per acre results depicted in Table 1. Net return per acre was significantly higher for the 66-foot spacing and significantly lower for the 16-foot spacing. The difference in the net return per acre for the 33-foot and 133-foot spacings was not statistically significant. The 33-foot spacing has a higher corn yield and gross return per acre but also exhibits a substantially higher tile investment and EAC per acre than the 133-foot spacing.

RESULTS

The base case results are illustrated in the first line of Table 2. The 16-foot spacing results are not illustrated because this drainage spacing was not part of the FSD set. The average net return for the 66-foot spacing was $37 per acre higher than the average net return for the 133-foot spacing and $47 per acre higher than the average net return for the 33-foot spacing. The certainty equivalent of net return for each drainage spacing and scenario in Table 2 was computed using a relative risk aversion level of 3, which represents moderate risk aversion. The certainty equivalent of net return can be thought of as a risk-adjusted return. The difference between the certainty equivalent of net returns for the 66-foot and 133-foot spacing narrowed to $25 per acre and widened to $65 per acre for a comparison between the 66-foot and 33-foot spacings. The SSD results for the base case scenario were consistent with the certainty equivalent results. The 66-foot spacing was the only drainage spacing included in the SSD set. This indicates that this drainage spacing would be preferred by all risk-averse decision-makers. It is also important to note that the results for the base case are consistent with those found by Skaggs, Youssef, and Chescheir (2006).

Average net returns and the certainty equivalent of net returns are sensitive to changes in the base case assumptions pertaining to the discount rate, tile installation cost, and useful life of the drainage system. Table 2 presents the average net return and certainty equivalent of net returns for the base case as well as the sensitivity of the results to increases in the discount rate, cost of tile installation, and a longer useful life for the tile. It is important to note that each assumption was changed in isolation of the other assumptions. For example, the line depicted as using a 7.5% discount rate used a $1 installation cost and assumed a useful life of 30 years.

Increasing the discount rate or the cost of tiling (i.e., installation cost per foot) reduced average net returns and the certainty equivalent of net returns but did not appreciably change the base case results. Using the certainty equivalent of net returns—which incorporates net return, variability in net returns, and downside risk—the 66-foot spacing is preferred under the relatively higher discount rate and cost of tiling scenarios by a rather large margin to the 33-foot spacing and the 133-foot spacing (i.e., the undrained control) alternatives. Also, increasing the useful life of the tile drainage system increases average net returns and the certainty equivalent of net returns but does not change the relative results illustrated in the base case scenario.

Although this analysis shows little economic difference between the 33-foot spacing and the undrained control, several important qualifications should be noted. The undrained control in this field, although wetter than the other spacings, was not as wet as other, larger undrained fields in the area; thus the yields were not as low as in more typical Clermont soil fields. Also, in later years of the experiment, yield differences were much larger because of much wetter spring conditions, leading to yield losses of 50 or more bushels per acre for the undrained control. As precipitation has increased over the past few decades, these wetter springs are likely to make the benefit of drainage versus none even more pronounced. Finally, this experimental field (approximately 15 acres) had better surface drainage than most large fields in the area, meaning there was little surface ponding of water. Therefore, the undrained control was not as bad for crop growth as it would be if portions of the field remained ponded for days. These limitations to the study suggest that the undrained control would likely be worse than what our analysis suggests.

SUMMARY AND CONCLUSIONS

This paper examined optimal tile drainage spacing using data for the 1984–2021 period from an experimental field in southeast Indiana. Four drainage spacings were compared: 16 feet, 33 feet, 66 feet, and 133 feet. Gross return per acre was highest for the 16-foot spacing. However, due to high tile investment and cost per acre for this spacing, the net return per acre for this spacing was significantly lower than for the other drainage spacings. The 66-foot spacing had a significantly higher average net return than the other spacings. Moreover, the 66-foot spacing was favored when risk was added to the analysis. Specifically, the 66-foot spacing was preferred to other drain tile spacings regardless of the risk aversion level.

The analysis in this paper provides a framework that can be utilized when making tile installation decisions. In addition to agronomic and water quality aspects such as soil erosion, nutrient runoff and leaching, and crop yields, it is imperative to incorporate crop prices and the annualized cost of tile in drainage spacing decisions.

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Table 1. Summary Statistics for Tile Drainage Experimental Field in Southeast Indiana, 1984–2021

	Drainage Spacing			
	16 ft	33 ft	66 ft	133 ft
Corn Yield (bu/acre)	170.9[a]	165.9[b]	164.5[b]	146.4[b,c]
Soybean Yield (bu/acre)	59.4[a]	58.2[a,b]	59.4[a,b]	57.6[a]
Gross Return ($/acre)	$713[a]	$694[b]	$693[b]	$632[c]
Net Return ($/acre)	$514[c]	$598[b]	$645[a]	$608[b]

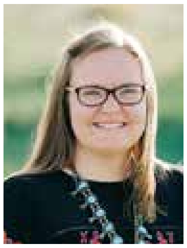
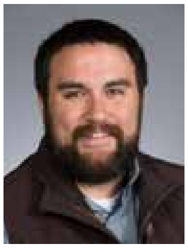
Note: a, b, and c indicate whether the values were statistically different. Values with unlike letters were statistically different.

Table 2. Sensitivity Analysis of Net Return per Acre to Discount Rate, Cost of Tiling, and Useful Life of Drainage System

	33 ft		66 ft		133 ft	
	Avg	CE	Avg	CE	Avg	CE
Base Case	$598	$475	**$645**	**$540**	$608	$515
Discount Rate						
7.5%	$582	$455	**$637**	**$531**	$604	$510
9.0%	$565	$435	**$628**	**$521**	$600	$505
Cost of Tiling, per Foot						
$1.25	$574	$445	**$633**	**$526**	$602	$508
$1.50	$550	$415	**$621**	**$512**	$596	$501
Useful Life, Years						
40	$606	$484	**$649**	**$545**	$610	$518
50	$610	$489	**$651**	**$547**	$611	$519

Notes: Avg = average net return per acre; CE = certainty equivalent of net return per acre (defined in the text). Bold values indicate preferred drainage spacing for each scenario. For the base case, the discount rate was 6.0%, the cost of tile drainage per foot was $1, and the useful life of the drainage system was 30 years.

Surveyed Characteristics of Non-Operating Landowners in Texas

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Acknowledgment

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Abstract

A survey of producers and non-operator landowners in Texas yielded data on demographics, land holdings, assets, debts, transition plans, lease types, tenure of ownership, and more. This manuscript isolates and discusses the characteristics of non-operator landowners and their holdings in the state of Texas. This study is the first in a series of publications intended to characterize the needs of landowners and lessees in the state, as well as determine the educational and market needs of those stakeholders.

INTRODUCTION

Non-operator landowners are a significant and growing class of landowners in the state of Texas. In a survey intended to ascertain the educational needs of the agricultural sector in Texas, participants were given the option to self-select into one or more categories indicating their status as a farmer, rancher, agricultural employee, agribusiness owner, non-operator landowner, or combinations of those categories. A non-operator landowner in this survey indicated a respondent who owned land that is in use in agricultural production, energy production, or some combination of those activities but who did not engage in the day-to-day production activities on that land. Some are first-generation landowners leasing to producers, whereas others are the second, third, or even fourth generation to own a property despite no longer being engaged in production agriculture. In an effort to understand the characteristics of non-operator landowners in the state of Texas, this manuscript isolates data from 624 respondents collected via survey to detail information specific to 103 non-operator landowners.

This manuscript is laid out in the following sections. First, we describe the methods used to survey producers and landowners in Texas. We then detail the characteristics of non-operating landowners from our survey. Next, we review the characteristics of non-operating landowners' holdings, including the leases they extend. Finally, we summarize the concerns non-operating landowner respondents provided regarding the future of their operation.

METHODS

The survey effort from which this manuscript draws data was developed to determine characteristics of agricultural producers and rural landowners in Texas regarding business practices, estate planning, and succession planning. Specifically, the survey set out to address four main criteria:

1. Determine the current estate planning status of Texas farmers, including information related to the existence of wills, knowledge of transfer-on-death deeds, and understanding of applicable legal issues

2. Determine the current transition planning status of Texas farmers, including identification of potential heirs, selection of business entities, and plan for transferring ownership
3. Determine the current business structure and operation of Texas farms, including ownership structure, operator status, and utilization of risk management tools
4. Determine the current knowledge of Texas farmers related to these issues, including knowledge of potential tax liabilities related to estate planning, documents needed, and professionals to engage

The primary survey instrument was developed in Qualtrics for delivery through digital means, although paper surveys were distributed upon request at numerous in-person presentations around the state and subsequently aggregated with the digitally collected data. Upon release, the survey link was widely published on Facebook, LinkedIn, and Twitter; in various Texas A&M AgriLife Extension outlets; on external websites, and via other forms of media. To capitalize on extension audiences, a QR code directing meeting attendees to the survey was provided on slideshows to display at county, regional, and statewide meetings. Physical copies were also provided to attendees of extension meetings upon request.

The survey was available digitally from January 15, 2022, to April 1, 2022. During that time, 646 respondents submitted responses to the survey, although response rates varied by question. In total, the respondents represented 1.97 million acres in the state of Texas. Any reported survey statistic or graphic detailing the result of a question is documented with the associated response volume.

Of the 646 unique responses to the question "Are you a(n): (1) Agribusiness owner, (2) Agricultural employee, (3) Farmer, (4) Rancher, (5) Agricultural landowner (who does not personally farm/ranch)?"—which allowed for selection of multiple categories—103 respondents indicated that they were an "Agricultural landowner (who does not personally farm/ranch)." The remainder of this manuscript details the characteristics of those respondents and their holdings.

DEMOGRAPHICS

A wide range of ages were represented in the surveyed population of non-operating landowners. The minimum age of non-operating landowners responding was 36–40 years old, whereas the oldest respondent was more than 75 years old (Figure 1). The weighted average age (assuming a mean age per response category) was 67.3 years. A majority of respondents (68) were more than 65 years old. These findings are in line with the information reported in Bigelow, Borchers, and Hubbs (2016), in which they reported that 70% of non-operating landlords were 65 and older.

The age of non-operating landowners responding to the survey was slightly older on average compared to the respondents operating a farm or ranch (61.2 years old). When comparing respondents age 50 or less, there were significantly fewer non-operating landowners (3.8%) compared with operating landowners (20.4%). Inherently, this makes sense if we consider the normal progression of a family and the generational transfer of land. Those respondents who participated in the survey as landowners who purchased and did not inherit their holdings may still be operating their land to offset the purchase cost. Those non-operators who stand to inherit land rather than purchase may not yet have inherited property, and thus were not likely to participate in the survey.

The majority (58.25%) of non-operating landowner respondents were male (Figure 2). A greater percentage of non-operating landowner respondents were female (41.7%) than that of the full survey population (37.4%). Female respondents indicated that they owned 8,336 acres of farmland and 29,121 acres of pasture, totaling 37,457 acres or 44% of all acres represented by non-operating respondents.

The makeup of ownership by gender of the surveyed population is similar to that of the population detailed in Bigelow, Borchers, and Hubbs (2016), in which 46% of Texas's non-operator landlords were female.

CHARACTERISTICS OF HOLDINGS

Where in Texas is land held by non-operator landowners? The Texas Chapter of the American Society of Farm Managers and Rural Appraisers' "Texas Rural Land Value Trends" and the Texas Real Estate Research Center divide the state into seven regions (Figure 3). Our survey instrument allowed respondents to select the region in which their land was held. Note that responses to this question do not indicate where respondents live, but where their land is held, which is particularly important for the category of non-operating landowners. Although they may live on their property but do not engage in an agricultural operation on it, they may also live in another town, county, or market region entirely.

Respondents indicated that the plurality of non-operator owners hold their land in the Austin-Waco-Hill Country market region (Figure 4). The regions representing the fewest non-operating landowners were South Texas and Far West Texas. The number of owners did not correlate exactly to the acres owned by region. Although only 20 respondents of 103 indicated they own land in the Panhandle and South Plains and South Texas market regions, a majority of acres (53%) owned by non-operator landowners are in those regions. This aligns with the regions of Texas with significant agricultural cash receipts (Beck and Robinson, 2022).

When comparing non-operating landowner responses with responses from those who are actively farming or ranching the land, differences emerged in certain regions. Although many regions were similar, there were significant differences in both the Panhandle and South Plains region and the South Texas region. Whereas 13% of operating landowner respondents own land in the South Texas region, only 3.9% of non-operating landowner respondents reported owning land in the same region. On the other hand, whereas 9.7% of operating landowners own land in the Panhandle and South Plains region, 15.5% of non-operating landowners own land in this portion of the state.

The majority of respondents across the entire survey were engaged in ranching rather than farming. The trend held for the acres represented and the leases held by non-operating landowners. Of the 85,038 acres leased to others by non-operating landowners, 19.5% were farmland and 80.5% were pasture (Table 1). The average non-operating landowner with only farmland leased 486 acres to another party. The average non-operating landowner with only pasture leased 1,292 acres to another party. The average non-operating landowner with both farmland and pasture leased 1,181 acres to another party.

A variety of leases were held by non-operating landowners. The survey instrument allowed respondents to indicate the types of leases in which they were engaged, with many lease holders and landowners engaged in more than one type of lease (Table 2). The majority of respondents (52) leased for grazing, either exclusively (24) or in combination with some other enterprise combination that including farming, hunting, or both (28). A total of 29 respondents leased for farming, with 16 of those respondents leasing for a combination of farming and some other enterprise(s). A total of 25 respondents leased for hunting, with 19 of those respondents leasing for a combination of hunting and some other enterprise(s).

Respondents were also given the opportunity to identify the type of energy leases in which they were engaged (Table 3). The surveyed group indicating engagement in an energy lease was less than half the number engaged in a grazing, farming, or hunting lease. When considering only energy leases, oil and gas leases represented the majority of responses, with 23 respondents engaged in oil and gas leases exclusively or in combination with wind.

While it might seem more likely that solar leases would be of interest to a non-operating landowner, the opposite was true for survey respondents. While two operating respondents reported having a solar lease in place, only one non-operating landowner reported having a solar lease. This may be a function of the sample reached via the survey instrument.

An important risk mitigation tool for both lessors and lessees is a written contract. Significant educational efforts across Texas have been directed at increasing the use of written leases. Of the 78 non-operating respondents who have lease agreements, one-quarter do not have any of their leases in writing (Figure 5). Another one-fifth reported having some leases written but others that are not in writing. This means that 46% of respondents have at least some lease agreements that are not in writing. In comparing responses by non-operating landowners and operating landowners, 4% more operating landowners indicated all of their leases are in writing, and 5% fewer have none of their leases in writing—indicating that operating landowners are more likely to have written leases than non-operating landowners.

Respondents also provided information regarding the tenure of land ownership. Respondents identified the time frame during which land currently owned was initially obtained (Figure 6). For respondents with multiple land acquisition dates, the question asked them to identify the earliest date range during which property was initially purchased.

The survey results indicated that non-operating landowners are more likely to have land that has been continually owned by their family for a longer duration. Specifically, comparing land initially purchased by the family purchased since 1975, 60% of operating landowners reported land purchased whereas only 45% of non-operating landowners have land purchased since 1975. For the plurality of non-operating landowner respondents (20 respondents, or 21.5%), the land was initially purchased prior to 1925. Interestingly, it was new landowners making up the second largest response category, as 12 respondents

(12.9%) reported land purchased initially within the past six years.

CONCERNS

One unique aspect of the survey was the collection of non-operator landowner concerns. The survey allowed respondents to include a free-form response to the question of what they perceive as the biggest concern for the future of their operation.

Just over one-third of non-operating landowners indicated that their biggest concern was the land being sold (Figure 7). This was also the largest concern for operating landowners. When comparing the two groups, non-operating landowners are slightly less than operating landowners, of which 40% are concerned about land being sold. Just under one-quarter of respondents expressed a concern about taxes (estate taxes, capital gains taxes, and property taxes combined), and one-fifth reported a concern about the qualifications of their heirs.

SUMMARY AND CONCLUSIONS

The survey effort detailed in this study will continue to offer a wealth of data for exploration. Here, we chose to address the characteristics of non-operating landowners as a growing class of stakeholders in the state of Texas.

The survey results indicate that non-operating landowners are far more likely to be over age 50 than are operating landowners. Moreover, the plurality of respondents' land has been in the family for nearly 100 years or longer, with a greater percentage of non-operating landowners obtaining the land prior to 1975 than operating landowners.

For the agricultural producer, the non-operating landowner will offer a potential partner to grow an operation. Of particular significance for strong agricultural production regions in Texas, the survey results would suggest that the Panhandle and South Plains and South Texas market regions have a greater number of acres for lease than do the remainder of Texas regions. For the real estate profession, these survey data suggest that an increasing number of landowners are seeking the opportunity to purchase land as a non-operator (Figure 6).

The findings of this survey will continue to provide insight into landowners operating an agricultural enterprise and non-operator landowners. The strong correlation with the findings of the USDA's 2016 report (Bigelow, Borchers, and Hubbs, 2016) provide confidence that our faculty may draw relevant conclusions regarding Texas landowners and producers. The strong response rate (646 respondents representing 1.97 million acres) is made all the more valuable by the data the survey collected. In addition to the data reported in this manuscript, the survey team collected and intend to draw conclusions from data on assets held, total debts, status of heirs, estate planning, and more.

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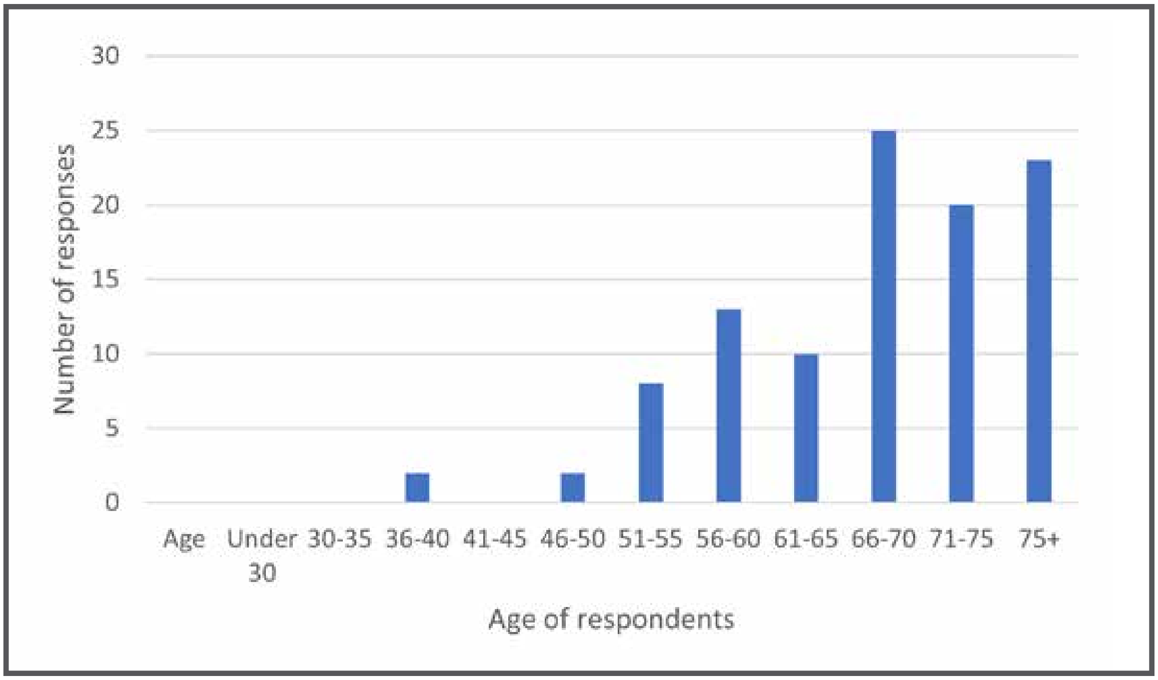


Figure 1. Age of non-operating landowner respondents (103 responses)

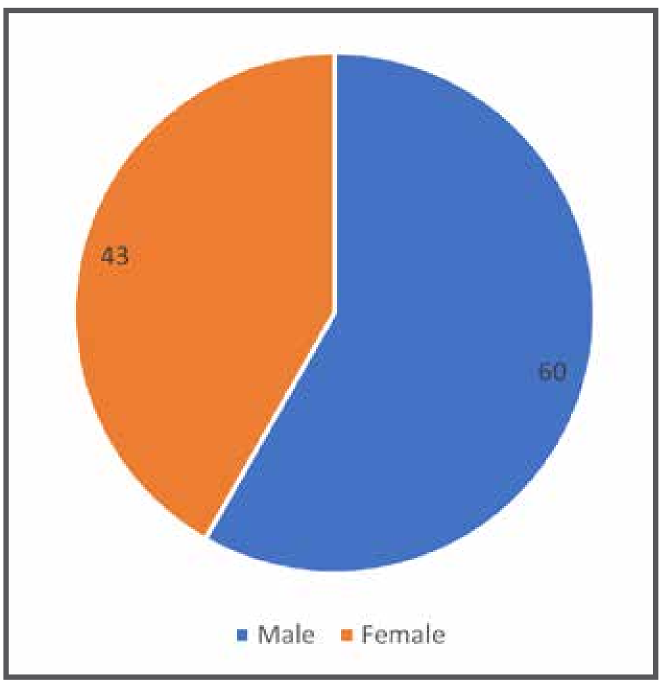


Figure 2. Gender of non-operating landowner respondents (103 responses)

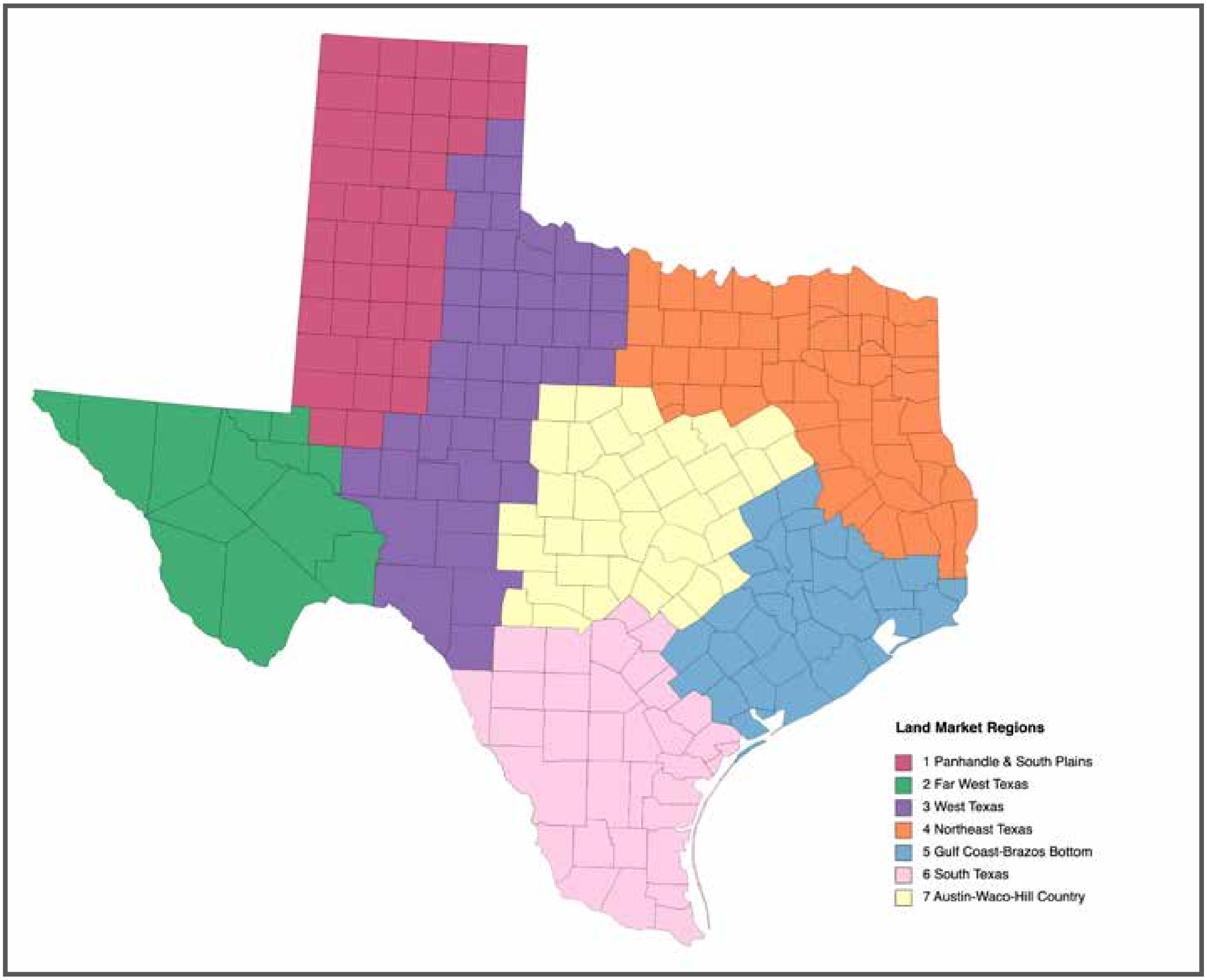


Figure 3. Texas Real Estate Research Center map of land market regions

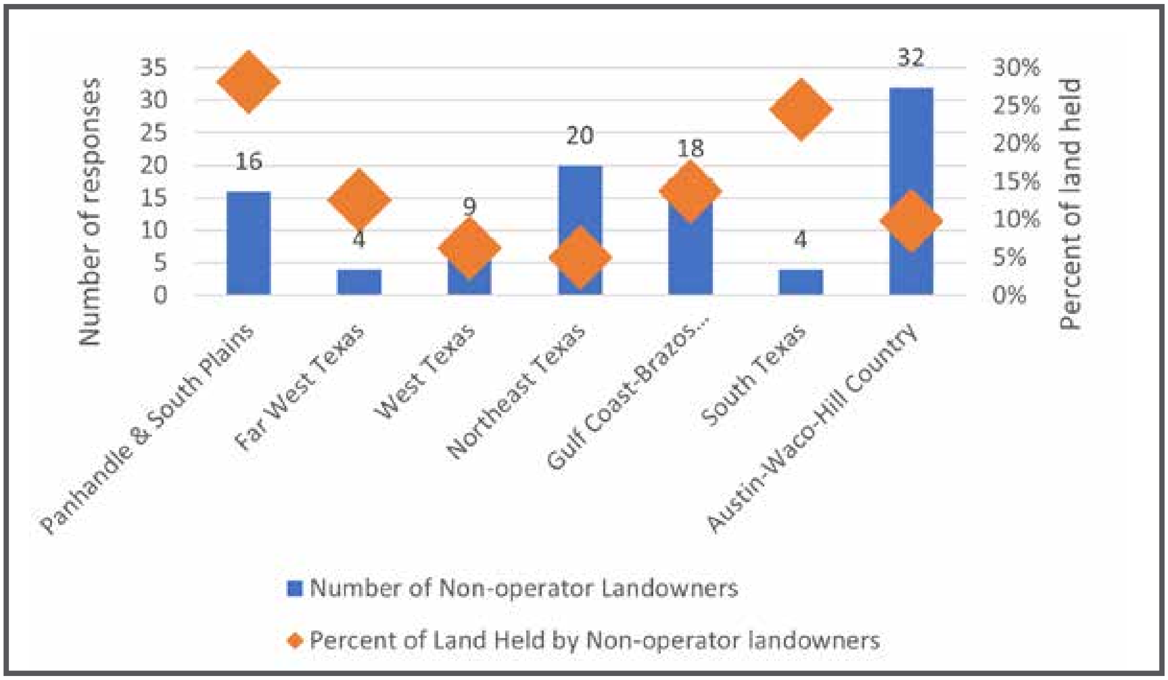


Figure 4. Location of land owned by non-operating landowners (103 responses)

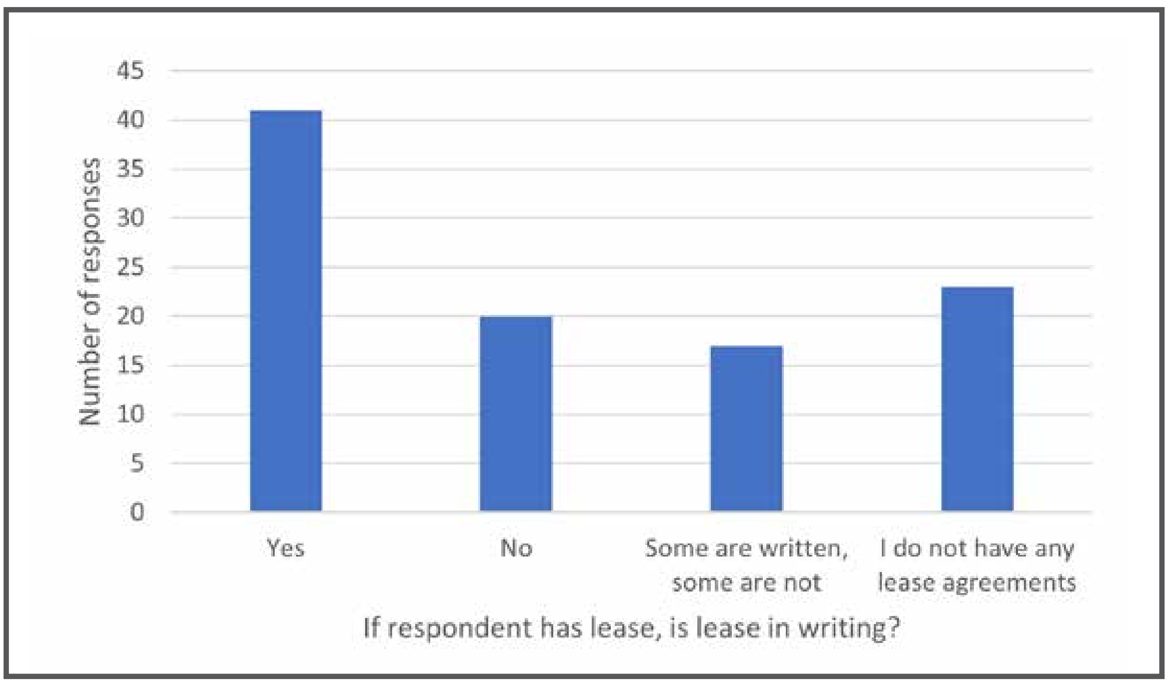


Figure 5. Leases held in writing by non-operating landowners (101 responses)

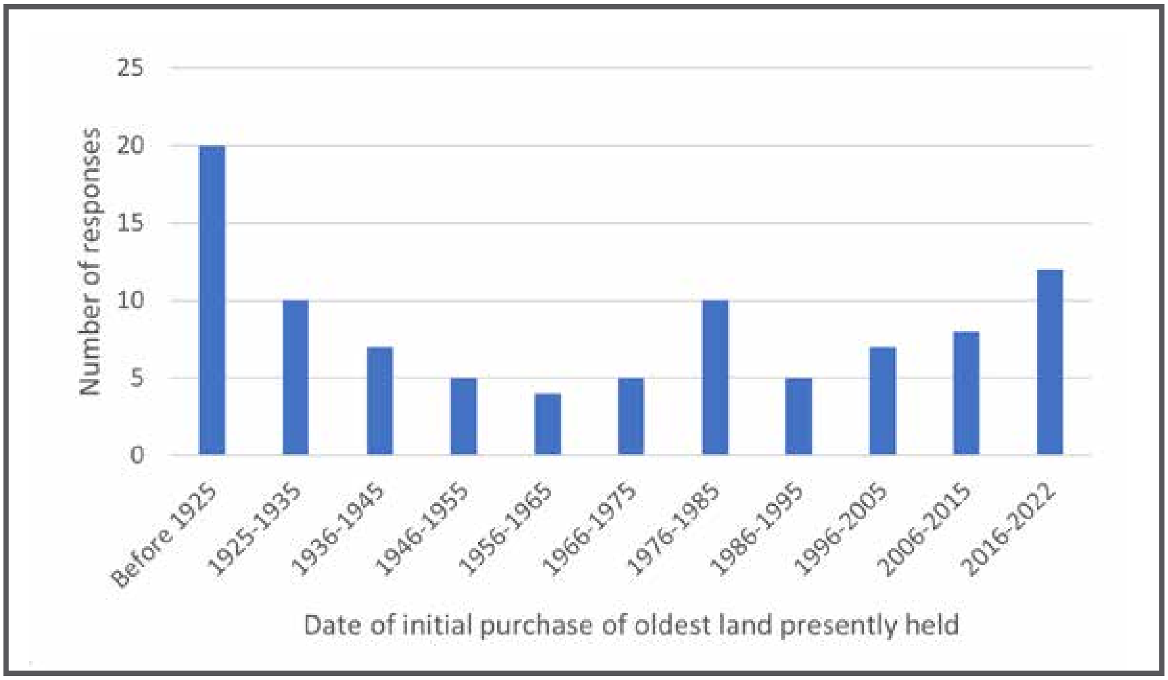


Figure 6. Duration of ownership considering oldest land continuously owned by family from initial purchase to present (93 responses)

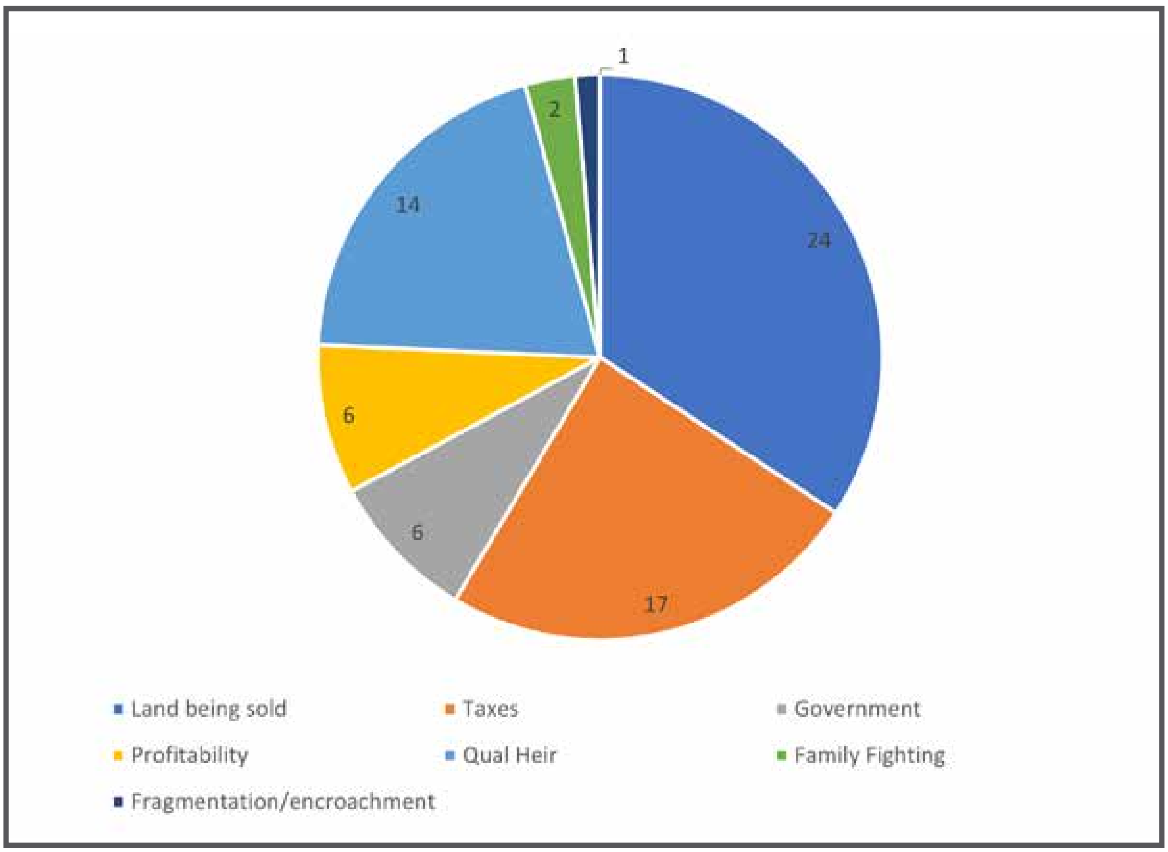


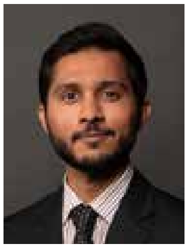
Figure 7. Categorized non-operator landowner responses to “What is your biggest concern about a succession plan/the future of the operation after you are gone?” (70 responses)

Table 1. Type of Land Leased to Others by Non-Operating Landowners (72 responses)				
	Sum	Average	Minimum	Maximum
Farmland	16,545	486	11	2,200
Pasture	68,493	1,292	49	25,000
Farmland and Pasture	85,038	1,181	10	25,000

Table 2. Type of Agricultural Lease Held by Non-Operating Landowners (72 responses)				
	Grazing	Farming	Hunting	Farming + Hunting
Grazing	24	10	13	5
Farming		13	1	
Hunting			6	

Table 3. Type of Energy Lease Held by Non-Operating Landowners (30 responses)				
	Wind	Solar	Oil & Gas	Solar + Oil & Gas
Wind	5	1	1	0
Solar		1	0	
Oil & Gas			22	

Automatic Milking Systems: An Exploratory Study of Wisconsin Dairy Farms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Acknowledgment

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Abstract

Automatic milking systems (AMS) are seen as an alternative to manual milking using agricultural labor and have been shown to decrease labor dependence while improving milk yield. This study is based on a survey mailed to 500 randomly selected Wisconsin licensed herds in January 2022. The study shows that although AMS are still in nascent stages, they are already the second most common type of primary milking facility used by respondents. Our survey also shows important implications for adopting AMS on dairy farms. During the COVID-19 pandemic, AMS dairies opted for reducing herd size to reduce milk production, whereas non-AMS dairies used a combination of smaller herd sizes and less animal feed. AMS farmers also claim price risk is the most significant barrier to grow their business, but non-AMS farmers consider labor recruitment and management as the most crucial adversity. AMS adopters also seem to have a more positive attitude toward the future outlook of the dairy industry relative to non-AMS farms.

INTRODUCTION

Wisconsin is the second largest milk producer in the United States, producing 14% of the U.S. milk output. Although dairy production in Wisconsin has steadily grown in the past decade (Figure 1), total cow head count has remained relatively stable at 1.2 million dairy cows statewide, indicating substantial increases in milk yield per cow. In 2021, Wisconsin's average milk yield was 24,884 pounds per cow and annual production of fluid milk was 31.7 billion pounds (Figure 1), generating an annual revenue of $45.6 billion (Dairy Farmers of Wisconsin, 2022).

Dairy farms rely heavily on family and hired agricultural labor, which constitutes about 20% to 30% of the daily operational cost (Tranel, 2017). Labor activities include feeding animals, cleaning and maintaining barns, milking cows, and managing manure. On average, a farm with at least fifty cows employs 5.1 full-time equivalent (FTE) workers, a number that has remained relatively constant since 2006 (Charlton and Kostandini, 2021).

Although dairy owners were expected to report positive profits in 2022, driven primarily by inflation-induced increases in milk prices (Liebrand, 2022), the dairy industry is facing supply chain bottlenecks (Luckstead, Nayga, and Snell, 2021) and labor shortages that have been intensified by the COVID-19 pandemic (Peña-Lévano, Burney, and Adams, 2020). Rising inflation has also led to higher feed cost, freight, fertilizer, and fuel, further exacerbating production costs (Liebrand, 2022) and shrinking margins. In addition, dairy enterprises face a high labor turnover ratio, an 11.9% rate during 2008 according to Rosson (2012), further decreasing efficiency in production and feeding. The uptrend in input costs (including a recent rise in domestic wages) may offset the spike in dairy product prices (Kiel, 2021), reducing farmers' profit margin in the upcoming years.

These challenges have adversely affected dairy farms in Wisconsin, a state that is home to 23% of all U.S. dairy farms—95% of which are family owned. Small farms and those unable to cope with this turmoil have either consolidated into larger enterprises or exited the industry. On average, 43 Wisconsin licensed herds have shut down every month in the period 2012–2022 (Figure 1), a 46% decline in the past 10 years, leaving only 6,275 dairy farms still in business as of September 2022 (USDA NASS, 2023).

In an effort to overcome the limited availability of domestic and foreign farm workers, dairies are opting to adopt labor-saving technologies such as automatic milking systems (AMS), also known as milking robots, which are able to milk 60–70 cows per day (Salfer and Minegishi, 2018). AMS offer a potential solution to the need for manual labor in the milking process and enhance operations by permitting farmers to devote more time to farm management (Tranel, 2017). Although the literature on AMS is sparse since it is a relatively new technology, some studies have quantified the economic benefits of AMS. For example, Tse et al. (2018) conducted a survey that showed that small-scale farmers experienced a 20% reduction in the number of workers after adopting AMS, in addition to higher milk yields and improved animal health. Not surprisingly, the most important reason farmers adopt AMS is the potential labor savings (Lage et al., 2021). Salfer et al. (2017) simulated the profitability differences between AMS and traditional parlor-style milking methods and showed that 120- and 240-cow dairies are more profitable with AMS. Duplessis et al. (2021) provide evidence from Canadian producers that AMS may lead to better milk yields. In their study, about 34% of producers reported having higher milk yields after transitioning to AMS and only 18% experienced a decline. Finally, Malacco (2022) discusses how AMS can generate a wealth of valuable data on cow health, welfare, animal behavior, and nutrition that can assist farmers in management.

However, AMS also require large up-front investments, estimated to be $150,000 to $275,000 per robot, not accounting for maintenance cost and infrastructure needed to adapt the barn to this technology (Salfer et al., 2019). This up-front cost is a significant barrier to adoption for small- and medium-sized dairies. Thus, it is not immediately clear whether adopting AMS may lead to positive returns (Charlton and Kostandini, 2021; Salfer et al., 2019).

In light of this need, this study is the first to explore whether implementing AMS may improve farmers' perception of the dairy industry's future outlook and alleviate some of the challenges of managing a dairy operation. Specifically, this case study focuses on the differences in perceptions between AMS vs. non-AMS dairies in the state of Wisconsin. Our findings are based on an exploratory survey conducted in spring 2022. Results shed light on differences in farmers' background and dairy operations, barriers to expansion, risk aversion, perception on future challenges for the industry, and changes in management practices and production due to the pandemic.

SURVEY IMPLEMENTATION

The exploratory survey was mailed to 500 randomly selected Wisconsin dairy farmers in January 2022. The contact information for survey recipients was obtained from the Wisconsin Department of Agriculture, Trade, and Consumer Protection's (DATCP) repository of licensed milk producer profiles. Data collection was conducted by the Survey Research Center (SRC) at the University of Wisconsin–River Falls over an eight-week period, with two reminders sent to non-respondents. Specifically, using Dillman's (1978) Total Design Method, the SRC sent one postcard reminder three weeks after the initial survey mailing and a second copy of the survey three weeks after the postcard reminder. Based on historical experience of the SRC and literature on survey methodology (e.g., Hoddinott and Bass, 1986), this method has been proven to boost response rates in a cost-effective way. A total of 183 responses were received, a robust response rate of 37%, which shows some evidence of the interest of dairy farmers in learning about robotic adoption. After data cleaning and dropping incomplete responses, a sample size of 172 licensed herds was used for this study.

AMS ADOPTION

Overall, three-quarters of survey respondents indicate their dairy operations were established more than 30 years ago. Over half of the dairy facilities are primarily stall barns with pipelines (54%), followed by parabone/swing (11%) and herringbone (10%) pit parlors (Figure 2). Stanchion/stall barns have continued to be the most common barn type in the past decade, when compared to the results of the USDA (2010) survey report.

The use of robotic milking units is still in its infancy stages (Charlton and Kostandini, 2021), but adoption is increasing at a steady pace. AMS dairies comprised about one-fifth of the overall sample (i.e., 34 responses). DeLaval and Lely are the two leading brands, encompassing 67% of robotic milking systems in the state (Figure 2). DeLaval's major technology is the Voluntary Milking System, including the VMS V300 and V310 series (DeLaval, 2022), a robotic arm that includes four milk-meters that attach to each teat and collect data on milk flow and yield. Lely's most recent robot is the Astronaut (A5) series (Lely, 2022), which is a hybrid arm with a 3D camera that detects the cow's position within the box and a three-laser system used to correctly attach the arm to each teat. New technologies created by GEA and BouMatic are also emerging. Particularly, GEA specializes in automatic rotary parlors, called the DairyRotor T800 series (GEA, 2022), whereas BouMatic focuses on simultaneous milking systems, such as the Gemini series (BouMatic, 2022), which allows two cows to be milked concurrently.

DIFFERENCES IN DAIRY FARM OPERATIONS

Survey results show that herd size correlates with land ownership, when contrasting AMS vs. non-AMS adopters. Greater than 90% of AMS dairies possess more than 100 acres of land compared to 74% of non-AMS farms. This may allow AMS farms to obtain large sources of financing by offering a significant amount of land as collateral. Similarly, two-thirds of AMS operations expressed the need for renting an additional 100–1,000 acres (Figure 3), as most AMS adopters are midsized farms (100–250 cows, 38%) and large farms (more than 250 cows, 24%).

Notably, most dairies milk cows an average of two times a day, regardless of the milking process, contrary to the previous research stating that cows are milked more frequently by robots. This will be explored further in a subsequent survey with smaller intervals (by 0.1 times a day), to investigate if rounding up or down may be influencing the results. Nevertheless, milk yield per cow was higher under AMS, with over half of these operations (56%) producing more than 76 pounds per day, whereas only 43% of non-AMS farms yielded over 76 pounds per cow per day. This fact, along with the result that AMS dairies do not milk cows more frequently than non-AMS dairies, suggests that the use of robots in the milking process may improve efficiency as the accessibility to the robot is tailored to the cow's specific needs.

FARMERS' CHARACTERISTICS AND PERCEPTIONS

Survey results show that young farmers (age 18–34) and experienced farmers (over age 65) are more inclined to adopt AMS relative to middle-aged farmers. This may be because young farmers may be more amenable to technology adoption and older farmers generally own and manage larger farms with more capital access to invest in robotics, relative to middle-aged farmers. Interestingly, higher education does not necessarily translate to higher likelihood of AMS adoption. Relative to non-AMS farmers, a greater percentage of AMS farmers (38%) have an associate or technical degree but a smaller portion (9%) have a bachelor's or graduate degree.

Survey responses also suggest that AMS may reduce time spent on farm management (Figure 4), as a greater proportion of AMS dairies (26%) have off-farm employment when compared to non-AMS farmers (18%). Notwithstanding, about 41% of AMS owners/operators expressed having more difficulty training farm workers (Figure 4). This is likely because additional instructions are needed to operate robotic milking. Once workers have learned how to use this technology, time devoted for supervision is about the same as that for traditional facilities.

PANDEMIC CONDITIONS

The COVID-19 pandemic induced many operations to change their management practices, particularly during stay-at-home regulations. Most Wisconsin dairy operations (more than 90%) did not have to dump their milk output due to low sales (which was not the case for other states). However, about 23% of non-AMS and 18% of AMS farmers reported a decrease in milk production at the onset of the pandemic. Although non-AMS farms reduced both herd size (39%) and animal feed (35%), AMS dairies focused mostly (66%) on lowering the herd size (Figure 5). However, as noted earlier, despite the decline in production by many dairies and the closure of 343 licensed herds in one year (January to December 2020), Wisconsin production remained relatively stable in 2020 at about 30.7 billion pounds compared to the previous two years (Figure 1).

Figure 6 shows that non-AMS farmers were more inclined to raise hourly wages of agricultural workers over the previous year. About 15% of both groups increased wages by $3 to $4 per hour. However, about 5% of non-AMS operations raised hourly rates by $5 to $6 per hour, whereas only one AMS adopter raised wages by $5 or more. This fact may be correlated to a higher need for farm labor of non-AMS dairies.

PERCEPTION OF THE DAIRY INDUSTRY'S FUTURE OUTLOOK

About one-quarter of AMS operators reported investing a value equivalent to over 25% of their herd size, and most (65%) of them felt that they made the right decision. This expansion may be linked to additional infrastructure needed to accommodate the milking robot systems in their barns. Thus, only 18% of surveyed AMS operations said they would be likely to make equivalent growth in the next five years. In contrast, around one-fifth of non-AMS dairies made an investment of over 25% of their enterprise value. Nevertheless, non-AMS farmers did express concerns about their decision, as 24% said they would not have made this investment under similar circumstances and 87% stated they are unlikely to expand operations in the medium-term.

Dairy farmers were also asked their opinion regarding the most significant barriers limiting the expansion of operations. From eight possible challenges, four were the most prominent for all farmers (shown in Figure 7): environmental regulations, price risk, recruitment and management of labor, and lack of access to capital (e.g., loans). AMS dairies emphasized price risk (37%) as the most important barrier to grow the business, with significant difference when compared to non-AMS adopters who consider labor recruitment (22%) as a more significant barrier. In addition, environmental regulations are an impending concern for 17% of AMS dairies but only for 7% of their counterparts.

Finally, respondents were asked to evaluate their perception of risk of 15 factors that may have an impact on dairy farms in the next five years. Figure 8 lists nine of these factors, which were selected because most respondents had a strong opinion on the risk level for that factor (i.e., high or low risk). Although both AMS and non-AMS adopters show similar general attitudes toward each factor, about half of non-AMS farmers reveal a higher risk aversion to environmental and policy regulations, cost of raw materials, labor availability (consistent with their perception of barriers to expansion), milk production and yield, and shipping cost (i.e., national and international freight rates). In contrast, 50% to 60% of AMS operators have expressed lower concerns for water availability, impact of extreme weather events, and consolidation of farms into larger units. Thus, Figure 8 shows that AMS dairies may have a more positive perception regarding the outlook of dairy farms in the next five years.

CONCLUSIONS AND FINAL REMARKS

In recent years, dairy farmers have experienced labor shortages and an increase in animal feed and freight cost, contributing to a decline in the number of milking operations in Wisconsin. In the past decade, 46% of Wisconsin licensed herds have shut down, leaving only 6,275 farms (Figure 1). Driven by tight agricultural labor market conditions, dairy operations are increasingly adopting AMS, which are also perceived to improve yield per cow. In light of these facts, this study is a first attempt to explore whether AMS can improve farmers' attitudes toward the future outlook of the Wisconsin dairy sector, understand changes of management practices during the COVID-19 pandemic, and learn the differences in farm and operator characteristics between AMS and non-AMS dairies.

Dairy farmers have expressed interest in learning about robotic adoption, evidenced by high response rate (37%) of our exploratory survey, which was mailed to 500 randomly selected Wisconsin licensed herds in January 2022. This study shows that although AMS are still in nascent stages, they are the second most common type of milking facility used by respondents (Figure 2), characterized by four major AMS manufacturers. Not surprisingly, larger farms are more likely to implement AMS (Figure 3), due to better access to capital. Moreover, although AMS managers devote more time in training workers relative to non-AMS managers (Figure 4), AMS may reduce the time owners or family members spend on farm operations. During the COVID-19 pandemic, both types of dairy farms (AMS and non-AMS) decreased their milk production. Although AMS dairies opted for reducing herd size, non-AMS dairies used a combination of smaller herd sizes and less animal feed (Figure 5). In terms of investment barriers, AMS respondents claimed price risk to be the most significant barrier to growth, whereas non-AMS farmers considered labor recruitment and management as the most significant barrier (Figure 7). Interestingly, when asked for their perception of risk factors that may cause future challenges to the dairy sector, AMS adopters reported more positive responses (i.e., stating lower risk levels) than non-AMS operators (Figure 8).

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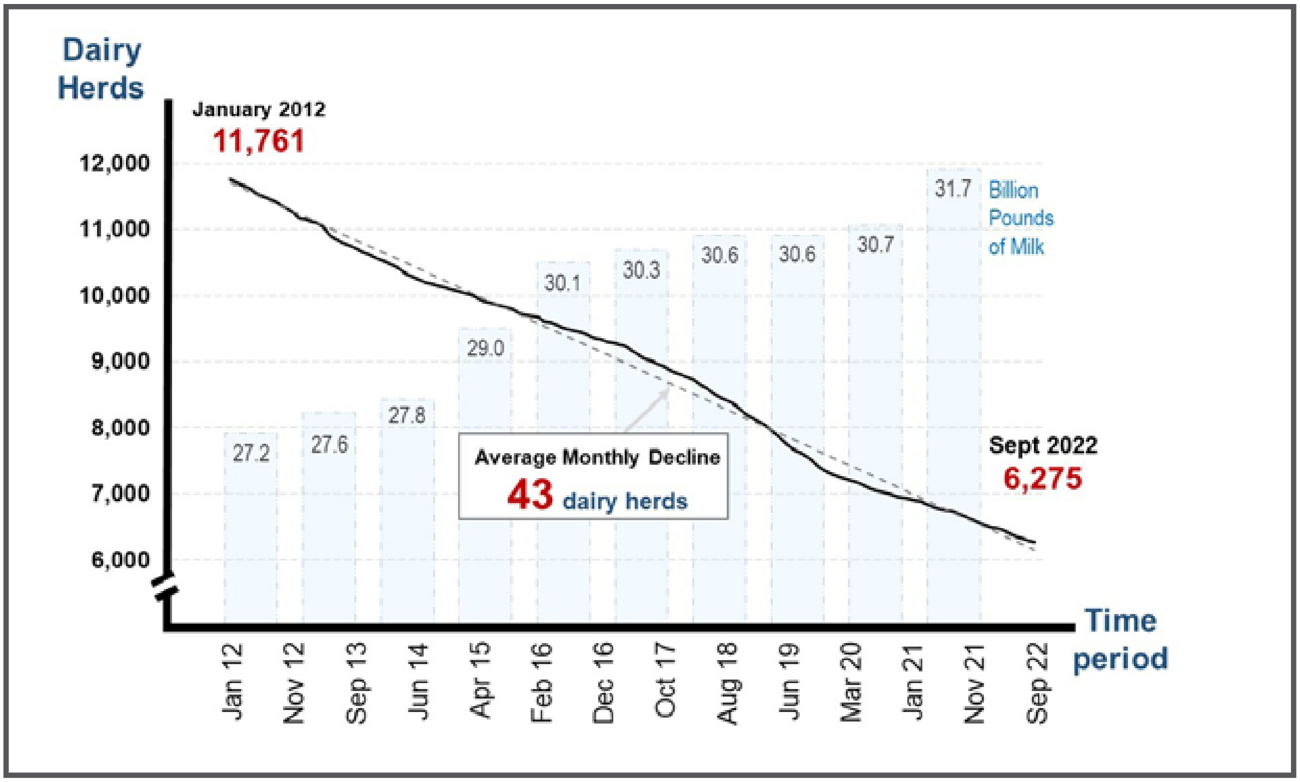


Figure 1. Number of dairy herds, Wisconsin, 2012–2022. (Source: Original calculations using data from USDA NASS, 2022.)

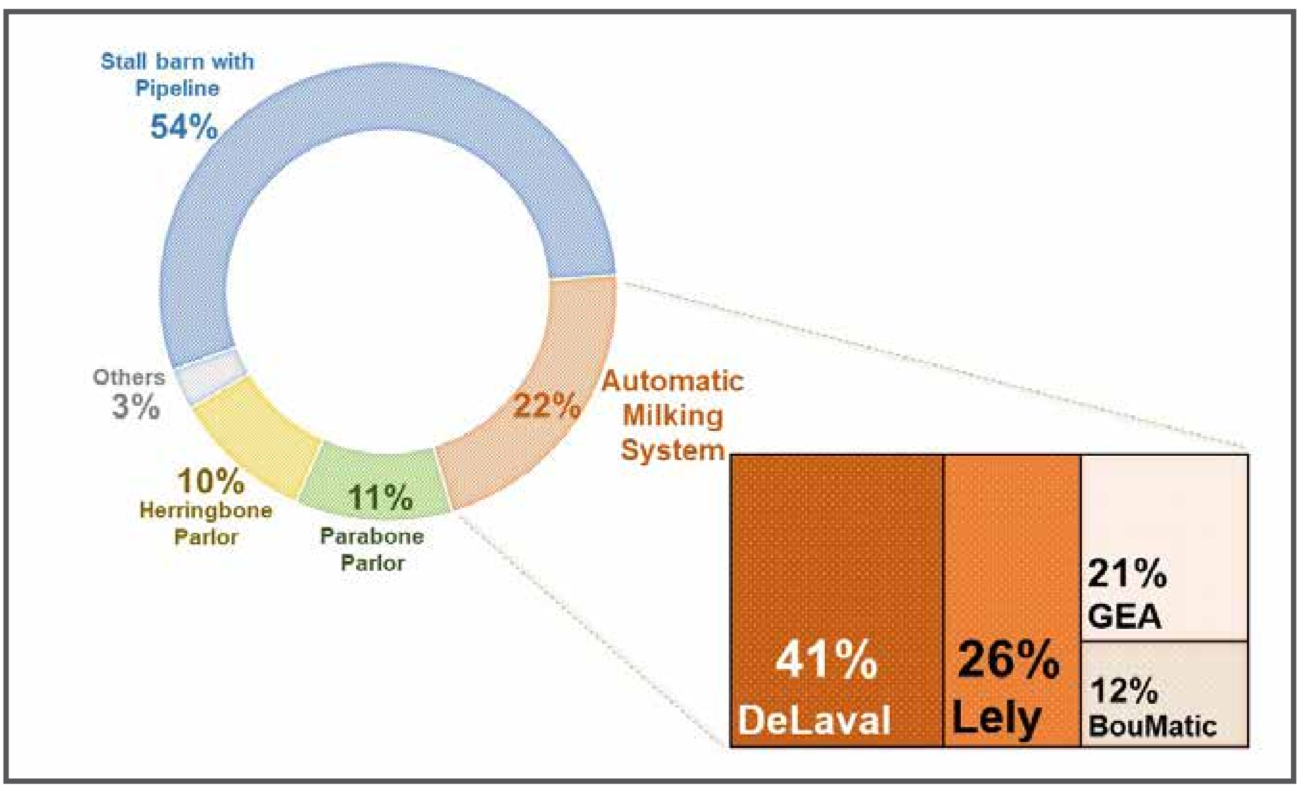


Figure 2. Type of milking systems used in Wisconsin dairy farms, 2022. (Source: Original calculations.)

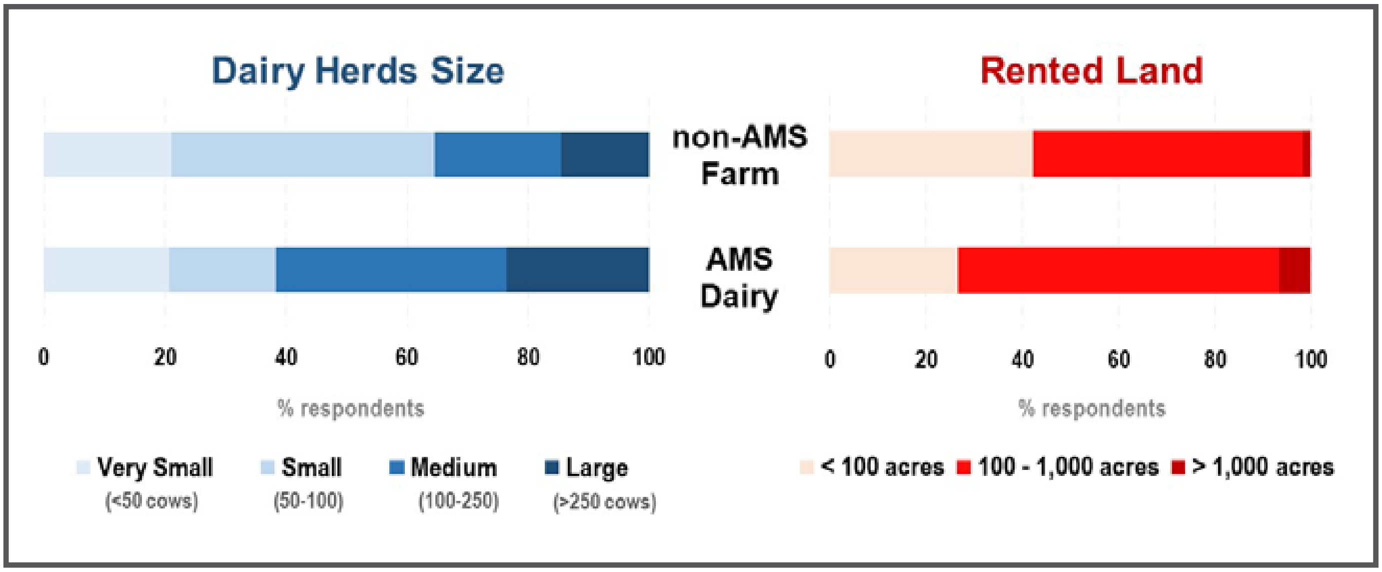


Figure 3. Dairy herd size and amount of land rented by technology type in Wisconsin dairy farms, 2022. (Source: Original calculations.)

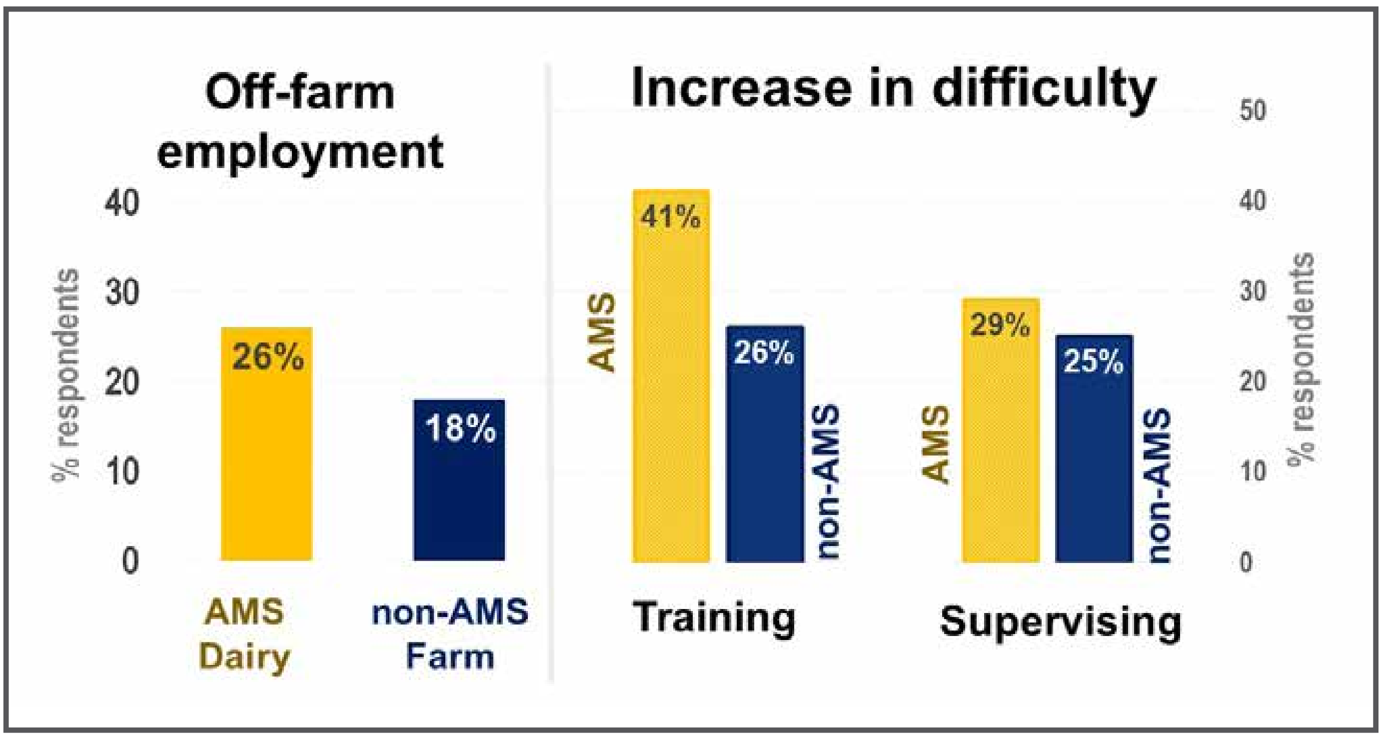


Figure 4. Off-farm employment and increase in training and supervising difficulty. (Source: Original calculations.)

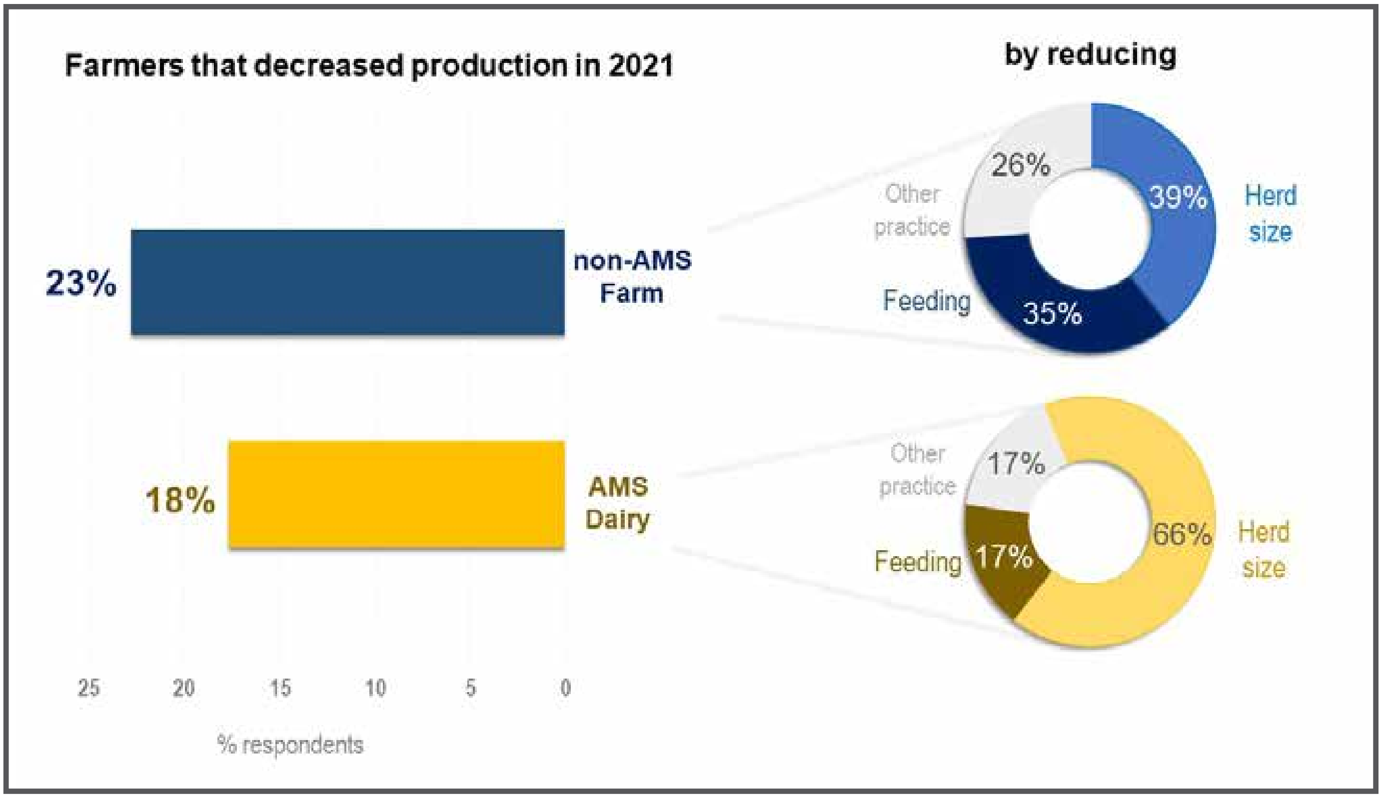


Figure 5. Fraction of farmers that reduced production in 2021 (*left*) and the methods used to achieve this reduction (*right*). (Source: Original calculations.)

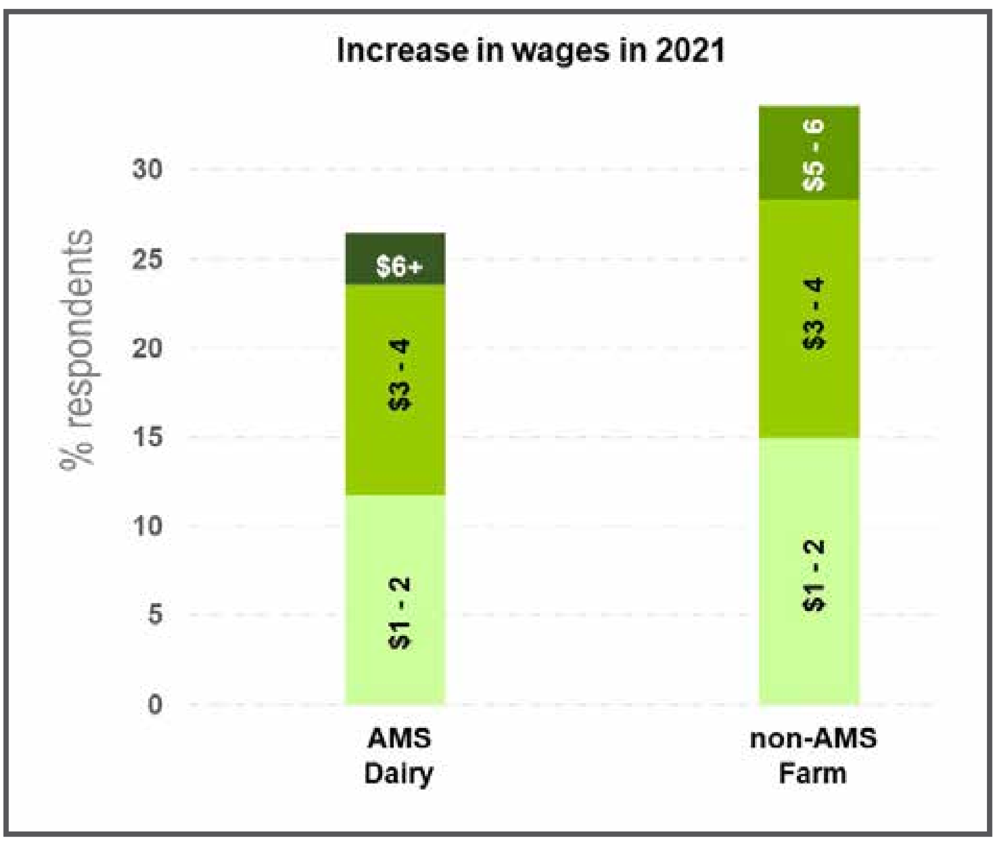


Figure 6. Increase in nominal wages in 2021 (in USD). (Source: Original calculations.)

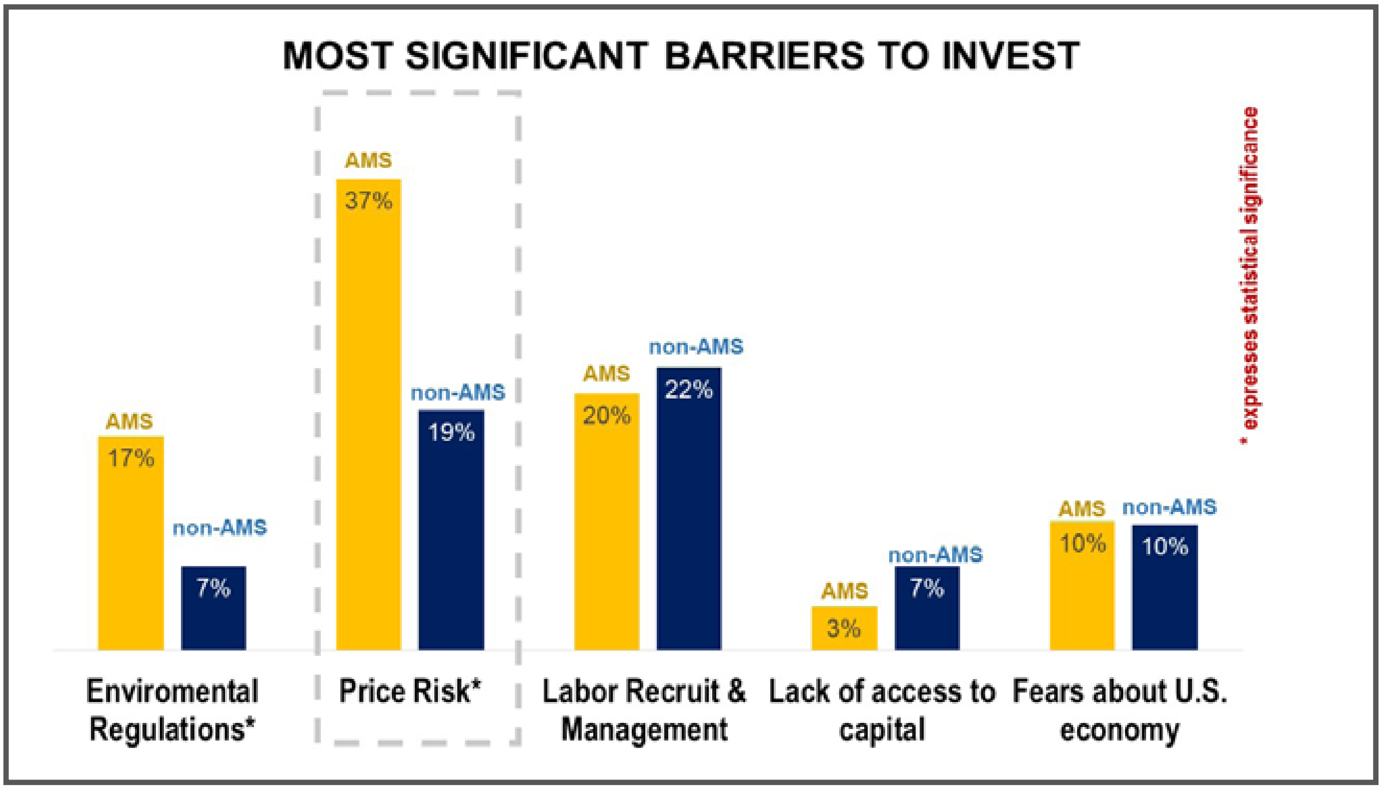


Figure 7. Most significant barriers to invest as reported by farmers (in % of respondents). (Source: Original calculations.)

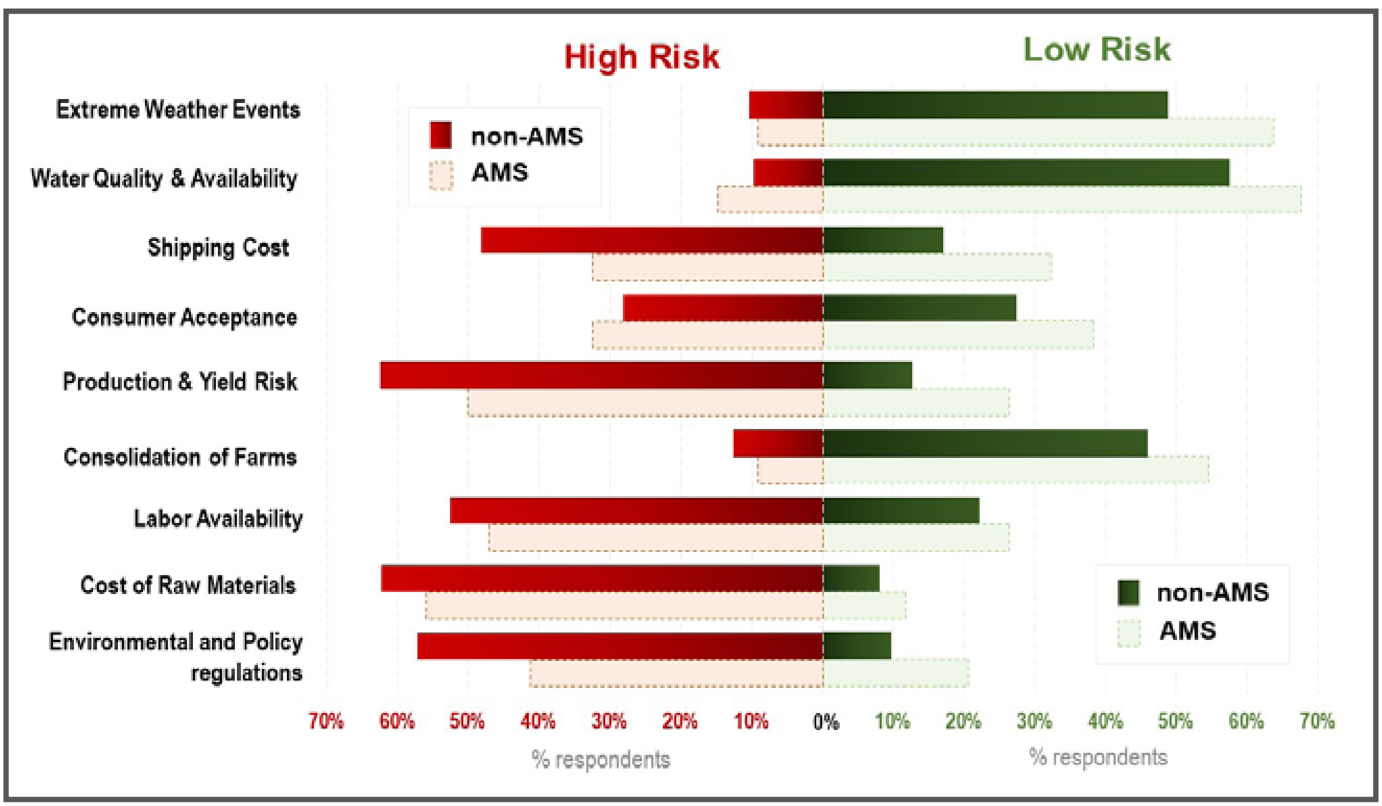
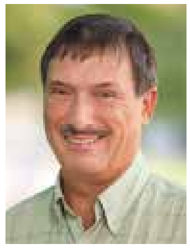


Figure 8. Risk perception of each factor on dairy's future outlook. (Source: Original calculations.)

Benefit-Cost Analysis of Equipment Purchases for Calf Health Management



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Abstract

Lack of access to cattle handling equipment is sometimes cited as a hindrance to cow-calf producer adoption of recommended calf management practices, although those practices are shown to add market value to calves. We measure correlations between equipment access and adoption along with implementing partial budget analysis to calculate break-evens of equipment purchases for specific practice implementation. Break-even measures are calculated in number of head and in years for cash- and loan-based purchases across different operation sizes. This is a first step toward quantifying the benefit-cost relationship of cattle handling equipment with calf management practice adoption.

INTRODUCTION

Cow-calf producers strive to wean healthy calves that perform efficiently in later stages of production. Weaning and receiving periods, however, are difficult and stressful for calves. The adoption of calf health management practices on the ranch safeguards health and maximizes performance of calves, preparing them to move to stocker and feeder phases. Basic calf health management practices include a significant pre-marketing weaning period, dehorning, castrating, vaccinating, deworming, and feed bunk training. Preconditioning encompasses bundling these practices together for marketing. Cow-calf producers face many constraints when it comes to the adoption of these practices. For some, that may include limited access to proper cattle handling equipment that facilitates practice adoption, resulting in healthier calves moving through the beef supply chain. Research has shown that cattle buyers are willing to pay premiums for these practices, whether implemented individually or as a bundle (Williams et al., 2012; 2014; Bulut and Lawrence, 2007). When equipment investment can make the difference between practice adoption or non-adoption, partial budgeting estimates of break-even periods or number of head to break-even provides valuable information to producers.

The objectives of this study are to (1) preview producer equipment access and producer calf management practice adoption rates, (2) calculate and analyze correlation coefficients between producer equipment access and adoption of specific calf management practices, and (3) build budgets and implement break-even analysis of specific cattle handling facilities and equipment relevant for adoption of calf management practices included in the preconditioning bundle, individually and collectively.

DATA AND METHODS

Data pertaining to producer demographics, adoption of specific calf management practices, and access to various types of facilities and equipment used for processing cattle and calves are taken from the 2017 Oklahoma Beef Management and Marketing Survey of Oklahoma beef cattle producers. The survey is conducted on an approximate five-year cycle by beef team members at Oklahoma State University, including faculty in Agricultural Economics and Animal Sciences. The United States Department of Agriculture's (USDA's) National Agricultural Statistics Service assists with implementation. The survey solicits producer information regarding operation characteristics, resource base and facility access, herd and calf management, forage use, marketing choices, and incentives and constraints to adoption of specific practices. Access to facilities and equipment is defined as own, rent/lease, borrow, or none. A total of 1,495 producers responded to the survey from an initial sample of 5,000, resulting in a 30% response rate and a 95% confidence level associated with the data. The sample was specifically drawn to be representative of Oklahoma cattle producers. Of the 1,495 responses, 1,210 had cow-calf operations. Data regarding facility and equipment costs (initial purchase and installation as well as operation) and life expectancies of various types of facilities were obtained from an industry source. Base cattle prices are taken from the Livestock Marketing Information Center's weekly summary of USDA Agricultural Marketing Service (AMS) feeder cattle prices for medium and large number 1 steers at Oklahoma City (LMIC, n.d.). Fall marketing is assumed in the partial budgets.

We use Microsoft Excel's correlation feature (@correl) to calculate correlations between specific equipment access and practice adoption of specific management practices. Partial budgeting scenarios are developed using Excel to simulate the benefits and costs associated with adopting practices that are facilitated by specific cattle handling facilities or equipment. Different scenarios can then be simulated to calculate break-evens across several different dimensions including but not limited to herd size, market premiums associated with various practices, equipment acquisition costs, prevailing interest rates, etc. Feeder calf market premiums for specific management practices are taken from Williams et al. (2012; 2014) and represent the market value of specific practices as estimated from livestock auction data collected in person by Oklahoma State University at Oklahoma livestock auctions.

RESULTS

Equipment Access

Access to equipment can be through ownership, whether outright or shared, or through borrowing. Producer survey responses in Figure 1 indicate that nearly all producers have access to working pens (91%) and a squeeze chute or headgate (93%). This equipment is considered by most as the necessary minimum for gathering and working cattle. The headgate or a headgate/squeeze chute combination allows producers to work cattle while minimizing the risk of injury to the producer and the cattle. Access to preconditioning pens is far less at approximately 57% of producers. Preconditioning pens allow weaned calves to be separated from their dams while adjusting during the weaning process but without the added stress of leaving the ranch. Only roughly 20% of producers report access to scales or to a calf tilt table. Scales facilitate more precise management of animals, particularly when measuring performance, calculating feed rations, or administering medication. A calf tilt table (sometimes called a calf chute) makes the process of branding, vaccinating, and castrating calves easier and faster.

Practice Adoption

Recommended calf health management practices can improve calf health on the ranch and as the animal moves through the beef supply chain. Figure 2 reports adoption rates for six management practices that are typically bundled to market calves as preconditioned. Preconditioning builds the stress tolerance and immune system of the calf and facilitates a healthy transition to the next phases of production (Lalman and Mourer, 2017). Of the producers surveyed, 45% indicate that they dehorn cattle. However, this number could be misleading regarding the number of horned cattle marketed, since polled genetics are also a form of horn management. The fact that only 49% of producers administer respiratory vaccinations prior to marketing is of concern, given that bovine respiratory disease (BRD) is a major worry as cattle move through the system. Preconditioning can decrease the incidence of BRD by as much as 90% for future owners of calves, which decreases cost by decreasing medical treatments and increasing the production efficiency of animals and ultimately the quality of beef for the final consumer (Lalman and Mourer, 2017).

Weaning periods of at least 45 days also strengthen immune systems, with approximately 63% of producers implementing this practice. Perhaps the other practice commanding the most interest is castration, with 82% of producers indicating that they castrate bull calves prior to marketing. Although castration has one of the highest rates of adoption, the fact that 18% of producers do not castrate bull calves prior to marketing them as feeder calves is troubling. The stress of castration on the animal is greater as calves get older and heavier. Somewhere down the line, someone has to castrate a larger, more dangerous animal while giving up health advantages and efficiencies gained from earlier castration. And the cow-calf producer is leaving $6 to $12 per hundredweight on the table by not implementing castration on the ranch (Williams et al., 2012; 2014).

Correlations between equipment access and practice adoption

Table 1 reports correlation coefficients between selected cattle handling equipment and producer adoption of selected calf management practices, based on data from the Oklahoma Beef Management and Marketing Survey. The t-statistics values are reported in parentheses for each correlation value, with statistical significance denoted by asterisks.

The survey asks producers about access to six types of cattle handling equipment, including calf tilt table, scales, loading chute and/or ramp, preconditioning pens, processing pens, and a squeeze chute/headgate. In a separate question, the survey also asks producers about calf management practices implemented on their cattle operation. We specifically examine the correlations of adoption of castration, dehorning, deworming, 45-day weaning, feed bunk training, and respiratory vaccinations with producer access to the equipment listed above.

Although these correlations can indicate the importance of some equipment in adoption of specific practices, we should be clear that the correlations represent only the correlation between access and adoption for those who have access and do adopt. That is, the correlations do not measure whether access to a certain piece of equipment would directly correlate to a producer implementing a practice not previously done. They do, in some sense, provide a measure of the importance producers who are currently implementing a specific practice have placed on equipment relative to that practice.

Nearly all correlations are statistically different from zero. A few correlations of interest are highlighted in Table 1. Access to preconditioning pens has the highest correlation with implementation of each of the six practices examined here. Recall that these are the practices typically bundled together for marketing calves as preconditioning and even more so for VAC-45 certified preconditioning programs. The highest correlations are with 45-day weaning, respiratory vaccinations, and feed bunk training, with relatively lower correlations with the other practices. This likely reflects the fact that these three practices are implemented over time, as opposed to instant implementation, and preconditioning pens facilitate holding calves for that extended time.

Castration is weakly correlated with calf tilt table access (0.16) and with squeeze chute/headgate access (0.17). In fact, castration is weakly correlated with all six facilities/equipment pieces examined. Although 82% of Oklahoma cattle producers castrate their bull calves, only 19% report access to a calf tilt table. Since castration can be facilitated in various ways, including traditional open field roping of calves, a calf tilt table, a squeeze chute/headgate, or pen and catch, weak correlation with any one piece of equipment is not surprising. Nearly all producers report access to a squeeze chute/headgate, but it is not strongly correlated with any particular practice. The two strongest correlations are with castration (0.17) and feed bunk training (0.19).

Partial Budget Analysis for Equipment Purchases

As producers consider equipment purchases that could make incorporating recommended management practices into their operation's management plan easier, it is important to consider the applicable benefits and costs. We use partial budget analysis to calculate break-even for equipment purchases relevant to the six practices mentioned above. Premiums for adoption and marketing of a specific practice or practice bundle are based on previous research of the market value of various calf management practices at Oklahoma livestock auctions (e.g., Williams et al., 2012; 2014). We use conservative estimates of market premiums to generate conservative benefit estimates. Equipment costs are based on cost estimates from private dealers and are reported in Table 2.

In addition to calculating break-evens for the reported equipment cost, we also calculate break-evens for cost plus 10% and cost minus 10%. The analysis assumes that the additional market value associated with implementing a specific practice is fully assigned to equipment payoff. Equipment break-even is calculated on a per-head basis as well as on a time-period basis. Break-evens on a time-period basis are calculated using a cash scenario and a borrowing scenario where the borrowing scenario assumes a 5% interest rate.

Partial budgets for purchasing specific equipment to facilitate a specific calf health management practice are calculated for five scenarios. For each budget, the base and alternative scenario are described in the footnotes, as is the assumed premium for the management practice considered. Premium per hundredweight for implementation is reported on the left-hand side as management premium. Changes in management cost (excluding equipment purchase) associated with a specific practice are reflected in the top section of the right-hand side column. The middle section of the right-hand side indicates "Net return from additional management." The bottom section calculates equipment break-even across three equipment cost scenarios in number of head, years to break-even for a cash scenario, and years to break-even for a borrowing scenario based on practice implementation on calves for 20 head, 100 head, and 250 head. The exception is in the case of preconditioning pens, for which scenarios are in terms of 50, 100, and 250 head.

A calf tilt table stabilizes the calf and can be rotated so that the calf is secured safely on its side for implementation of recommended management practices. It is typically designed to be used with cattle weighing 500 pounds or less. The scenario in Figure 3 calculates benefits, costs, and break-evens for castration facilitated by purchase of a calf tilt table. The comparison of management revenue assumes a $9 premium per hundredweight for castrating a bull calf prior to marketing (Williams et al., 2012; 2014). The comparison of management costs indicates a small increase in labor cost per head for castration. Net return from castration is calculated as $49.80 per head, as shown in the "Net return from additional management" row. Recall that the partial budget assumes all net returns from castration are used toward equipment payoff. At the base equipment cost of $2,790, the break-even number of head (i.e., bull calves to castrate) is calculated as 57. For a producer with 20 bull calves to castrate, years to break-even in the cash scenario is 2.85, reflecting nearly three bull calf crops. Larger producers would see a shorter time to break-even with 0.57 years for 100 head of bull calves and 0.23 years for a large producer with 250 bull calves. Both larger-sized scenarios pay for the calf tilt table with less than one calf crop. For the borrowing scenario, years to break-even is slightly higher at 3.09, 0.58, and 0.23, respectively, moving from 20 to 100 to 250 bull calves to castrate. The partial-budget scenario here examines only break-even related to benefits and costs of castration implementation. Although a calf tilt table can facilitate multiple recommended practices on a calf crop, its use is limited to calves because of equipment size and weight restrictions.

Another piece of equipment that can facilitate castration is a standard squeeze chute. The partial budget for purchasing a squeeze chute to implement castration of bull calves is shown in Figure 4. The premium for castration is again presumed to be $9 per hundredweight, as shown in the second section of the left-hand column. A small increase in labor cost per head for castration is indicated in the comparison of management costs. The net return from castration in this scenario is identical to the net return from the previous scenario, at $49.80 per head as shown in net return from additional management. All net returns from castration are used toward equipment payoff. At the base equipment cost of $5,307, the break-even number of head (i.e., bull calves to castrate) is calculated as 102. For a producer with 20 bull calves to castrate, years to break-even in the cash scenario is 5.10, or slightly more than five calving seasons. Larger producers would see a shorter time to break-even, with 1.02 years for 100 head of bull calves and 0.41 years for a large producer with 250 bull calves. The borrowing scenario years to break-even is slightly higher at 5.98, 1.06, and 0.42, respectively, moving from 20 to 100 to 250 bull calves to castrate. In this scenario, larger producers again are able to pay off the equipment cost in approximately one calving season or less.

The partial budget for a squeeze chute purchase to implement respiratory vaccinations in calves is shown in Figure 5. BRD is the most common illness in beef cattle. Wittum and Perino (1995) found that calves affected by BRD weighed significantly less at weaning than their herd mates and those performance impacts tend to follow the calf through the supply chain. Calves can be vaccinated for the BRD complex effectively as early as two months of age. Two rounds of respiratory vaccinations prior to marketing feeder calves are recommended, with one round early and another round either two to four weeks prior to weaning or at weaning. Respiratory vaccinations have been shown to garner market premiums ranging from approximately $2 to $6 per hundredweight (Williams et al., 2012; 2014). We use a conservative estimate of $2 in the partial budget. Producers can adjust premiums to reflect local market premiums. The comparison of management costs indicates a small increase in labor cost per head, as well as $5 per head for vaccines and supplies for vaccination implementation. Calves are assumed to have two rounds of respiratory vaccinations. The net return from additional management (respiratory vaccinations) is calculated as $5.85 per head. Note that this includes only the benefit from the market premium and does not account for benefits from any reductions in death loss of calves. However, producers can enter historical death loss rates for calves from their own operations in the base scenario and estimate the improved rate in the alternate scenarios. Those values will vary by operation.

At the base squeeze chute cost of $5,037, the break-even number of head (i.e., number of calves vaccinated) is calculated as 861. Years to break-even for 20 calves under the cash scenario is 43.05 years, but under the borrowing scenario, a vaccination premium of $2 per hundredweight never pays off the loan. At 100 head and 250 head, the cash break-even period is 8.6 years and 3.4 years, respectively, whereas under the borrowing scenario, those break-even periods are 11.53 years and 3.87 years. Certainly, a squeeze chute can facilitate multiple cattle management practices, including castration and vaccinations, so payoff head and years to break-even could be shorter if net returns to multiple practices are allocated to equipment payoff.

Preconditioning pens can facilitate 45-day weaning by providing a place to hold calves separate from dams during the weaning period. The partial budget in Figure 6 examines the break-even periods for 50-head capacity, 100-head capacity, and 250-head capacity preconditioning pens. Recall that the budget looks only at the benefit and cost of 45-day weaning and not at any potential joint practices that could also be implemented. Here, a conservative estimate of the 45-day weaning premium is $2 per hundredweight (Williams et al., 2012; 2014). Additional revenue comes from the weight gained during the 45-day period. Costs associated with 45-day weaning include the interest associated with holding calves beyond weaning rather than marketing at weaning, as well as an allowance for death loss, labor, forage, feed, and minerals as seen in the comparison of management costs. Net return to 45-day weaning in this scenario is estimated at $20.34 per head.

Due to the incremental nature of increasing capacity for preconditioning pens, break-even number of head is calculated separately for each capacity. Break-even number of head by capacity is 227 head for 50-head pens, 404 head for 100-head pens, and 1,111 head for 250-head pens. Years to cash break-even across capacities are similar to each other at 4.54, 4.04, and 4.44 for 50-head, 100-head, and 250-head pens, respectively, with slightly longer break-even periods for the borrowing scenario at 5.25, 4.61, and 5.15 years.

Preconditioning pens can facilitate adoption of the bundle of recommended practices commonly referred to as preconditioning, including castration, dehorning, two rounds of respiratory vaccinations, bunk training, and a minimum of 45-day weaning. The budget in Figure 7 illustrates cost-benefit calculations for purchase of preconditioning pens to facilitate adoption of this bundle. The market premium for preconditioned calves is assumed to be $10 per hundredweight (Williams et al., 2012; 2014). Note that for steer calves, this is in addition to the premium for castration. In this case, the increase in revenue for preconditioning comes from the combination of the market premium and the value of gain over the 45-day period. Producers who choose to precondition calves do incur higher up-front costs generally, although that cost will differ depending on feed type and source. When the cost of preconditioning is considered, net return from preconditioning management is conservatively estimated at $50.13 per head. Based on this value, the break-even number of head is 92 for a 50-head pen, 164 for a 100-head pen, and 451 for a 250-head pen. Break-even is slightly less than two calving seasons for all sizes. The exception is when equipment cost is base plus 10%. In that scenario, equipment break-even for 50-head pens is slightly more than two calving seasons, as is the borrowing scenario for 250-head pens.

IMPLICATIONS/CONCLUSIONS

In this study, we report on survey results pertaining to cow-calf producer equipment access and calf management practice adoption rates. We then calculate and analyze correlation coefficients between producer equipment access and adoption of specific calf management practices. Finally, we evaluate break-even cattle numbers needed to cover the costs of obtaining various facility/equipment combinations that would facilitate the implementation of calf management practices that have been shown to garner price premiums (and therefore increase total revenue) at sale time. We also evaluate time to break-even for cash-based and loan-based equipment purchases for different operation sizes.

A large majority of cow/calf producers responding to our survey indicated that they have access to some version of a cattle squeeze chute or headgate, as well as access to working/processing pens. Most also have access to a loading chute or ramp to facilitate loading of cattle for transport. Just over half of the survey respondents indicated they have preconditioning pens. A much smaller percentage of producers (less than 20%) reported having access to scales or a calf tilt table. With regard to specific calf management practices, a large majority of surveyed producers indicated that they castrate bull calves, deworm, and bunk train calves. More than half reported that they wean calves at least 45 days before selling. Less than half of the respondents indicated that they administer respiratory vaccinations and dehorn. Even though a significant portion of respondents indicated that they utilize at least some of these calf management practices, given the magnitude of price premiums attributed to these practices it seems there is still room for improvement in practice adoption.

We find a statistically significant correlation between the adoption of most of the surveyed calf management practices and access to various facility and equipment components, leading to questions concerning the economic feasibility of acquiring specific facility and equipment that would help facilitate adoption of various calf management practices for representative cow-calf producers. Preconditioning pens, in particular, have a strong correlation with adoption of 45-day weaning, bunk training, and respiratory vaccinations, likely because these practices include a time element that preconditioning pens would facilitate.

Partial budget analysis indicates that the largest net returns for practice adoption are associated with castration and preconditioning, which encompass the entire bundle of practices examined here. Note that for calves marketed as steers rather than bulls, the net returns for preconditioning would be additive to the net returns for castration. The scale of a producer's operation significantly influences break-even periods, with the exception of preconditioning pens. For producers who purchase preconditioning pens in order to precondition their calves, all operation sizes reached break-even within two years or two calving seasons. For other equipment purchases to facilitate practice adoption, larger operations attain break-even at a faster pace than smaller operations.

The preconditioning adoption scenario (i.e., adoption of a bundle of practices) is the only scenario where we examined break-even periods relative to practice bundling. It is true that some equipment is multi-use and, as such, can be used for implementation of multiple calf health management practices and also for management related to other cattle in the operation. The partial budgets here are specifically related to calf management but are useful in evaluating the contribution of equipment to the overall returns to management in an operation. These results are a first step in demonstrating the extent to which a lack of resources (facilities and equipment) could be a constraint for some producers in adopting calf management practices that have long been shown to enhance revenue. The findings also suggest that the acquisition of equipment and facilities can be an economically feasible investment in many instances.

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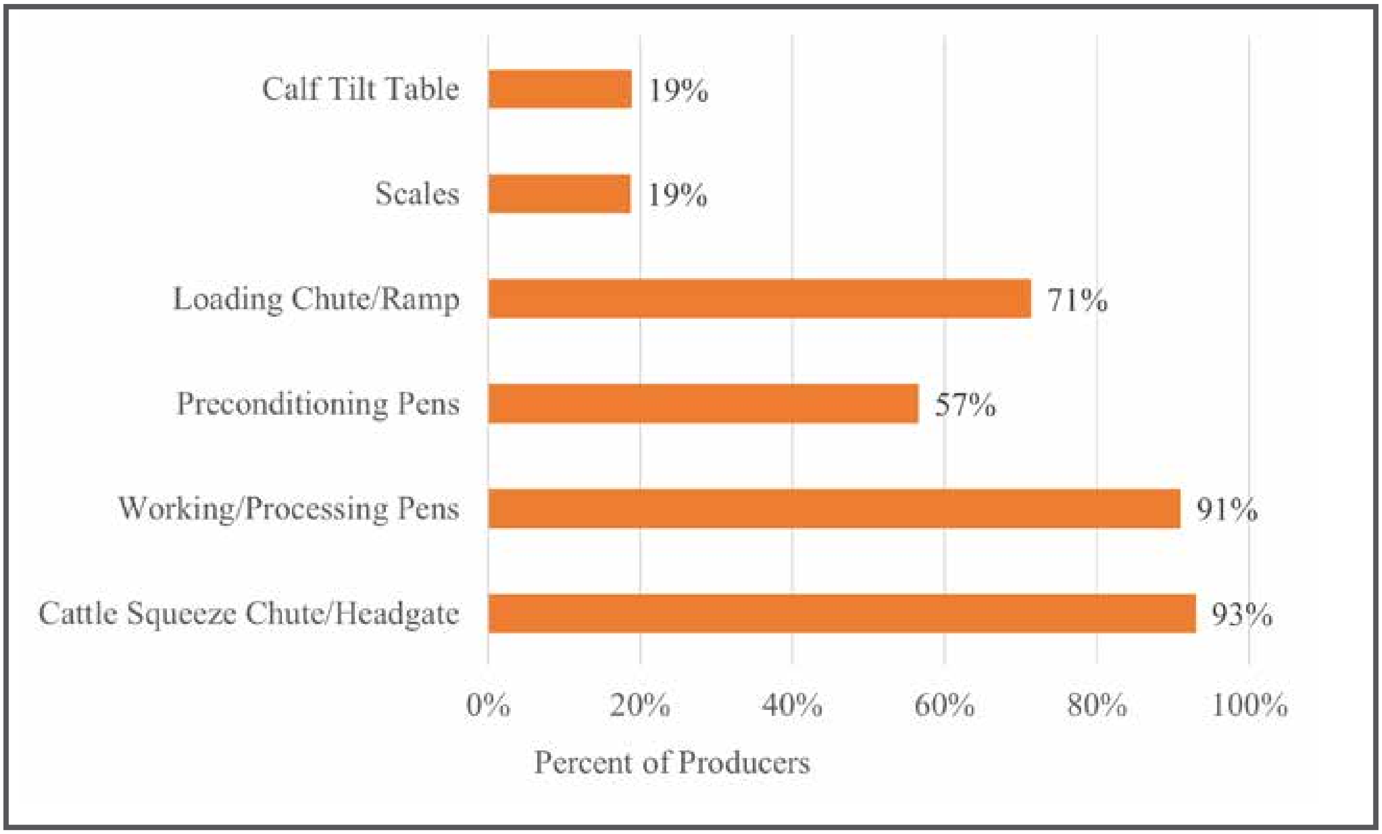


Figure 1. Producer access to cattle facilities and equipment. (Source: 2017 Oklahoma Beef Management and Marketing Survey.)

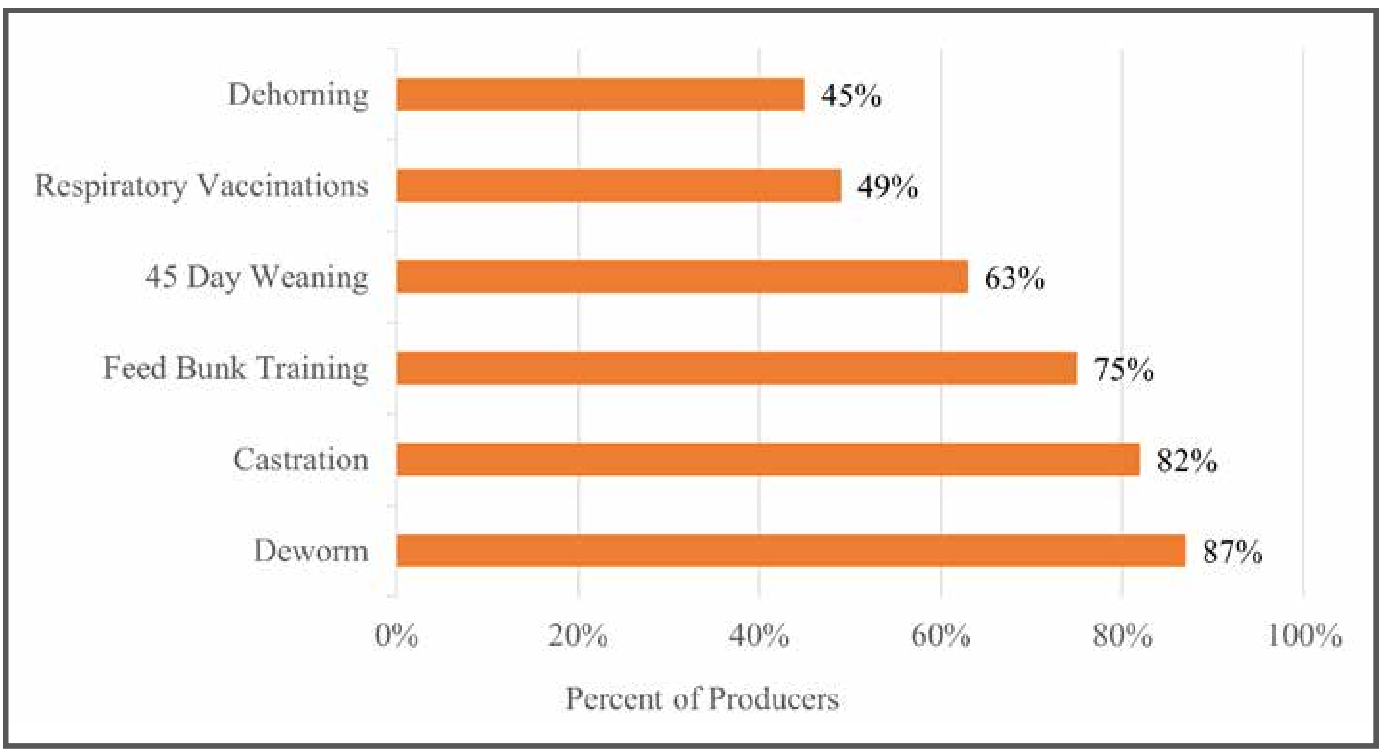


Figure 2. Producer adoption of calf management practices. (Source: 2017 Oklahoma Beef Management and Marketing Survey.)

Partial Budget Calculator - Castration/Calf Tilt Table

EXTENSION

Sell at Weaning Revenue	Base	Alternate
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	146.00	146.00
Gross revenue ($/head)	814.32	814.32

Comparison of Management Revenues	Base	Alternate
Management practice	No Castration	Castration
Days from weaning to marketing	0	0
ADG (lbs./day)	0.00	0.00
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	0.00	0.00
Calculated price change due to heavier weight ($/cwt)	0.00	0.00
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)	0.00	9.00
Final price ($/cwt.)	**146.00**	**155.00**
Gross revenue ($/head)	814.32	864.51

Footnotes:
Base = Market at weaning as bulls
Alternate = Market at weaning as steers
Management premium: $9 premium for castrating and marketing as steers
Sources: Bulut and Lawrence, 2007; Williams, Raper, DeVuyst, Peel, McKinney, 2012.
Price source: AMS/USDA Feeder Cattle Prices, Oklahoma City, Weekly, Medium and Large Steers, Fall 2019. Livestock Marketing Information Center.

Comparison of Management Costs	Base	Alternate
Management practice	No Castration	Castration
Interest rate (%)	5.0	5.0
Cattle interest ($/head)	0.00	0.00
Vaccine, health supplies and medicine ($/head)	0.00	0.00
Death loss (%)		
Death loss ($/head)	0.00	0.00
Labor ($/head)	0.00	0.40
Equipment ($/head)	0.00	0.00
Pasture ($/head)	0.00	0.00
Fertilizer ($/head)	0.00	0.00
Hay ($/head)	0.00	0.00
Feed/supplement ($/head)	0.00	0.00
Mineral ($/head)	0.00	0.00
Added marketing costs (tags, commission) ($/head)	0.00	0.00
Total cost ($/head)	**0.00**	**0.40**

Management Comparison Summary ($/head)	Base	Alternate
Management practice	No Castration	Castration
Sell at weaning gross revenue	$ 814.32	$ 814.32
Additional management gross revenue	$ 814.32	$ 864.51
Increased revenue	$ -	$ 50.20
Less management costs	$ -	$ 0.40
Net return from additional management	**$ -**	**$ 49.80**
Weight gain (lbs.)	0	0
Total cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Feed cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Value of gain ($/cwt)	#DIV/0!	#DIV/0!

Equipment Break-even	Base - 10%	Base	Base + 10%
Calf tilt table cost	$ 2,511.00	$ 2,790.00	$ 3,069.00
Net return from additional management	$ 49.80	$ 49.80	$ 49.80
Break-even point (# head)	**51**	**57**	**62**
Years to break-even: Cash			
20 head	2.55	2.85	3.10
100 head	0.51	0.57	0.62
250 head	0.20	0.23	0.25
Years to break-even: Borrowing (5% interest)			
20 head	2.76	3.09	3.43
100 head	0.52	0.58	0.64
250 head	0.21	0.23	0.25

Figure 3. Partial budget for castration with calf tilt table

OSU EXTENSION

Partial Budget Calculator - Castration/Squeeze Chute

Sell at Weaning Revenue	Base	Alternate
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	146.00	146.00
Gross revenue ($/head)	814.32	814.32

Comparison of Management Revenues	Base	Alternate
Management practice	No Castration	Castration
Days from weaning to marketing	0	0
ADG (lbs./day)	0.00	0.00
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	0.00	0.00
Calculated price change due to heavier weight ($/cwt)	0.00	0.00
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)	0.00	9.00
Final price ($/cwt.)	**146.00**	**155.00**
Gross revenue ($/head)	814.32	864.51

Footnotes:
Base = Market at weaning as bulls
Alternate = Market at weaning as steers
Management premium: $9 premium for castrating and marketing as steers
Sources: Bulut and Lawrence, 2007; Williams, Raper, DeVuyst, Peel, McKinney, 2012.
Price source: AMS/USDA Feeder Cattle Prices, Oklahoma City, Weekly, Medium and Large Steers, Fall 2019. Livestock Marketing Information Center.

Comparison of Management Costs	Base	Alternate
Management practice	No Castration	Castration
Interest rate (%)	5.0	5.0
Cattle interest ($/head)	0.00	0.00
Vaccine, health supplies and medicine ($/head)	0.00	0.00
Death loss (%)		
Death loss ($/head)	0.00	0.00
Labor ($/head)	0.00	0.40
Equipment ($/head)	0.00	0.00
Pasture ($/head)	0.00	0.00
Fertilizer ($/head)	0.00	0.00
Hay ($/head)	0.00	0.00
Feed/supplement ($/head)	0.00	0.00
Mineral ($/head)	0.00	0.00
Added marketing costs (tags, commission) ($/head)	0.00	0.00
Total cost ($/head)	**0.00**	**0.40**

Management Comparison Summary ($/head)	Base	Alternate
Management practice	No Castration	Castration
Sell at weaning gross revenue	$ 814.32	$ 814.32
Additional management gross revenue	$ 814.32	$ 864.51
Increased revenue	$ -	$ 50.20
Less management costs	$ -	$ 0.40
Net return from additional management	**$ -**	**$ 49.80**
Weight gain (lbs.)	0	0
Total cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Feed cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Value of gain ($/cwt)	#DIV/0!	#DIV/0!

Equipment Break-even	Base - 10%	Base	Base + 10%
Squeeze chute cost	$ 4,533.30	$ 5,037.00	$ 5,540.70
Net return from additional management	$ 49.80	$ 49.80	$ 49.80
Break-even point (# head)	**92**	**102**	**112**
Years to break-even: Cash			
20 head	4.60	5.10	5.60
100 head	0.92	1.02	1.12
250 head	0.37	0.41	0.45
Years to break-even: Borrowing (5% interest)			
20 head	5.29	5.98	6.68
100 head	0.95	1.06	1.17
250 head	0.38	0.42	0.46

Figure 4. Partial budget for castration with squeeze chute

Partial Budget Calculator - Respiratory Vaccinations/Squeeze Chute

OSU EXTENSION

Sell at Weaning Revenue	Base	Alternate
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	155.00	155.00
Gross revenue ($/head)	864.51	864.51

Comparison of Management Revenues	Base	Alternate
Management practice	No Vaccinations	Vaccinations
Days from weaning to marketing	0	0
ADG (lbs./day)	0.00	0.00
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	0.00	0.00
Calculated price change due to heavier weight ($/cwt)	0.00	0.00
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)	0.00	2.00
Final price ($/cwt.)	**155.00**	**157.00**
Gross revenue ($/head)	864.51	875.67

Footnotes:
Base = Market at weaning as steers
Alternate = Market at weaning as steers with respiratory vaccinations
Management premium: $2.00 premium for vaccinated calves
Sources: Bulut and Lawrence, 2007; Williams, Raper, DeVuyst, Peel, McKinney, 2012.
Price source: AMS/USDA Feeder Cattle Prices, Oklahoma City, Weekly, Medium and Large Steers, Fall 2019. Livestock Marketing Information Center.

Comparison of Management Costs	Base	Alternate
Management practice	No Vaccinations	Vaccinations
Interest rate (%)	5.0	5.0
Cattle interest ($/head)	0.00	0.00
Vaccine, health supplies and medicine ($/head)	0.00	5.00
Death loss (%)		
Death loss ($/head)	0.00	0.00
Labor ($/head)	0.00	0.30
Equipment ($/head)	0.00	0.00
Pasture ($/head)	0.00	0.00
Fertilizer ($/head)	0.00	0.00
Hay ($/head)	0.00	0.00
Feed/supplement ($/head)	0.00	0.00
Mineral ($/head)	0.00	0.00
Added marketing costs (tags, commission) ($/head)	0.00	0.00
Total cost ($/head)	**0.00**	**5.30**

Management Comparison Summary ($/head)	Base	Alternate
Management practice	No Vaccinations	Vaccinations
Sell at weaning gross revenue	$ 864.51	$ 864.51
Additional management gross revenue	$ 864.51	$ 875.67
Increased revenue	$ -	$ 11.16
Less management costs	$ -	$ 5.30
Net return from additional management	**$ -**	**$ 5.85**
Weight gain (lbs.)	0	0
Total cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Feed cost of gain ($/cwt)	#DIV/0!	#DIV/0!
Value of gain ($/cwt)	#DIV/0!	#DIV/0!

Equipment Break-even	Base - 10%	Base	Base + 10%
Squeeze chute cost	$ 4,533.30	$ 5,037.00	$ 5,540.70
Net return from additional management	$ 5.85	$ 5.85	$ 5.85
Break-even point (# head)	**775**	**861**	**947**
Years to break-even: Cash			
20 head	38.75	43.05	47.35
100 head	7.8	8.6	9.5
250 head	3.1	3.4	3.8
Years to break-even: Borrowing (5% interest)			
20 head	#N/A	#N/A	#N/A
100 head	10.03	11.53	13.13
250 head	3.45	3.87	4.30

Figure 5. Partial budget for vaccinations with squeeze chute

Partial Budget Calculator - 45 Day Weaning/Preconditioning Pens

EXTENSION

Sell at Weaning Revenue	Base	Alternate
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	155.00	155.00
Gross revenue ($/head)	864.51	864.51

Comparison of Management Revenue	Base	Alternate
Management practice	Sell at Weaning	45-Day Weaning
Days from weaning to marketing	0	45
ADG (lbs./day)	0.00	1.60
Ranch (marketing) weight (lbs.)	575	647
Shrink (%)	3.0	1.0
Sale weight (lbs.)	558	641
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	0.00	-10.00
Calculated price change due to heavier weight ($/cwt)	0.00	-8.28
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)	0.00	2.00
Final price ($/cwt.)	**155.00**	**148.72**
Gross revenue ($/head)	864.51	952.61

Comparison of Management Costs	Base	Alternate
Management practice	Sell at Weaning	45-Day Weaning
Interest rate (%)	5.0	5.0
Cattle interest ($/head)	0.00	5.33
Vaccine, health supplies and medicine ($/head)	0.00	0.00
Death loss (%)		0.01
Death loss ($/head)	0.00	0.10
Labor ($/head)	0.00	10.00
Equipment ($/head)	0.00	0.00
Pasture ($/head)	0.00	5.00
Fertilizer ($/head)	0.00	23.19
Hay ($/head)	0.00	0.00
Feed/supplement ($/head)	0.00	19.39
Mineral ($/head)	0.00	0.75
Added marketing costs (tags, commission) ($/head)	0.00	4.00
Total cost ($/head)	**0.00**	**67.75**

Management Comparison Summary ($/head)	Base	Alternate
Management practice	Sell at Weaning	45-Day Weaning
Sell at weaning gross revenue	$ 864.51	$ 864.51
Additional management gross revenue	$ 864.51	$ 952.61
Increased revenue	$ -	$ 88.10
Less management costs	$ -	$ 67.75
Net return from additional management	**$ -**	**$ 20.34**
Weight gain (lbs.)	0	83
Total cost of gain ($/cwt)	#DIV/0!	$ 81.85
Feed cost of gain ($/cwt)	#DIV/0!	$ 58.38
Value of gain ($/cwt)	#DIV/0!	$ 106.42

Equipment Break-even	Base - 10%	Base	Base + 10%
Preconditioning pens cost (50 head)	$ 4,140.00	$ 4,600.00	$ 5,060.00
Net return from additional management	$ 20.34	$ 20.34	$ 20.34
Break-even point (# head)	**204**	**227**	**249**
Years to break-even: Cash	4.08	4.54	4.98
Years to break-even: Borrowing (5% interest)	4.66	5.25	5.86
Preconditioning pens cost (100 head)	$ 7,380.00	$ 8,200.00	$ 9,020.00
Net return from additional management	$ 20.34	$ 20.34	$ 20.34
Break-even point (# head)	**363**	**404**	**444**
Years to break-even: Cash	3.63	4.04	4.44
Years to break-even: Borrowing (5% interest)	4.10	4.61	5.14
Preconditioning pens cost (250 head)	$ 20,340.00	$ 22,600.00	$ 24,860.00
Net return from additional management	$ 20.34	$ 20.34	$ 20.34
Break-even point (# head)	**1000**	**1111**	**1223**
Years to break-even: Cash	4.00	4.44	4.89
Years to break-even: Borrowing (5% interest)	4.57	5.15	5.74

Footnotes:
Base = Market at weaning as steers
Alternate = Market as steers after 45-day weaning
Management premium: No premium for selling at weaning; $2.00 45 day weaning premium
Sources: Bulut and Lawrence, 2007; Williams, Raper, DeVuyst, Peel, McKinney, 2012.
Price source: AMS/USDA Feeder Cattle Prices, Oklahoma City, Weekly, Medium and Large Steers, Fall 2019. Livestock Marketing Information Center.

Figure 6. Partial budget for 45-day weaning with preconditioning pens

EXTENSION

Preconditioning Partial Budget Calculator - Preconditioning Pens

Sell at Weaning Revenue	Base	Alternate
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	155.00	155.00
Gross revenue ($/head)	864.51	864.51

Preconditioning Management Revenue	Base	Alternate
Management practice	Sell at Weaning	Preconditioning
Days from weaning to marketing	0	45
ADG (lbs./day)	0.00	1.60
Ranch (marketing) weight (lbs.)	575	647
Shrink (%)	3.0	1.0
Sale weight (lbs.)	558	641
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	0.00	-10.00
Calculated price change due to heavier weight ($/cwt)	0.00	-8.28
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)		10.00
Final price ($/cwt.)	**155.00**	**156.72**
Gross revenue ($/head)	864.51	1003.85

Footnotes:
Base = Market at weaning as bulls
Alternate = Market as dehorned, vaccinated, and dewormed steers after a 45-day weaning period
Management premium: $5.50 premium for preconditioning
Sources: Bulut and Lawrence, 2007; Williams, Raper, DeVuyst, Peel, McKinney, 2012.
Price source: AMS/USDA Feeder Cattle Prices, Oklahoma City, Weekly, Medium and Large Steers, Fall 2019. Livestock Marketing Information Center.

Preconditioning Management Costs	Base	Alternate
Management practice	Sell at Weaning	Preconditioning
Interest rate (%)	5.0	5.0
Cattle interest ($/head)	0.00	5.33
Vaccine, health supplies and medicine ($/head)	0.00	10.75
Death loss (%)		0.01
Death loss ($/head)	0.00	0.10
Labor ($/head)	0.00	13.20
Equipment ($/head)	0.00	7.50
Pasture ($/head)	0.00	5.00
Fertilizer ($/head)	0.00	23.19
Hay ($/head)	0.00	0.00
Feed/supplement ($/head)	0.00	19.39
Mineral ($/head)	0.00	0.75
Added marketing costs (tags, commission) ($/head)	0.00	4.00
Total cost ($/head)	**0.00**	**89.21**

Sell at Weaning vs Preconditioning Summary ($/head)	Base	Alternate
Management practice	Sell at Weaning	Preconditioning
Sell at weaning gross revenue	$ 864.51	$ 864.51
Preconditioning gross revenue	$ 864.51	$ 1,003.85
Increased revenue	$ -	$ 139.34
Less preconditioning costs	$ -	$ 89.21
Net return from preconditioning management	**$ -**	**$ 50.13**
Weight gain (lbs.)	0	83
Total cost of gain ($/cwt)	#DIV/0!	$ 107.77
Feed cost of gain ($/cwt)	#DIV/0!	$ 58.38
Value of gain ($/cwt)	#DIV/0!	$ 168.32

Equipment Break-even	Base - 10%	Base	Base + 10%
Preconditioning pens cost (50 head)	$ 4,140.00	$ 4,600.00	$ 5,060.00
Net return from preconditioning management	$ 50.13	$ 50.13	$ 50.13
Break-even point (# head)	**83**	**92**	**101**
Years to break-even: Cash	1.66	1.84	2.02
Years ti break-even: Borrowing (5% interest)	1.77	1.97	2.18
Preconditioning pens cost (100 head)	$ 7,380.00	$ 8,200.00	$ 9,020.00
Net return from preconditioning management	$ 50.13	$ 50.13	$ 50.13
Break-even point (# head)	**148**	**164**	**180**
Years to break-even: Cash	1.48	1.64	1.80
Years to break-even: Borrowing (5% interest)	1.57	1.75	1.93
Preconditioning pens cost (250 head)	$ 20,340.00	$ 22,600.00	$ 24,860.00
Net return from preconditioning management	$ 50.13	$ 50.13	$ 50.13
Break-even point (# head)	**406**	**451**	**496**
Years to break-even: Cash	1.62	1.80	1.98
Years to break-even: Borrowing (5% interest)	1.73	1.94	2.14

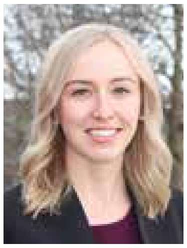
Figure 7. Partial budget for preconditioning bundle with preconditioning pens

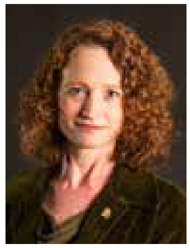
Table 1. Correlation Between Calf Management Practice and Facility/Equipment Access						
Facilities/Equipment	**Calf Management Practice**					
	Castration	**Dehorning**	**≥45-Day Weaning**	**Respiratory Vaccinations**	**Deworming**	**Feed Bunk Training**
Calf Tilt Table	0.16*	0.06*	0.00	0.08*	0.04	0.07*
	(5.377)	(2.138)	(0.017)	(2.706)	(1.470)	(2.289)
Scales	0.06*	0.10*	0.12*	0.22*	0.05	0.11*
	(2.020)	(3.282)	(4.166)	(7.640)	(1.545)	(3.666)
Loading Chute/Ramp	0.07*	0.06*	0.11*	0.12*	0.04	0.11*
	(2.471)	(2.074)	(3.685)	(4.272)	(1.290)	(3.719)
Preconditioning Pens	0.18*	0.18*	0.33*	0.31*	0.21*	0.36*
	(6.043)	(6.000)	(11.939)	(11.045)	(7.193)	(12.991)
Processing Pens	0.15*	0.10*	0.12*	0.16*	0.10*	0.21*
	(5.354)	(3.337)	(4.199)	(5.558)	(3.411)	(7.445)
Squeeze Chute/ Headgate	0.17*	0.08*	0.06*	0.12*	0.07*	0.19*
	(5.873)	(2.604)	(2.020)	(4.252)	(2.464)	(6.386*

Note: Values in parentheses are t-statistics.
*Indicates that the correlation value is statistically different from zero with 95% confidence.

Table 2. Estimated Equipment Costs, 2019	
Equipment	**Estimated Cost ($)**
Calf Tilt Table	2,790
Scales	3,108
Preconditioning Pens (per 50 head)	4,600
Cattle Squeeze Chute/Headgate	5,037

Cover Crops on Illinois Farms





By Sarah C. Sellars, Gary D. Schnitkey, and Laura F. Gentry

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Abstract

Cover crop use is increasing on U.S. farms, but it remains low. The main reason for low adoption rates is the financial and management challenges of cover crops. Using a unique, field-level dataset from Illinois farms, we find that on average, cover crop fields have a lower operator and land return due to the additional seed, planting, and termination cost. Financial assistance is necessary for cover crop fields to be as profitable as non-cover crop fields. We also consider the carbon sequestration potential of cover crop fields using the Cool Farm Tool and estimate farmer carbon credit payments for cover crops.

INTRODUCTION

Cover crop use dates back thousands of years to ancient civilizations that incorporated cover crops into their rotation to replenish the soil. Throughout the nineteenth century, cover crops were used extensively and referred to as "green manure" for their fertility properties. With the introduction of synthetic nitrogen fertilizer and herbicides, cover crop use decreased, and from the 1960s to the 1980s, cover crop use was rare (Groff, 2015). Although cover crop use remains low today, cover crop acres are increasing over time. The most recent Census of Agriculture states that in 2017, cover crops in the United States totaled 15.4 million acres, representing 3.9% of all U.S. cropland, an increase of 5.1 million acres from the 2012 census (Zulauf and Brown, 2019). Financial incentives from federal and state governments along with private organizations are one reason for the increase in cover crop adoption (Wallander et al., 2021).

Cover crops have financial and management challenges. Research suggests that cover crops require three or more years to pay off without financial assistance or special agronomic circumstances (Myers, Weber, and Tellatin, 2019). Farmers incur costs from cover crop seed and planting, and they also incur termination costs with some cover crops. The farmer must consider the direct benefits such as an increase in yield, direct production costs, indirect benefits such as saving on nutrient application, opportunity cost, risk, and agricultural policy such as potential federal support for planting cover crops when making their cover crop decision (Bergtold et al., 2017). There is also the management challenge of selecting the cover crop seed or seed blend and deciding on the optimal planting and termination dates.

Cover crops provide societal environmental benefits, which is one reason the federal government provides incentives for cover crop adoption. Societal benefits occur through reduction of nitrate runoff, soil carbon sequestration, increasing microbial biodiversity, and reduced soil erosion (Bergtold et al., 2017; Sharma et al., 2018). Incentives exist through the United States Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). The NRCS programs offering incentives for cover crops are the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). The federal government also provides temporary assistance to farmers for planting cover crops through the USDA's Risk Management Agency (RMA) Pandemic Cover Crop Program (PCCP). This program provided a $5 per acre premium support to producers who insured their crop and planted a qualifying cover crop. In 2021, farmers received $59.5 million in premium subsidies for 12.2 million acres of cover crops (USDA RMA, 2022).

Although federal incentive opportunities exist, the challenge of limited funding to offset added costs related to cover crop planting and management remains an obstacle to scaling cover crop use. Discussions have emerged about more widespread incentives for cover crops, and possibilities exist for the next farm bill to address cover crop adoption. The objective of this article is to provide an evaluation of the cost and return of fields with and without cover crops. Several other studies evaluate the economics of cover crops and find that cover crops do not increase returns for farmers and can even decrease returns (Plastina et al., 2018; Mahama et al., 2016; Zhou et al., 2017). The dataset in this paper is a unique field-level panel dataset from Illinois that adds to the existing literature about the financial evaluation of cover crops. The Precision Conservation Management (PCM) differs from other studies because it is not survey data from farmers, and it is not experimental field trial data. The data is actual field-level data collected from central Illinois farmers who use cover crops on their fields, and the quality and accuracy of the data is ensured by the PCM specialists who assist farmers with inputting their data into the online system. The dataset is also unique because it is a panel dataset, so operator and land return and yield can be observed on the same cover crop fields through time.

PRECISION CONSERVATION MANAGEMENT

The data for this study come from PCM. PCM is a farmer service program led by the Illinois Corn Growers Association and Illinois Soybean Association in partnership with more than 30 entities, including other commodity associations, conservation groups, private foundations, supply chain providers, the Soil and Water Conservation Districts, and the NRCS. In an effort to address the goals of the Illinois Nutrient Loss Reduction Strategy, the mission of PCM is to help farmers make decisions about adopting on-farm conservation practices in a financially responsible way. Through PCM's regional specialists, PCM works one-on-one with nearly 400 Illinois farmers enrolled in its 32-county service area, representing over 350,000 acres of Illinois farmland. Figure 1 shows the service area PCM currently covers in Illinois. PCM also collects data on farms in Kentucky and Nebraska, but the focus of this analysis is Illinois.

PCM's precision conservation specialists help farmers report data through an online data collection platform. The precision conservation specialists offer one-on-one technical support for farmers, compile and review farm reports, and assess farm data to ensure quality and accuracy. The farmer reports all operations for each field enrolled in the PCM program. Any applications or field passes made on the field throughout the growing season, the amount and types of inputs applied, and yield are entered into the PCM system. The anonymized and aggregated data are used to provide reports to farmers to help them make business decisions about adopting conservation practices, focusing on financial and environmental comparisons.

PCM collects data about all inputs used, agricultural practices performed, and yields for each field but does not collect crop price or input cost data from the farmers. Instead, standard prices and costs are uniformly applied to all fields. Multiplying the field's yield by a standard yearly price results in revenue from crop sales that is the same across all farms. Multiplying actual input amounts by a standard input price provides the direct costs. These costs include seed, fertilizer, pesticide, drying, storage, and crop insurance. Assigning field passes a cost based on machinery cost estimates from the University of Illinois and summing the costs represents machinery-related power costs. Overhead costs are based on Illinois Farm Business Farm Management (FBFM) data and are the same for all farms. Subtracting costs from revenue results in operator and land return, a measure of return for farmland. Operator and land return does not include a land cost. Using the same costs and prices for all farmers removes the effect of farmer grain marketing skill, volume discounts on input purchases based on farm size, and negotiating skills from the data. The historical data change from year to year because as new farmers join the program, they share both current and historical production records.

The data is cleaned to select entries with representative typical practices that occur on central Illinois fields. A standard to remove outliers was applied to select Illinois fields with a corn-corn or corn-soybean rotation, as well as conventional or non-GMO seed with a yield between 100 and 300 bushels per acre, direct costs less than or equal to $500 per acre, and power costs less than or equal to $210 per acre from 2015 to 2020.

COVER CROP BENCHMARKS

Each field in the PCM dataset is classified into a cover crop benchmark based on the practices used on that field. The benchmarks are as follows:

- None: The field had no cover crop.
- Overwintering: The cover crop survives the winter and continues to grow in the spring until it is chemically or mechanically terminated.
- Winter terminal: The cover crop dies during the winter.

Many of the benefits of cover crops take time to accrue, so it is important to consider multiple years of data when looking at cover crop outcomes. Figure 2 shows the years of data for fields with cover crops from 2015–2021. There are 158 fields (15%) that have been planted in cover crops for three years or more. It also takes time for farmers to learn how to grow cover crops cost effectively. For the fields with cover crops, 67% of fields that use cover crops for one year continue using cover crops in the next year. For the fields without cover crops, 91% did not use cover crops the next year. Once a PCM farmer tries cover crops on a field, they are likely to continue to use cover crops on that field in the following year.

There are 1,033 cover crop fields in the PCM dataset. The cover crop fields represent 71,398 acres. Of the fields with a cover crop, there are 350 corn fields and 683 soybean fields. Figure 3 shows the percentage of cover crop observations by crop. Overwintering cover crops are planted on more soybean fields than corn fields, and winter terminal cover crops are planted on more corn fields than soybean fields. There are more soybean fields planted with cover crops than corn fields. This is likely due to the use of cereal rye, which was planted on 48% of cover crop field observations. When many farmers first start planting cover crops, they begin with planting cereal rye into corn stalks before planting soybeans (Schnitkey et al., 2018). Many of the PCM farmers are beginning cover crop users, so cereal rye is a common cover crop in the dataset, but other cover crops include annual rye grass, barley, clover, vetch, other legumes, oats, radishes, and mixtures of cover crops.

RESULTS FROM COVER CROPS ON CORN

Table 1 shows the average yield, productivity, costs, and returns for corn fields with high productivity soil from 2015–2021. Subtracting the average total non-land costs from the average gross revenue for each benchmark results in a range for the operator and land return. On average, the non-cover crop fields have higher operator and land return and yield than the cover crop fields, although some of the winter terminal cover crop fields have higher operator and land return than the non-cover crop fields. There is a cost to utilizing cover crops. Incentives exist to help defray some costs, but sometimes this does not cover the full cost of cover crop seed and planting, which ranges from $18 to $39 per acre in the PCM dataset. On average, the cover crop seed cost and cover crop planting cost add up to $25 per acre for overwintering cover crops and $29 per acre for winter terminal cover crops.

Farmers in the PCM dataset who are growing cover crops are typically receiving some financial assistance through PCM ranging from $5 to $35 per acre, which is not reflected in the operator and land return shown here. Another consideration is the estimated greenhouse gas emissions for the cover crop fields compared to the no cover crop fields. The cover crop fields are sequestering carbon dioxide equivalent (CO_2-eq), with a modeled net sequestration of 0.72 metric tons of CO_2-eq per acre determined using the Cool Farm Tool (release 1.0.0), representing a total emissions reduction of 1.02 metric tons of CO_2-eq if "no cover crop" is accepted as the baseline value and both emissions reductions and sequestration are acceptable assets. Farmers have potential to receive ecosystems payments for their fields, such as from agricultural carbon credit programs. Currently, agricultural carbon credit prices range from $10 to $20 per metric ton of CO_2-eq (Sellars et al., 2021). If a carbon credit is $20 per metric ton and the farmer is paid for CO_2-eq emissions reduced, then the farmer would receive $20 per acre for their cover crop fields. The financial assistance farmers are receiving from PCM can put them at or above their cover crop cost, and factoring in the carbon credit payment could have a farmer generating extra revenue just from planting cover crops.

Considering the averages over all years is a useful benchmark, but the variability from differences in weather and price affects the averages. Looking at the averages by year may be a more useful way to see an effect on yield or returns from cover crops. Table 2 shows the average yield and operator return by year for high productivity corn fields. For all years except 2016, fields with no cover crops have the highest average operator and land return. In 2016, winter terminal cover crops had the highest operator and land return. One explanation for winter terminal cover crop fields having the highest average operator and land return may be above-normal precipitation and temperatures. The winter of 2016 had much higher than normal temperatures and above normal precipitation in central and southeast Illinois (Geelhart, 2016). Most corn fields in the PCM dataset are in the fall nitrogen benchmark, which means the field receives 40% or more of its total nitrogen application in the fall. There are 31% of fields in the fall nitrogen benchmark, and other fields in the dataset may receive some nitrogen applied in the fall as well. A warm, wet winter is the perfect condition to lose fall-applied nitrogen. The cover crop could have helped retain nutrients on the field, increasing yield and preventing nitrogen losses.

The average corn yield for winter terminal cover crop fields in 2016 is only one bushel less than the fields with no cover crops. Winter terminal cover crops had a higher average yield than fields with no cover crops in 2015, but there are only four winter cover crop fields in the PCM dataset for 2015, so this may be a factor. On average, winter terminal cover crops appear to be more profitable than overwintering cover crops. This is likely because there is no termination cost for the winter terminal cover crops, so farmers do not have the cost of the herbicide or extra field pass to kill them.

RESULTS FROM COVER CROPS ON SOYBEANS

Table 3 shows the average yield, productivity, costs, and returns for soybean fields with high productivity soil from 2015–2021. Subtracting the average total non-land costs from the average gross revenue for each benchmark results in a range for the operator and land return.

As with the corn fields, on average, the non-cover crop soybean fields have higher operator and land return and yield than the cover crop fields, although some of the winter terminal cover crop fields have higher operator and land return than the non-cover crop fields. On average, the cover crop seed cost and cover crop planting cost add up to $23 per acre for overwintering cover crops and $29 per acre for winter terminal cover crops. Again, returns for the soybean fields do not factor in any cost share programs, which typically pay between $5 and $35 per acre for PCM farmers.

A big advantage of cover crop fields on soybeans is their high CO_2-eq sequestration potential. On average, cover crop soybean fields on high productivity soils sequester a net 1.76 metric tons of CO_2-eq per acre determined using the Cool Farm Tool (release 1.0.0), representing an emissions reduction of 1.48 metric tons of CO_2-eq if "no cover crop" is accepted as the baseline value and both emissions reductions and sequestration are acceptable assets. At a carbon credit price of $20 per credit, then the farmer would receive $30 per acre for their soybean cover crop fields. The cost of cover crop seed and planting ranges from $18 to $39 per acre, so receiving a carbon credit or ecosystems payment could cover all or most of the cost of planting cover crops.

Table 4 shows the average yield and operator and land return for high productivity soybean fields by year. On average, fields with no cover crops had higher yield and higher operator and land return for all years except in 2016 and 2017. In 2020, fields with no cover crops had the same yield as fields with winter terminal cover crops.

In 2016 and 2017, winter terminal cover crops had the highest average yield and operator and land return. In 2016, there were only two winter terminal soybean cover crop fields, so the sample is very small. In 2017, there were seven winter terminal soybean cover crop fields. These fields had slightly higher yields than the fields with no cover crops or with overwintering cover crops, and on average they had lower non-land costs than fields with overwintering cover crops. Again, this is likely due to the additional termination cost that overwintering fields incur. Winter terminal cover crops have higher average operator and land return and higher or the same yield than overwintering cover crops for almost every complete year in the dataset.

CONCLUSION

On average, the cover crop fields in the PCM dataset on high productivity fields have a lower operator and land return. Cover crop fields incur an additional seed and planting cost that ranges from $18 to $39 per acre, and there also could be additional termination costs depending on the cover crop. Without financial assistance, cover crops would have negative returns. Our study validates previous studies which also find that cover crop fields have lower returns than non-cover crop fields. Farmers can receive financial assistance that covers a portion of the cover crop cost, and carbon credit or ecosystems payments have potential to even generate revenue from planting cover crops. Cover crops on corn fields may be more competitive in years with warm, wet winters with higher chances of nitrogen losses. Most PCM farmers are new to cover crops, so they are still learning how to use them profitably. Many of the fields have not had very many years of cover crops, and it typically takes a few years to begin to see the benefits from cover crops. This paper provides evidence of the financial challenges farmers face when they begin adopting cover crops and shows the potential for increasing cover crop adoption with cost share support. Financial support is necessary for cover crop fields to be as profitable as non-cover crop fields. The PCM dataset is a unique and useful panel dataset for thinking about benchmarking, costs, returns, profitability, and sequestration potential of cover crops.

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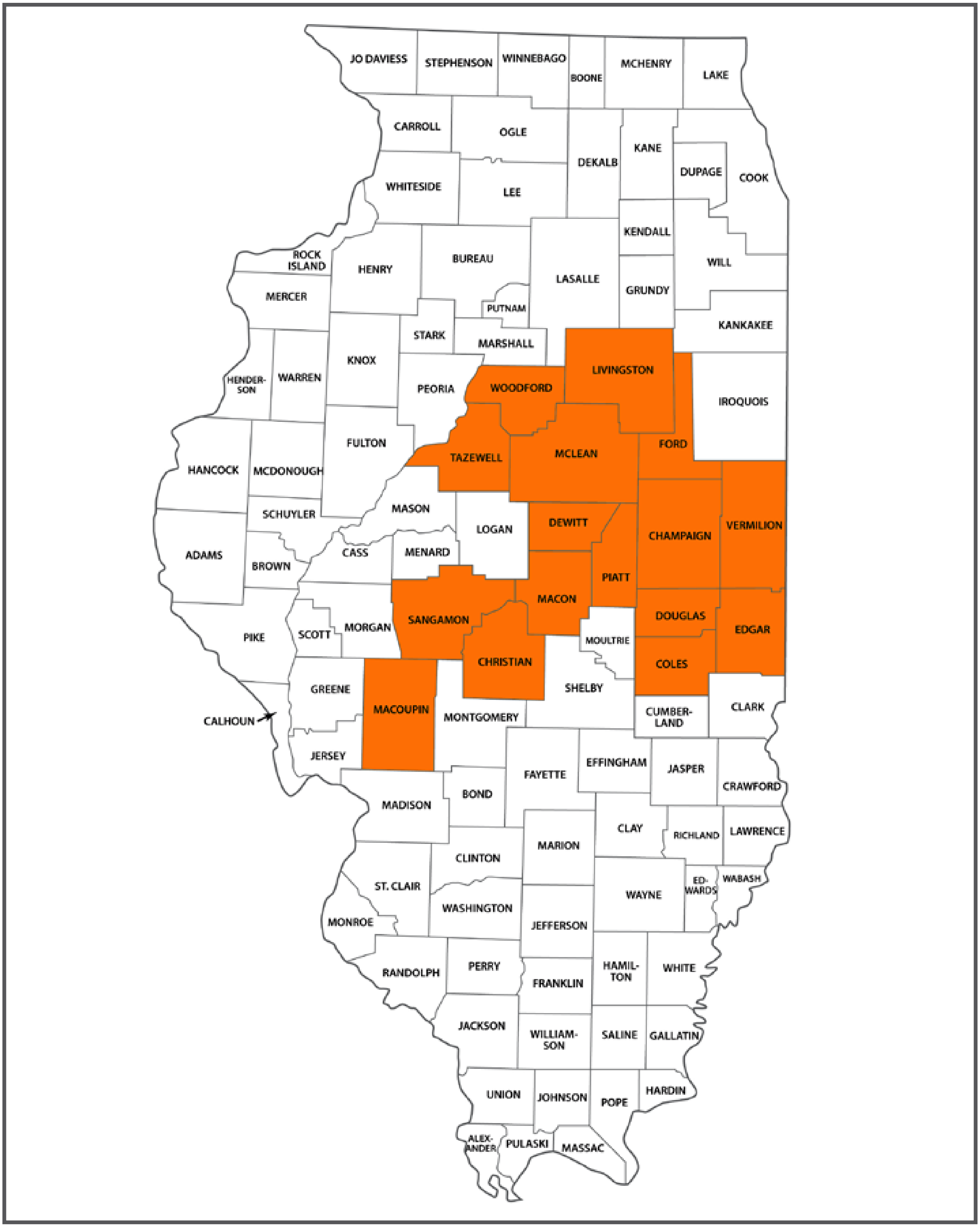


Figure 1. PCM service area

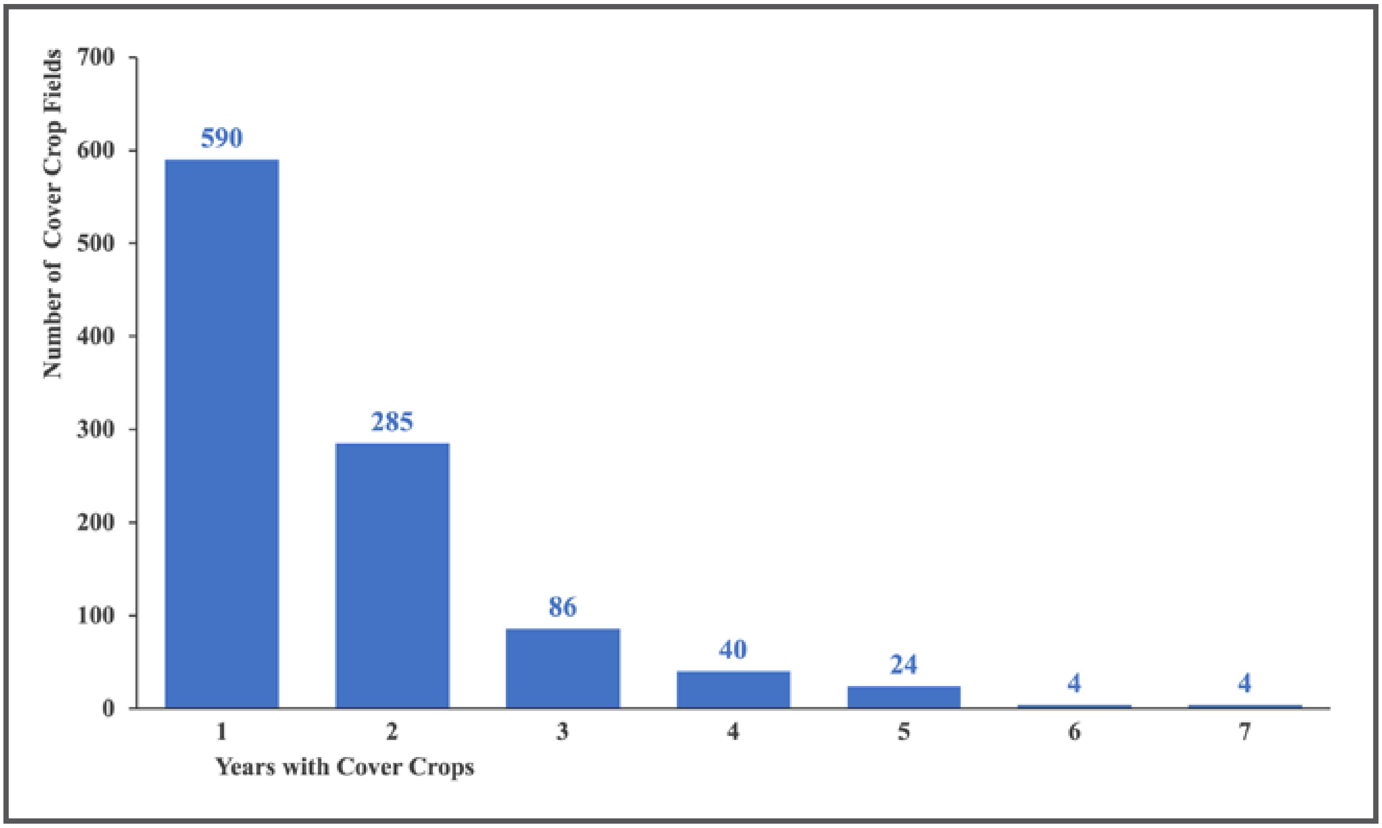


Figure 2. Cover crop fields, number of years with cover crops, 2015–2021

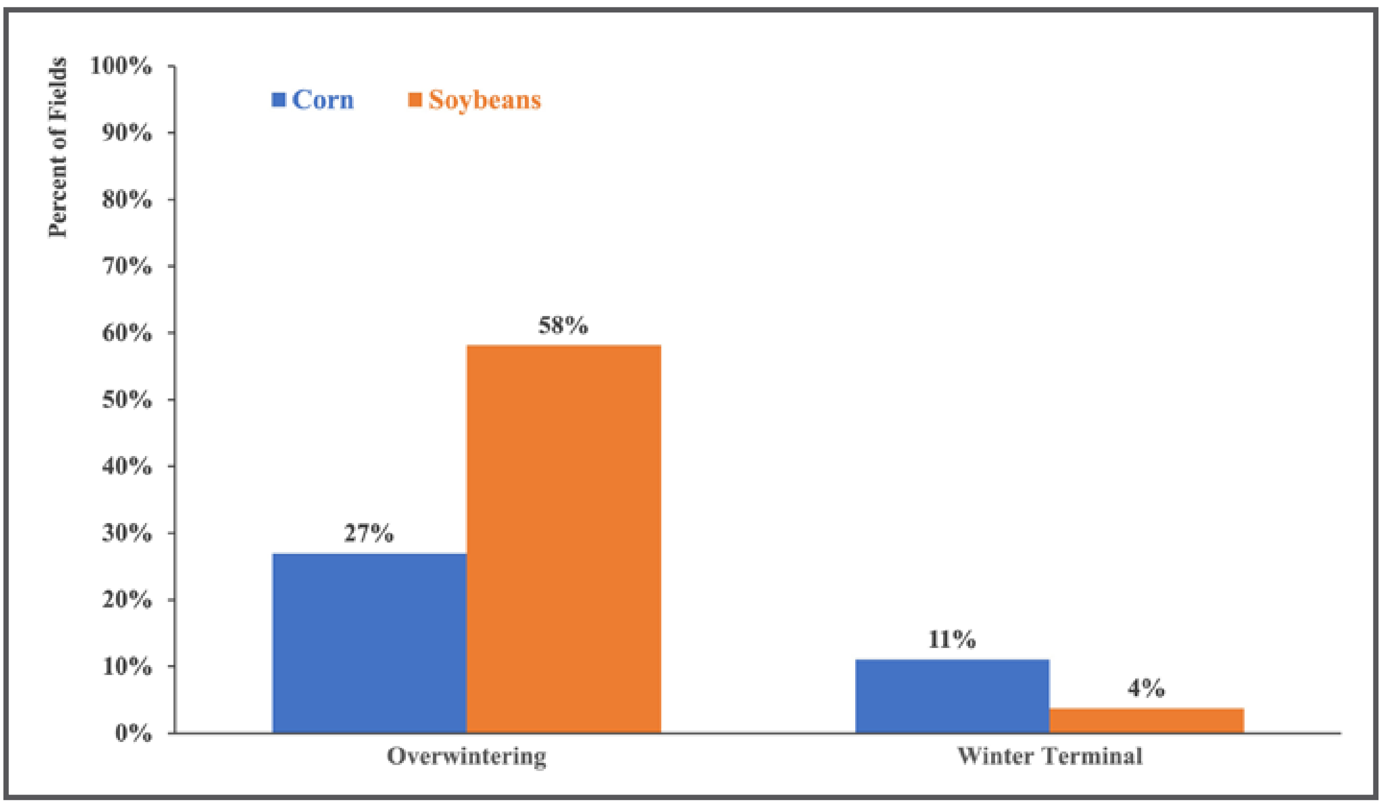


Figure 3. Percent of cover crop fields by benchmark, 2015–2021

Table 1. Averages for Corn (High Soil Productivity Rating), 2015–2021			
	Overwintering	Winter Terminal	No Cover Crop
# of Observations	243	109	3523
Yield (bu/acre)	214	215	221
Soil Productivity Rating	139	139	140
Gross Revenue	$833	$834	$856
Cover Crop Seed	$13	$13	$0
Total Direct Cost[a]	$395	$374	$393
Cover Crop Planting	$12	$16	$0
Other Power Cost	$117	$106	$112
Total Power Cost	$129	$122	$112
Overhead Cost	$37	$37	$37
Total Non-Land Cost	$562	$533	$54
Operator and Land Return	$271	$301	$313
Estimated Soil Loss (tons/acre)	0.64	0.67	0.93
GHG Emissions (metric tons CO_2-eq/acre)	−0.72	−0.72	0.30

[a]Includes fertilizer, pesticide, seed, cover crop seed, drying, storage, and crop insurance.

Table 2. Averages by Year for Corn (High Soil Productivity Rating), 2015–2021			
	Overwintering	Winter Terminal	No Cover Crop
Panel A: Yield			
2015	–	206	201
2016	222	223	224
2017	217	217	221
2018	225	222	234
2019	200	204	209
2020	210	208	217
2021	213	216	223
All Years	213	213	220
Panel B: Operator and Land Return			
2015	–	207	214
2016	204	267	251
2017	202	194	205
2018	255	313	324
2019	206	244	263
2020	266	269	313
2021	528	590	598
All Years	335	373	330

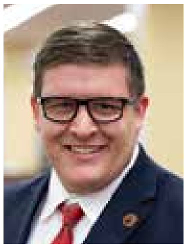
Table 3. Averages for Soybeans (High Soil Productivity Rating), 2015–2021

	Overwintering	Winter Terminal	No Cover Crop
# of Observations	588	28	3066
Yield (bu/acre)	68	68	70
Soil Productivity Rating	139	139	140
Gross Revenue	$666	$675	$686
Cover Crop Seed	$13	$13	$0
Total Direct Cost[a]	$158	$159	$151
Cover Crop Planting	$10	$16	$0
Other Power Cost	$90	$70	$84
Total Power Cost	$100	$86	$84
Overhead Cost	$31	$31	$31
Total Non-Land Cost	$290	$276	$266
Operator and Land Return	$376	$399	$420
Estimated Soil Loss (tons/acre)	0.96	1.03	1.29
GHG Emissions (metric tons CO_2-eq/acre)	–1.76	–1.76	–0.28

[a]Includes fertilizer, pesticide, seed, cover crop seed, drying, storage, and crop insurance.

Table 4. Averages by Year for Soybeans (High Soil Productivity Rating), 2015–2021			
	Overwintering	Winter Terminal	No Cover Crop
Panel A: Yield			
2015	66	–	67
2016	69	70	69
2017	67	69	67
2018	71	70	75
2019	62	62	64
2020	66	67	67
2021	70	70	73
All Years	67	68	69
Panel B: Operator and Land Return			
2015	369	–	379
2016	422	460	438
2017	337	398	375
2018	311	332	375
2019	278	316	327
2020	357	366	396
2021	550	553	621
All Years	408	412	409

Nutrient Loss Reduction in the Mississippi/Atchafalaya River Basin



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Abstract

The United States Environmental Protection Agency's Hypoxia Task Force was established to address the hypoxic zone in the Gulf of Mexico caused by excess nutrient loading and to coordinate efforts between the 12 states in the Mississippi/Atchafalaya River Basin to reduce their nutrient runoff. This case study focuses on the Illinois Nutrient Loss Reduction Strategy (NLRS) and compares it to the strategies implemented by the other Basin states. In the years ahead, farm operators, landowners, and farm managers will be challenged to voluntarily meet nutrient loss goals while balancing the costs of implementing best management practices recommended to reduce the size of the Gulf hypoxic zone.

INTRODUCTION

In 1972, the U.S. Congress passed, among other environmental legislation, the Clean Water Act and established the Environmental Protection Agency (EPA). The EPA is charged with both regulating and protecting the environment (US EPA, 2022). In 1997, the EPA established the Hypoxia Task Force with the goal of "understand[ing] the causes and effects of eutrophication in the Gulf of Mexico; coordinat[ing] activities to reduce the size, severity, and duration of the hypoxic zone; and ameliorat[ing] the effects of hypoxia" (US EPA, 1998). Under the Hypoxia Task Force's charter, the relationship and roles of various federal, tribal, state, and local agencies were defined, and several committees were formed to perform specific tasks. The Hypoxia Task Force also set forth nutrient reduction goals and strategy guidelines for the several states in the Mississippi/Atchafalaya River Basin based on priority watersheds identified by the task force, with 12 states containing priority watersheds. Each state that contains a priority watershed is tasked with creating goals that align with the overall goals of the Hypoxia Task Force and developing tailored strategies that can be implemented in that state to meet its respective goals. In 2015, the State of Illinois, through the Illinois Department of Agriculture, Illinois EPA, and other agencies, released the final strategy for nutrient loss reduction in Illinois following the EPA Gulf Hypoxia Action Plan.

This case study aims to analyze the Illinois Nutrient Loss Reduction Strategy (NLRS), focusing on its goals and strategies and the progress made to reach those goals, with particular attention paid to agricultural non-point sources of runoff. In addition, nutrient loss efforts in the 11 other states under the jurisdiction of the Hypoxia Task Force are analyzed and compared to Illinois. The primary evidence and literature for this case study are the original nutrient loss reduction strategies from the 12 states and federal agencies.

HYPOXIA TASK FORCE ACTION PLANS OF 2001 AND 2008

Although nitrogen and phosphorus are essential nutrients that aquatic ecosystems need to thrive, an excess of these nutrients can cause many different adverse reactions in a local ecosystem. Excess nitrogen in the northern Gulf of Mexico has driven excessive algae growth. It deprives underwater life of the oxygen it needs, causing aquatic life to die and the underwater habitat to be lost (US EPA, 2001). Water quality in the Mississippi and Atchafalaya River Basins is also affected by excessive nutrients, particularly phosphorus, from many different sources, such as storm runoff, wastewater treatment plants, and nutrient loss from farmland. The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 required that the Hypoxia Task Force submit action plans to address nutrient runoff in the Gulf. In 2001, the Hypoxia Task Force released its first action plan, entitled "Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico," with the purpose of "describ[ing] an adaptive approach, based on implementation, monitoring, and research to address known problems, clarify scientific uncertainties, and evaluate the effectiveness of efforts to reduce hypoxia" (US EPA, 2001). The Hypoxia Task Force developed this plan with input from several officials and citizens concerned about hypoxia in the Gulf of Mexico. Eleven priority actions and recommendations were proposed in the 2001 Action Plan, with adjustments made as data and results became available. The plan cites that 90% of the nitrate load in the Gulf comes from non-point sources,[1] with 56% coming from the Mississippi River Basin above the Ohio River and 34% added from the Ohio River—with the states that add the highest amounts of nitrate load being Iowa, Illinois, Indiana, Ohio, and southern Minnesota (US EPA, 2001). The primary goals to reduce hypoxia outlined in the plan were to (1) reduce nitrogen loads into the basins and (2) enhance denitrification in Louisiana along the northern shore of the Gulf, with the overall goal being to reduce nitrate loads in the hypoxic zone by 40% compared to the average between 1955 and 1970. Eleven short-term actions were outlined in the plan to achieve the long-term goals of the task force and are summarized in Table 1.

Following the 2001 Action Plan, the Hypoxia Task Force submitted a 2008 Action Plan that "reflect[ed] the Task Force's efforts to track progress, update[d] the science, and adapt[ed] actions to improve the effectiveness of the efforts throughout the Basin," and "la[id] out specific steps that need[ed] to be accomplished to reach the goals. It also reiterate[d] the long-term goals and continue[d] the Task Force's commitment to an adaptive management approach to reduce the size and impact of the Gulf hypoxic zone and improve water quality in the Basin" (US EPA, 2008). Three primary goals were reiterated from the 2001 Action Plan and followed the same guiding principles, including "encourag[ing] actions that are voluntary, incentive-based, practical, and cost-effective; [and] identify[ing] opportunities for, and potential barriers to, innovative and market-based solutions" (US EPA, 2008). The 2008 Action Plan provided updates to the science of the 2001 Action Plan and analyzed the progress made toward reaching the 2001 Action Plan's goals. The 2001 Action Plan established a goal of reducing the size of the hypoxic zone to less than 5,000 square kilometers (approximately 1,900 square miles). The average size of the zone between 2003 and 2007 was 14,644 square kilometers (5,600 square miles), and in 2007 the size of the zone was 20,500 square kilometers (7,900 square miles) (US EPA, 2008). Data also showed that 80% of the nitrogen load and 64% of the phosphorus load in the Gulf came from either the Upper Mississippi or Ohio/Tennessee sub-Basins. Between 2001 and 2005 there was a 21% decrease in nitrogen load and a 12% increase in phosphorus load. However, most of the reduction in the nitrogen load was from nitrogen forms other than nitrate, the leading cause of hypoxic activity (US EPA, 2008). Of the 11 short-term actions in the 2001 Action Plan, actions 2, 3, and parts of 4, 5, 6, 9, 10, and 11 had been completed by 2008. Action 1; a portion of actions 4, 5, and 6; and actions 7 and 8 had not been completed (US EPA, 2008). To reduce the amount of nitrogen and phosphorus that runs off into the sub-basins and Gulf, the 2008 Action Plan provided recommendations to landowners and managers as well as guidance to state, federal, tribal, and local leaders to help in the fight to reduce nitrogen and phosphorus loads. One such recommendation was for states within the Mississippi/Atchafalaya Basin to create nutrient loss reduction strategies no later than 2013. These strategies "should target those watersheds with significant contributions of nitrogen and phosphorus to the surface waters of the Mississippi/Atchafalaya River Basin and ultimately to the Gulf of Mexico" (US EPA, 2008). In addition to state strategies, federal programs for nutrient reduction and utilizing existing state programs for cost-effective nutrient reduction were also recommended actions to meet the 2001 Action Plan (US EPA, 2008). From the 2008 Action Plan, the 12 states with priority watersheds, including Illinois, adopted nutrient loss reduction strategies.

2015 ILLINOIS NUTRIENT LOSS REDUCTION STRATEGY

In addition to the 2008 Action Plan's call for the 12 Mississippi/Atchafalaya River Basin states to create strategies to reduce nitrogen and phosphorus loads, the EPA released "Recommended Elements of a State Nutrients Framework" (Stoner, 2011). Its recommendations included "set[ting] watershed load reduction goals based upon best available information . . . targeting adoption of the most effective agricultural practices . . . [and establishing] accountability and verification measures" (Stoner, 2011, 5–6). Based on these recommendations, a Policy Working Group was established by the Illinois EPA and Illinois Department of Agriculture that was tasked with advising the two agencies on several matters, including "strategies for point source reductions in watersheds with high contributions of nutrients to the Mississippi River . . . [,] accountability and verification measures, specifically for non-point sources . . . [, and] strategies for promoting identified Best Management Practices (BMPs) to maximize widespread implementation throughout a priority watershed" (Illinois EPA, 2015). The Policy Working Group comprises members from various groups and entities, ranging from water treatment agencies and university personnel to industry associations and non-governmental organizations (NGOs). Under the Policy Working Group, three subcommittees were created to address specific portions of the plan. The Point Source, Agricultural Non-Point Source, and Urban Non-Point Source subcommittees provided guidance and advice to the writing teams drafting the central parts of the strategy. The strategy outlines the legal and regulatory framework that allows the U.S. EPA, Illinois EPA, and Illinois Department of Agriculture to set the goals and recommendations outlined, among which are the Clean Water Act (33 USC 1313(c)), the Illinois Environmental Protection Act (415 ILCS 5), and the regulatory power of the agencies.

Following the 2008 Action Plan, the main goals of the Illinois NLRS are to reduce the annual loading of nitrate-nitrogen and phosphorus to the Mississippi River, with "phase 1 milestones" of 15% reduction in nitrate-nitrogen and 25% reduction in phosphorous by 2025 and a final target goal of 45% reduction of both compared to the loading average of nitrate-nitrogen and phosphorus between 1980 and 1996 (Illinois EPA, 2015). Data in the NLRS from 2015 indicate that agricultural non-point sources are responsible for 80% of nitrate-nitrogen load and 48% of phosphorus load in the Mississippi River, with 45% of reductions amounting to a decrease of 150.61 million pounds per year of nitrate-nitrogen and 8.97 million pounds per year of phosphorus from agricultural non-point sources (Illinois EPA, 2015). It is important to note that the NLRS does not explicitly state a deadline for achieving the 45% goal. For agricultural non-point sources, the NLRS outlines best management practices for farmers to voluntarily implement to meet the strategy's goals of reducing nitrate-nitrogen and phosphorus loss. The NLRS predicted that implementing best management practices will increase as education and outreach efforts, as well as incentives for adoption, become more available for farmers. Recommended in-field practices for nitrate-nitrogen loss reduction include reducing nitrogen application to the rate recommended by the Maximum Return to Nitrogen (MRTN) calculation (possible removal of 2.3 million pounds per year), changing the time of the year when fertilizer is applied (reduction estimated between 13 and 26 million pounds per year), and the use of cover crops (reduction of 84 million pounds annually) (Illinois EPA, 2015). Three edge-of-field practices are recommended in the NLRS: bioreactors, wetlands, and buffers. Bioreactors are "trenches filled with wood chips located at the edge of fields and intercept tile flow" (Illinois EPA, 2015, 3–33). The NLRS estimates that bioreactors in Illinois could reduce nitrate-nitrogen loads by 35 million pounds per year (Illinois EPA, 2015). Constructed wetlands at the end of tile lines are usually between 0.5 and 2 acres in size, and they are projected to reduce nitrate-nitrogen runoff by 49 million pounds per year. Buffers along streams and ditches in non-tiled fields can effectively reduce streams' losses while increasing plant uptake and denitrification in water that flows through buffers. If buffers are installed along agricultural streams that currently do not have them, the NLRS estimates that nitrate-nitrogen runoff could be reduced by 36 million pounds annually (Illinois EPA, 2015). Overall, if these recommendations and practices are implemented across the state, the estimated reduction of nitrate-nitrogen into the Mississippi River would be approximately 357.6 million pounds per year, well above the target 45% goal of 150.61 million pounds per year. Removing this nitrate-nitrogen load would cost approximately $3.30 per pound (Illinois EPA, 2015).

In addition to the recommendations for nitrate-nitrogen loss reduction, the NLRS suggests practices to reduce phosphorus runoff. The strategy attributes the loss of phosphorus to surface water runoff and soil erosion because phosphorus clings to soil particles. Because soil erosion is a significant factor in phosphorus loss, the best management practices recommended for reducing phosphorus loss are also recommendations to reduce soil erosion rates. One recommended practice is the establishment of buffers along streams. When the NLRS was published, approximately 64% of Illinois stream miles did not have a buffer. Introducing buffers to as many miles as possible may reduce 4.8 million pounds annually (Illinois EPA, 2015). The NLRS recommends the use of riparian buffers, which are "vegetative buffer-strip[s] near a stream, which helps to shade and partially protect the stream from the impact of adjacent urban, industrial, or agricultural land use" (Burden, 2015). The buffers should be 35 feet wide, but the strategy cautions against using aquatic buffers due to a lack of scientific studies proving their effectiveness in reducing phosphorus runoff compared to nitrate-nitrogen runoff. In addition to riparian buffers along streams, other recommendations in the report include terraces, strip cropping, and sediment control basins. Implementing the recommended practices could result in a significant non-point source reduction of 8.3 million pounds, or 22% of the goal, per year, with an estimated cost of $13.71 per pound removed (Illinois EPA, 2015).

COMPARISON OF THE ILLINOIS NLRS TO OTHER STATE STRATEGIES

Each of the 12 states in the Mississippi/Atchafalaya Basin plays an essential and integral role in reducing nitrate-nitrogen and phosphorus runoff to the hypoxic zone. Like Illinois, each state has a nutrient loss reduction strategy that explicitly addresses nitrate-nitrogen and phosphorus loading and practices to reduce loading. There is much similarity among the states' approaches. Table 2 illustrates which entity was responsible for creating each state's nutrient loss reduction goals, the composition of that entity, and the specific reduction goals established in each state. Most state strategies rely on groups and task forces led by government officials at either a department of agriculture, a state EPA, or a department of conservation/natural resources. However, Mississippi took a different approach. Each sub-group that developed its initial 2009 strategy included a representative of a group called Delta Farmers Advocating Resource Management (F.A.R.M.). This group was formed in 1997 to "facilitate environmental improvements on the farm and help the region address growing natural resource concerns" (Delta F.A.R.M., n.d.). With the help of industry sponsors such as Syngenta, support from the Mississippi State University Extension, and governmental bodies such as the U.S. Army Corps of Engineers, the USDA Economic Research Service, and the U.S. Geological Survey, the group has played a vital role in advocating for nutrient and resource management and was instrumental in the creation of the 2009 Mississippi strategy.

Another unique situation arose in Ohio, whose nutrient loss reduction efforts include the Mississippi River Basin and Lake Erie. Before the Hypoxia Task Force, Ohio had started working on a specific strategy for Lake Erie due to increased phosphorus loads in that body of water, particularly in the summer months (Ohio EPA, 2013). This resulted in the United States and Canada entering into a water quality agreement to address water quality in shared waters, including Lake Erie, in the Great Lakes Water Quality Agreement (GLWQA), first signed in 1972 and amended numerous times since then (Government of Canada and Government of the United States of America, 2012). Therefore, when it came time to draft Ohio's state strategy in 2011, the Lake Erie Phosphorus Task Force was one of the major entities responsible for establishing its goals. It should be further noted that some state strategies do not contain specific nutrient reduction goals, opting to either set goals for priority watersheds in their state (e.g., Kentucky) or to simply state that a goal is to monitor nutrient loading into priority watersheds to get a better understanding of the scenario in that state (e.g., Mississippi and Louisiana).

Table 3 compares the best management practices recommended by the Illinois NLRS and the other 11 state strategies to reduce nitrogen and phosphorus loss from agricultural non-point sources. While some state strategies outline specific practices targeted at either nitrogen or phosphorus loss, others have blanket approaches that can be used for nitrogen and phosphorus. There is little difference in the recommended best management practices among most of the 12 states, except for Mississippi, whose strategy includes a goal of determining appropriate best management practices. At the time of this case study, there is no further information on progress toward that goal.

PROGRESS TOWARD MEETING GOALS IN ILLINOIS AND NEXT STEPS

The ultimate objective of the Illinois NLRS, as with each of the 12 states in the Mississippi/Atchafalaya River Basin, is to reduce nutrient loading to acceptable levels with voluntary measures. The first benchmark date (2025) is rapidly approaching, and the 2021 Biennial Report (Illinois EPA, 2021) notes advancements and successes in reducing the state's impact on the hypoxic zone and hypoxia in the Gulf of Mexico but also notes further work that needs to be done for the state to fully meet the goals.

The report also provides updates on the progress made by several working groups in monitoring and implementing the strategic objectives. The report includes a science assessment update from the 2015 strategy, which notes that the statewide loads of nitrate-nitrogen and phosphorus are correlated with increased water yield, defined as the difference between the amount of precipitation that falls in a watershed and evapotranspiration.[2] Water yield is further connected with precipitation. Between 2015 and 2019, the statewide average for nitrate-nitrogen load was 448 million pounds per year, whereas the statewide average for phosphorus load in the same period was 46 million pounds per year (Illinois EPA, 2021). Those totals are 13% and 35% greater than the 1980–1996 baseline averages, which are the foundation of the 2015 goals. The report attributes the 2015–2019 averages to the unusually high precipitation and river flows in 2019. The largest nitrate-nitrogen and phosphorus loads were found in the Illinois River, which the report partially attributes to the fact that the river drains the largest area of rivers in the state, in addition to runoff from tiled cropland in central Illinois and wastewater treatment from Chicago and Decatur (Illinois EPA, 2021). The largest overall increase in nitrate-nitrogen loads came in the Rock River between Rockton and Joslin, which saw an increase of 135% over the 1980–1996 averages. This increase in nitrate-nitrogen loads is most likely attributed to heavy rainfall and flow through groundwater aquifers. The Vermilion and Kaskaskia Rivers saw decreases of 17% and 28%, perhaps caused by increased efficiency of nitrogen fertilizer use. The Kaskaskia, in addition to the Little Wabash River, had the greatest percent increase in phosphorus loads (86% and 77%) (Illinois EPA, 2021). In the Kaskaskia, legacy phosphorus sediment loads may have played a factor in the increase, whereas greater surface runoff is the likely cause for increases in the Little Wabash.

The 2021 Biennial Report also discusses current programs and projects devoted to reducing agricultural non-point sources of nutrient loss. Resources for this effort include 132 full-time equivalent positions in several different agencies and organizations in 2020 that were engaged in outreach, implementation, or research for the agricultural sector under the NLRS (this figure does not include private sector employees or farmers). Private and public funds made available by agricultural sector partners in 2020 totaled $13,982,060, an increase of approximately $1 million from 2019 (Illinois EPA, 2021). The report also discusses the challenges presented by the COVID-19 pandemic related to outreach and education events. Before the pandemic, hundreds of events were held across the state to share research and data on topics ranging from cover crops, effective nutrient management, and edge-of-field practices sponsored by various agricultural organizations and commodity groups (Illinois EPA, 2021). The pandemic made holding events more difficult due to stay-at-home orders and attendance limits for certain events. Nevertheless, just over 1,000 events were held between 2019 and 2020, with more than 72,000 people in attendance. This figure is slightly lower than the 84,000 attendees between 2017 and 2018.

The 2021 Biennial Report also discusses progress in implementing conservation practices recommended in the 2015 Illinois NLRS with assistance from state and federal conservation programs. The USDA Farm Service Agency (FSA) administers a Conservation Reserve Program in Illinois, which provides resources and assistance to farmers to establish and maintain wetlands and other practices. In 2020, there were 57,867 acres enrolled as wetlands under the program, whereas 250,784 acres were in buffer zones (Illinois EPA, 2021). The FSA also reports the number of acres that had cover crops planted and harvested, regardless of financial assistance from government conservation programs. In 2020, 131,757 acres were reported in cover crops by producers, which was drastically lower than the 2019 figure of 427,410 acres (Illinois EPA, 2021). This is likely attributed to the number of acres in prevent plant following widespread flooding. Other programs at the federal level include the Environmental Quality Incentives Program, the Conservation Stewardship Program, the Mississippi River Basin Healthy Watersheds Initiative, and the National Water Quality Initiative. In addition, there are various programs and projects supported by state agencies, including the Conservation Reserve Enhancement Program, the Illinois Department of Natural Resources Contaminant Assessment Section, and the Streambank Stabilization and Restoration Program. The 2021 Biennial Report also outlines efforts by NGOs such as the Illinois Sustainable Ag Partnership, Nutrient Research and Education Council, and Illinois Farm Bureau (Illinois EPA, 2021). The report also summarizes the findings of the NLRS survey, administered by the National Agricultural Statistics Service (NASS) in 2019 and 2020. The survey results showed that most farmers know more about cover crops and nitrogen fertilizer rates. At the same time, they are less knowledgeable about edge-of-field practices such as wetlands and bioreactors (Illinois EPA, 2021).

CONCLUSION

In response to the U.S. EPA Gulf Hypoxia Task Force, the state of Illinois released the Illinois NLRS that established nutrient load reduction goals and recommended best management practices to reduce nutrient loads into the Mississippi/Atchafalaya River Basin. Eleven other states in that basin produced similar strategies. This case study analyzed the Illinois NLRS and compared it to the strategies of the other 11 states. As discussed in the 2021 interim report, Illinois may not be making adequate progress toward meeting its interim 2025 goals, which begs the question: What if voluntary adoption of best management practices is insufficient? State and federal agencies could use their broad administrative and rule-making powers to implement specific programs and practices to reduce nutrient loss, similar to the maximum daily load limits established in the Chesapeake Bay watershed (Chesapeake Bay Program, 2004). A survey of Illinois corn growers revealed that over 88% of respondents are concerned about implementing regulations to address nutrient loss concerns (Hoselton and Boerngen, 2021), which would significantly impact on-farm decision-making. As states in the Mississippi/Atchafalaya River Basin work toward achieving their nutrient loss reduction targets, farm operators, landowners, and farm managers will continue balancing the benefits of working to achieve the greater goals with the cost of implementing the best management practices that contribute to meeting those goals.

FOOTNOTES

1. The U.S. National Oceanic and Atmospheric Administration (NOAA) and U.S. EPA define "non-point source" pollution as runoff from various sources. Examples may include oil from a car parking lot being washed into a stream due to rainfall. "Point source" pollution is "any single identifiable source of pollution from which pollutants are discharged." An example of point source pollution is a factory's smokestack putting pollutants into the atmosphere (NOAA, n.d.).
2. Evapotranspiration is "loss of water from the soil both by evaporation from the soil surface and by transpiration from the leaves of the plants growing on it" (Encyclopedia Britannica, 2022).

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Table 1. Short-Term Action Plans Established by the Gulf Hypoxia Task Force		
Recommendation	**Time Frame for Achievement**	**Responsible Party**
#1: Comprehensive budget proposals to support the action plan	By December 2000	Hypoxia Task Force, with input from states and tribes in the Mississippi/Atchafalaya Basin
#2: Establish sub-basin committees	By summer 2001	States and tribes in the Basin, along with the Hypoxia Task Force
#3: Develop an integrated Gulf of Mexico Hypoxia Research Strategy	By fall 2001	Hypoxia Task Force
#4: Expansion of long-term monitoring programs for the hypoxic zone	By spring 2002	Coastal states, tribes, and relevant federal agencies
#5: Expansion of the existing monitoring programs within the Basin	By spring 2002	States, tribes, and federal agencies within the Mississippi/Atchafalaya Basin
#6: Develop strategies for more significant nutrient reduction	By fall 2002	States, tribes, and federal agencies within the Mississippi/Atchafalaya Basin
#7: Complete a reconnaissance-level study of potential nutrient reduction strategies	By December 2002	Army Corps of Engineers, Congress, states, tribes, and other federal agencies
#8: Identify point-source dischargers	By January 2003	Sub-Basin committees and other Clean Water Act authorities
#9: Increase assistance to landowners for voluntary actions	By spring 2003	Sub-Basin committees, states, tribes, and federal agencies
#10: Increase assistance to agricultural producers to implement best management practices	By spring 2003	Sub-Basin committees, states, tribes, and other federal agencies
#11: Assess nutrient load reductions and changes in the hypoxic zone	By December 2005 and every five years after	Hypoxia Task Force

Source: EPA, 2001.

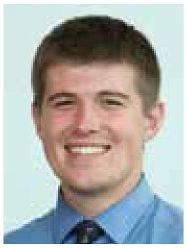
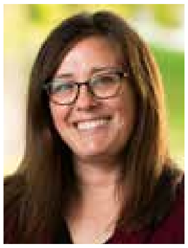
Table 2. Comparison of the Illinois NLRS to Other State Strategies			
State	**Body/Entity Responsible for Creating State Strategy**	**Composition of the Body/Entity**	**Nutrient Reduction Goals for the State**
Illinois	Policy Working Group	Members include representatives from the Illinois EPA, Department of Agriculture, academia, NGOs, and industry	By 2025, a 15% reduction in nitrate-nitrogen and a 25% reduction in phosphorus with a long-term goal of 45% reduction of both
Arkansas	Nutrient Reduction Strategy Coordination Team	Members include representatives from state agencies, academia, and extension	40% reduction of the baseline goal in the Illinois River watershed
Indiana	Indiana Department of Environmental Management and Department of Agriculture	Department of Agriculture and Department of Environmental Management, along with other state organizations and Purdue Extension	Nutrient benchmark goals for phosphorus loads are not to exceed 0.3 mg/L and nitrate-nitrite not to exceed 10 mg/L
Iowa	Iowa Department of Agriculture and Department of Natural Resources	In addition to the Department of Agriculture, Department of Natural Resources, Iowa State University Extension, and other state and federal agency partners	45% reduction of nitrogen and phosphorus losses
Kentucky	Kentucky Division of Water and other partners	Kentucky Center of Excellence for Watershed Management, academia, and other state agencies	No overall goals for the state; goals are set for each specific priority watershed
Louisiana	Louisiana Nutrient Reduction and Management Strategy Interagency Team	Various state and federal agencies and LSU Extension	No specific goals are listed
Minnesota	Interagency Coordination Team	Various state and federal agencies, academia, and local government bodies	45% reduction from average 1980–1996 conditions for nitrogen and phosphorus by 2040, with a 2025 milestone of 20% reduction for nitrogen and 45% for phosphorus
Mississippi	Planning Team	Various state and federal agencies, farmer advocacy organizations, and water management districts	No specific goals are listed
Missouri	Missouri Department of Natural Resources	In addition to the Department of Natural Resources, other state and federal agencies, community, and farmers groups were consulted	No specific goals are listed
Ohio	Ohio Department of Agriculture, Department of Natural Resources, Ohio EPA	Various state agencies, U.S. EPA Region V, Point Source, and Urban Nutrient Workgroup	In the Ohio River Basin, maximum phosphorus permit limits of 1.0 mg/L
Tennessee	Tennessee Department of Environment and Conservation, Division of Water Resources, and Tennessee Nutrient Strategy Taskforce	Various state and federal agencies, agricultural industry representation, NGOs, and other advocacy groups	Short-term goal of reducing nitrogen and phosphorus by 20%; long-term goal of reducing nitrogen and phosphorus by 40%
Wisconsin	Wisconsin Department of Natural Resources, Targeting Workgroup, Tracking & Reporting Workgroup, and Monitoring Workgroup	Department of Natural Resources, along with University of Wisconsin Extension, Wisconsin Department of Agriculture, Trade & Consumer Protection, and the U.S. Geological Survey	45% reduction of phosphorus to the Mississippi River; no specific goal for nitrate-nitrogen reduction

Sources: Individual states' nutrient reduction strategies.

Table 3. Comparison of Best Management Practices Recommended by Each State Strategy for Agricultural Sources		
State	**Nitrogen Practices**	**Phosphorus Practices**
Illinois	Reduce the application of nitrogen to the MRTN recommendations; change the timing of fertilizer application; use cover crops, bioreactors, wetlands, and riparian buffers	Riparian buffers, water and sediment control basins, strip cropping, terraces
Arkansas	Riparian buffer zones and functional wetland areas; improved grazing, pasture management, and use of nutrient-inhibiting substances	Same as Nitrogen Practices
Indiana	No fall application of nitrogen; apply sulfur to make nitrogen more available to plants and use nitrogen stabilizers	Same as Nitrogen Practices
Iowa	Timing of nitrogen application, cover crops, living mulches, bioreactors, extended rotations, planting perennials	Erosion control, tillage, crop change, wetlands, buffers, and sediment control
Kentucky	Contour farming, grass/legume rotation, mulching, strip cropping, and cover crops	Same as Nitrogen Practices
Louisiana	Cover crops, contour farming, grassed waterway, riparian buffers, wetland creation	Same as Nitrogen Practices
Minnesota	Cover crops, prescribed grazing, contour farming, strip cropping, terracing, and vegetative barriers	Same as Nitrogen Practices
Mississippi	[Do not list any practices, just the goal of recommending practices]	
Missouri	Manage manure, 4R nutrient management, cover crops, and gully erosion control	Same as Nitrogen Practices
Ohio	Implementing whole farm conservation practices, grass waterways, cover crops, reduced tillage, applying manure/fertilizer to meet the needs of the plants, retiring highly vulnerable land	Same as Nitrogen Practices
Tennessee	4R nutrient management, cover crops, vegetative waterways, conservation tillage	Same as Nitrogen Practices
Wisconsin	Manage manure systems, riparian buffers, prescribed grazing, sediment basins, strip cropping	Same as Nitrogen Practices

Sources: Individual states' nutrient reduction strategies.

Estimating the Impact of Swine Feedlots on Residential Values in Southern Minnesota

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Abstract

A hedonic analysis, or revealed preference analysis, was used to estimate the effect of hog barn proximity on prices of rural residents' real estate in the southern region of Minnesota using Minnesota Pollution Control Agency (MPCA) and county home sales data. Explanatory variables in the dataset include number of bedrooms and bathrooms, lot size, age of home, year sold, feedlot characteristics, and proximity calculated using GIS software. This analysis included 2,795 observations in Blue Earth County, Jackson County, and Freeborn County from 2017 to 2020 and reveals that homes located between one-half to one mile away from swine feedlots were associated with an increase in value, whereas a distance of less than one-half mile away was not found to have an effect.

INTRODUCTION

Minnesota has an estimated 18,000 livestock feedlots registered under the state's feedlot rule, and the Minnesota hog industry is one of the largest in the nation with over $2.7 billion in annual hog sales in 2019. Hog farms also support their local communities; the average hog farm contributed roughly $33,000 in state and local taxes in 2019 (Hadrich, Roberts, and Tuck, 2020). Swine farms have also been a point of contention in the recent past, with nuisance lawsuits providing a precedent to limit construction, expansion, and renovation. Livestock owners are seeking solutions to these problems and concerns posed by community members. Researchers have conducted studies on feedlots and the effect they have on home prices, but these studies are applicable only to the area where they took place. The last study evaluating Minnesota feedlots and home values was completed in 1996. The study examined this relationship in two counties, Redwood and Renville, using a total of 292 residential sale observations. Since 1996, the number of residential sales near production agriculture has increased as urban sprawl continues to expand, even in more rural areas. Updating the 1996 studying using home sales transactions and feedlot proximity will provide a comparison to the earlier study while also giving additional insight on the potential relationship between production agriculture and rural communities. Further, this study collects data from 2017 to 2021 that results in 2,795 observations of residential home sales within a one-mile proximity of livestock feedlots. This results in an expanded dataset that includes variables that were not previously available or easy to collect, such as school districts.

Since 1990, there have been several studies completed across North America seeking to assess the impact of feedlots on residential property values. Most of these studies have concluded that proximity to feedlots is statistically negatively associated with home values (Abeles-Allison and Connor, 1990; Hamed, Johnson, and Miller, 1999). Some of these studies discuss limitations of their results due to concerns surrounding potential biases associated with unobservable variables, such as the spatial correlation of houses, and overall market differences across regions and studies. Researchers at the University of Missouri (Massey and Horner, 2021) completed a meta-analysis of previous studies to find that the impact of feedlots on housing values is still unknown due to the complexity of the question but estimate the effect is likely negative. A study evaluating farms in Indiana (Indiana Business Research Center, 2008) found that homes within half a mile of a feedlot decrease in value, but values increase from one-half mile to three miles. These results were a combination of all livestock, but negative effects were observed when studying swine exclusively. Taff, Tiffany, and Weisberg (1996) conducted a study of homes sold in rural areas for two counties in southern Minnesota in 1996 and found that nearby feedlots increased housing prices. They did not include factors for homes downwind, animal density, or spatial correlation.

This study's objective is to provide the scientific findings of the impact that swine feedlots have on home prices in southern Minnesota. As previously mentioned, the staff paper conducted at the University of Minnesota by Taff, Tiffany, and Weisberg attempted to answer this same question in 1996. Although this paper has its merits, the study was conducted in counties with lower hog density than other Minnesota counties and had a low sample size of only 292. This paper improves on the last Minnesota study by expanding the number of observations used by utilizing GIS to calculate the distance from homes to feedlots as well as including three of the largest swine producing counties in the state in the dataset.

MODEL AND METHODS

This study uses a regression analysis, known as hedonic price analysis, to determine the impact that house characteristics, feedlot and proximity characteristics, and school district have on the sale price of a home. Ordinary least squares (OLS) is used to estimate the impact of the independent variables on the dependent variable. OLS minimizes the sum of the squared residuals in the model (Wooldridge, 2015). The model for this study is

$$y_i = \beta X_i + \gamma X_i + \delta X_i + \varepsilon_i, \qquad (1)$$

where y_i represents the quarter root of the sales price of the home i divided by 1000, β is a vector of home and sale characteristics, γ is a vector of feedlot characteristics and proximity to the nearest feedlot, δ is a school district dummy variable (used only for individual county datasets), and ε_i is the error term for the house sale.

Following Taff, Tiffany, and Weisberg (1996), a Box-Cox transformation was used on the dependent variable—selling price—to transform the home sale price into a normally distributed variable. The results of the Box-Cox transformation in SAS (SAS Institute, 2022) indicated that the quarter root of selling price would yield the most normally distributed variable. Normal distribution aids in the applicability of the model and sets the mean predicted error near zero, making the OLS parameter significance more reliable. This study was therefore focused on the sign associated with each parameter estimate rather than magnitude. Results are displayed as positive or negative, with asterisks corresponding to the significance levels. Outliers within the home characteristic data are addressed using studentized residuals. Any observations with a studentized residual less than negative two and greater than positive two are removed. To remove the outliers, a regression of the three counties was run just using home characteristics and year sold as independent variables. This resulted in only one observation being removed that was within one mile of a feedlot.

Distance (the proximity variable) was created using ArcGIS geocoding. Home sale addresses as well as feedlot addresses were geocoded. Proximity was determined by multiple buffer rings at 0.25, 0.5, and 1.0 miles around each feedlot, as illustrated in Figure 1. These distances were chosen based on findings by previous studies that showed little to no impact on sale prices after one mile (Bayoh, Irwin, and Roe, 2004; Herriges, Secchi, and Babcock, 2005; Ready and Abdalla, 2005). These rings were centered on the address and may not be centered directly over the feedlot or buildings containing livestock. These overlapping feedlots were then spatially joined with the home sale data. Another distance variable, one-mile boundary, was created to capture any homes within one mile of a feedlot as shown in Figure 2. School district areas were also overlaid on the house sales and spatially joined together with the home sales in Blue Earth, Freeborn, and Jackson Counties (Figures 3–5).

DATA

Home sale data and its corresponding housing characteristics from 2017 to 2021 were compiled from three southern Minnesota counties. A five-year timespan was used to account for the variation in home sale prices due to market conditions impacting home sales over this time period (COVID-19, increased housing demand, etc.). Home data was collected through Beacon (https://beacon.schneidercorp.com), a public online tool that contains property information that participating cities and counties provided. County data that was not available in Beacon was gathered through the county assessor's office. Home characteristics and sales prices were collected. These include number of bedrooms, number of bathrooms, lot size, date of the sale, and age of the home at time of the sale. Blue Earth data was available only from 2017 to 2020. Homes that sold for less than $70,000 were removed from the data, as were home sales that included more than 80 acres since they were not considered to be arm's length transactions. Other variable outliers were removed utilizing studentized residuals.

Blue Earth County and Martin County are part of the top 20 hog producing counties in the United States. This study captures 827 observations in Blue Earth County but is not able to utilize any home sale data from Martin County due to missing variables and lack of consistency within their data reporting processes. Counties examined for this study had differing levels of home sale information available in Beacon and from county assessors, with some counties in Beacon providing only three of the variables needed to conduct the analysis. Of 11 counties that were intended for this study, only three (Blue Earth, Freeborn, and Jackson) had data with all the required variables. The other two counties used in this study, Freeborn and Jackson, supplied the remaining 1,968 observations and are both high swine producing counties located in southern Minnesota.

Publicly available feedlot information was collected through the Minnesota Pollution Control Agency (MPCA). MPCA maintains a database within ArcGIS that contains the geospatial data and accompanying data for each feedlot in Minnesota. The MPCA is the governing body for these livestock feedlots and regulates the handling of animal manure. MPCA feedlot rules apply to location, design, construction, operation, and management of feedlots. Owners of feedlots are required to register when the feedlot meets one of two conditions: an animal feedlot capable of holding 50 or more animal units, or an animal feedlot capable of holding 10 or more and fewer than 50 animal units that is located within shoreland (Minnesota Legislature, 2014). One animal unit is equivalent to the amount of manure produced by a steer or heifer. One head of swine that is over 400 pounds is equivalent to 0.4 animal units. Between 55 pounds and 300 pounds is equivalent to 0.3 animal units. Under 55 pounds is 0.05 animal units (Minnesota Legislature, 2019). This data contains the number of animal units, a dummy variable for primary animal, and a yes/no variable if liquid storage is used. For this study, only feedlots that are required to register were considered.

Another key variable for analyzing individual counties was the school district sold homes were located in. School district areas were collected through ArcGIS utilizing shape files generated at the University of Minnesota in February 2022 (Crosson, 2022). Dummy variables were created for each of the 21 school districts and were used only in individual county analyses.

The resulting dataset contains house sales from 2017 to 2021 and includes 2,795 observations with averages: sale value of $170,938, roughly three bedrooms, two bathrooms, and one acre (see Table 1). Age of homes at the time of sale ranged from less than a year to 151 years old.

In this dataset, only two primary animal types, swine and beef, were within a mile of home sales. Eleven swine feedlots had an average of 551 animal units or 1,837 head (0.3 hogs per 1 animal unit). Table 2 shows the number of feedlots within proximity of a home sale by livestock type. Of the 11 swine feedlots within a mile of a home sale, nine homes are one-half to one mile away. Ten of the swine feedlots also have liquid manure storage on the farm. The 10 remaining feedlots in the study area had beef as their primary livestock, so a dummy variable was created for the category. The majority of these beef feedlots are also from one-half to one mile away. Only two of the beef feedlots have liquid manure storage.

Table 3 shows the frequency of home sold in a particular school district in that county. Albert Lea School District, located in Freeborn County, makes up a large percentage of total observations for the entire sample at 57.78%, followed by Mankato School District in Blue Earth County with 12.31%.

RESULTS

In conjunction with ArcGIS (Esri, 2022), SAS software (SAS Institute, 2022) was used to run OLS regressions for the three-county dataset and for the individual counties. Table 4 displays the regression results for the full dataset of three counties using home characteristics, the multiple buffer rings at a quarter mile, half mile, and one mile away from the feedlot address, and the group of all home sales within one mile of a feedlot.

Home characteristics and year sold, in comparison to the omitted year of 2021, are statistically significant in explaining variation in the selling price. Increasing the number of bedrooms, bathrooms, or acreage, holding all else equal, is associated with a higher selling price. Older homes are associated with a lower selling price when holding other parameters constant. Sales from 2017 to 2019 are associated with lower sales prices compared to 2021. Additionally, home sales in 2020 are not statistically different from sales in 2021.

The second column of Table 4 presents results including the home characteristics as well as multiple ring buffers around the feedlot as explanatory variables in the regression. The magnitude and significance of the home and sale parameters did not change. As for the feedlot characteristics, only the swine feedlot distance parameter of one-half to one mile was significant. Shockingly, swine feedlots within this distance are associated with an increase in selling price This finding is similar to the previous Minnesota study (Taff, Tiffany, and Weisberg, 1996) where nearby feedlots increase the value of the home and should be a valuable asset in supporting producers when disputes arise regarding the impact feedlots will have on the community and home values. The other swine feedlot parameters—quarter to one-half mile, animal units, and liquid manure storage—were not statistically significant at the 10% level. There were no homes sold within a quarter mile of a feedlot, so only quarter-mile to one-half mile and one-half to one-mile distances were used in this buffer ring analysis. Beef feedlot parameters were included to isolate the effects that each type of primary livestock had on home sales. One of the buffer ring distance parameters for beef feedlots was statistically significant at the 1% level as well as the animal unit count at the 5% level.

The last column of Table 4 uses a different distance parameter, a dummy variable that equals one if the home was within a mile of a feedlot, rather than the multiple buffer rings. Once again, home and sale characteristics were significant and did not differ in magnitude from the first regression. With the new distance, dummy variable results show that home sales within a mile of a swine feedlot are associated with a higher selling price and statistically significant at the 10% level. Parameter estimates for swine lagoon and number of animal units differ slightly in magnitude from the previous regression but are not statistically significant from zero and are not associated with a change in selling price. This differs from Taff, Tiffany, and Weisberg (1996), who found that the number of animal units and liquid manure storage had a significant and positive effect on home sale prices. Within a mile of a beef feedlot results in a positive and significant effect on home sales price at the 5% level. The beef animal unit count also changes signs from positive to negative and is significant at 1%. The three-county dataset was divided into individual county datasets to incorporate school district dummy variables into the regression. Table 5 displays regressions for each county, one with home, sale year, and feedlot characteristics and the other including all of the former regressions and school districts. Although the three-county models used two distance parameters, these county-level regressions use the ring distance variables since no difference was found between using the multiple rings and distance dummy variable on the county level. Parameters signified with # were dropped due to the low sample size of feedlots when separating the counties apart.

Jackson County

Jackson County had only one of the home characteristics significant at the 1% level (age of home); number of bathrooms and acres were significant at the 5% and 10% level, respectively. There were no swine feedlots located within this county's dataset. Adding school districts into the regression in Table 5, home characteristic parameters did not change in significance or magnitude but the R-squared increased by 1.5 percentage points. The school district variables are compared to Jackson County Central and are not significant.

Freeborn County

Freeborn County had statistically significant home attribute variables as well as sale years, with price decreases associated with older homes and selling prior to 2021. Swine feedlot parameters are insignificant but biased due to sample size. Analyzing the school district regression section of Table 5, Freeborn home and sale parameters had no sign changes or significance level changes.

Freeborn County feedlot parameters are consistent with the findings in the previous section. The parameter estimates for sales within one-half to one mile are positive but insignificant and biased. School district estimates were in comparison to Albert Lea, and R-squared increased by 0.8 percentage points.

Although adding these school districts did not change parameter estimates from the feedlot regression, they did add explanatory information on sales price.

Blue Earth County

Similar to Freeborn County, Blue Earth County had statistically significant home attribute variables as well as sale years (Blue Earth did not have data for 2021, so 2020 is dropped). Number of bedrooms, bathrooms, and acres are all associated with an increase in home price. Swine feedlots with lagoons were associated with a decrease in sales price, and the parameter estimate is significant at the 10% level. The swine animal unit count parameter estimate was positive and significant, meaning that one additional animal unit is associated with an increase in the home selling price. Adding school districts results in similar findings. There were no sign changes or significance level changes regarding the home and sale parameter estimates for Blue Earth County. The parameter estimates for swine lagoons and swine animal unit counts were still marginally significant and hold the same signs as the feedlot characteristics regression. Blue Earth County School District parameters are in comparison to the Mankato School District and increased the R-squared 5.1 percentage points to 74%.

CONCLUSION

The results from this study differ based on the granularity of the dataset used. The three-county dataset shows that homes sold within one mile of swine feedlots are associated with an increased selling price. This increase may be limited to the one-half to one-mile range, as demonstrated by the multiple buffer ring regression. The effect on home sales closer to swine feedlots was not determined since there were no home sales recorded within a quarter mile of a swine feedlot. Liquid storage and the number of animal units on swine feedlots were not found to have an effect on a home's selling price. Individual county level results differ, with Blue Earth County homes having a higher selling price with the addition of swine animal units and a lower selling price when the swine feedlot uses a lagoon. Home sale prices were not affected when considering distance to the nearest swine feedlot in these three counties. Feedlot effects differ from region to region, and southern Minnesota is an outlier with swine feedlots increasing home prices—unlike in many other states.

This research could be extended by looking at the magnitude of parameter estimates and using spatial correlation measures to test for bias within neighborhoods. Overall, this study emphasizes the need for accurate public data and standardization so that questions similar to this can be answered. Minnesota collects thousands of data points on feedlots and home sales every year. Over 8,000 additional home sale observations covering eight additional counties could have been used in this analysis if the data collection methods were standardized across counties. The results of this study show that this type of research needs to be conducted not only to provide evidence in support of farmers for nuisance suits and permitting meetings but also to provide more information about the effects of agriculture on different communities.

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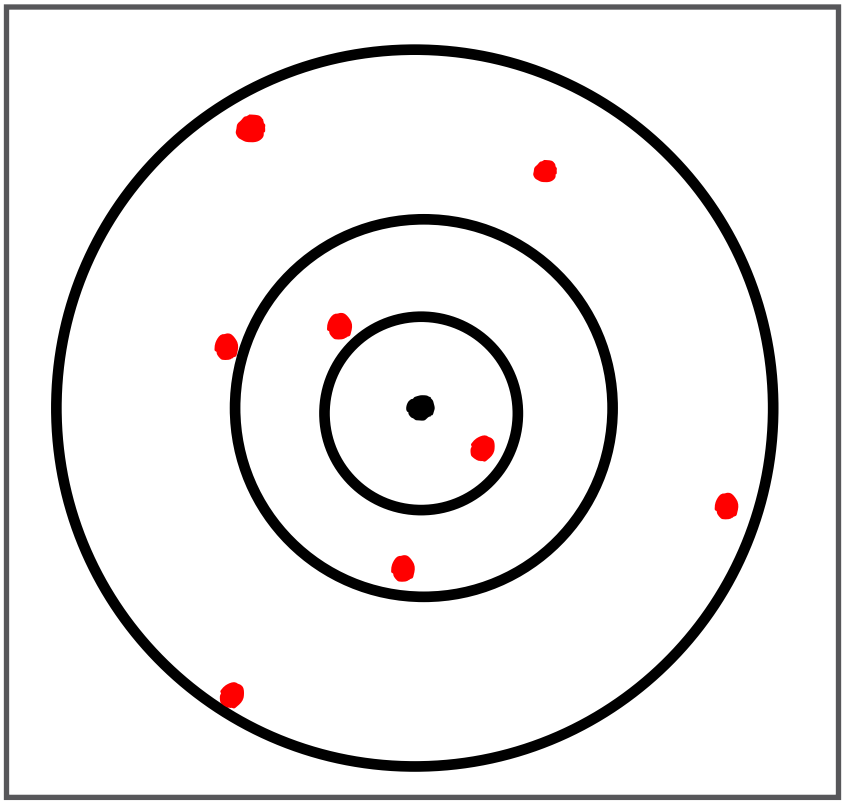


Figure 1. Multiple ring buffer

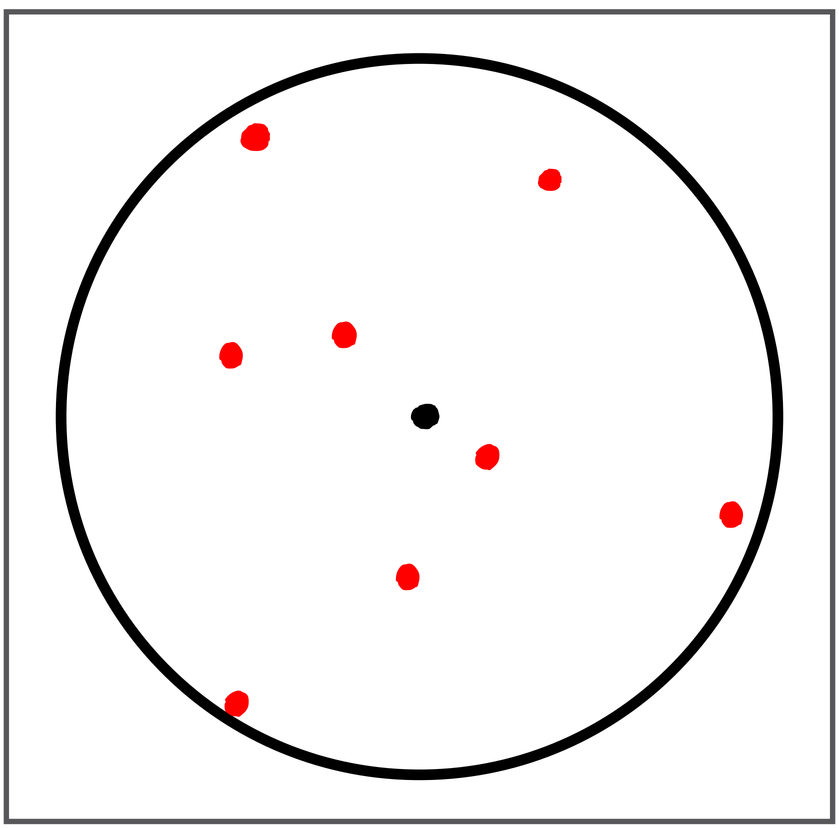


Figure 2. One-mile boundary

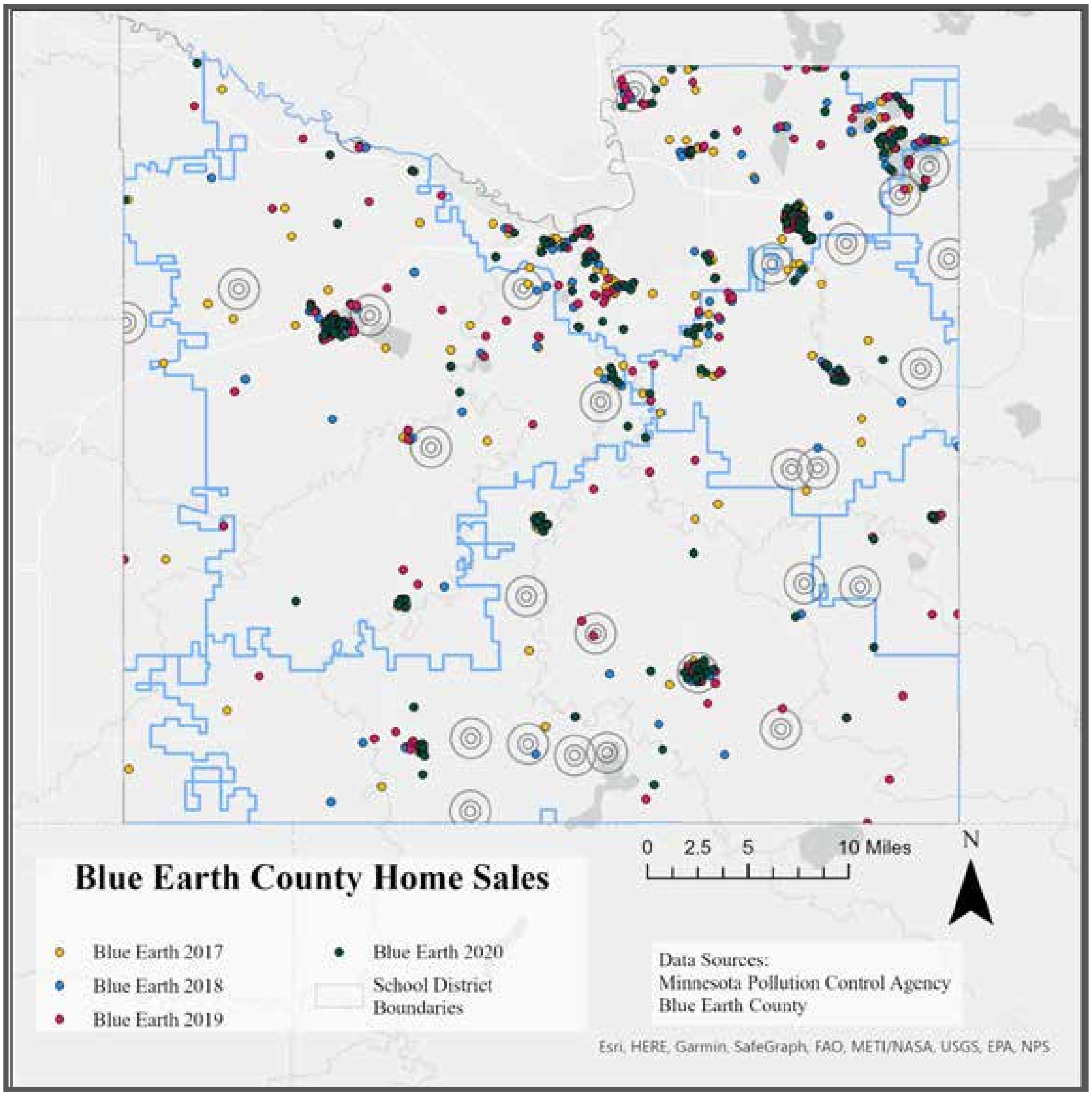


Figure 3. Blue Earth County in ArcGIS, 2017–2020. (Note: Buffer rings indicate feedlot locations.)

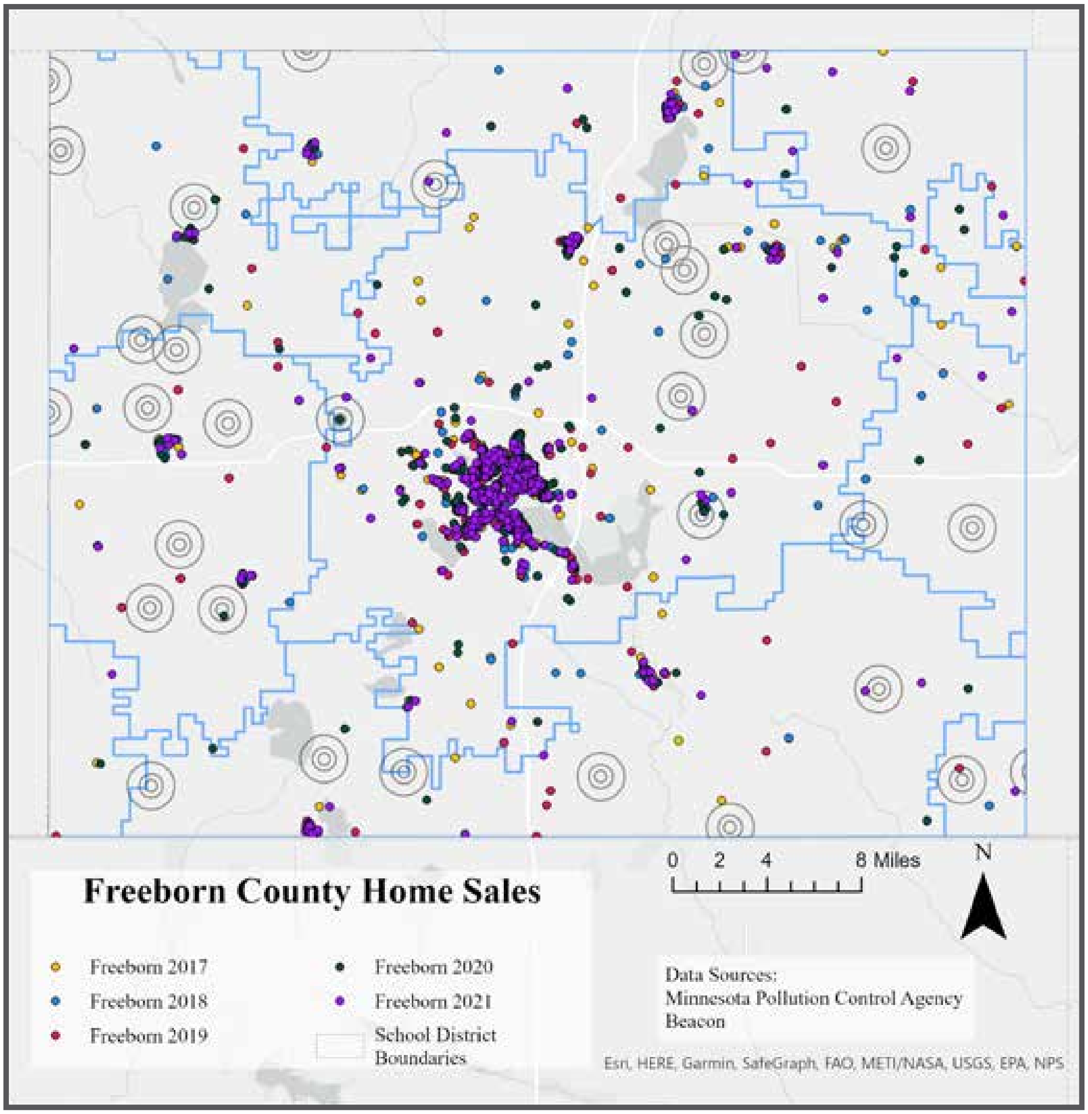


Figure 4. Freeborn County in ArcGIS, 2017–2021

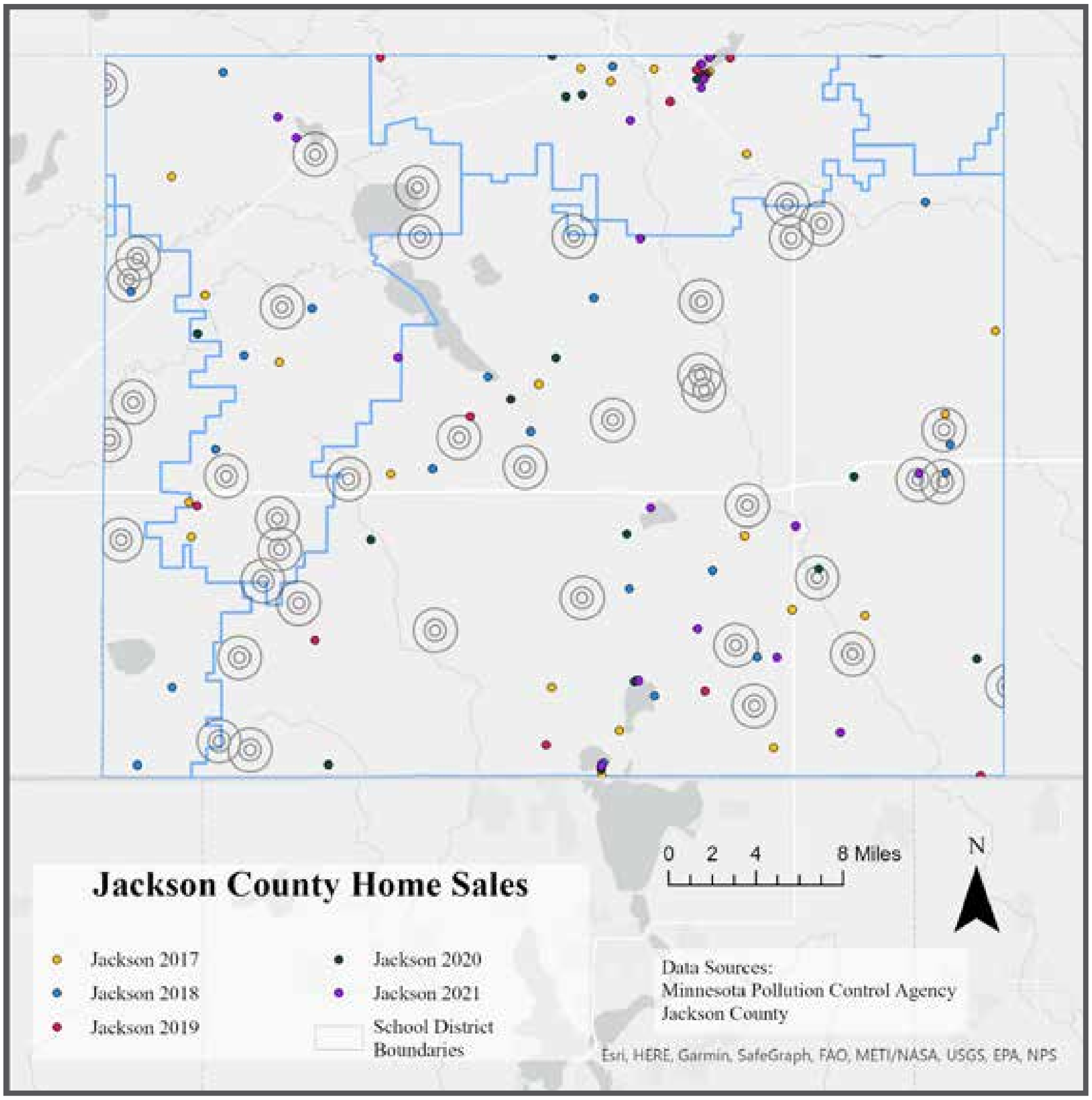


Figure 5. Jackson County in ArcGIS, 2017–2021

Table 1. Descriptive Statistics, Three-County Model, 2017–2021

Variable	Obs.	Mean	Std. Dev.	Minimum	Maximum
Home Characteristics					
Sale Amount	2795	$170,938	$83,174	$70,000	$535,000
Number of Bedrooms	2795	3.16	0.85	1.00	7.00
Number of Bathrooms	2795	1.95	0.69	0.75	4.50
Age of Home	2795	59.44	32.85	0.00	151.00
Acres	2795	1.02	2.98	0.00	45.08
Feedlot Characteristics					
Swine AU Count	11	551.08	452.39	94.40	1500.00
Beef AU Count	10	74.05	90.20	13.55	249.90
Year Sold					
2017	597				
2018	583				
2019	594				
2020	602				
2021	419				

Table 2. Descriptive Statistics, Feedlot Proximity Characteristics by Livestock Type, 2017–2021

	Beef		Swine	
Variable	Obs.	Percent of Obs.	Obs.	Percent of Obs.
Total Observations	10		11	
Distance Half	2	20.00%	2	18.18%
Distance One	8	80.00%	9	81.82%
Lagoon	2	20.00%	10	90.91%

Table 3. Descriptive Statistics, School Districts by County, 2017–2021		
School District	**Obs.**	**Percent of Total Obs.**
Blue Earth County	827	29.59%
Cleveland	3	0.11%
Janesville-Waldorf-Pemberton	21	0.75%
Lake Crystal-Wellcome-Memorial	213	7.62%
Madelia	3	0.11%
Mankato	344	12.31%
Maple River	161	5.76%
New Ulm	1	0.04%
St. Clair	80	2.86%
Truman	1	0.04%
Jackson County	67	2.40%
Heron Lake-Okabena	12	0.43%
Jackson County Central	36	1.29%
Round Lake-Brewster	3	0.11%
Windom	16	0.57%
Freeborn County	1901	68.01%
Albert Lea	1615	57.78%
Alden-Conger	49	1.75%
Austin	14	0.50%
Blooming Prairie	20	0.72%
Glenville-Emmons	86	3.08%
Lyle	3	0.11%
NRHEG	85	3.04%
United South Central	29	1.04%
Total	**2795**	**100%**

Table 4. Regression Results for Three-County Model, 2017–2021						
Variable	**Home Characteristics**		**Home & Multiple Buffer Rings**		**Home & One-Mile Boundary**	
Intercept	0.9846	***	0.9854	***	0.9855	***
Home & Sale Characteristics						
Age of Home at Sale	–0.0015	***	–0.0015	***	–0.0015	***
Number of Bedrooms	0.0272	***	0.0270	***	0.0272	***
Number of Bathrooms	0.0762	***	0.0763	***	0.0761	***
Acres	0.0124	***	0.0123	***	0.0123	***
Sale in 2017	–0.0511	***	–0.0512	***	–0.0516	***
Sale in 2018	–0.0337	***	–0.0344	***	–0.0343	***
Sale in 2019	–0.0204	***	–0.0214	***	–0.0214	***
Sale in 2020	–0.0073		–0.0073		–0.0072	
Swine Feedlot Characteristics						
Within Quarter to Half Mile of Swine Feedlot			0.0687			
Within Half to One Mile of Swine Feedlot			0.1439	*		
Within One Mile of Swine Feedlot					0.1407	*
Swine AU Count			0.0000		0.0001	
Swine Lagoon			–0.0851		–0.1192	
Beef Feedlot Characteristics						
Within Quarter to Half Mile of Beef Feedlot			–0.6981	***		
Within Half to One Mile of Beef Feedlot			0.0027			
Within One Mile of Beef Feedlot					0.0886	**
Beef AU Count			0.0024	**	–0.0010	***
Beef Lagoon			–0.0204		0.1015	
Number of Observations	**2795**		**2795**		**2795**	

Note: *** indicates significance at 1%; ** indicates significance at 5%; * indicates significance at 10%.

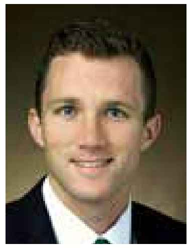
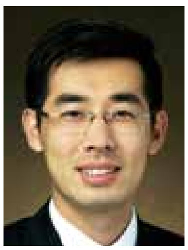
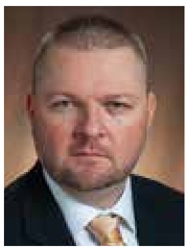
Table 5. Regression Results for County Level Multiple Buffer Rings, 2017–2021

Variable	Feedlot Characteristics						Feedlot Characteristics & School Districts					
	Blue Earth		Freeborn		Jackson		Blue Earth		Freeborn		Jackson	
Intercept	1.0283	***	0.9958	***	1.1223	***	1.0607	***	1.0001	***	1.1075	***
Home & Sale Characteristics												
Age of Home at Sale	–0.0013	***	–0.0015	***	–0.0017	***	–0.0011	***	–0.0014	***	–0.0018	***
Number of Bedrooms	0.0279	***	0.0190	***	0.0106		0.0284	***	0.0185	***	0.0129	
Number of Bathrooms	0.0691	***	0.0824	***	0.0578	**	0.0609	***	0.0817	***	0.0555	**
Acres	0.0102	***	0.0130	***	0.0041	*	0.0103	***	0.0122	***	0.0045	*
Sale in 2017	–0.0511	***	–0.0746	***	–0.0452		–0.0501	***	–0.0737	***	–0.0397	
Sale in 2018	–0.0345	***	–0.0581	***	–0.0030		–0.0377	***	–0.0571	***	0.0126	
Sale in 2019	–0.0229	***	–0.0448	***	0.0451		–0.0244	***	–0.0447	***	0.0464	
Sale in 2020			–0.0272	***	0.0066				–0.0268	***	0.0085	
Swine Feedlot Characteristics												
Within Quarter to Half Mile of Swine Feedlot	0.1079						0.114					
Within Half to One Mile of Swine Feedlot	0.1196		0.0091				0.1118		0.0409			
Swine Lagoon	–0.1832	**		#			–0.1471	*		#		
Swine AU Count	0.0002	**		#			0.0002	**		#		
Beef Feedlot Characteristics												
Within Quarter to Half Mile of Beef Feedlot					0.0152						0.0209	
Within Half to One Mile of Beef Feedlot	–0.0305						–0.0311					
Beef Lagoon												
Beef AU Count	–0.0022	**				#	0.0027	***				#
School Districts												
Cleveland							0.0888	**				
Janesville-Waldorf-Pemberton							–0.0927	***				
Lake Crystal-Wellcome-Memorial							–0.0368	***				
Madelia							–0.0673					
Maple River							–0.0802	***				
New Ulm							0.0292					
St. Clair							–0.0132					
Truman							–0.0356					
Alden-Conger									–0.0313	***		
Austin									0.0398	*		
Blooming Prairie									0.0634	***		
Glenville-Emmons									–0.0311	***		
Lyle									–0.0093			
NRHEG									0.0009			
United South Central									–0.0081			
Heron Lake-Okabena											0.0083	
Round Lake-Brewster											–0.0450	
Windom											0.0277	
Number of Observations	**827**		**1901**		**67**		**827**		**1901**		**67**	
R-Squared	**0.6896**		**0.5659**		**0.5355**		**0.7406**		**0.5742**		**0.5500**	

Note: *** indicates significance at 1%; ** indicates significance at 5%; * indicates significance at 10%; # indicates a dropped parameter.

Returns to Zone Management Under Varying Conditions



By Mohsina Jahan, Cheryl Wachenheim, Erik Hanson, Xin Sun, and Bryon Parman

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Abstract

A framework for individual-farmer evaluation of the net benefits of adopting precision agricultural technologies was developed and tested. Partial budgeting analysis was used to calculate the net profit effect of adopting precision agriculture technology bundles on three farms differing in input use and location. @Risk was used to account for risk. Results show that adopting zone application of fertilizers and seed can be profitable for farms with moderately variable soils and this is amplified with higher prices, but that adoption of zone application may not be profitable for farms with low input use variation such as those irrigated.

INTRODUCTION

Precision Agriculture Technologies (PAT) refers to a set of technologies designed to reduce input costs or optimize field management practices and yield by providing farmers with detailed spatial information (National Research Council, 1997). PAT include grid/zone soil mapping, guidance systems, yield monitoring (YM), yield mapping (Ymap) with Global Positioning System (GPS)/Global Navigation Satellite System (GNSS),[1] unmanned aerial vehicle (UAV)/drone imagery, and variable-rate technology (VRT) input application.

PAT have gained increased importance in the agricultural industry over the past two decades. For major U.S. field crops, guidance systems have been adopted for 40% to 60% of planted acres, GPS soil mapping for 15% to 25%, and VRT fertilization for 10% to 30% (Schimmelpfennig and Lowenberg-DeBoer, 2020). Dealers report that their availability of precision agriculture (PA) service offerings increased drastically from 2008 to 2019 and again from 2019 to 2021 (Erickson and Lowenberg-DeBoer, 2021). Eighty-eight percent of dealers report offering grid or zone soil sampling and VRT fertilizer application, and 44% offer UAV/drone imagery.

PA manages yield potential and within-field variability caused by heterogeneity in soil physiochemical properties. It can contribute to the long-term sustainability of agriculture through more tailored input applications that reduce losses from excess applications and due to nutrient imbalances (Carrer et al., 2022; Finco et al., 2021; Kolady and Van Der Sluis, 2021; Nawar et al., 2017). PAT have particular potential where input costs are high, inputs are applied at variable rates, high value crops are grown, field variability is high, and environmental deterioration needs to be mitigated (Van Evert et al., 2017). However, the benefits of PA depend on many factors such as region, type of crops grown, soil variability, and farm size (DeLay and Comstock, 2021; Van Evert et al., 2017; Schimmelpfennig and Lowenberg-DeBoer, 2020). Thus, although there is interest among farmers in using PAT (Carrer et al., 2022; Van Evert et al., 2017), many farmers are yet to be convinced of their profitability for their own operations.

Economics of PA

The results of previous research considering the economics of adopting PAT have been mixed. Schimmelpfennig (2016) reported that the adoption of GPS soil and Ymap, guidance systems, or VRT led to a positive but small increase (1.1% to 2.8%) in net return and operating profits for corn. Schimmelpfennig (2018) found similar results with a small increase (1.1% to 1.8%) in operating profit for soybeans. Dhoubhadel (2020) found that PAT-adopting farms had higher returns than non-adopters and that variability of net returns was higher for non-adopters than for farms having adopted two or more technologies. He found that grid soil sampling technology helped farms increase net returns by an average of $53 per acre over farms with no PAT and that any combination of technologies that includes grid soil sampling can positively contribute to the net returns of the farm. Schimmelpfennig and Ebel (2016) found that most PAT combinations, including YM, Ymap, GPS, soil sampling, and guidance systems, show some cost savings. The largest average variable costs savings ($25 per acre) was found from the combination of YM and Ymap. Adding VRT to this combination did not bring any further cost reduction, which validates its lower adoption rate. However, adding VRT with soil mapping and YM brought additional cost reductions of $13 to $21 per acre. Schimmelpfennig and Ebel (2016) hypothesized that the inconsistency in cost savings associated with VRT is because it may result in increased input costs in some cases where increased input use can lead to an increase in output and profits.

Overall, existing literature suggests that the benefits of PAT can be very farm specific and vary significantly based on farm size (Dhoubhadel, 2020; Van Evert et al., 2017; Finco et al., 2021; Schimmelpfennig and Lowenberg-DeBoer, 2020), region (Schimmelpfennig and Lowenberg-DeBoer, 2020), type of crops grown (Dhoubhadel, 2020; Schimmelpfennig and Lowenberg-DeBoer, 2020), soil variability (Finco et al., 2021; Schimmelpfennig and Lowenberg-DeBoer, 2020; Srinivasan, Shashikumar, and Singh, 2022), and uncertainty about output and input prices (Finco et al., 2021). However, most research efforts have been generalized across farms and, as such, do not provide individual farmers with a clear understanding of the potential profitability of PAT for use on their unique farms. More research is needed on the economic viability of PA based on soil variability and other farm characteristics so that farmers can make informed choices about its adoption. We look at the effect of adopting a PAT bundle (soil sampling, zone mapping, and VRT) on the profitability of three farms and develop a model to calculate profitability that can be applied to individual farm situations.

METHODS

Our primary goal was to develop a model to help farmers estimate net benefits for their unique farms. A partial budgeting model was developed in Microsoft Excel. The process measures net benefits of a project starting with benefits realized (additional revenues or cost savings) and subtracts additional expenses. In our model, the net benefit of adopting a PAT bundle including soil sampling, zone mapping, and variable rate seed and fertilizer application is assessed. We consider profits on three case farms with and without adoption.

Our analysis assumes that yield goals are similar whether the farmer is adopting the PAT bundle or not, and that yield goal is not dependent on input cost or output price. This is consistent with regional farmer decision-making. Farmers generally plant to maintain or improve on their current yields and to maintain their actual production history yields. Federally subsidized crop insurance provides some incentive to apply inputs for yields on marginal acres above that which an economist might recommend. With a similar yield goal under traditional production and employing the PAT bundle, the focus is on the difference in input costs. Output price and input cost risk were added to the analysis using @Risk.

DATA

Revenues and costs that differ between adopters and non-adopters are included in the model. The primary cost difference is due to variable inputs of fertilizers and seed. Other costs differing between the scenarios are soil sampling, zone mapping, fertilizer recommendation, dry fertilizer application, and a hydraulic pump. Input use and yield data for the example farms come from three corn farms, one farm each in Richland County (North Dakota), Barnes County (North Dakota), and Boone County (eastern Nebraska) (Table 1; Figure 1). The PAT scenarios are estimated using yield goals, seeding rates, and fertilizer application rates for these three farms provided by Agveris in Casselton, North Dakota. The National Agriculture Imagery Program (NAIP) and Normalized Difference Vegetation Index (NDVI) imagery along with yield data are used to create five management zones for each field. Each management zone is then soil sampled after harvest, and those results are used to provide fertilizer and seed recommendations. The non-adoption scenarios assume traditional and field-common yields and application rates for inputs.

Table 2 shows a sample fertilizer recommendation. The first column lists the yield goals and names of inputs differing due to zone management. The last column shows the traditional rate of applications used before adopting PA. In most cases, yield goals are similar for both PA and traditional fields, but input recommendations are lower for PA. Other costs that differ are shown in Table 3.

In addition to a static analysis, for which December 2020 prices are used, @Risk is used to develop cost and price distributions to estimate the expected range of changes in net return from PAT adoption. For the latter, historical monthly prices of corn and fertilizers (except sulfur) are collected from the DTN ProphetX application. The historical monthly North Dakota price series from 2010 to 2020 was used for corn, nitrogen (urea), phosphorus (MAP),[2] potash, pop-up (10-34-0), and UAN[3] 28. The yearly price series of sulfur from 2010 to 2022 is used (Ron Haugen, Personal communication, May 10, 2022) due to unavailability of monthly prices. Corn seed price data is collected from annual North Dakota State University crop budgets. Excluded from the analysis are 2021 and 2022 prices because price of corn and all fertilizers started to increase sharply from 2021.

RESULTS

The objective was to identify the differential profit per acre between adopters and non-adopters of VRT under different price scenarios and considering price and input cost risk. Reported are static results, sensitivity analysis, and risk analysis.

Static Results

Table 4 shows static annual net profit results using prices from December 2020, when prices began to increase substantially associated with trade policy and COVID-19–related anomalies. Differential profit per acre—defined as profit under PAT adoption less profit under non-adoption—is $23 for ND1, whereas it is $13 for ND2. This was unexpected because of the higher soil variability on ND2. Economic theory indicates that the benefits of PAT adoption increase with variability in soil productivity. Here, there was a slight difference in yield goal between the PA and traditional scenarios of both farms. ND1's PA yield goal is slightly higher than the traditional rate and ND2's PA yield goal is slightly lower. The higher yield goal for the PA scenario in ND1 brings additional revenue, increasing the differential profit per acre for ND1.

Sensitivity Analysis

Sensitivity analysis calculates net profit differential using June 2022 prices to compare the change in profits when prices have almost doubled (Table 5). When prices increase, the profits of farms adopting the PAT bundle increase more than those not adopting. This was expected because the benefit of reduced input use under PAT grows with higher-priced inputs.

Figure 2 shows this graphically, demonstrating sensitivity of profits to changes in prices. Depicted are the three case farms. The base point uses December 2020 prices.

The horizontal axis shows the assumed increase in prices. Differential profits for ND1, ND2, and NE in the base case were $23, $13, and –$4 per acre, respectively. When prices were increased by 100%, which is slightly less than 2022 prices, the profit differentials almost doubled. Among all three farms, the rate of increase in differential profits with respect to increases in prices is the highest for ND2. This farm is using some of the more expensive fertilizers. The reduced cost associated with ND2 applying less fertilizer is therefore greater under higher fertilizer prices. Ultimately, higher per unit costs of inputs variable rate applied leads to an increase in profits associated with using PA for ND2 as compared to the other case farms, leading to convergence of the profit differential.

Risk Analysis

The Monte Carlo simulation feature in @Risk simulation was used to develop profit distributions. For the static analysis, December 2020 prices were used. But for the @Risk simulation, price series from 2010 to 2020 were used.

ND1 can earn a minimum differential profit of $26 per acre and a maximum of $66 per acre. The mean is $30 per acre. There is a 90% probability that the differential profit will be between $27 and $35 per acre (Figure 3), which is much higher than our static results. It is evident that adopting PA is highly profitable for ND1, not only under a higher price but also in a historic market environment.

The range of differential profit for ND2 is between $10 and $29 per acre. The average is $13 per acre. There is a 90% probability that the differential profit will be between $11 and $16 per acre, which is a little higher than the average static results (Figure 4). So, adopting PA for ND2 is moderately profitable in a normal market environment.

NE can earn a minimum differential profit of –$3 per acre and a maximum of $4 per acre. The mean is –$2 per acre. There is a 90% probability that the differential profit per acre will be between –$3 and $0 per acre, which is higher than our static results (Figure 5). NE was an irrigated field, and they applied some fertilizer through irrigation to all zones at a flat rate. Fertilizer recommendations were only slightly different between PA and the traditional scenarios.

CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this research was to build a model that farmers can use to calculate the net benefits of adopting PAT based on their unique farm characteristics. Our hypotheses were that adoption of PA would increase net profit and that an increase in prices would result in a larger differential profit between farms adopting PA and those not because applying fewer inputs will lead to a greater savings in input costs under higher prices.

Results support the hypothesis that a bundle of PAT including soil sampling, zone mapping, and VRT can be moderately to highly profitable for farms that are variable in terms of soil fertility. Typically, the more variable the field, the higher the increased differential. Exceptions occur when other revenues or costs are affected, as was the case here when ND1 benefited more from adoption of PA than the more variable ND2 because yield goal slightly increased for ND1 and slightly decreased for ND2 with adoption. For farms with little variability in soil productivity or conditions that do not accommodate more than minimal input application variability, adoption of this PAT bundle may not be economically viable. Supporting the second hypothesis, sensitivity analysis shows that differential profit per acre increases significantly with an increase in prices.

Recommendations

The PAT bundle (soil sampling, zone mapping, VRT) considered for this research can be suggested to farmers who have a variable field in terms of soil productivity, noting that more field variability should increase the differential profit per acre of the farm above operating without the PAT bundle. It is important that farmers estimate and use their own soil variability information, prices, and costs associated with adopting PAT in estimating the potential for their farm operation and consider not just current crop and price levels but those forecast over time. To circumvent a focus on the importance of intermediate to long-term price forecasting accuracy, a farmer can custom hire PA operations if current and short-term market forecasts support this. Although adopting PA may be profitable for non-irrigating farms, a traditional rate of input application may be more appropriate for irrigated farms due to the lack of variability in the input application rate over the field.

Challenges and Directions for Future Research

Even though the potential benefits of PA are widely recognized, many farmers remain uncertain about how it will affect their profits. Investment in PAT is therefore hindered. Challenges for farmers include increased application or management costs, investment in new equipment, training of employees for technology use, and uncertainty (Finco et al., 2021; Schimmelpfennig, 2016). Unless custom hired, adoption of PAT increases expenditures on machinery and equipment due to the capital-intensive nature of these technologies. This may in part explain why larger farms that can spread capital expenditures across more acres adopt PAT at a faster rate than smaller farms. Farm implements with VRT capabilities in particular have a relatively high capital cost and require additional operator time. Therefore, many producers have chosen to hire service providers when selecting VRT, particularly in smaller operations (Schimmelpfennig, 2016). Concerns over data privacy and security may also constrain adoption (Idowu, 2022).

Future studies on the profitability of adopting PAT can be done with a large dataset and varied types of fields that have adopted PA on their farms. Taking sample farms from different states and including farms producing different types of crops would also shed additional light. More research investigating the impact of soil variability and differing PAT bundles on the profitability of farms adopting PAT would also be of value.

FOOTNOTES

1. GNSS is formerly referred to as GPS. The main distinction between GPS and GNSS is that GNSS provides global coverage. Although these terms can be used interchangeably, GNSS is used worldwide. Most of the recent research on PA uses GNSS instead of GPS.
2. Monoammonium Phosphate is referred to as MAP.
3. Urea Ammonium Nitrate is referred to as UAN.

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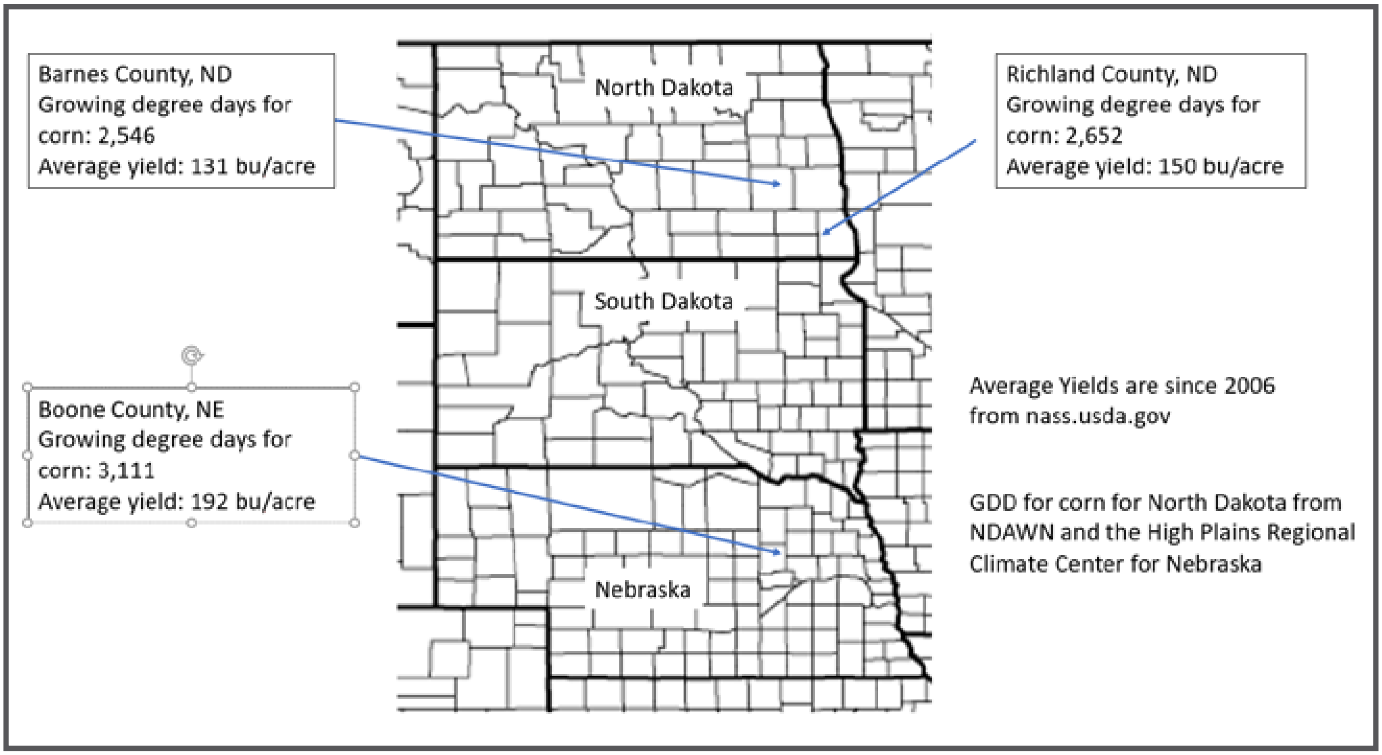

Figure 1. Case farms

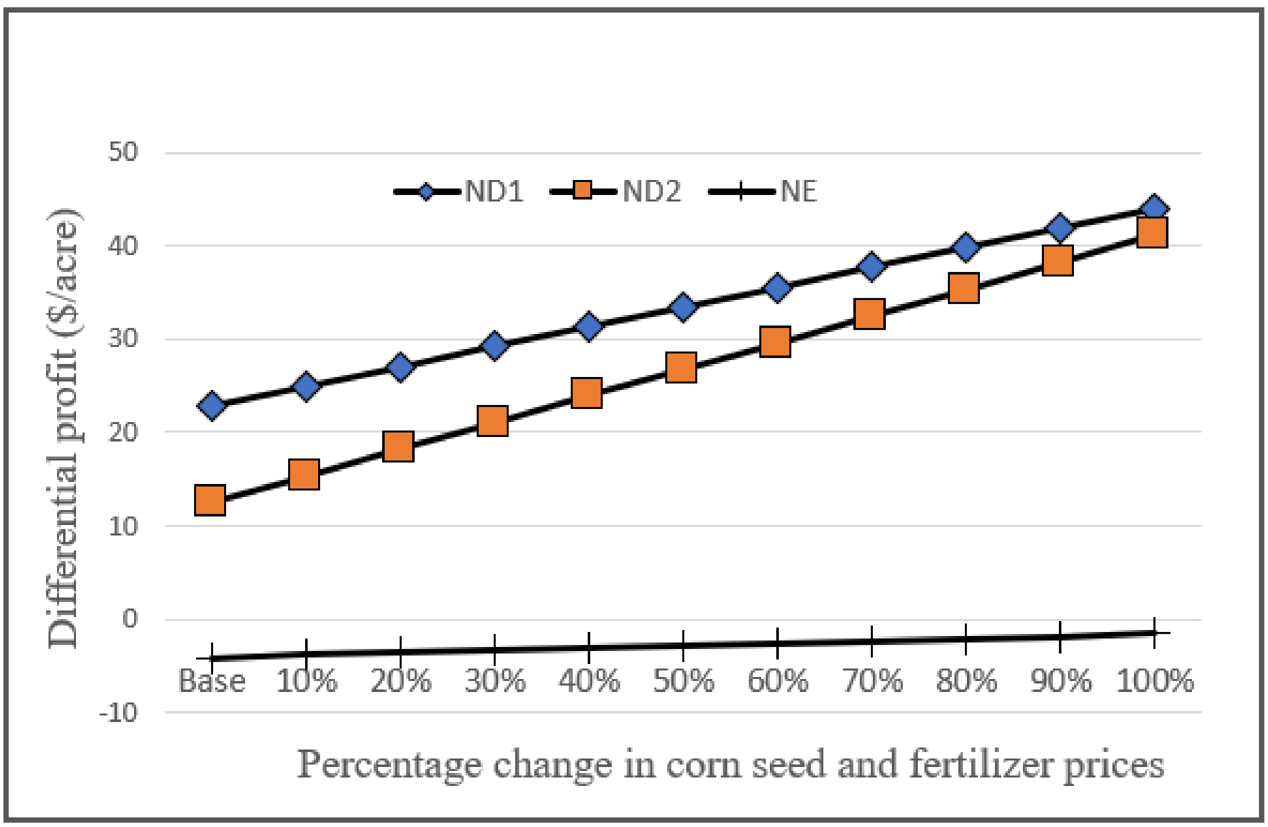

Figure 2. Sensitivity of differential profits to price changes

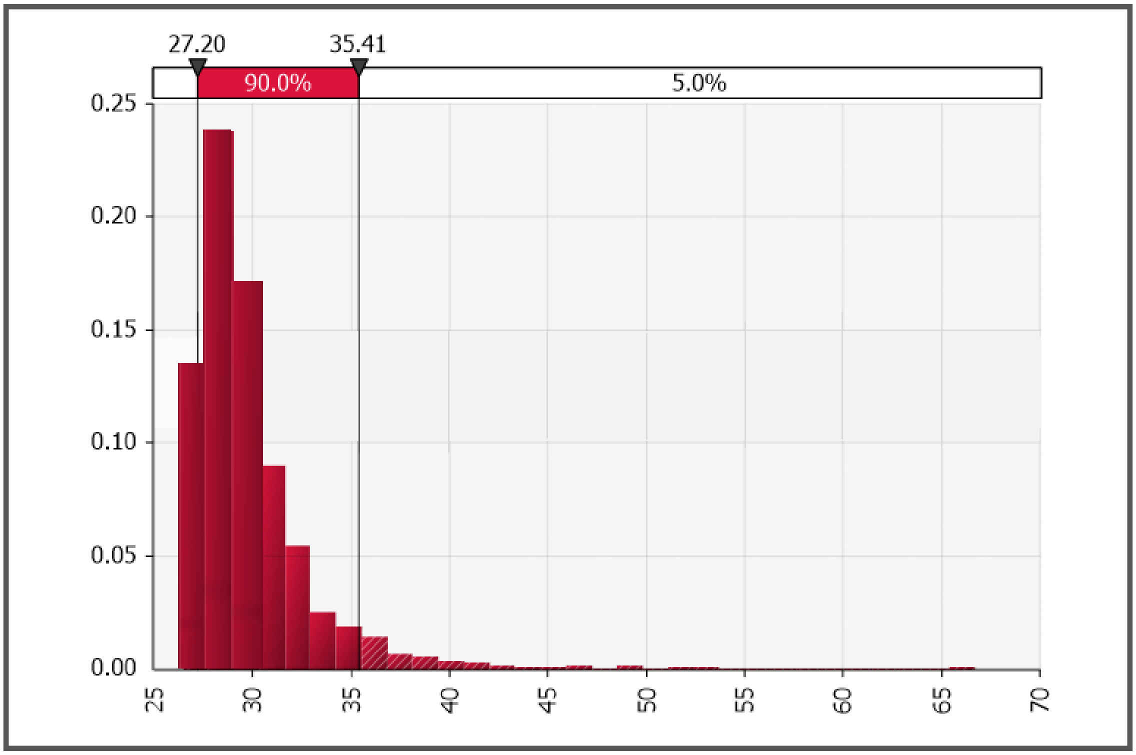

Figure 3. Differential profit ($/acre) for ND1

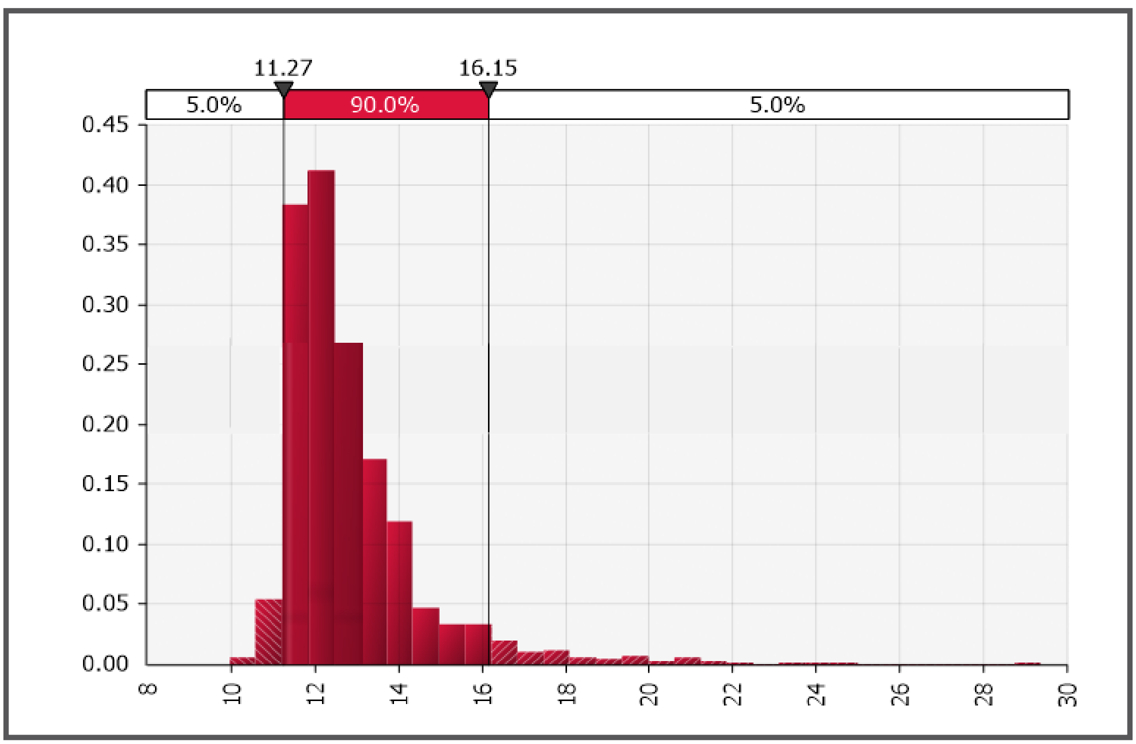

Figure 4. Differential profit ($/acre) for ND2

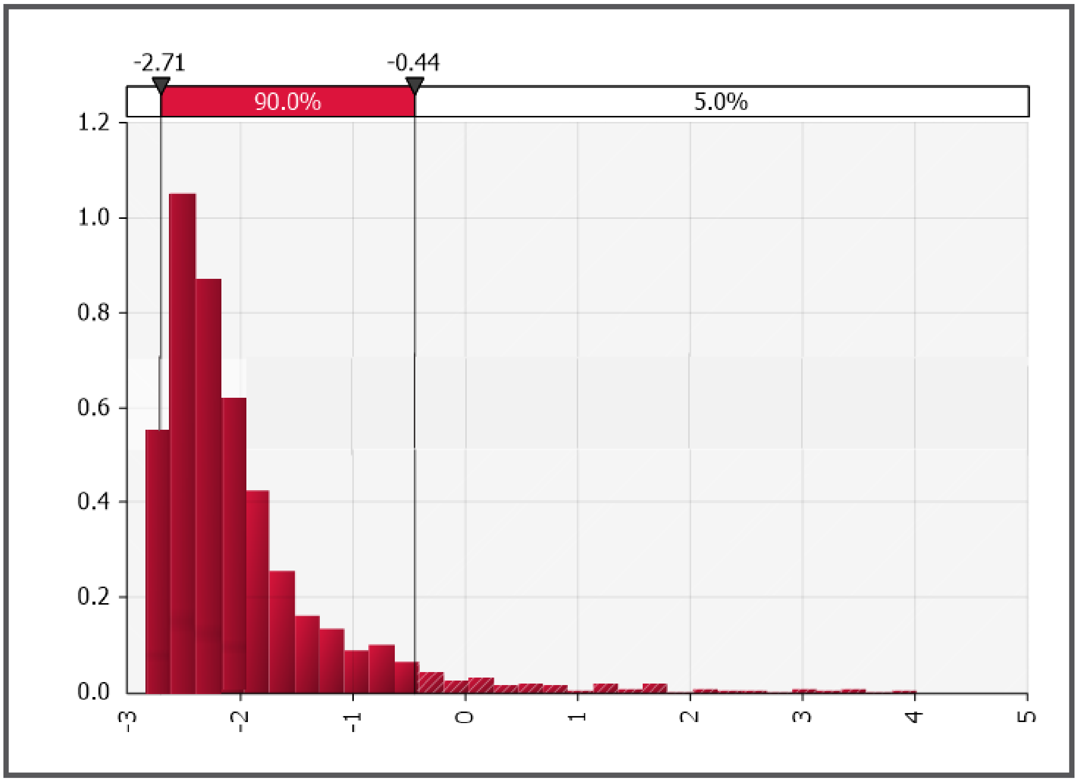

Figure 5. Differential profit ($/acre) for NE

Table 1. Case Farm Characteristics				
Farm	**Location**	**Size (acres)**	**Irrigation Type**	**Soil Variability**
ND1	Richland County, ND (South Valley Region)	158	Non-irrigated	Little to no soil variability, flat
ND2	Barnes County, ND (Southeast Region)	161	Non-irrigated	Significant soil variability, moderate slope
NE	Boone County, Eastern Nebraska	125	Irrigated	Moderate soil variability, flat

Table 2. Sample Corn Input Recommendations by Zones[a]							
Value/Zones	**1**	**2**	**3**	**4**	**5**	**Weighted Average**	**Traditional**
Yield Goal (bushels)	120	150	160	180	200	189	185
Seeding Rate (1000)	24	27	29	31	35	31.6	32
Nitrogen, Urea	195	215	268	270	295	271	325
Phosphorus, MAP	0	19	50	100	140	102	100
Potassium-Potash	0	0	70	74	75	65	100
Sulfur, AMS	20	47	51	60	66	58	75
Pop-up Fertilizer 6-24-6 (gallons)	3.0	3.0	4.5	4.5	5.0	4	5.0

[a]Unless indicated, input use is noted in pounds.

Table 3. Cost Differences Between PA and Traditional Rate ($/acre)		
Costs	**PA Rate**	**Traditional Rate**
Soil Sampling	2.5	1.25
Zone Mapping	3	–
Fertilizer Recommendation	6	–
Dry Fertilizer Application	10	8
Hydraulic Pump	1	–

Table 4. Static Results[a]						
	ND1		**ND2**		**NE**	
	PA	**Traditional**	**PA**	**Traditional**	**PA**	**Traditional**
Revenues						
Revenue from Corn	633.38	619.75	545.65	552.75	892.84	887.75
Costs						
Nitrogen (Urea ND, 28% NE)	49.73	59.64	44.22	50.46	86.30	89.20
Seed	94.92	96.00	92.12	96.00	106.62	108.00
Phosphorus (MAP)	27.39	26.85	25.78	33.56	0.00	0.00
Potassium (Potash)	11.90	18.30	0.55	9.15	0.00	0.00
Sulfur (AMS)	9.43	12.19	8.94	12.19	0.00	0.00
Pop-up Fertilizer	10.76	13.46	10.76	13.46	13.81	13.46
Dry Fertilizer Application	10.00	8.00	10.00	8.00	10.00	8.00
Soil Sampling	2.50	1.25	2.50	1.25	2.50	1.25
Hydraulic Pump	1.00		1.00		1.00	
Fertilizer Recommendation	6.00		6.00		6.00	
Zone Map	3.00		3.00		3.00	
Total Differential Costs	226.62	235.68	204.87	224.07	229.23	219.91
Returns	406.76	384.07	340.77	328.68	663.61	667.84
Differential Return	22.70		12.09		–4.23	

[a]All numbers are reported in $/acre. Returns are to labor, management, fixed costs, and variable costs that are not different between systems. These variable costs include herbicides, crop insurance, fuel and lubrication, repairs, drying, and operating interest. Fixed costs include machinery investment and depreciation, land charge, and miscellaneous overhead.

Table 5. Sensitivity Analysis of Profits and Differential Profits			
Differential Profit, $/acre[a]	**ND1**	**ND2**	**NE**
June 2022 Prices	52	38	3
December 2020 Prices	23	13	–4

[a]Profit per acre is the return to fixed costs, management, and input costs except those noted as different between the adoption and non-adoption scenarios.

Submission Guidelines

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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.

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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.

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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.

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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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